Nativeness, dominance, and

the flexibility of listening to spoken language

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te Nijmegen

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Abstract

The way we listen to language is shaped by the properties of our L1, such as its phonology or its vocabulary. While L1 listening is generally efficient and effortless, L2 listening is typically less efficient and much harder by comparison, as our listening strategies are attuned to the L1 and may not always be appropriate for the L2. Even highly proficient L2 listeners appear unable to fully exploit the skills that provide them with such great efficiency in L1 listening. It is unclear, however, how L1 and L2 listening compare in listeners who predominantly use the L2 in daily life, such as emigrants, and how this is affected by language dominance. This dissertation aims to address this gap by investigating various phonetic and lexical aspects of L1 (Dutch) and L2 (English) speech processing in Dutch-English bilingual emigrants in Australia. In contrast to the existing literature, the studies reported here are the first to make these comparisons within the same listeners.

Using the lexically-guided perceptual learning paradigm (Norris, McQueen, & Cutler, 2003), the first set of experiments examined the emigrants' phonetic adaptability to an ambiguously pronounced fricative between /f/and /s/, in L1 and L2 listening. A comparison across languages within the same listeners showed that while the emigrants flexibly adapted to the ambiguous pronunciation in L2 listening, no such adjustments were made in L1 listening. Thus, regular exposure to new talkers may be essential for listeners to maintain this type of phonetic flexibility, and L1 flexibility may decrease when such variability is not available.

The second study consisted of a series of visual world eyetracking experiments that investigated the processes of lexical activation and competition in L1 and L2 listening, and were based on a study by McQueen and Huettig (2012). A comparison

of looking patterns revealed a great resemblance between the bilingual emigrants' lexical activation and competition in L1 listening and in L2 listening. In both languages, onset competitors competed similarly strongly for recognition, yet neither L1 nor L2 listening, displayed the rhyme competition that is typically found for L1 listeners who live in an L1 environment.

The final two studies focused on the emigrants' use of language-specific listening strategies. First, a replication of a phoneme-monitoring study by Wagner, Ernestus, and Cutler (2006) showed that the Dutch emigrants ignored the cues to fricative identity provided by formant transitions that were previously shown to be exploited by native English listeners but not by native Dutch listeners in the Netherlands. This suggests that the emigrants applied a listening strategy from their L1 and had not adopted a strategy more appropriate to their L2. The second experiment concerned the exploitation of suprasegmental stress cues for word recognition and was a replication of a two-alternative forced choice experiment by Cooper, Cutler, and Wales (2002). Dutch emigrants' use of suprasegmental stress cues closely resembled that of English but not Dutch listeners, suggesting that emigrants had abandoned their L1 strategy in favour of a strategy more appropriate for the L2. Combined results from these two studies suggest that it may be harder to acquire a new listening skill than it is to lose or ignore an existing strategy.

No significant correlations were found between the emigrants' language dominance – as measured by relative language proficiency, frequency of L1 use, and self-reported dominance – and the experimental outcomes, perhaps suggesting that a definitive test of language dominance is yet to be discovered. However, overall, the results demonstrated that although, in principle, the way we listen to language is tailored to our L1, this may be altered by extensive use of the L2. Acoustic cues that are attended to in L1 listening may be ignored in L2 listening if their exploitation does not improve L2 processing efficiency. It may be harder for listeners, however, to make use of cues that are typically ignored in L1 listening. Furthermore, listeners appear to be able to adapt to idiosyncratic pronunciations in L2 listening. Importantly, however, this adaptability may disappear or be temporarily suspended in L1 listening when insufficient exposure to the L1 is available.

Nederlandse samenvatting

De manier waarop we naar onze moedertaal (L1) luisteren, hangt af van de eigenschappen van die taal, zoals de fonologie of de woordenschat. Hoewel het luisteren naar de L1 over het algemeen efficiënt en moeiteloos verloopt, gaat het luisteren naar een tweede taal (L2) ons meestal veel minder gemakkelijk af. Dit komt doordat onze luisterstrategieën op onze L1 zijn afgestemd en niet altijd even geschikt zijn voor de L2. Zelfs luisteraars die hun L2 zeer goed beheersen, lijken niet in staat om optimaal gebruik te maken van de vaardigheden waar ze in hun L1 zoveel baat bij hebben. Het is echter nog onbekend hoe het luisteren naar L1 en L2 zich tot elkaar verhouden bij luisteraars die in hun dagelijks leven voornamelijk hun L2 gebruiken, zoals bijvoorbeeld emigranten, en wat voor rol taaldominantie hierbij speelt. Dit proefschrift heeft tot doel deze lacunes op te vullen. Het hier gerapporteerde onderzoek betreft verschillende fonetische en lexicale aspecten van spraakverwerking door Nederlandse emigranten in Australië, zowel in het Nederlands (hun L1), als in het Engels (hun L2). Dit laatste maakt de experimenten in dit proefschrift uniek, aangezien het luisteren naar L1 en L2 tot nu toe nog nooit vergeleken werden in één en dezelfde groep luisteraars.

In de eerste reeks experimenten werd met behulp van het *lexically-guided perceptual learning* paradigma (Norris, McQueen, & Cutler, 2003) onderzocht of, en in welke mate, de geëmigreerde luisteraars zich in hun L1 en in hun L2 aanpassen aan een ambigue fricatief waarvan de uitspraak tussen /f/ en /s/ in ligt. Uit een vergelijking binnen dezelfde groep deelnemers bleek dat de emigranten zich weliswaar flexibel aanpasten aan de ambigue uitspraak bij het luisteren naar L2, maar dat deze aanpassing achterwege bleef bij het luisteren naar L1. Voor het behoud van dit soort fonetische flexibiliteit lijkt het daarom essentieel te zijn dat luisteraars regelmatig in aanraking komen met nieuwe sprekers. Wanneer een dergelijke variatie niet voorhanden is, kan de flexibiliteit in de moedertaal afnemen.

De tweede studie in dit proefschrift bestond uit een serie *visual world eyetracking*-experimenten, gebaseerd op een studie van McQueen and Huettig (2012). In deze experimenten werden lexicale activatie en competitie vergeleken tussen het luisteren naar L1 en naar L2. De kijkpatronen van de tweetalige emigranten lieten grote overeenkomsten zien tussen lexicale activatie en competitie in het luisteren naar L1 enerzijds en lexicale activatie en competitie in het luisteren naar L2 anderzijds. In beide talen concurreerden *onset competitors* in vergelijkbare mate voor herkenning, terwijl de concurrentie van *rhyme competitors* die normaalgesproken gevonden wordt in L1-luisteraars die in hun moedertaalomgeving wonen noch in L1 noch in L2 optradt.

Tot slot worden in dit proefschrift twee experimenten beschreven die het gebruik van taalspecifieke luisterstrategieën onderzochten. Uit het eerste van deze experimenten, een replicatie van een *phoneme monitoring* experiment van Wagner, Ernestus en Cutler (2006), bleek dat de Nederlandse emigranten voor de identificatie van fricatieven /f/ en /s/ geen gebruik maakten van informatie uit de formantovergangen in het spraaksignaal. Aangezien het bekend is dat deze aanwijzingen ook niet worden gebruikt door moedertaalluisteraars van het Nederlands die in Nederland wonen, maar wèl door moedertaalluisteraars van het Engels, wijst dit resultaat erop dat de emigranten een luisterstrategie uit hun L1 toepasten en geen gebruik maakten van een strategie die beter zou passen bij de L2. Het andere experiment ging over het gebruik van klemtoon voor het herkennen van woorden en was een replicatie van een *two-alternative forced choice*-experiment van Cooper, Cutler, en Wales (2002). Het klemtoongebruik van de Nederlandse emigranten leek zeer op dat van moedertaalluisteraars van het Engels, maar niet op dat van moedertaalluisteraars van het Nederlands die in Nederland wonen. Dit wijst erop dat de emigranten de strategie uit hun L1 hadden losgelaten en in plaats daarvan een strategie toepasten die geschikter was voor hun L2.

Er was geen aantoonbare correlatie tussen de resultaten van de experimenten en de taaldominantie van de emigranten – gemeten aan de hand van hun relatieve taalvaardigheid in L1 en L2, aan de hand van de frequentie waarmee ze hun L1 gebruiken, en met behulp van hun zelfgeschatte dominantie. Dit zou erop kunnen wijzen dat dé dominantietest nog altijd niet ontdekt is. De resulta-ten wijzen er echter op dat hoewel de manier waarop we naar taal luisteren in principe toegespitst is op onze L1, dit kan veranderen als gevolg van veelvuldig gebruik van de L2. Akoestische aanwijzingen waar we tijdens het luisteren naar de L1 goed op letten, kunnen bij het luisteren naar de L2 genegeerd worden als ze de verwerking van de L2 niet efficiënter maken. Het lijkt daarentegen moeilijker voor luisteraars om bij het luisteren naar de L2 gebruik te maken van aanwijzingen die bij het luisteren naar de L1 normaalgesproken genegeerd worden. Bovendien lijken luisteraars in staat zich bij het luisteren naar de L2 aan te passen aan een atypische uitspraak, maar lijkt deze flexibiliteit verloren te gaan, danwel tijdelijk opgeschort te worden, voor het luisteren naar de L1 wanneer luisteraars onvoldoende blootgesteld worden aan de L1.

Introduction

Chapter 1

In today's world of internationalisation and globalisation, international travel is increasingly common for many people. Moreover, every day hundreds of people worldwide leave their home country behind to move abroad, some for a short period of time, others permanently. Although their reasons for emigration may be vastly different, there is one thing that many emigrants have in common: in their new country, they no longer live surrounded by their native language (L1) but are instead immersed in a second language (L2). While some emigrants may nonetheless continue to predominantly use their L1, for others the L2 may eventually become the more dominant language. This dissertation concentrated on these types of listeners and investigated how they process speech. The focus of the project was on Dutch emigrants in Sydney, who live immersed in their L2, English, and whose L1 was Dutch. The experiments compared the way they process sounds (phonetic processing) and words (lexical processing) in L1 and L2, and examined the effects that a shift in language dominance may have on these processes.

The structure of the dissertation is as follows. The present chapter starts with a discussion of L1 listening and the way it is tailored to the properties of the L1. This section is followed by an examination of L2 listening and its associated difficulties. Chapter 2 contains a review of previous studies on speech perception by emigrants, and a discussion of the concept of language dominance and how it can be operationalised. Then, in Chapter 3, the first of three experimental chapters, Dutch emigrants' phonetic flexibility in L1 and L2 is compared, using the lexically-guided perceptual learning paradigm. Subsequently, in Chapter 4, their lexical activation and competition processes in L1 and L2 are examined with visual world eyetracking experiments, and the potential malleability of these processes is assessed. Chapter 5 then focuses on two aspects of speech processing (one phonetic and one lexical) for which L1 speakers of Dutch and English are known to employ different strategies, and assesses the strategies used by Dutch emigrants. Chapter 6 investigates whether the findings from Chapters 3, 4, and 5 can be explained by the bilinguals' language dominance. Finally, Chapter 7 provides a general discussion of the overall findings. The introductory chapters, Chapters 1 and 2, do not contain in-depth literature reviews. Instead, each experimental chapter starts with a review of literature concerning the experimental methods used in the chapter in question.

1.1. L1 Listening

1.1.1. Recognising sounds

The way we listen to our L1 is determined very early in life (Werker & Tees, 1984) and depends on the L1's specific characteristics. For instance, how many phonemes does the language have? A language with a large phoneme repertoire, such as the Khoisan language !Xũ which contains 141 phonemes (Maddieson, 1984), requires its listeners to distinguish more phonetic contrasts than a language such as Hawaiian, which has a very small phoneme inventory by comparison (eight consonants and five vowels; Maddieson, 1984). It is not merely the <u>number</u> of phonemes in a language that influences how listeners process it. The <u>features</u> of the phonemes in the inventory play an important role as well. Dutch and German, for instance, only contain fricatives that are clearly distinct from one another on a spectral level (i.e., the fricatives can be distinguished by looking at the way the acoustic energy is distributed across the frequency spectrum). Polish, English and Spanish, on the other hand, contain fricative pairs that are spectrally much more similar (such as the English /f/ and /θ/) and this means that listeners of each of these languages may have to rely on other, non-spectral, cues to distinguish between fricatives. Wagner et al. (2006) carried out a series of phoneme monitoring experiments with native listeners of each of these five languages and their results suggest that Polish, English and Spanish listeners use vowel formant transitions[1] as a cue to help them identify fricatives. Dutch and German listeners, on the other hand, appear to ignore this additional information as their native phoneme repertoire does not require them to use it (see Chapter 5 for more details regarding this study). In all languages, the information is there in the signal; whether listeners use it depends on whether it is useful, and that depends on the structure of the phoneme inventory.

1.1.2. Segmenting the speech stream

Other levels of speech processing are also attuned to a listener's L1. When listeners try to understand speech, they have to segment a continuous stream of speech input into separate words. This is not a trivial task, as it is not always clear where one word ends and the next one begins, and longer words can contain shorter words embedded within them. Take, for instance, the phrase *The catalogue in a library*, which, when pronounced in British English, contains embedded words such as *cattle*, *login*, *inner*, and *eye* (example from Norris & McQueen, 2008). The strategies that listeners use in

[1] These transitions are present in the vowel preceding a consonant and consist of a gradual change in the formant frequencies of that vowel. This change is due to the movement of the articulatory organs (such as the tongue and the lips) as they prepare to pronounce the upcoming consonant. As place of articulation is the main determinant of where the articulators move to, the transitions thus provide the listener with information about the place of articulation of the following consonant.

this process of speech segmentation are influenced by the rhythmic properties of the listener's L1. Although it is difficult to unambiguously classify languages based on their rhythmic structure (Grabe & Low, 2002), languages such as French and Spanish are traditionally said to be syllable-timed (Abercrombie, 1967); they have a regular syllable structure with predictable syllable boundaries, which makes it efficient for listeners to process speech syllable by syllable. French listeners indeed segment speech based on syllables, as was shown by Mehler, Dommergues, Frauenfelder, and Segui (1981) in a fragment detection experiment. In that study, French listeners were presented with a series of French words and were asked to press a button each time they heard a certain sequence of phonemes at the beginning of those words. Sequences that matched the entire first syllable, such as *pa-* in *palace* (palace) and *pal-* in *palmier* (palm tree), were detected more easily than sequences that were longer or shorter than a syllable, such as *pa-* in *palmier*, or *pal-* in *palace*. Syllabic segmentation was taken to underlie this difference; to recognise the word *palace*, listeners had already segmented it into the syllables *pa-* and *-lace*. As a result, they could quickly detect that the target sequence *pa-* was present. Detecting *pal-* in the same word could not be based on syllables and required further analysis, which thus led to slower detection. A Spanish version of Mehler et al.'s fragment detection experiment showed that Spanish listeners also apply syllable-based strategies for speech segmentation (Bradley, Sánchez-Casas, & García-Albea, 1993).

A different type of rhythm occurs in Japanese, which is said to be mora-timed (Ladefoged, 1975) as morae (units of syllable weight) form an essential part of the Japanese phonological structure. And indeed, another fragment detection experiment demonstrated that Japanese listeners appear to segment speech mora by mora (Otake, Hatano, Cutler, & Mehler, 1993). In this study, Japanese listeners heard words such as *tanishi* ‘snail’ or *tanshi* ‘terminal’, that were chosen not only for their moraic but also for their syllabic structure. The word *tanishi* has three morae (ta-ni-shi) and each of its morae corresponds to a syllable. The word *tanshi*, on the other hand, also consists of three morae (ta-n-shi), but of only two syllables (tan-shi). This pattern allowed a simultaneous investigation of both syllable- and mora-based segmentation in Japanese listeners. As in Mehler et al.’s study with French listeners, participants were given the task to respond as soon as possible every time a spoken word started with a certain target sequence, such as *ta-* or *tan-*. If Japanese listeners use syllable-based segmentation strategies, they should find it easier to detect *ta-* in *tanishi* (with syllables ta-ni-shi) than in *tanshi* (with syllables tan-shi) as it matches the entire initial syllable of the former but not the latter word. On the other hand, if Japanese listeners use mora-based segmentation, there should be no difference between responses to *ta-* in *tanishi* or in *tanshi*, as *ta-* corresponds to the first mora in both of these words. This latter response pattern was exactly what Otake and colleagues observed; results showed that listeners were quicker and more accurate in their detection of *tan-* in *tanshi* than in *tanishi*. Following the same logic applied above for Mehler et al.’s study with French listeners, this suggests that listeners benefited from by their previous segmentation of *tanshi* and hindered by their segmentation of *tanishi*, but the results for *tan-* did not point exclusively towards either the syllable or the mora as the underlying unit for this segmentation. After all, the target *tan-* (two morae, ta-n, that make up a single syllable) has a complete overlap with both the moraic and syllabic onsets of *tanshi*, but not *tanishi*, and the response pattern was therefore in line with both segmentation strategies. This is why targets such as *ta-*, which consists of a single mora that constitutes one syllable, were included in the experiment. The combined results for *ta*- and *tan*- allowed them to conclude that Japanese listeners segment speech based on the mora.

Further evidence of the usefulness of morae for Japanese speech segmentation was provided by a study that used a phoneme monitoring task (Cutler & Otake, 1994). Japanese listeners in this study heard series of words and were instructed to respond as quickly as possible whenever they heard a target phoneme such as /ɔ/ or /n/. In some of the words, the target phoneme was moraic (i.e., it formed a single-phoneme mora), in others it was not moraic and formed part of a larger mora. Listeners were significantly faster and more accurate in detecting the target phonemes when they were moraic than when they were not.

A third type of speech rhythm occurs in languages such as English and Dutch, which are said to be stress-timed (Abercrombie, 1967). In these languages, certain syllables within words are accentuated. Which syllables are accentuated is determined by the stress pattern of each word, which is a fixed property of that word (i.e., it is always WINdow, never winDOW). All syllables in stress-timed languages are either strong (such as the initial syllable of *window*) or weak (such as the final syllable of *window*), and this distinction is what listeners of stress-timed languages employ in speech segmentation. This was shown for English listeners, for instance, in a study in which listeners heard a series of spoken nonwords and were asked to press a button as soon as they heard a nonword that started with a real English word (Cutler & Norris, 1988). Those critical nonwords either consisted of two strong syllables (SS), like *mintayf* and *thintayf*, or started with a strong syllable that was followed by a weak syllable (SW), such as *mintef* and *thintef*. Cutler and colleagues hypothesised that English listeners segment words at strong syllables, so that *mintayf* and *thintayf* (both SS) would each be segmented into two parts (*min* and *tayf*, and *thin* and *tayf*, respectively), whereas *mintef* and *thintef* (both SW) would not be segmented and remain intact. As the word *mint* thus crosses a segmental boundary in *mintayf* but not *mintef*, detection of *mint* was expected to be more difficult in *mintayf*. No difference was expected for the detection of thin in *thintayf* and *thintef*, as no segmental boundaries were crossed. This was exactly what was found; listeners were slower and less accurate in their responses to *mintayf* than to *mintef*, but equally fast to detect *thin* in *thintayf* and *thintef*. Similar findings for Dutch listeners were obtained by Vroomen, van Zon, and de Gelder (1996), who conducted a Dutch analogue of Cutler and Norris' (1988) experiment described above.

1.1.3. Word recognition

Once a word has successfully been segmented, it still needs to be recognised. During the recognition process, lexical candidates are activated based on their overlap with the speech input and are discarded once they no longer form a viable option (for more details on the word recognition process, see section 1.2 and Chapter 4). This process is also influenced by the properties of the listener's L1, as illustrated by findings from studies with Spanish, Dutch and English listeners. Spanish, Dutch and English are all languages with free lexical stress. In such languages, there is no rule for the position of stress within words; it can fall on a syllable in any word position (cf. *LANGuage*, *poSItion*, and *withIN*; note that the position of stress within each individual word is not free, so neither *POsition* nor *posiTION* would be correct in English). In languages with free lexical stress, stress can thus also be used contrastively, to distinguish between words such as *INsight* and *inCITE*.

The fact that stress patterns vary from word to word may make stress cues useful to listeners during word recognition, and Spanish listeners indeed use them very efficiently during spoken-word recognition, as was shown by Soto-Faraco, Sebastián-

Gallés, and Cutler (2001). In their cross-modal priming study, Spanish listeners heard sentences that ended with a word fragment that served as the auditory prime. The prime fragment consisted of the first two syllables of a Spanish word, such as *princi-*. Sentences were semantically neutral, so that the final word could not be predicted. After each sentence, a written target word was presented and listeners made a lexical decision (i.e., they had to decide whether it was an existing Spanish word or not). Pairs of target words were selected that were segmentally identical for the first two syllables but differed in their suprasegmental stress pattern, such as *PRINcipe* 'prince' and *prinCIpio* 'principle'. In the matching condition, the prime fragment was taken from a recording of the target word, and prime and target therefore had identical stress patterns (e.g., *PRINci-* and *PRINcipe*, and *prinCI-* and *prinCIpio*). In the mismatching condition, targets within a pair were exchanged, so that there was no longer any stress overlap between prime and target (e.g., *PRINci-* served as the prime for *prinCIpio*, and *prinCI-* for *PRINcipe*). Primes in the control condition shared neither segmental nor stress overlap with the target word (e.g., *mosQUIto* as a prime for *PRINcipe*). Compared to the control condition, listeners' lexical decision responses were faster in the matching condition and slower in the mismatching condition, which indicates that listeners used lexical stress during word recognition.

Like Spanish listeners, Dutch listeners also use the cues provided by lexical stress. This was demonstrated, for instance, by Donselaar, Koster, and Cutler (2005) who replicated Soto-Faraco et al.'s (2001) cross-modal priming study with Dutch materials and found similar facilitation and inhibition effects for the Dutch listeners. English listeners, however, appear to use stress cues to a lesser extent than Spanish and Dutch listeners, as evidence from another cross-modal priming task shows (Experiment 1a, Cooper et al., 2002). Like the Spanish listeners in the experiment described above, listeners in Cooper et al.'s study were presented with neutral sentences ending in a prime fragment (e.g., *ADmi-*). After each sentence a written target was presented for lexical decision. Primes in the matching condition overlapped the first two syllables of the target word both in segments and in stress pattern (e.g., *ADmi-* and *ADmiral*). In the mismatching condition, primes also overlapped with the first two syllables of the target word but only in segments and not in stress pattern (e.g., *ADmi-* and *admiRAtion*). In the control condition, prime and target overlapped neither segmentally nor suprasegmentally. Cooper et al. found that, like the Spanish and Dutch listeners in the studies by Soto-Faraco et al. (2001) and Donselaar et al. (2005), English listeners made faster lexical decision responses in the matching condition than in the control condition. In the mismatching condition, however, English listeners barely experienced any inhibition; lexical decision responses in this condition were no slower than in the control condition.

Cooper et al. (2002) explain the difference between English listeners on one hand, and Spanish and Dutch listeners on the other, by looking at the lexicon of each language. In English, the vowel in a syllable that follows a stressed syllable is frequently reduced, which means that English listeners do not gain any additional information by taking stress cues into account; they can already disambiguate the first syllables of words such as *ocTOber* (with a stressed and therefore full vowel in the second syllable) and *OCtopus* (with a reduced vowel in the second syllable) based on segmental differences alone. Spanish and Dutch, on the other hand, contain many words of three syllables or more that have full vowels in the first two syllables (e.g., *PRINcipe* and *prinCIpio*), so for listeners of these languages, the use of suprasegmental stress cues is efficient, as it provides them with disambiguating information that was not available on a segmental level.

1.1.4. Adaptation to unfamiliar accents

Languages differ from one another in many aspects, and, as illustrated by the examples in the previous paragraphs, this has implications for the way listeners perceive languages and for the strategies they employ when listening. The most efficient way of processing language X is not necessarily the most efficient way for language Y or Z. Listeners tailor the way they process speech to the particularities of their L1 and develop a system that is maximally efficient for that language (Cutler, 2012). The benefit of this efficiency is especially apparent in the flexible adjustments that L1 listeners make to accommodate for a variety of speakers and listening situations.

When listeners encounter a speaker they have never heard before, they are able to understand what he or she says, even if this new speaker speaks atypically (e.g., because of a speech impediment) or with a foreign or unfamiliar accent. Evidence for this comes, for instance, from a study by Norris et al. (2003), in which Dutch listeners learned to interpret an ambiguously pronounced fricative as either /f/ or /s/, depending on the words in which they had heard the ambiguous sound. Listeners who, during a lexical decision task, heard the ambiguous sound in words such as *karaf* 'carafe' or *olijf* 'olive', later categorised it mostly as /f/. Listeners who had heard the same ambiguous sound in words like *muis* 'mouse' or *karkas* 'carcass' categorised it more as often as /s/. This finding showed that L1 listeners are able to retune the boundaries of their phoneme categories to accommodate for a speaker's atypical pronunciation.

In a study on foreign accents, Clarke and Garrett (2004) asked English listeners to verify whether a visually presented word corresponded to the final word of a spoken English sentence they had heard just before. Sentences were produced by a speaker who had either a Chinese accent, a Spanish accent or an American-English accent. While listeners in the foreign-accented conditions were initially noticeably slower than the listeners who heard American-English (unaccented) speech, after as little as one minute of exposure they had overcome this difference and responded as rapidly as listeners in the unaccented condition.

More recently, Witteman, Weber, and McQueen (2013) conducted a cross-modal priming study to investigate whether Dutch listeners who were relatively unfamiliar with German-accented Dutch would experience priming from auditory primes that had either a weak, medium or strong German accent. Prior to the priming task, one group of listeners was exposed to a 4-minute story, spoken by the same speaker as the priming stimuli, while the other group had no pre-exposure. While all listeners immediately experienced priming from the weakly and medium-accented primes, the strongly accented prime words only caused priming for listeners who had been exposed to the short story. Thus only four minutes of exposure was sufficient for listeners to adapt to strongly foreign-accented speech.

Evidence for adaptation to an unfamiliar native-like accent was provided by Maye, Aslin, and Tanenhaus (2008) in a two-session experiment. In the first session, which served as a baseline, American listeners were exposed to a story spoken with a regular American-English accent, and subsequently completed an auditory lexical decision task. In the second session, listeners heard the same story, but this time all front vowels had been acoustically altered to create a novel L1 accent (e.g., 'witch' was pronounced as 'wetch'). They then completed the same lexical decision task as in the first session, which crucially contained several items that were non-words in American-English but would be considered words as pronounced with the novel accent (e.g., *wetch*). Results showed that listeners accepted more of these critical items as words in the second session than in the first, indicating that they had adapted to the novel accent of the speaker. The aforementioned studies thus demonstrate listeners' flexibility in adjusting to atypical pronunciations and foreign or unfamiliar accents in L1 speech.

1.2. Perceptual Difficulties in L2 Listening

While the language-specific strategies that listeners develop for listening to their native language result in a system that processes native speech with maximal efficiency, this specialisation seems to come at a cost. When listening to speech in their L2, listeners typically use the same listening strategies they developed for their L1, whether these strategies are appropriate for the L2 or not. Japanese listeners, who segment their L1 based on morae, have been shown in syllable- and phoneme-monitoring tasks to apply this same strategy to French and Spanish (Otake, Hatano, & Yoneyama, 1996) and to English (Cutler & Otake, 1994), even though these languages are segmented by their L1 listeners on the basis of the syllable structure or lexical stress patterns, respectively. In contrast, French L2 listeners inappropriately use syllables and not morae to segment Japanese (Otake et al., 1993). While it may occasionally prove beneficial to L2 listeners to employ their L1 strategies (e.g., Broersma, 2006; Cooper et al., 2002; Cutler, 2009), it generally puts L2 listeners at a disadvantage and poses difficulties at both the phonetic and the lexical level of L2 speech processing.

1.2.1. Phonetic misperception

As a result of L1 attunement, listeners often experience difficulties perceiving L2 phonetic contrasts. It is very difficult, for instance, for Dutch and German listeners to distinguish between the English phonemes /æ/ and /ɛ/ (Schouten, 1975, as cited by Broersma & Cutler, 2011) and for Japanese listeners to distinguish between English

/l/ and /r/ (Goto, 1971). This is not for acoustic reasons, as L2 listeners are capable of detecting acoustic differences between L2 phonemes (e.g., Rivera-Gaxiola, Csibra, Johnson, & Karmiloff-Smith, 2000). For reasons of efficiency, however, phonemes are quickly categorised according to listeners' L1 phoneme categories. Whether this leads to perceptual problems depends on the phoneme repertoires of both the L1 and the L2. Phonetic misperception by L2 listeners has been the topic of many studies and theoretical models (e.g., the Perceptual Assimilation Model, Best, 1994; 1995; and the Speech Learning Model, Flege, 1995; 1999, 2003).

1.2.2. Word recognition

Phonetic misperception has a knock-on effect on L2 word recognition. As the speech signal unfolds, words that overlap with parts of the speech signal are activated in the listener's mind until they are no longer supported by the speech signal and can be ruled out as viable candidates. The words that 'win' this lexical competition are those words that, when they are put in sequence, account best for the speech input without leaving any phonemes unaccounted for (Eisner & McQueen, in press). The previously described phonetic confusion therefore has immediate consequences for L2 word recognition as it leads to activation of additional (incorrect) lexical candidates. Eyetracking evidence shows that when Japanese listeners hear the English fragment *rock-*, this not only activates the word *rocket*, but the word *locker* is temporarily activated as well (Cutler, Weber, & Otake, 2006). Likewise, the difficulties Dutch L2 listeners of English have in distinguishing /æ/ from /ɛ/ lead to the temporary activation of additional words. This was shown, for instance, by Broersma (2012) in a cross-modal priming study. Both English L1 and Dutch L2 listeners heard primes that consisted of fragments of English words, such as *daf-*. After each prime, they made a lexical decision on a visually presented target, such as *daffodil* (i.e., the matching target), *deficit* (the mismatching target). As expected, both L1 and L2 listeners' responses were facilitated by the prime in the matching condition. However, L2 listeners also experienced facilitation from the prime in the mismatching condition, which suggested that they not only activated *daffodil* but also *deficit* upon hearing *daf-*.

As more of the speech signal becomes available, L2 listeners will eventually deactivate lexical candidates such as *locker* and *deficit* from the examples above, since a fragment such as *daffod-* will no longer match the onset of *deficit*. However, phonetic confusion also affects minimal pairs, so that *rice* and *lice* sound like homophones to Japanese listeners (Cutler & Otake, 2004), and *cattle* and *kettle* become homophones for Dutch listeners (Broersma, 2012; Cutler & Otake, 2004; Díaz, Mitterer, Broersma, & Sebastián-Gallés, 2012). In cases like that, the incorrectly activated lexical candidate cannot be deactivated as the speech signal unfolds, which leaves L2 listeners with additional lexical competitors.

Also due to phonetic confusion, non-words may be misinterpreted as real words, as shown, for example, by two experiments with, again, English L1 and Dutch L2 listeners of English (Broersma & Cutler, 2011). The first of these experiments was a lexical decision task that included nonwords such as *lemp* and *chast*, which, to Dutch listeners, would sound like the real English words *lamp* and *chest*. L2 listeners accepted significantly more of these 'near-words' as words than L1 listeners. Near-words were also used in the second experiment from Broersma and Cutler's study, which was a cross-modal priming task. The target word that was presented visually to listeners for lexical decision (e.g., *deaf* or *cat*) was either preceded by a spoken version of the target word itself (the matching prime), or by a near-word (the mismatching prime; e.g., *daf* or *ket*). Matching primes facilitated recognition of the target word for L1 and L2 listeners, but mismatching primes did so only for L2 listeners.

Phonetic confusion also leads to prolonged activation of lexical competitors, as suggested by findings from an eyetracking study[2] with English L1 and Dutch L2 listeners of English (Experiments 1 and 2; Weber & Cutler, 2004). Listeners saw visual displays containing four pictures of objects and four geometrical shapes, while they heard English sentences instructing them to click on a certain picture (the target) and move it do a specific location on the computer screen (e.g., "Click on the panda. Now put it on top of the circle."). One of the pictures on the screen was always a picture of the target, while another picture was chosen as a potential lexical competitor. Target – competitor pairs in the high-confusability condition were pairs such as *panda – pencil* that contained vowels that Dutch listeners find difficult to distinguish. In the low-confusability condition, pairs like *beetle – bottle* were used, with vowels that are not easily confused by Dutch listeners. Results showed that, for L2 listeners, competitors like *pencil* remained activated longer than competitors like *bottle*, whereas for L1 listeners, no such difference was found. In addition, the activation of competitors such as *pencil* lasted longer in L2 listeners than in L1 listeners; L1 listeners dismissed *pencil* as a lexical candidate as soon as they heard the phoneme /æ/, whereas for Dutch listeners, *pencil* remained active until the beginning of the second syllable. Competitors such as *bottle* can be discarded by L1 as well as by L2 listeners upon hearing the first vowel of *beetle*, since the vowels /iː/ and /ɒ/ are sufficiently distinct for Dutch listeners; phonetic confusion does not slow them down.

The lexical activation caused by phonetic confusion is not symmetric. While hearing *rock-* causes activation of both *rocket* and *locker* in Japanese listeners, hearing *lock-* activates *locker* but not *rocket* (Cutler et al., 2006). For Dutch listeners, hearing

[2] See Chapter 4 for a detailed account of the eyetracking paradigm.

pan- activates both *panda* and *pencil*, but hearing *pen-* only activates *pencil* and not *panda* (Weber & Cutler, 2004).[3]

As can be concluded from the above, phonetic confusion thus leads to the activation of extra 'false' lexical competitors (that are not present in the speech signal) alongside the real competitors (that are supported by the speech input). Since the time it takes to recognise a spoken word increases with the number of lexical candidates competing for recognition (Luce, Pisoni, & Goldinger, 1990; Norris, McQueen, & Cutler, 1995), the extra competitors might be expected to slow L2 listeners down. It is not the mere presence of false competitors that makes word recognition harder for L2 listeners, however. The strength of their activation plays an important role as well. Real competitor words may be seen as weaker candidates than false competitors and 'lose' the lexical competition process. This happens, for instance, when Dutch listeners hear the English word *daffodil* (Broersma & Cutler, 2011). Misperception of the first vowel, /æ/, as /ɛ/ leads to the activation of the false competitor *deaf*. As the lexical representation of *daffodil* contains the actual spoken vowel and not the vowel that is perceived by the listener, *deaf* remains active even after the entire speech signal for *daffodil* has unfolded. The strength of activation of false competitors thus further complicates word recognition for L2 listeners.

[3] This asymmetry is thought to be influenced by the way lexical items are represented in the listener's mind. Weber and Cutler (2004) suggested that even though Dutch listeners have difficulties discriminating between /æ/ and /ɛ/ on a perceptual level, the contrast may still be represented lexically. Escudero, Hayes-Harb, and Mitterer (2008) provided further evidence that supports this suggestion. In their experiment, Dutch listeners were taught novel English words containing the vowels /æ/ and /ɛ/ for pictures of non-objects. One group of listeners only heard an auditory form of the novel words, whereas a second group of listeners was presented with the spelling of each novel word as well. A subsequent eye-tracking task revealed an asymmetric pattern of confusion for the /æ/-/ɛ/ contrast, but only for the listeners who had been presented with orthographic information about the novel words. Listeners in the auditory-only group performed symmetrically.

In addition to phonetic confusion, co-activation of lexical items from the L1 also increases the number of activated and competing lexical candidates in L2 listening.[4] In Experiments 3 and 4 of the study that Weber and Cutler (2004) conducted with English L1 and Dutch L2 listeners of English, listeners were given the same task as described in the previous paragraph for Experiments 1 and 2 from the same study. Targets in this experiment were English words (e.g., *desk*), while competitors were pictures whose Dutch but not English referent had phonological overlap with the target word (e.g., *deksel*, 'lid'). Weber and Cutler (2004) found that the Dutch but not the English listeners experienced significant competition from the Dutch competitors. Participants in the aforementioned study were relatively proficient L2 listeners, who had learned their L2 in school and lived in an L1 environment where they predominantly used their L1. Yet co-activation of L1 lexical items is a problem for more experienced L2 listeners as well, as was demonstrated by an eyetracking study with Russian students at an American university, who had been living in the US for several years. In this experiment (Marian & Spivey, 2003), participants were told in English to pick up one of four objects positioned on a display in front of them and move it to another position. In addition to the target object (e.g., *marker*), some displays contained an object that was a phonological competitor in the language of the experiment (the L2 competitor; e.g., *marbles*). Other displays contained an object whose Russian referent formed a phonological competitor (the L1 competitor; e.g., *marka*, 'stamp'). Analysis of their eye movements revealed that, in

[4] Note that, under certain conditions, activation of L2 words during L1 listening also occurs (Ju & Luce, 2004; Marian & Spivey, 2003; but see Weber & Cutler, 2004).

addition to competition from the L2 competitor, the L2 listeners also experienced competition from the L1 competitor.

Co-activation of words from the L1 slows down L2 word recognition even further. And, since a larger vocabulary provides more potential lexical candidates than a small vocabulary, the speed of word recognition is also influenced by vocabulary size. The fact that listeners typically have a smaller vocabulary in their L2 than in their L1 seems to suggest that recognition in L2 should be faster than in L1. However, evidence for the opposite has been provided by studies such as a gating experiment by Nooteboom and Truin (1980), in which L1 and L2 listeners were asked to identify Dutch words, and L2 listeners were found to need more stimulus information for correct recognition than L1 listeners.

Even very proficient L2 listeners who have overcome all individual perceptual difficulties may still struggle with tasks that require a certain amount of listening flexibility and that L1 listeners accomplish seemingly without effort, such as speaker recognition (Bregman & Creel, 2014), dialect identification (Clopper & Bradlow, 2009) and listening in noise (see Garcia Lecumberri, Cooke, & Cutler, 2010, for a review). Although the flexibility that characterises L1 listening should, in principle, also be available in an L2, these results suggest that this may not be the case. L2 listening may lack the flexibility that is typical of L1 listening, even though recent research suggests that listeners can acquire a certain degree of phonetic flexibility in their L2, at least under certain circumstances (Drozdova, Van Hout, & Scharenborg, 2014; Reinisch, Weber, & Mitterer, 2013; Schuhmann, 2014; see Chapter 3 for more details about these studies).

The studies reported in this dissertation investigate these flexibility differences by comparing phonetic and lexical aspects of L1 and L2 speech processing within the same listeners. Can L2 listening become as flexible as L1 listening? Are there any prerequisites for this? And what happens to L1 listening in these situations? The experiments that address these questions are discussed in Chapter 3, 4, and 5[5]. First, however, in Chapter 2, we take a closer look at the different types of L2 listeners and at the matter of language dominance.

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[5] The results presented in Chapter 3 have been reported, in part, at Architectures & Mechanisms for Language Processing 2015 in Valletta, Malta, and the 43rd Annual Australasian Experimental Psychology Conference (EPC2016) in Melbourne, Australia. Findings reported in Chapter 4 have been presented at the 41st Annual Australasian Experimental Psychology Conference (EPC2014) in Brisbane, Australia, at the 42nd Annual Australasian Experimental Psychology Conference (EPC2015) in Sydney, Australia, at the Third International Conference on Cognitive Hearing Science for Communication (CHSCOM2015) in Linköping, Sweden, and at the 18th International Congress of Phonetic Sciences (ICPhS2015) in Glasgow, UK. The experimental findings of Chapter 5 have been presented at the Centre of Excellence for the Dynamics of Language Fest 2016 in Sydney, Australia, at the 43rd Annual Australasian Experimental Psychology Conference (EPC2016) in Melbourne, Australia, and at the 171st Meeting of the Acoustical Society of America (ASA2016) in Salt Lake City, USA.
Please see Appendix P for the ICPhS conference proceedings paper.

Language Dominance I: How Dominance Is Defined

Chapter 2

The previous chapter discussed the differences between L1 and L2 listening and highlighted some of the problems listeners may experience in L2 speech comprehension. From this discussion, it becomes clear that when listening to the L2, listeners appear unable to fully exploit the listening skills that provide them with such great efficiency and flexibility in their L1, even though one might assume that these skills should be available to them in L2 listening as well. L1 listening seems to be special, and appears to have a privileged position over L2 listening. It is unclear, however, what causes this special status. Is it the result of prioritisation during a critical period of L1 acquisition (Newport, Bavelier, & Neville, 2001), so that it is a fixed property of L1 speech comprehension? Or are listeners able to attain similarly efficient levels of phonetic and lexical processing in their L2 as they seem to demonstrate in their L1? If so, does this have consequences for L1 speech comprehension? Bilingual listeners typically have one language that is more dominant than the other. This raises a question of what happens to the special status of L1 listening when the L2 is the more dominant language. And, on a related note, does a shift in dominance lead listeners to abandon their L1 listening strategies in favour of strategies more appropriate to the L2? The studies reported in this dissertation addressed this issue and compared L1 and L2 speech processing in Dutch emigrants in Australia. When people emigrate, their language dominance may change over time as the language of their new environment takes more and more precedence in everyday communication. The L2 may thus become their dominant language.

This chapter starts with a review of the literature on L1 listening in adult emigrants (section 2.1), and continues with a discussion of the concept of language dominance (section 2.2). This is followed by a review of the various methods that have been used in the literature to determine bilinguals' language dominance (section 2.3). Finally, three measures of language dominance are presented that were used in this dissertation (section 2.4).

2.1. L1 speech perception in adult emigrants

While an increasing number of studies focus on L1 speech production of emigrants, only a few studies have examined L1 speech <u>perception</u> in adult emigrants. Because of their limited number, a detailed description is provided below for each of these studies.

Celata and Cancila (2010) examined whether first and second-generation Lucchese-Italian immigrants in the USA were able to perceive the singleton-geminate contrast that exists for certain consonants in Standard Italian (such as /t/-/tː/). One group of participants consisted of eight first-generation immigrants from northern Tuscany, whose L1 is the Italian dialect of Lucchese. The second group of participants consisted of seven second-generation immigrants, who were raised by Lucchese–speaking parents and could understand them, but were unable to speak the Lucchese dialect themselves and considered American English their L1. Participants listened to minimal pair phrases, as spoken by a native speaker of Italian, that differed only in the duration of the critical singleton/geminate consonant (e.g., grata forte – gratta forte) and had to mark on a sheet of paper whether they heard a singleton or a geminate consonant. The same participants also completed a categorisation task in which they had to categorise non-word stimuli from a VCV-VC:V continuum, using the vowel /a/. The consonant contrasts that were tested in both tasks were /r/-/r:/, /s/-/s:/ and /t/-/t:/. In addition to the bilingual immigrants, a group of 16 Lucchese speakers in Italy was tested. On the sentence task, the first-generation immigrants were less accurate than the native Lucchese speakers residing in Italy – but more accurate than the second-generation immigrants. Their performance on the non-word task differed from the native Lucchese speakers in Italy, and from the second-generation immigrants as well. Unsurprisingly, the second-generation immigrants, who considered themselves native speakers of American-English and not of Lucchese or Italian, showed a clear overall impairment in their perception of the singleton-geminate contrast. Celata et al. tentatively suggest that the performance of the immigrants in their study is a sign of phonological-perceptual attrition.

A few audiometric studies have examined bilingual listeners' ability to understand speech in noise in their L1. Weiss and Dempsey (2008) tested Spanish-English bilinguals on the English and Spanish versions of the Hearing in Noise Test (HINT; Nilsson, Soli, & Sullivan, 1994; Soli, Vermiglio, Wen, & Filesari, 2002) to determine whether the bilinguals' results would be equivalent for both tests. Participants were either early bilinguals (18 participants who started to learn English before age 7) or late bilinguals (seven participants; started to learn English after age 11). Most of the early bilinguals were born in the USA and, on average, they spoke English nearly 70% of the time. Over half of the early bilinguals spoke primarily Spanish at home. All of the late bilinguals were born in Latin America and on average they spoke English and Spanish about 50% of the time. Six of the seven late bilinguals spoke primarily Spanish at home. Both participant groups performed better on the

Spanish (L1) HINT than on the English (L2) HINT and the less experience a participant had with L2, the better their L1 speech perception. According to Weiss et al. this could be caused by a deterioration of L1 speech perception as experience with the L2 increases, or it may also be attributed to the fact that the participants' L1 speech perception abilities were possibly never fully developed.

Von Hapsburg and Bahng (2009) investigated how listeners' L1 speech perception abilities are influenced by their L2 proficiency. Two groups of Korean students at the University of Tennessee participated in the Korean Speech Perception In Noise test (KSPIN). One group consisted of eight students that considered themselves to be moderately proficient speakers of English. The other group consisted of 12 students with a self-reported low proficiency in English. The group with moderate proficiency in English performed significantly worse than the group with low English proficiency on the two most difficult Korean test conditions (i.e., sentences with low predictability and a low Signal-to-Noise-Ratio), suggesting that the ability to perceive L1 speech in noise deteriorates as L2 proficiency increases. The participants in this experiment, in contrast to those in the previously described experiment by Weiss and Dempsey (2008), did not start to learn English until after puberty and had only arrived in the USA at over 20 years of age. It is therefore highly unlikely that this finding is caused by the participants' under-developed abilities to perceive speech in their L1.

Nakamura and Gordon-Salant (2011) examined the L1 and L2 speech perception abilities of native Japanese speakers living in an English-speaking environment. They administered the English (HINT) and Japanese (J-HINT) versions of the Hearing in Noise Test (Nilsson et al., 1994; Shiroma, Iwaki, Kubo, & Soli, 2008) to a group of 10 Japanese immigrants in the USA and compared their results to the normative data that are available for both versions of the test. These normative data were obtained from native speakers of American English residing in the USA, and from native Japanese speakers residing in Japan. (It is not reported whether all participants in the normative experiments were monolingual.) While the Japanese immigrants performed significantly worse on the HINT than the native American-English speakers, no significant differences were found between the Japanese immigrants and the normative data for the J-HINT, suggesting that the Japanese immigrants' L1 speech perception abilities remained intact. It should be noted, however, that the Japanese immigrants who were tested for this study had, with the exception of one participant, only lived in the USA for a relatively short period of time (4 – 9 years). This may be too short a period for a change in L1 listening abilities to occur. Furthermore, the majority of participants in this study reported using their L1 more often than the L2.

Unlike the studies discussed so far in this section, the final study, by Major (2010), does not concern sound recognition, but examined listeners' ability to perceive a foreign accent in their L1. The participants in this study were two groups of native listeners of Brazilian Portuguese. The first group consisted of 28 university students of English, aged 19 – 45, who lived in Brazil and had never visited an English-speaking country. The second group consisted of 18 Brazilian immigrants in the USA, aged between 27 and 63 years, who had lived in the USA for 8 – 33 years. Most of the participants in the latter group still used Portuguese on a daily basis. All participants listened to 25 Portuguese speech samples, spoken by five native and 20 non-native (i.e., American) speakers of Brazilian Portuguese, and were asked to rate each sample for the degree of foreign accent on a 9-point scale. The results showed that listeners in both groups rated the accentedness of the L1 speech samples as significantly different from that of the L2 samples. The Brazilian immigrants living in the USA, however, rated more samples with a foreign accent as native, and fewer native samples as accented, than the Brazilians residing in Brazil. Major interpreted this as a sign of perceptual attrition.

From the studies discussed above some tentative conclusions may be drawn. L1 phoneme discrimination may become less accurate for listeners who have emigrated to an L2 environment (Celata & Cancila, 2010) and listeners' ability to detect a foreign accent in their L1 may also deteriorate after emigration (Major, 2010). Listeners' L1 speech perception abilities in noise may deteriorate as experience with or proficiency in the L2 increases (Von Hapsburg & Bahng, 2009; Weiss & Dempsey, 2008), whereas those skills do not appear to be affected necessarily by merely residing in the L2 environment (Nakamura & Gordon-Salant, 2011). Unfortunately, however, most of these studies did not systematically group participants according to their language background. In particular, none of them controlled for participants' language dominance. Finally, all the studies compared across groups of participants, which means other unknown factors may have influenced the findings. No studies to date have compared L1 and L2 listening within the same listeners. The aim of this dissertation is to fill that gap by investigating L1 (Dutch) and L2 (English) phonetic and lexical processing, in Dutch adult emigrants in Australia whose language dominance varied. Unlike emigrants from many other countries, Dutch emigrants have a tendency to abandon their L1 in favour of the language of their new environment (Clyne & Pauwels, 1997), which means the likelihood of finding L2-dominant bilinguals in this population is reasonably high.

2.2. What is language dominance?

Before any effects of language dominance can be investigated it is necessary to define what language dominance is and how an individual's language dominance can be established, as there does not appear to be a consensus in the literature. Language dominance refers to the idea that a speaker of more than one language typically has one language that is 'stronger' or 'preferred' and is therefore considered the dominant language. To date, however, there has been little agreement on what exactly is meant by the 'stronger language'. Is it the language in which the bilingual is most competent (and then, by what measure)? Is it the language that is used most often, or in most domains of a bilingual's life? Is it the language of the environment in which the bilingual resides? Although bilinguals often lack a clear preference for one of their languages, language preference is a rather more straightforward concept, yet a bilingual's preferred language is not always necessarily the stronger one on other measures. Thus, determining language dominance is complicated. And even if one could determine a bilingual's overall dominant language, this does not necessarily mean it is dominant in all aspects of the bilingual's life. For example, a Dutch emigrant in Australia might use English as the dominant language at work while predominantly using Dutch at home with his Dutch-speaking relatives (cf. Grosjean's complementary principle; Grosjean, 1997). Furthermore, language dominance is not a fixed property but may change depending on circumstances in the bilingual's life, such as schooling, emigration, or marriage (e.g., Grosjean, 1982; Meisel, 2007).

Determining bilinguals' language dominance can be important for a variety of reasons. In clinical practice, language disorders such as stuttering may seem more or less severe depending on whether they are assessed in the dominant or in the non-dominant language (e.g., Lim, Lincoln, Chan, & Onslow, 2008) and the outcome of many cognitive tests (e.g., hearing, IQ, working memory) will be influenced by which language they were performed in (e.g., Ramkissoon, 2001). In research, a consistent and correct classification of participants according to dominance ensures comparability of experimental outcomes and replicability of studies.

The literature on language dominance includes studies that differ greatly in their approach to defining dominance. Some studies simply assume an intuitive understanding of the construct of dominance, while others have attempted to capture it in a quantifiable measure. Table 2-1 provides several examples of definitions of language dominance from the literature. From this overview, it becomes clear that there is no real consensus on how dominance should be defined.

Table 2-1. Examples from the literature of definitions of language dominance.

Study	Definition of 'dominance' or 'dominant language'
Argyri and Sorace (2007, p. 83)	"the language to which the bilingual child is predominantly exposed in the majority of social situations, i.e. the language in which the bilingual child obtains more input on a regular basis"
Bedore et al. (2012, p. 618)	"measure of relative performance"
Birdsong (2006, p. 47)	"greater speed, fluency, automaticity, or efficiency (accuracy) in processing"
Birdsong (2014, p. 374)	"observed asymmetries of skill in, or use of, one language over the other"
Dornic (1980)	the dominant language is the language most resistant to emotional stress, mental fatigue or informational overload
C. L. Harris, Gleason, and Aycicegi (2006, p. 264)	"[the language that] is generally most accessible in day-to-day life"
Heredia (1997, p. 38)	"the more active […] language"
Hemàndez-Chávez, Burt, and Dulay (1978, p. 41)	"the degree of bilingualism manifested by individuals who know two languages, that is, the relative level of proficiency in each of the languages"
Langdon, Wiig, and Nielsen (2005, p. 323)	"degree of automaticity"
Macnamara (1967, p. 63)	the most frequently used language in a test "in which a bilingual is confronted with an ambiguous stimulus (which could belong to either of two languages) and asked to pronounce or interpret it"
Marian, Blumenfeld, and Kaushanskaya (2007, p. 943)	"global […] measure of [relative] language competence"
Montrul (2015, p. 16)	"the relative weight and relationship of the two languages of a bilingual in terms of language use and degree of proficiency"
Schmeißer et al. (2015, p. 38)	"the difference in proficiency in a bilingual's two languages"
Wang (2013, p. 739)	"global measure of relative frequency of use and proficiency in each language"

2.3. The operationalisation of language dominance in the literature

Despite the lack of an agreed-upon definition of language dominance, for certain bilinguals it may nevertheless be quite self-evident which language is dominant. Teenagers learning a foreign language in high school, for instance, typically use their

L1 most often and in the majority of domains, are most competent in it and most likely prefer it over the L2 as well. It is also the language of the environment they live in. One may therefore safely assume their L1 to be the dominant language, regardless of which specific criteria are used. However, not all bilinguals are as easily classified and this certainly applies to the Dutch-English bilingual emigrants that form the participant pool for the studies reported in this dissertation. A quantifiable, objective measure of language dominance is therefore required. However, just as previous studies vary considerably in the ways they defined language dominance, the studies also show great variation in the methods that they used to operationalise language dominance. Table 2-2 provides a (non-exhaustive) overview of these methods and further illustrates the lack of uniformity in the literature.

While the tests used in the studies in Table 2-2 had not originally been created to determine participants' language dominance, several tests have been developed over the years specifically for that purpose. One of these is a self-report dominance classification tool for use with simultaneous English-Mandarin bilinguals in Asia (Lim, Liow, Lincoln, Chan, & Onslow, 2008). Participants rated their language proficiency and frequency of language use in four aspects of both languages (reading, writing, speaking and listening) and indicated their most used language at home, at school/work and in social settings. These combined ratings classified participants as Mandarin-dominant, English-dominant, or balanced bilinguals. When the self-ratings were validated against the results of a vocabulary picture naming task in English and in Mandarin (the MBPVS), however, the vocabulary tests were shown to be a less reliable method of classification, which led the authors to conclude that "objective assessments like the MBPVS may not be suitable for determining language dominance" (Lim, Liow, et al., 2008, p. 402).

Table 2-2. Examples from the literature of measures of language dominance.

Study	Classification based on
Chincotta, Hyönä, and Underwood (1997)	language of instruction at university attended
Bullock, Toribio, González, and Dalola (2006)	native language
Talamas, Kroll, and Dufour (1999)	unspecified “criteria for English dominance”
Cutler, Mehler, Norris, and Segui (1992)	answer to the question: “Suppose you developed a serious disease, and your life could only be saved by a brain operation which would unfortunately have the side effect of removing one of your languages. Which language would you choose to keep?”
Golato (2002)	answer to the question: “Of your languages, which is the most important to you? To help answer this question, imagine a hypothetical situation where you had to stop using all of your languages except one: which one would you keep?”
Gollan, Salmon, Montoya, and da Pena (2010)	answer to question that asked in which languages the bilingual expected to achieve higher neuropsychological test scores
Hazan and Boulakia (1993)	a combination of “country of birth, self-determined primary language, language use with parents, general language use, country of residence, and language usage at school/university”
Lambert (1955)	reaction time ratios for a speeded response test in each language
Peal and Lambert (1962)	dominance score calculated from difference scores for a word association, word detection and picture vocabulary test in each language
Gollan and Silverberg (2001)	number of successfully produced target words in each language upon reading their definitions
Bahrick, Hall, Goggin, Bahrick, and Berger (1994)	a combination of a vocabulary test, lexical decision task, category fluency test and comprehension of spoken passages in each language
Ervin (1961)	correct responses in picture naming task in each language
Hernandez and Meschyan (2006)	correct responses in picture naming task in each language
Kohnert, Bates, and Hernandez (1999)	correct responses in picture naming task in each language
Moreno and Kutas (2005)	correct responses in picture naming task in each language
Müller and Hulk (2001)	mean length of utterance in each language
Paradis, Crago, Genesee, and Rice (2003)	a combination of various morphosyntactic and lexical measures obtained from bilinguals’ speech in each language
Treffers-Daller (2011)	lexical diversity of bilinguals’ speech in each language
Tokowicz, Michael, and Kroll (2004)	self-ratings of understanding, speaking, reading and writing proficiency in each language

Table 2-2. (continued)

Study	Classification based on
Taube-Schiff and Segalowitz (2005)	self-ratings of speaking, reading and writing proficiency, combined with reaction times from an animacy-judgment task with written words, in each language
Gollan, Weissberger, Runnqvist, Montoya, and Cera (2012)	a combination of self-rated proficiency, performance on two different picture naming tasks and a proficiency interview, in each language
Flege, Mackay, and Piske (2002)	self-ratings of understanding, speaking, reading and writing proficiency, and ratio of the mean sentence duration in a sentence repetition task, in each language
Langdon et al. (2005)	self-ratings of proficiency and frequency of use, and number of correct responses in a word association and a dual-dimension naming task, in each language

A more recent tool for identifying simultaneous bilinguals' dominant language is the pencil-and-paper Bilingual Dominance Scale (BDS) proposed by Dunn and Fox Tree (2009), which consists of a twelve-question questionnaire about participants' language use, age of acquisition and potential language restructuring (i.e., the process of becoming more proficient in one language and/or of losing fluency in another language). A standardised weighted scoring procedure is provided, which places bilinguals' language dominance on a gradient scale ranging from -30, (indicating dominance in language A) to +30 (indicating that language B is dominant). Scores on the BDS were found to correlate with bilinguals' performance on a lexical task and a sentence translation task. While Dunn and Fox Tree claimed that this confirmed the validity of the scale, one could argue that it merely validates the BDS as a tool to assess bilinguals' fluency rather than dominance.

These two dominance assessment tools (i.e., the MBPVS and the BDS) formed the foundation for the Bilingual Language Profile (BLP; Gertken, Amengual, & Birdsong, 2014). The BLP is a multiple-choice questionnaire made up of four modules, for which language scores can be calculated separately. These modules address bilinguals' language history, language use, language proficiency, and attitudes towards each of their languages, respectively. Overall scores for each language, and a composite dominance score can also be computed. The BLP is available in several languages and was designed for use with both sequential and simultaneous bilinguals.

Unfortunately, none of the existing tools discussed above could be used in this dissertation. Lim, Liow, et al.'s (2008) self-report dominance classification tool cannot be used with Dutch-English bilinguals as it was specifically designed for English-Mandarin bilinguals in Singapore, and the BDS (Dunn & Fox Tree, 2009) is not intended for sequential bilinguals. The BLP (Gertken et al., 2014) is appropriate for the participant population of this project but was not published until 2014, by which time experiments for the present project were already underway. An assessment method was therefore developed specifically for the purpose of this dissertation. It was based on measures from the existing literature, and involved three different measures of language dominance. These measures are discussed in the next section.

2.4. Selected measures for the present project

Two of the measures of language dominance were derived from participants' responses in a language background questionnaire (see Appendix A) that was created based on Keijzer (2007). Each measure addressed a different aspect of bilingual language use that are likely to be a potentially important indicator of language dominance (i.e., self-reported dominance, relative proficiency in L1 and L2, and self-reported L1 use; see below). Thus, all participants received three dominance scores, one for each measure, and the role of language dominance in L1 and L2 speech processing was investigated separately for dominance as indicated by each score. The correlation between these measures is discussed in Chapter 6.

Measure A: Self-reported language dominance

The first of the measures was participants' self-reported language dominance, as determined by their response to the multiple-choice question "Which language do you consider to be your dominant language?" (Appendix A, question 82). Only participants' L1 (Dutch) and L2 (English) were provided as answer options, 'neither' was not included. As can be seen in Table 2-2, previous studies have sometimes used more expressive questions to elicit bilinguals' self-reported dominance (e.g., Cutler et al., 1992). In the case of Cutler et al.'s (1992) study, however, this was necessitated by the nature of their participant population, which consisted of bilingual teenagers, and the test setting. Their study was conducted at the teenagers' bilingual high school, an environment in which they were not expected to express a preference for any one of their languages and which made them reluctant to answer questions regarding their language dominance when they were phrased more neutrally. As this reluctance was not expected from the participants in the studies reported here, a neutral phrasing was chosen for this project.

Measure B: Relative proficiency in L1 and L2

The second measure of language dominance was based on participants' language proficiency in the L1 and L2. Proficiency in each language was objectively determined with the appropriate language version of the Lexical Test for Advanced Learners of English (LexTALE; Lemhöfer & Broersma, 2012), a lexical decision task that takes participants less than 5 min to complete and provides a score ranging from 0 – 100. Scores from 0 – 59 indicate lower to lower-intermediate proficiency, scores between 60 – 79 indicate upper-intermediate proficiency, and scores between 80 – 100 indicate advanced proficiency. The English version of the LexTALE has been shown to be a good indicator of L2 users' vocabulary size and general proficiency in English, and was developed for use with adults "who started learning English at school at an age of about 10 – 12 years […] and who continue to use English in daily life" (Lemhöfer & Broersma, 2012, p. 326). This makes it very appropriate for use with the emigrant participant population in the present project, who are all L2 users of English. Unfortunately, the validity of the Dutch version of the LexTALE as a measure of language proficiency has not yet been established. However, the test was developed in conjunction with the English version, "as parallel to the English version as possible" (Lemhöfer & Broersma, 2012, p. 346), and should therefore still be able to provide some indication of participants' relative vocabulary size and general proficiency in Dutch. Like its English counterpart, the Dutch LexTALE was designed for L2 users, assuming that L1 users will most likely perform at ceiling level. While Dutch is the L1 for all participants in the current study, they have all lived in an L2 environment for considerable amounts of time, which has likely led to (varying degrees of) language attrition in the L1. The resulting differences in participants' L1 proficiency may therefore still be brought to light by the Dutch LexTALE.

Measure B was computed by subtracting participants' LexTALE score for the L1 from the score they obtained on the LexTALE for the L2. Thus, a positive score indicated L2-dominance, whereas a negative score was interpreted as L1-dominance. Participants who obtained identical scores in both languages were excluded from classification as dominant in either language.

Measure C: Self-reported L1 use

Participants' self-reported frequency of L1 use formed the basis for the final measure of language dominance. The multiple-choice question used to collect this information (Appendix A, question 34) was "How often do you speak Dutch nowadays?", and five answer options were provided. These were ‘rarely’, ‘a few times a year’, ‘monthly’, ‘weekly’, and ‘daily’. Language dominance according to Measure C was interpreted either as a variable with five dominance categories or as a binary variable. The latter interpretation classified participants who indicated that they used Dutch ‘rarely’, ‘a few times a year’, or ‘monthly’ as L2-dominant, and participants who reported daily use of Dutch as L1-dominant. Participants who used Dutch ‘weekly’ were not classified as dominant in either language.

Phonetic Flexibility in L1 and L2 Listening

Chapter 3

It has been well established that L1 listeners adjust rapidly to a new speaker's idiosyncrasies, such as foreign or novel accents, or other atypical pronunciations (e.g., Bradlow & Bent, 2008; Clarke & Garrett, 2004; Maye et al., 2008; Norris et al., 2003; Witteman et al., 2013). Listeners use their lexical knowledge to disambiguate any ambiguous pronunciations and shift the boundaries of their existing phoneme categories to accommodate for the idiosyncrasies in the new speaker's speech, in a process that is referred to as perceptual learning. Findings of recent perceptual learning studies suggest that this retuning process is also available to some L2 listeners (Drozdova et al., 2014; Drozdova, van Hout, & Scharenborg, 2015; Reinisch et al., 2013; Schuhmann, 2014; these studies are discussed in greater detail later in this chapter), but very little is known about how the L2 process compares to the retuning that is done in L1 listening, and many questions remain unanswered. The experiments reported in this chapter investigate perceptual learning in Dutch-English bilingual emigrants, and use an approach that is novel in several ways. Most importantly, the present study is, to the author's knowledge, the first to compare L1 and L2 perceptual learning within the same listeners. Furthermore, it is the first perceptual learning study with a population of emigrants that have lived in an L2 immersion environment for many years. Finally, as explained below in section 3.1, an innovative methodology is used for stimulus selection that takes into consideration the individual differences in the participant population.

The experiments reported in this chapter use the lexically guided perceptual learning paradigm developed by Norris et al. (2003). In their original study, Dutch listeners participated in a lexical decision task during which they were exposed to an ambiguous sound between /f/ and /s/. For one group of listeners, this ambiguous sound consistently occurred in a lexical context that favoured an interpretation as /f/ (e.g., *karaf*, 'carafe'). Another group of listeners heard the same ambiguous sound, but this time in lexical contexts that led them to interpret it as /s/ (e.g., *karkas*, 'carcass'). Listeners in a control group were exposed to the same ambiguous sound but always in a non-word context. The exposure phase was immediately followed by the test phase, which was the same for all listener groups and consisted of a phonetic categorisation task. Listeners heard stimuli from an [ɛf]-[ɛs] continuum and were asked to categorise them as containing /f/ or /s/. Listeners who had heard the ambiguous sound in lexical contexts favouring an /f/-interpretation categorised more stimuli from the [ɛf]-[ɛs] continuum as /f/ than listeners from the other, /s/-interpretation group. Listeners in the control group did not show such bias in their interpretation of the ambiguous sound; their responses fell in between those of the two other listener groups. This showed that listeners were able to shift the boundaries of their phoneme categories to allow for the correct interpretation of ambiguous sounds, and that the lexical context in which the ambiguous sounds occurred helped listeners decide how to reshape the categories.

It is not just lexical information that can induce perceptual learning. Phonotactics, for instance, can also guide the interpretation of ambiguous phonemes (Cutler, McQueen, Butterfield, & Norris, 2008). The phonotactic constraints of a language determine which phoneme sequences are permitted in that language. In English, for instance, words can start with /fr/ or /sn/, but sequences such as /fn/

and /sr/ are not permitted. Cutler et al. (2008) conducted an English experiment in analogue to Norris et al.'s (2003) study. The exposure phase consisted of a lexical decision task in which the ambiguous fricative [?] always occurred at the beginning of a nonword. For one group of listeners (the r-group), this was always before /r/ (e.g., *[?]rul*), for the other group (the n-group) it was always before /n/ (e.g., *[?]nud*). In the /r/-words, interpretation of the ambiguous sound as /f/ results in a consonant cluster that is phonotactically legal in English (e.g., *frul*), whereas interpretation as /s/ does not (e.g., **srul*). For the /n/ words, the /s/-interpretation was legal (e.g., *snud*) whereas the /f/-interpretation was not (e.g., **fnud*). During the test phase, listeners in the r-group were found to categorise the ambiguous fricative more often as /f/ than /s/ and listeners in the n-group categorised the ambiguous sound more often as /s/ than /f/. Because the ambiguous sounds only occurred in nonwords, listeners could not rely on lexical information for the interpretation of these fricatives. Therefore, listeners appear to have instead made use of phonotactic information for disambiguation.

Since the original study by Norris et al. (2003), perceptual learning for speech perception has been shown to be robust and has been demonstrated with variations on the tasks that are used during exposure and test (for an overview, see Samuel & Kraljic, 2009). For instance, training can consist of word-tallying (McQueen, Norris, & Cutler, 2006), picture verification (McQueen, Tyler, & Cutler, 2012), or listening to a story (Eisner & McQueen, 2006) or to highly predictable sentences (Zhang & Samuel, 2014).

Cross-modal identity-priming has successfully been used during the test phase to demonstrate perceptual learning (Eisner, Melinger, & Weber, 2013; McQueen, Cutler, & Norris, 2006; Sjerps & Mcqueen, 2010), and so has phoneme discrimination, as was shown by Clarke-Davidson, Luce, and Sawusch (2008), who used an AXB discrimination task to test perceptual learning. The visual world paradigm has been used in the test phase as well (Mitterer & Reinisch, 2013; Poellmann, McQueen, & Mitterer, 2011). The perceptual learning effect occurs for lexical tones (Mitterer, Chen, & Zhou, 2011), and for different types of phonemes, such as fricatives (Eisner & McQueen, 2006; Kraljic & Samuel, 2005, 2007; McQueen, Cutler, et al., 2006; McQueen, Norris, et al., 2006; Norris et al., 2003), stops (Eisner et al., 2013; Kraljic & Samuel, 2007), liquids (Mitterer, Scharenborg, & McQueen, 2013; Scharenborg, Mitterer, & McQueen, 2011) and vowels (McQueen & Mitterer, 2005). Evidence suggests that the effect is speaker-specific (i.e., listeners adjust their phoneme categories for a particular speaker but do not generalise this adaptation to other speakers), at least for fricatives produced by similar-sounding speakers (Eisner & McQueen, 2005; Kraljic & Samuel, 2005; Reinisch & Holt, 2014; see Kraljic & Samuel, 2007, for a different effect for stops), and long-lasting: Eisner and McQueen (2006) found perceptual learning 12 hours after exposure, regardless of whether participants spent most of those hours asleep or awake. And although the typical participants for many of these experiments are university students, perceptual learning occurs across the life span: the effect has been found for six- and twelve-year old children (McQueen et al., 2012) as well as for older listeners (Scharenborg & Janse, 2013; Scharenborg, Janse, & Weber, 2012; Scharenborg, Weber, & Janse, 2015). It has been shown that listeners adapt to a talker across languages (i.e., exposure to a speaker in one language leads to adaptation for that same speaker even in a different language; Reinisch et al., 2013; Schuhmann, 2014) and to talkers with a non-native accent (Eisner et al., 2013; Reinisch & Holt, 2014).

Lastly, and as noted at the beginning of this chapter, perceptual learning also occurs for L2 listeners (Drozdova et al., 2014; Reinisch et al., 2013; Schuhmann, 2014; but see Cutler, Bruggeman, & Antoniou, 2015). Reinisch et al. (2013) compared Dutch L1 listeners', and German L2 listeners' perceptual learning of a Dutch ambiguous fricative between /f/ and /s/. All participants lived in the Netherlands at the time of testing, which constituted an L2 immersion environment for the German-speaking participants. As in the original study by Norris et al. (2003), a lexical decision task served as the exposure phase. In the test phase, listeners categorised the ambiguous final phoneme of Dutch minimal pairs (e.g., *doos – doof*, 'box-deaf'). Results showed that retuning of Dutch phoneme categories /f/ and /s/ was just as strong for the L2 listeners as it was for the L1 listeners. No measures were taken, however, of the duration of the perceptual learning effect, nor of how quickly the effect occurred. While these results showed that perceptual learning can occur in L2, they were restricted to L2 listeners in an L2-immersion situation. An experiment with L2 listeners in a *non*-immersion environment is reported in Schuhmann (2014). Participants in this study were German L2 listeners of English who lived in Germany. The experiment consisted of a lexical decision task and a phoneme categorisation task, and used an American-English ambiguous fricative between /f/ and /s/. Schuhmann's (2014) results show that German L2 listeners retune their phoneme categories in English. However, please note that although German was the L1 for all listeners, over 20% of participants in this study grew up using other languages as well, which may have influenced their perception and categorisation of English fricatives. Additional evidence for perceptual learning by non-immersed L2 listeners comes from two studies by Drozdova et al. (2014; 2015). In these studies, Dutch L2 listeners in the Netherlands were exposed to a British-English story containing an ambiguous sound between /l/ and /r/, and subsequently performed a phonetic categorisation task in which they categorised the ambiguous sound in English minimal pairs, such as *arrive* and *alive*. Perceptual learning was found for listeners in both studies. As can be seen from the above, however, all of the aforementioned studies that examined perceptual learning in L2 listening were based on comparisons between different groups of listeners. To the best of the author's knowledge, no study to date has investigated whether there are any cross-language perceptual learning differences within the same listeners.

Thus, despite the fact that listeners in immersion and in non-immersion situations appear to possess the flexibility to adapt to novel talkers in the L2, there are still many unanswered questions. Can listeners become as flexible in L2 as they are in L1? Are there any prerequisites for achieving L2 flexibility? And does phonetic listening flexibility in the L2 come at the cost of a decline in L1 listening flexibility (whether it be temporarily or permanently)? The experiments reported in this chapter set out to address these questions by investigating L1 (Dutch) and L2 (English) lexically guided perceptual learning effects in Dutch-English bilingual emigrants. They assess whether these listeners retune the boundaries of their phoneme categories in L1 and L2 listening, and how this flexibility compares. Importantly, they do so within the same listeners. If the emigrants are as flexible in L2 listening as in L1 listening, similar perceptual learning effects are predicted for L1 and L2. If listening is less flexible in either of the emigrants' languages, the emigrants are predicted to show weaker or no effects of perceptual learning in that language.

3.1. Design of the series of experiments

Listeners participated in two perceptual learning experiments, approximately three weeks apart (M = 21.6 days, SD = 4.18, range: 14 – 28). During one session, all stimulus materials and tasks were in Dutch (the 'Dutch session'), while during the other session, they were in English (the 'English session'). The order of sessions was counterbalanced across participants. The experimenter was a native speaker of Dutch who is fluent in English and the language that was spoken with the experimenter during a session depended on the participant's preference. For the majority of participants this was Dutch. During the English session, several participants temporarily switched to speaking English immediately after completing an experimental task. To assess participants’ proficiency in Dutch and English, both experimental sessions contained the appropriate language version of the Lexical Test for Advanced Learners of English (LexTALE; Lemhöfer & Broersma, 2012).

The ambiguous sounds used in perceptual learning studies are typically created on a continuum by merging two sounds (e.g., /f/ and /s/) with a sample-averaging technique (e.g., Eisner & McQueen, 2005; Norris et al., 2003), or other morphing methods (e.g., Drozdova et al., 2014; Reinisch et al., 2013). Speech sounds tend to be perceived categorically (Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967), so that listeners perceive no gradual change between subsequent steps on the continuum. Instead, sounds on one end of, the continuum are perceived as belonging to one phoneme category (e.g., /f/), while sounds on the other end of the continuum are perceived as a different category (e.g., /s/). The most ambiguous sound on the continuum is the sound that is closest to the cross-over point between the two categories. In most studies investigating lexically-guided perceptual learning, the ambiguous sound that is used in the exposure and test phase is selected based on a pre-test that is carried out on a separate group of participants. Results of this pre-test reveal the cross-over point between phoneme categories. In this study, instead, an individual pre-test was conducted for each participant, allowing for individual tailoring of the exposure and test phase. This approach was chosen since participants' length of residence in Australia varied considerably (range: 9 months – 55 years), leading to differences in the total amount of exposure participants had received to both Dutch and English throughout their lives. This was expected to influence participants' initial perception and categorisation of the fricative continuum. Choosing the most ambiguous fricative sound [?] for each participant individually allowed for potential perceptual learning effects to be more easily observed.

The inclusion of a pre-test in the testing session, however, comes with a potential drawback. As mentioned before, most studies examining lexically-guided perceptual learning conduct a separate pre-test and do not include this task in the main experiment. Participants therefore start the exposure phase with no preconceived ideas regarding the purpose of the experiment. Preceding the exposure phase with an [f]-[s] phonetic categorisation task may draw participants' attention to the importance of these fricatives in the subsequent experimental tasks. To mask this importance, a filler task was inserted after the pre-test but before the exposure phase. In this filler task (henceforth referred to as vowel pre-test), participants were asked to categorise vowels on an [ɔ]-[ɑ] continuum. A similar filler task was added to the test phase of the first testing session (the vowel post-test), as participants still had to complete the second session of the experiment a few weeks later.

Thus, as can be seen in Table 3-1, each testing session started with two phoneme categorisation tasks: the fricative pre-test and subsequent vowel pre-test. This was followed in both sessions by the LexTALE proficiency test (Lemhöfer & Broersma, 2012), the auditory lexical decision task and the post-test. In the first experimental session, participants then completed the vowel post-test. Finally, participants' hearing acuity was assessed and participants completed a language background questionnaire (see Appendix A). In the second session, the vowel post-test, hearing test and questionnaire were omitted and replaced with an extra post-test, consisting of a phonetic categorisation task. This task was carried out in the language of the first session. So, for example, if a participant completed the Dutch session first and the English session second, the additional phonetic categorisation task in the second session was conducted in Dutch. This test was added to investigate the duration and strength of any potential perceptual learning effects found during the first session.[6] Participants had to remain inside the sound-attenuated booth between the lexical decision task and the post-test in an effort to keep testing circumstances the same for all participants, as interactions with the experimenter may have affected the outcome of the experiment, in particular since the language of communication may have varied between participants. Participants were allowed to leave the testing booth for a short break in between other components of the experiment.

Table 3-1. Order and duration of tasks in testing sessions 1 and 2 of Experiment-3-1.

	Session 1 – Language A	**Session 2 – Language B**	
(1)	fricative pre-test	fricative pre-test	(±25 min)
	vowel pre-test	vowel pre-test	
(2)	LexTALE	LexTALE	(±5 min)
(3)	exposure	exposure	(±20 min)
	fricative post-test	fricative post-test	
	vowel post-test	extra post-test (Language A)	
(4)	pure-tone audiogram		(±8 min)
(5)	language background questionnaire		(±30 min)

[6] Unfortunately, participant numbers were too small to draw any conclusions regarding this issue. Results of the extra post-test can be found in Appendix B.

3.2. Experiment 3-1a – English (L2)

3.2.1. Method

3.2.1.1. Participants

Thirty-two participants (21 females and 11 males; age range 24 – 73 years, *M* = 47.8, *SD* = 16.8) were recruited from the Dutch immigrant community in the wider Sydney area and paid for their participation. One additional participant's data were excluded from analysis because it was revealed after testing had been completed that he had lived in Australia during childhood, and a further participant's data were excluded because he did not complete the testing session. All included participants were born and raised in the Netherlands, were native speakers of Dutch and had migrated to Australia as adults (mean age at migration = 28.5 years, *SD* = 7.4, range: 18 – 52). The mean length of residence in Australia was 19.4 years (*SD* = 16.7, range: 9 months – 55 years). Participants' mean score on the English version of LexTALE (Lemhöfer & Broersma, 2012) was 91.4 % (*SD* = 8.8, range: 62.5 – 100%), indicating a relatively high proficiency in English. Pure-tone air conduction thresholds were determined for all participants. The mean threshold for the better ear (averaged over 0.5, 1, and 2 kHz) was 4.1 dB HL (range: -3.3 – 20.0 dB HL, *SD* = 20.0). High-frequency thresholds for the better ear (averaged over 4 and 8 kHz) ranged from -2.5 – 55 dB HL (*M* = 19.1 dB HL, *SD* = 19.1). None of the participants wore hearing aids in their daily life. Prior to the start of the experiment, written informed consent was obtained from each participant for whom this was the initial testing session.

3.2.1.2. Stimulus materials

3.2.1.2.1. Phonetic categorisation

The syllables /ɛf/, /ɛs/, and /ɛθ/, and /tɒ/, /tʌ/, and /tə/[7] were recorded by a female native speaker of Australian English. Recordings were made digitally (sampling rate 44.1 kHz, sampling resolution 16-bit) in a sound-attenuated booth. From the recordings of [ɛf] and [ɛs], the [f] and [s] sounds were isolated using PRAAT (Boersma & Weenink, 2013). Following Norris et al. (2003), fricatives were cut from a zero-crossing at frication onset to a zero-crossing near the end of frication. To facilitate the creation of a continuum, the duration of both fricatives was kept the same at 218 ms. Using a sample-averaging method (Repp, 1981), the isolated [s] and [f] sounds were then merged to create a 41-step [s]-[f] continuum. As its name suggests, this method entailed the sample-by-sample averaging of the amplitudes of [s] and [f]. Different proportions of each sound were used for each step of the continuum, so that all steps were equidistant from one another. Thus, step 1 consisted of 100% [s] and 0% [f], step 21 of 50% [s] and 50% [f], and step 41 of 0% [s] and 100% [f].

For use in the phonetic categorisation tasks, each step of this continuum was then spliced onto the [ɛ] part (173 ms) of the [ɛθ] recording to create a 41-step [ɛf]-[ɛs] continuum. Using [ɛ] from [ɛθ], and not from [ɛf] or [ɛs], ensured that the acoustic cues contained in the [ɛ] sound would not bias listeners' fricative categorisation towards either /f/ or /s/. Results of a pilot phonetic categorisation experiment (see Appendix C) confirmed that this continuum was perceived categorically. The pre-test consisted of six blocks. In each block, participants were presented once with all 41 steps of the [ɛf]-[ɛs] continuum, in random order, and were asked to categorise the

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[7] All phonetic transcriptions of Australian English in this dissertation follow Mitchell and Delbridge (1965).

final sound of each token as either /f/ or /s/. The results from each participant's pre-test determined which step of the [f]-[s] continuum was then used as the ambiguous fricative sound (denoted here as [?]) in the exposure phase for that participant. This was always the step that received closest to 50 percent /f/-responses in the pre-test. For each participant, four additional sounds from the continuum were selected for use in the test phase that followed the exposure. These sounds corresponded to the steps on the continuum that received approximately 90, 70, 30 and 10 percent /f/-responses in the pre-test.

In the vowel pre-test, participants categorised the vowel portion of a 41-step [tɒ]-[tʌ] continuum. This continuum was created using the same methodology as was used to construct the [ɛf]-[ɛs] continuum. Vowels were taken from the syllables [tɒ] and [tʌ], and after an [ɒ]-[ʌ] continuum had been created, each step was spliced onto a [t] that had been taken from the recorded syllable [tə]. This resulted in a 41-step [tɒ]-[tʌ] continuum. As the vowel pre-test was a filler task that was designed merely to mask the purpose of the present study, not all steps from this continuum were used. Instead, ten steps spanning the entire continuum were selected for the vowel pre-test. These were steps 1, 5, 9, 13, 17, 23, 29, 33, 37, and 41. As in the fricative post-test, five steps were used in the vowel post-test; these were steps 1, 11, 21, 31, and 41.

3.2.1.2.2. Auditory lexical decision

The stimulus materials for the exposure phase of the experiment were recorded by the same speaker as above. They consisted of 40 critical words (see Appendix D), 60 filler words and 100 non-words. Twenty of the critical words ended in /f/, and twenty ended in /s/. No [f], [v], [s], [z], [ʧ]or [ʤ] sounds occurred in any of the stimuli, apart from in word-final position in the critical stimuli. In addition, to avoid co-activation of lexical items in Dutch, none of the critical fricative-final items were cognates in Dutch and English. Six of the critical /f/-final and six of the critical /s/-final words were monosyllabic (such as *rough* and *dress*), 11 each were disyllabic (e.g., *midwife* and *embrace*) and three words of each type contained three syllables (e.g., *autograph* and *hideous*). Mean word form frequency as computed from the CELEX lexical database of English (Baayen, Piepenbrock, & Gulikers, 1995) was 37 per million for the /f/-final words, and 33 per million for the /s/-final words. All critical words were recorded both naturally and with a word-final [θ] (e.g., *embrace* was recorded both as [ɛm'breɪs] and as [ɛm'breɪθ]) and these latter recordings were used to create the ambiguous stimuli. Ambiguous versions of the critical words were created by removing the final [θ] sound and splicing the ambiguous fricative sound [?] onto the final vowel of the remaining word.

Two stimulus lists were created for the lexical decision task, both containing the 20 critical /f/-final words, the 20 critical /s/-final words, 60 filler words and 100 non-words. One of the lists contained natural versions of all /f/-final words, and ambiguous versions of all /s/-final words. The other stimulus list was constructed using ambiguous versions of all /f/-final words, and natural versions of all /s/-final words. Stimulus order was randomised per participant, with the exception of the first twelve trials, which contained the same six filler words and six non-words in the same order for all participants.

3.2.1.3. Procedure

Participants were tested individually and were seated in front of a computer screen in a sound-attenuated booth. The LexTALE task was presented in MATLAB (R2013b; The MathWorks, Inc.), all other computer tasks were conducted using DMDX (version 4.3.0.0; Forster & Forster, 2003). Auditory stimuli were presented over Sennheiser HD 650 headphones at a comfortable sound level, kept constant for all participants. Instructions for all tasks were provided in written form (displayed on the screen or printed on paper) in English and were subsequently repeated orally by the experimenter to ensure participants fully understood the tasks.

3.2.1.3.1. Pre-test: Phonetic categorisation

Each testing session started with two phoneme categorisation tasks. The first task, the pre-test, consisted of six blocks, each containing all 41 steps of the [ɛf]-[ɛs] continuum in random order, for a total number of 246 trials. Participants were asked to categorise the final sound of each token as either /f/ or /s/ using the left and right shift buttons on a keyboard. They were told to respond both quickly and accurately. The letters F and S were presented on either side of the computer screen, above the corresponding shift key. For half of the participants, the /f/-response was assigned to their dominant hand, for the other half of the participants the /s/-response was assigned to their dominant hand. There was no time limit for participants to respond to a trial and stimuli were always presented 1.5 s after the response to the previous trial. After each block, participants were given the opportunity to take a short break, although they had to remain in the experiment booth. Immediately after this task, participants completed the second phonetic categorisation task, that is, the vowel pre-test, which consisted of two blocks of 30 trials each (three repetitions of ten selected steps from the [tɒ]-[tʌ] continuum) in randomised order. Participants categorised the final sound of each token as either /ɒ/ or /ʌ/ using the left and right shift buttons on a keyboard. They were once again instructed to respond both quickly and accurately. All participants made /ɒ/-responses with their left hand and /ʌ/-responses with their right. Because of the weak phoneme-grapheme correspondence for /ɒ/ and /ʌ/, three words were displayed on either side of the screen to indicate which shift key corresponded to each response option. Thus, the words *on*, *dog*, and *cough* were displayed on the left side of the screen, while the words *up*, *mud*, and *rough* were displayed on the right. As in the fricative pre-test, the intertrial interval was 1.5 s and there was no time limit on participants' responses.

3.2.1.3.2. LexTALE

Upon completion of the pre-test, participants completed the English version of the LexTALE Lexical Test for Advanced Learners of English (Lemhöfer & Broersma, 2012). Participants were told to take as much time as they wanted to complete the task. Unbeknownst to participants, the experimenter analysed the results of the pre-test while participants completed the LexTALE test, so that the ambiguous fricatives for use in the exposure phase of the experiment could be selected.

3.2.1.3.3. Exposure: Auditory lexical decision

Participants then moved on to the auditory lexical decision task, in which they had to indicate, using the left and right shift buttons, whether the items they heard were real existing English words or nonsense words. Participants were told to answer both quickly and accurately. There were 200 trials and ‘word’-responses were always given with the participant's dominant hand. The texts ‘word’ and ‘not a word’ were displayed on either side of the computer screen, above the corresponding shift key. There was no time limit for participants' responses and the next word was presented 1 s after participants had responded to the previous trial.

3.2.1.3.4. Post-test: Phonetic categorisation

Immediately after the lexical decision task, participants continued with the post-test, which was a phoneme categorisation task. To keep the amount of interaction with the experimenter (i.e., the amount and type of language used) constant between participants, participants were required to remain in the testing booth in between the exposure and the post-test and not interact with anyone. Consequently, instructions for the post-test were only presented on the screen and not further explained orally. As the task in the post-test was identical to that of the pre-test, participants were expected to understand the written instructions easily.

During the fricative post-test, the procedure was identical to that of the pre-test. The same response button was assigned to a participant's dominant hand as during the pre-test, so that for half of the participants, the /f/-response was assigned to their dominant hand, and for the other half of the participants the /s/-response was assigned to their dominant hand. The post-test contained twelve repetitions of five steps of the [ɛf]-[ɛs] continuum, corresponding to those steps that had resulted in 10%, 30%, 50%, 70% and 90% /f/-responses during the participant's pre-test. In total, there were 60 trials in the post-test.

As shown in Table 3-1, if the English session was the second session of the experiment, the fricative post-test was followed only by the extra post-test from Experiment 3-1b. This extra post-test was identical to the fricative post-test of that experiment. If the English session was the first, however, the fricative post-test was followed by several further tasks, the first of which was the vowel post-test.

The vowel post-test immediately followed the fricative post-test and was identical to the vowel pre-test, with the exception of the stimuli that were used. The vowel post-test contained twelve repetitions of five steps of the [tɒ]-[tʌ] continuum, resulting in a total of 60 trials.

3.2.1.3.5. Pure-tone audiogram and language background questionnaire

In the first session only, once participants had completed the vowel post-test, a hearing assessment was conducted in the sound-attenuated booth, using a portable Earscan 3 screening audiometer (Micro Audiometrics Corp.). For screening purposes, pure-tone air conduction thresholds were obtained for octave frequencies from 250 Hz – 8kHz. Finally, participants filled in a background questionnaire. The questionnaire was available in Dutch and in English and participants chose which version they filled in.[8]

3.2.2. Results

3.2.2.1. Pre-test: Phonetic categorisation

Figure 3-1 shows categorisation results from the fricative pre-test, with natural /s/ on the left and natural /f/ on the right. Steps towards the natural /s/-end of the continuum were perceived as [s] most of the time, while steps towards the opposite end of the continuum were most frequently perceived as [f]. The most ambiguous step for the Dutch emigrants was, on average, step 20.

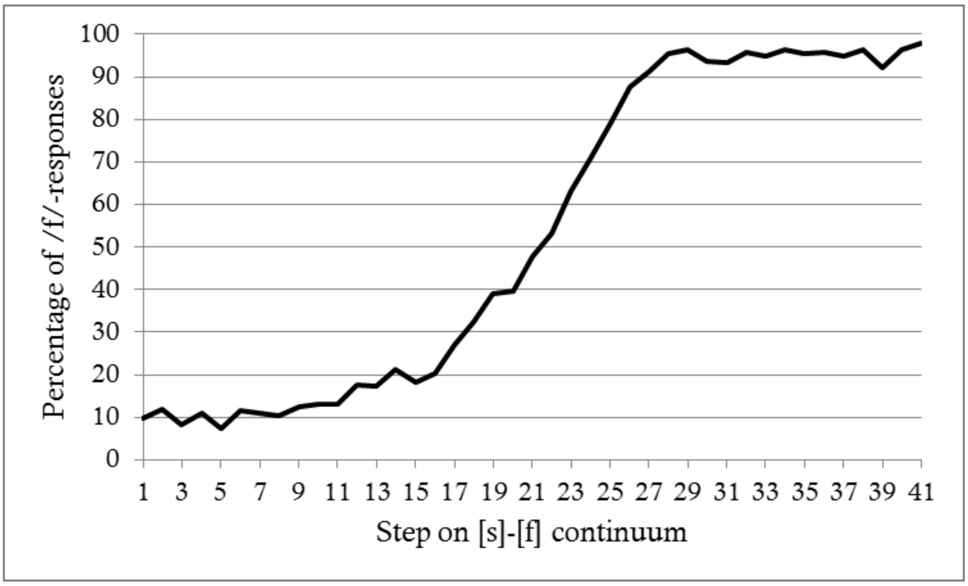

Figure 3-1. Mean percentage of /f/-responses to the 41-step continuum in the fricative pre-test of Experiment 3-1a. Step 1 corresponds to natural /s/, step 41 to natural /f/.

[8] Participants' questionnaire selection was intended to be used as an additional indication of their language dominance. However, only three participants chose the English questionnaire. Paired with the observation that the vast majority of participants opted to communicate with the experimenter in Dutch it appears that participants were making an effort to "be Dutch", so no inferences were made from participants' choice of questionnaire.

Stimulus selection for the exposure and post-test phases of the experiment was based on individual participants' categorisation of the 41-step [ɛf]-[ɛs] continuum during the pre-test. Three participants did not perceive the continuum categorically during pre-test and their results were therefore excluded from any further analysis. Note that while the age of these excluded participants ranged from 68-73, and their hearing thresholds were elevated in the 4-8 kHz range, these factors are unlikely to be related to their non-categorical perception, since these same participants did perceive the Dutch [ɛf]-[ɛs] continuum (as presented to them in the pre-test of the Dutch version of the experiment) categorically. In addition, two other participants with similar hearing deficits, aged 42 and 69, showed normal categorical perception, so that the non-categorical perception of the three excluded participants seems to be a language-specific matter.

For each of the remaining 29 participants, five steps of the [ɛf]-[ɛs] continuum were selected for use in the exposure and post-test phase. These were the steps that had received approximately 10%, 30%, 50%, 70% and 90% /f/-responses during that participant's pre-test (henceforth referred to as step A-E, respectively). Upon completion of the pre-test, participants were randomly assigned to one of two exposure conditions. To verify that the selected stimuli were equally ambiguous for the two exposure groups, the mean percentages of /f/-responses for steps A-E for participants in both groups were compared (see Figure 3-2). A repeated-measures ANOVA confirmed that there were no differences between the percentage of [f]-responses for steps A-E for participants in the f-bias group (i.e., participants exposed to natural /s/-final words (e.g., *dress*) and ambiguous /f/-final words (e.g., *bee[?]*) in the exposure phase) and participants in the s-bias group (i.e., participants exposed to natural /f/-final words (e.g., *beef*) and ambiguous /s/-final words (e.g., *dre[?]*) in the exposure phase). This means that any potential categorisation difference between the two exposure conditions in the post-test could not be due to pre-existing differences caused by poor stimulus selection or any other factor.

Categorisation results for the vowel pre-test are displayed in Figure 3-3 and show a clear categorical perception of the [tɒ]-[tʌ] continuum.

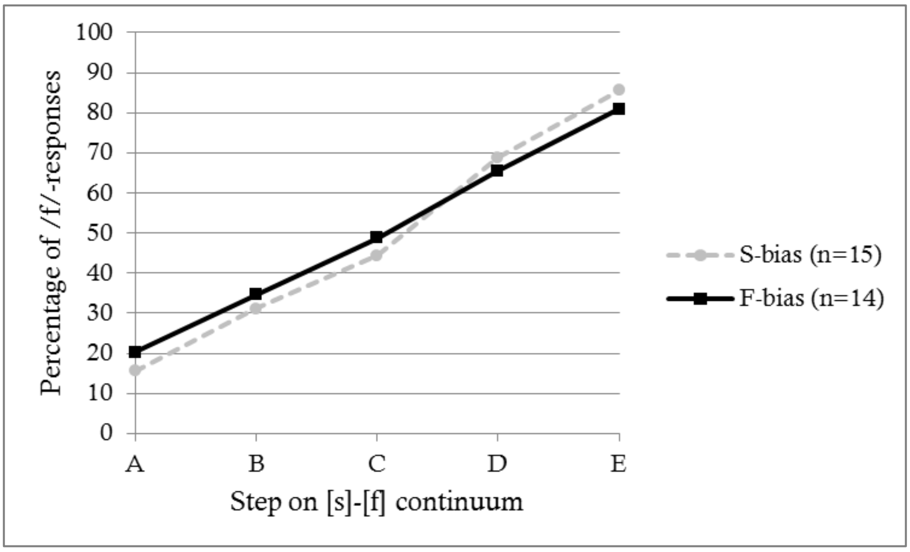

Figure 3-2. Mean percentage of /f/-responses to the five steps that were selected from the fricative pre-test of Experiment 3-1a for use in the exposure and post-test phase. The solid black line shows participants who were later assigned to the f-bias group, and the dashed grey line shows participants in the s-bias group.

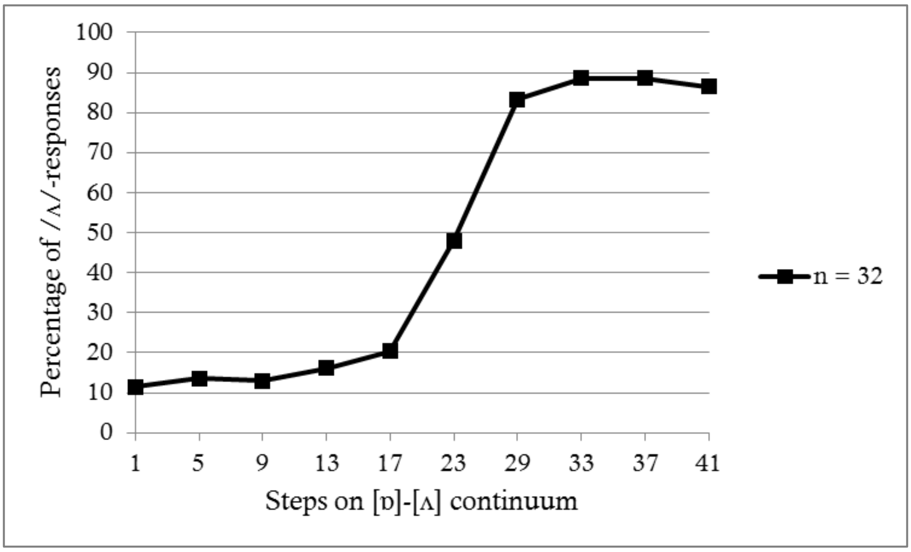

Figure 3-3. Mean percentage of /ʌ/-responses to the 41-step continuum in the vowel pre-test of Experiment 3-1a. Step 1 corresponds to natural /ɒ/, step 41 to natural /ʌ/.

3.2.2.2. Exposure: Auditory lexical decision

Following Norris et al. (2003), all participants who accepted less than 50% of [?]-final items as words during the exposure phase were excluded from further analysis. This was the case for three participants, who had all been exposed to natural /s/-final words and ambiguous /f/-final words (the f-bias group). Due to a technical glitch, results from one further participant were not saved and could therefore not be analysed. Thus, the results of 25 participants were included in the analyses reported below; 11 listeners in the f-bias group and 14 listeners who were exposed to natural /f/-final words and ambiguous /s/-final words (the s-bias group).

None of the filler items contained any fricatives, so all participants – regardless of exposure condition – were presented with the same filler words and non-words. Listeners in the f-bias group correctly responded ‘yes’ to 96.1% of word filler items and ‘no’ to 83.8% of non-word filler items. Listeners in the other exposure condition (i.e., the s-bias group) gave ‘yes’-responses for 94.3% of word filler items and ‘no’-responses for 88.8% of non-word filler items. A repeated measures ANOVA by participant (F_1) and by item (F_2) found no main effect of exposure bias, indicating that listeners in both groups responded to the filler words and non-words with equal accuracy.

Responses to the fricative-final experimental items are shown in Table 3-2. The ambiguous words were most often rejected as existing words by listeners in the f-bias group; only 84.1% of these items received a ‘yes’ response. (If the responses of the three excluded participants are included, this percentage drops to 70.7%.)

Table 3-2. Response times and percentage of correct responses to experimental items in Experiment 3-1a. Response times are measured from target word onset.

	f-bias group		**s-bias group**	
	natural fricatives	ambiguous fricatives	natural fricatives	ambiguous fricatives
Mean % 'yes'	88.6	84.1	93.2	90.0
Mean RT 'yes' (in ms)	1300	1399	1165	1262

Further ANOVAs by participant and by item revealed that the percentages of items accepted as words by listeners in the two exposure groups were not significantly different ($F_1(1,23) = 1.91$, $p = .180$; $F_2(1,38) = 2.51$, $p = .121$) likewise, naturally pronounced words were accepted as words equivalently often as words containing an ambiguous fricative ($F_1(1,23) = 1.05$, $p = .316$; $F_2(1,38) = 0.02$, $p = .878$).

3.2.2.3. Post-test: Phonetic categorisation

While one participant's lexical decision results were lost due to a technical fault and, therefore, could not be analysed, this same participant's phonetic categorisation data were available and were therefore included in the analyses. Thus, the results reported below are based on results obtained from 26 participants, 11 listeners in the f-bias group and 15 in the s-bias group.

Figure 3-4 shows the mean percentage of /f/-responses to all five ambiguous stimuli (steps A-E) in the phonetic categorisation task. The perceptual learning effect is represented by the difference between the two lines. An ANOVA on the percentage of /f/-responses to each of the five ambiguous fricative sounds showed main effects of step ($F_1(4, 96) = 31.26$, $p < .001$, $\eta_p^2 = .57$) and exposure bias ($F_1(1, 24) = 4.63$, $p = .042$, $\eta_p^2 = .17$). Listeners in the f-bias group, who were trained to interpret the ambiguous fricative sound [?]as /f/, categorised significantly more tokens as /f/ than listeners in the s-bias group (who had learned to interpret the ambiguous fricative

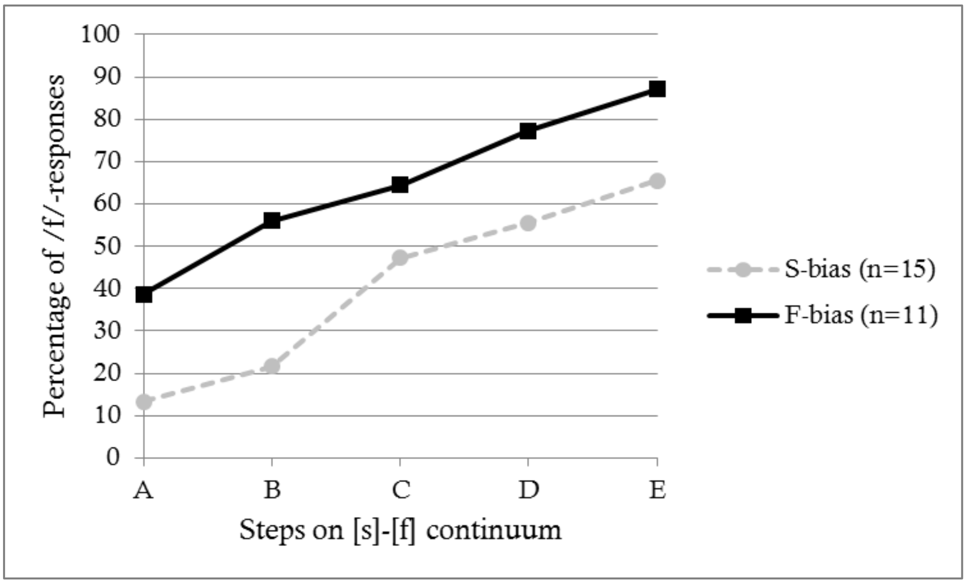

Figure 3-4. Mean percentage of /f/-responses in the fricative post-test of Experiment 3-1a for listeners in the f-bias and s-bias groups. Step A is the most /s/-like of the tested ambiguous stimuli, while step E is the most /f/-like.

sound [?] as /s/). This difference is an indication of perceptual learning; listeners have adjusted the boundaries of their phoneme categories to accommodate for the ambiguous pronunciation of the fricative sound [?] and have done so based on the lexical context in which this ambiguous fricative occurred. As some listeners completed the present experiment in session 1 and others in session 2 (i.e., after they had already participated in Experiment 3-1b), it was checked, by including session as a between-subjects factor in the analysis, whether the perceptual learning may have been the result of increased familiarity with the task. This was not the case.

Results from the vowel post-test are displayed in Figure 3-5 and show a clear categorical perception of the [tɒ]-[tʌ] continuum. As there was no vowel post-test in experiment session 2, only listeners for whom the English session was session 1 completed this task. Results are thus not available from all participants.

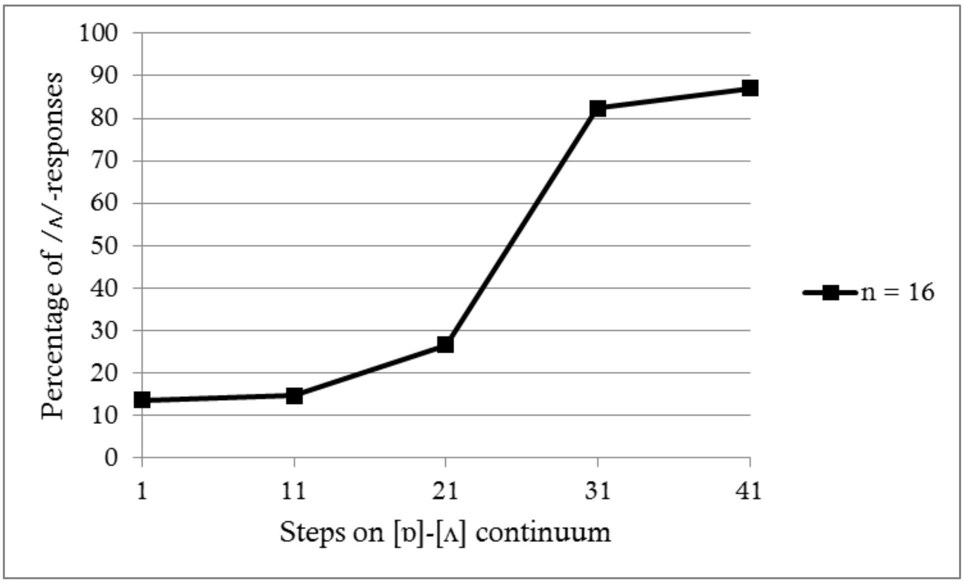

Figure 3-5. Mean percentage of /ʌ/-responses in the vowel post-test of Experiment 3-1a. Step 1 corresponds to natural /ɒ/, and step 41 to natural /ʌ/.

3.2.3. Discussion

The present experiment examined whether listeners who are immersed in an L2 environment possess the phonetic flexibility to adjust to new talkers in that L2 by adjusting their phoneme category boundaries. The results indicate that lexically guided perceptual learning occurs when native Dutch-speaking emigrants in Australia are exposed to English stimuli containing ambiguously pronounced fricatives. This finding provides support for previous research that found lexically guided perceptual learning in Dutch for German L2 listeners immersed in a Dutch language environment (Reinisch et al., 2013).

The experiment described above was the first in a series of experiments, the purpose of which was to investigate whether phonetic listening flexibility varies across different languages within the same listeners. The same listeners who participated in Experiment 3-1a therefore also completed Experiment 3-1b, a perceptual learning experiment with Dutch stimulus materials, which is discussed in the next section.

3.3. Experiment 3-1b – Dutch (L1)

3.3.1. Method

3.3.1.1. Participants

The same 32 participants from Experiment 3-1a (21 females and 11 males; aged 24 – 73 years, M = 47.8, SD =16.8) also participated in this experiment. Participants' mean score on the Dutch version of LexTALE (Lemhöfer & Broersma, 2012) was 92.2 % (SD = 5.08, range: 80 – 100%), indicating that, despite migration to a predominantly English-speaking country, all participants still maintained high proficiency in their L1. Prior to the start of the experiment, written informed consent was obtained from each participant who completed this experiment in the first testing session.

3.3.1.2. Stimulus materials

3.3.1.2.1. Phonetic categorisation

The syllables /ɛf/, /ɛs/ and /ɛθ/[9] were recorded by a female native speaker of Dutch. Recordings were made digitally (sampling rate 44.1 kHz, sampling resolution 16-bit) in a sound-attenuated booth. From these recordings, the [f] and [s] sounds were isolated and used to create a 41-step [f]-[s] continuum, using the same method as for the English continuum described in section 3.2.1.2.1 on page 47. Both fricative sounds were 345 ms in duration. For use in the phonetic categorisation tasks, each step of this continuum was then spliced onto the [ɛ] part (151 ms) of the [ɛθ] recording to create a 41-step [ɛf]-[ɛs] continuum. As in Experiment 3-1a, results of a pilot experiment (see Appendix E) confirmed that the continuum was perceived categorically.

[9] In this dissertation, phonetic transcriptions for Dutch follow Gussenhoven (1992).

The pre-test of the Dutch session was constructed in the same way as the pre-test of the English session, using the Dutch [ɛf]-[ɛs] continuum instead of the English.

The vowel pre-test was also constructed identically to that of the English session. Vowels for the 41-step [tɔ]-[tɑ] continuum were taken from two non-words that were recorded for the lexical decision part of this study; [ɑ] was excised from *medelkal* ([meːdəlkɑl]) and [ɔ] was taken from *kloerkotmood* ([klurkɔtmoːt]). Each step of the [ɔ]-[ɑ] continuum that was created from these vowels was spliced onto a [t] that had been taken from the word *datum* ([daːtʏm]), which had also been recorded for the lexical decision task. This resulted in a 41-step [tɔ]-[tɑ] continuum from which ten steps were selected for use in the filler task. As for the English session, these were steps 1, 5, 9, 13, 17, 23, 29, 33, 37 and 41.

3.3.1.2.2. Auditory lexical decision

The stimulus materials for the exposure phase of the experiment were recorded by the same speaker as above. Both stimuli and stimulus lists were constructed following the same method that was used to create the stimuli for Experiment 3-1a (see section 3.2.1.2.2). A list of all critical words can be found in Appendix F. The list of twenty /f/-final words and the list of twenty /s/-final words each consisted of two monosyllabic words (e.g., *braaf* 'honest' and *krijs* 'scream'), six disyllabic words (e.g., *doolhof* 'maze' and *matroos* 'sailor'), six words with three syllables (e.g., *ongeloof* 'disbelief' and *ananas* 'pineapple') and six words with four (e.g., *rentetarief* 'interest rate' and *bekentenis* 'confession'). Mean word form frequency as computed from the CELEX lexical database of Dutch (Baayen et al., 1995) was 3 per million for the /f/-final words, and 3 per million for the /s/-final words. By necessity, mean frequencies in this experiment were lower than those in Experiment 3-1a; after cognates had been excluded there were simply insufficient high-frequency /f/-final and /s/-final words available in Dutch.

3.3.1.3. Procedure

Participants were tested in the same way as described in section 3.2.1.3 for the English version of the experiment. Instructions for all tasks were provided in written form (displayed on the screen or printed on paper) in Dutch and were subsequently repeated orally by the experimenter to ensure participants fully understood the tasks. All text displayed on the screen during the experiment was in Dutch. Any differences between the English and Dutch sessions are listed in the sections below.

3.3.1.3.1. Pre- test: phonetic categorisation

During the vowel pre-test, the words *op*, *bot*, *post* ('on', 'bone', 'post') were displayed on the left side of the screen, and the words *as*, *tak*, *mand* ('ash', 'branch', 'basket') on the right, to indicate which shift key corresponded to each response option.

3.3.1.3.2. LexTALE

Upon completion of the pre-test, participants completed the Dutch version of the LexTALE (Lemhöfer & Broersma, 2012).

3.3.1.3.3. Exposure : auditory lexical decision

The texts *woord* ('word') and *geen woord* ('not a word') were displayed on either side of the computer screen, above the corresponding shift key to indicate which key corresponded to each response option.

3.3.1.3.4. Post-test: phonetic categorisation

The procedure for the fricative and vowel post-tests was identical to that of the English session. The extra post-test consisted of the fricative post-test of Experiment 3-1a.

3.3.2. Results

3.3.2.1. Pre-test: phonetic categorisation

Categorisation results from the fricative pre-test are shown in Figure 3-6. Steps on the /s/-side of the continuum (i.e., the left side) are clearly perceived as [s] most of the time, while steps towards the opposite end of the continuum are most frequently perceived as [f]. The fricative that was perceived as the most ambiguous, on average, was step 27.

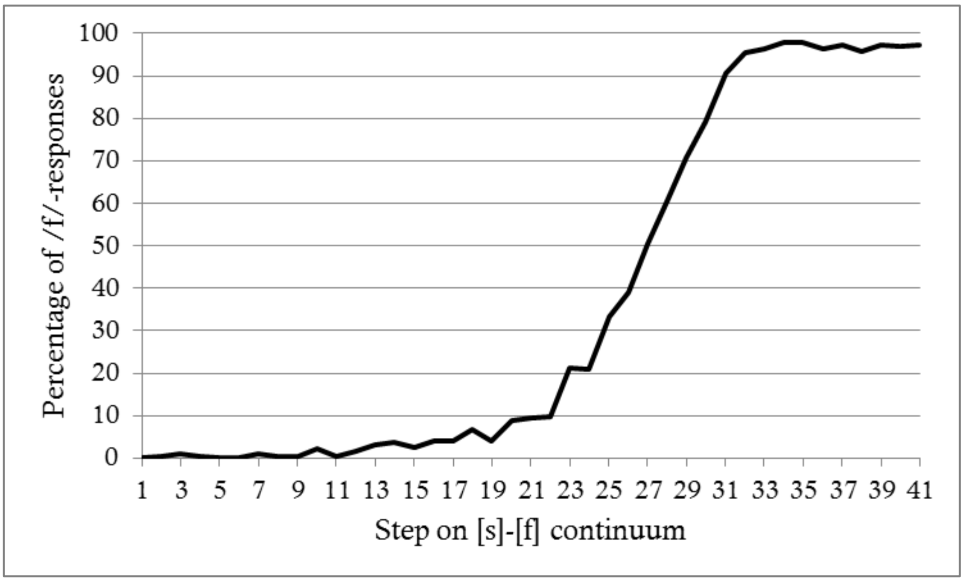

Figure 3-6. Mean percentage of /f/-responses to the 41-step continuum in the fricative pre-test of Experiment 3-1b. Step 1 corresponds to natural /s/, step 41 to natural /f/.

As in the English version of the experiment, stimulus selection for the exposure and fricative post-test phases was based each participant's own pre-test categorisation results; selected steps therefore varied from person to person. The selected ambiguous stimuli were those that received approximately 10% (step A), 30% (step B), 50% (step C), 70% (step D) and 90% (step E) /f/-responses from that particular participant. Upon completion of the pre-test, participants were randomly assigned to one of two exposure conditions. Figure 3-7 shows the mean percentages of /f/-responses for steps A-E for participants in both of these conditions.

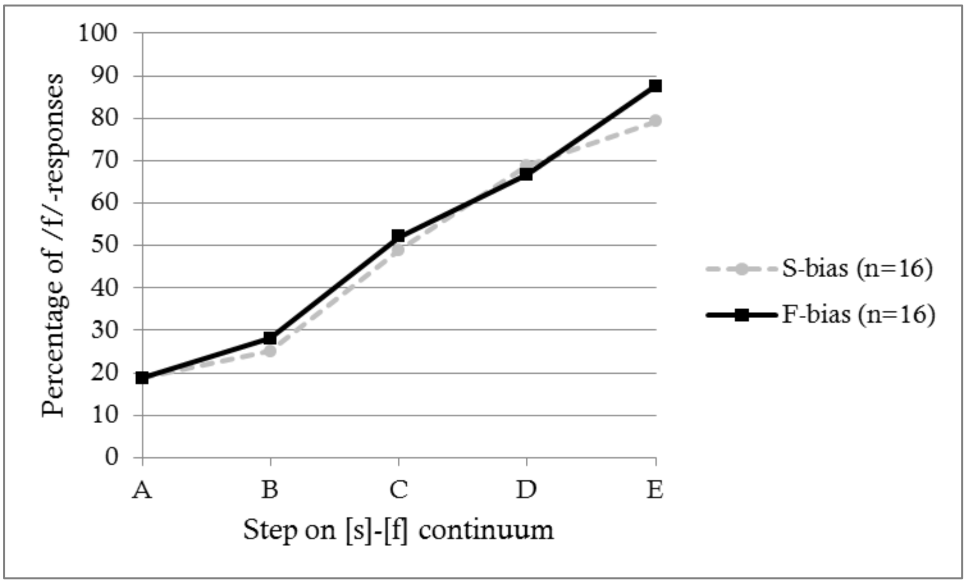

Figure 3-7. Mean percentage of /f/-responses to the five steps that were selected from the fricative pre-test of Experiment 3-1b for use in the exposure and post-test phase. The solid black line shows participants who were later assigned to the f-bias group, and the dashed grey line shows participants in the s-bias group.

A repeated-measures ANOVA revealed no differences between the percentage of [f]-responses for steps A-E for participants in the f-bias group (i.e., participants exposed to natural /s/-final words (e.g., *dress*) and ambiguous /f/-final words (e.g., *bee[?]*) in the exposure phase) and participants in the s-bias group (i.e., participants exposed to natural /f/-final words (e.g., *beef*) and ambiguous /s/-final words (e.g., *dre[?]*) in the exposure phase). Any categorisation differences that may be observed in the post-test are therefore unlikely to be due to stimulus selection.

Categorisation responses for the vowel pre-test are shown in Figure 3-9. Vowels of the [tɔ]-[tɑ] continuum are perceived categorically, albeit less so than in Experiment 3-1a. The observed pattern is not uncommon for vowels, as vowel categories are typically not perceived as discretely as those of consonants (Fry, Abramson, Eimas, & Liberman, 1962).

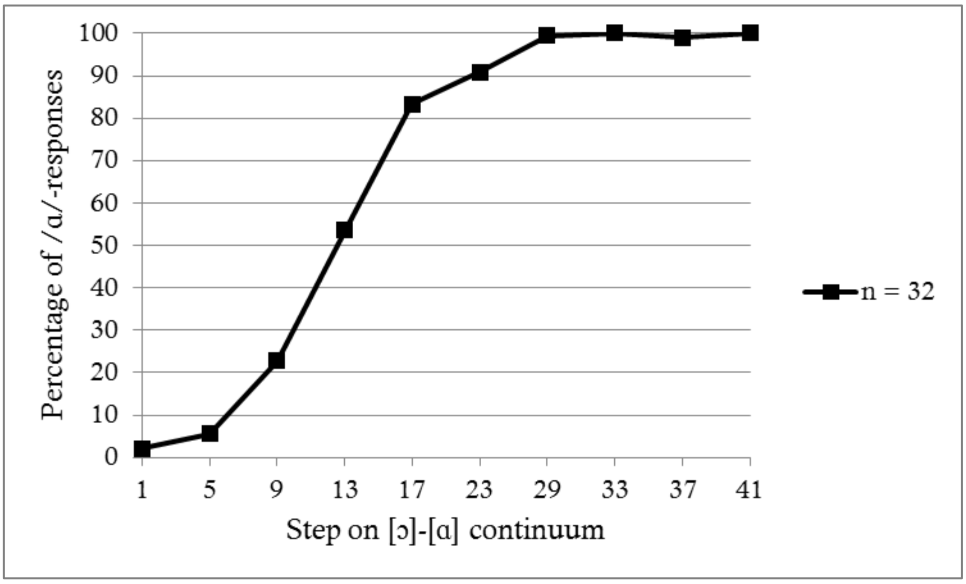

Figure 3-8. Mean percentage of /ɑ/-responses to the 41-step continuum in the vowel pre-test of Experiment 3-1b.Step 1 corresponds to natural /ɔ/, step 41 to natural /ɑ/.

3.3.2.2. Exposure : auditory lexical decision

The same exclusion criteria were used as in the English version of the experiment, so all participants who accepted less than 50% of [?]-final items as words during the exposure phase were excluded from further analysis. This was the case for three participants, who were all in the f-bias group (i.e., they had been exposed to natural /s/-final words and ambiguous /f/-final words). Thus, the results of 29 participants were included in the analyses; 13 listeners in the f-bias group and 16 listeners in the s-bias group (who were exposed to natural /f/-final words and ambiguous /s/-final words).

As none of the filler items contained any fricatives, all participants – regardless of exposure condition – were presented with the same filler words and non-words. Listeners in the f-bias group correctly responded 'yes' to 96.6% of word filler items and 'no' to 95.7% of non-word filler items. Similarly, listeners in the s-bias group correctly pressed 'yes' for 95.4% of word filler items and correctly responded 'no' for 96.2% of non-word filler items.

Responses to the fricative-final experimental items are shown in Table 3-3. Most often rejected were the ambiguous words presented to the f-bias group; only 82.3% of these items were accepted as existing words. If the responses of the three excluded participants are included, this percentage drops to 69.1%.

Table 3-3. Response times and percentage of correct responses to experimental items in Experiment 3-1b. Response times are measured from target word onset.

	f-bias group		**s-bias group**	
	natural fricatives	ambiguous fricatives	natural fricatives	ambiguous fricatives
Mean % 'yes'	97.3	82.3	96.9	92.5
Mean RT 'yes' (in ms)	1268	1479	1320	1325

Repeated measures ANOVAs by participant (F_1) and by item (F_2) found an interaction between exposure group and fricative type $F_1(1, 27) = 5.76$, $p = .024$, $\eta_p^2 = .18$; $F_2(1, 38) = 4.83$, $p = .034$, $\eta_p^2 = .11$). Simple main effects analysis shows that this interaction is driven by the relatively poor acceptance of the ambiguous /f/-final words (which were presented to listeners in the f-bias group). Whereas pronunciation (i.e., ambiguous vs natural) did not significantly affect the acceptance of /s/-final words ($F_1(1, 27) = 2.75$, $p = .109$), ambiguously pronounced /f/-final words were accepted significantly less often than naturally pronounced versions of these words ($F_1(1, 27) = 15.37$, $p = .001$).

3.3.2.3. Post-test: phonetic categorisation

Figure 3-9 shows the mean percentage of /f/-responses to all five ambiguous stimuli in the phonetic categorisation task. As expected, an ANOVA on the percentage of /f/-responses to each of the five ambiguous fricative sounds showed a main effect of step ($F_l(4, 108) = 30.17$, $p < .001$, $\eta_p^2 = .53$), indicating appropriate sensitivity to the continuum progression. However, it did not show any effect of exposure bias (F_l(1,

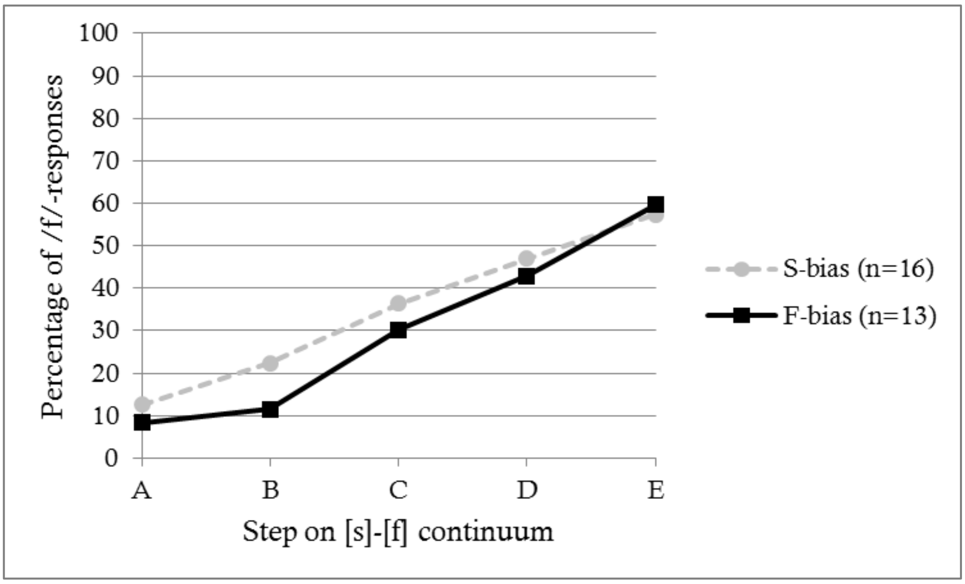

Figure 3-9. Mean percentage of /f/-responses in the fricative post-test of Experiment 3-1b for listeners in the f-bias and s-bias groups. Step A is the most /s/-like of the tested ambiguous stimuli, while step E is the most /f/-like.

27) = 0.26, p = .615), nor any interaction between exposure bias and step (F_1(4, 108) = 0.44, p = .780). Listeners in the two exposure conditions did not significantly differ in their categorisation of the ambiguous fricatives, which indicates that there is no evidence for perceptual learning. As in Experiment 3-1a, a separate analysis with session as a between-subjects factor showed that this finding does not appear to be related to the order of testing.

Results from the vowel post-test are displayed in Figure 3-10. As in the vowel pre-test, they show a clear categorical perception of the [tɔ]-[tɑ] continuum.

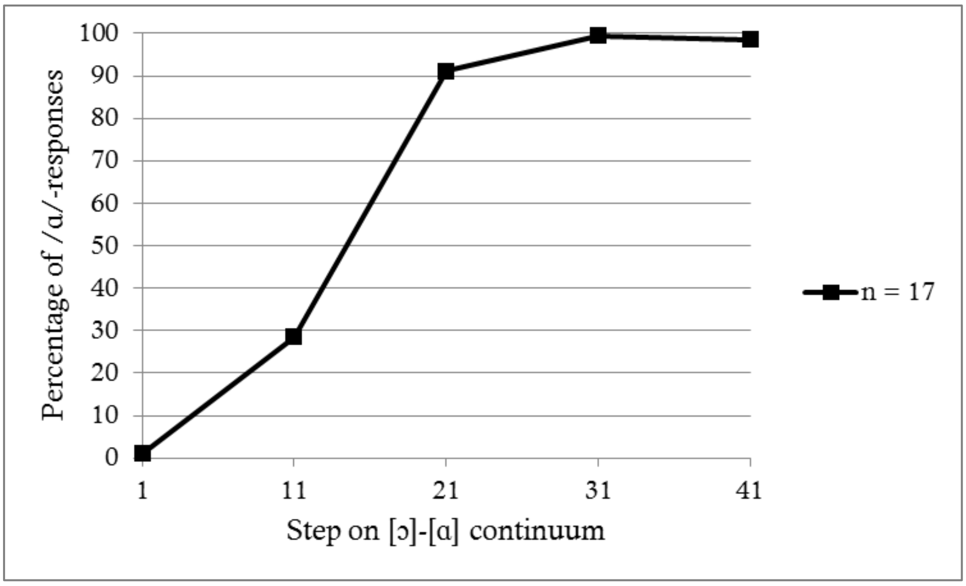

Figure 3-10. Mean percentage of /ɑ/-responses in the vowel post-test of Experiment 3-1b. Step 1 corresponds to natural /ɔ/, while step 41 corresponds to natural /ɑ/.

3.3.3. Interim discussion

No signs of lexically guided perceptual learning were found when native Dutch-speaking emigrants in Australia were exposed to Dutch stimuli containing ambiguously pronounced fricatives. While this finding suggests that the emigrants may have lost their ability to retune the boundaries of their phoneme categories in L1 listening, it is in stark contrast with the many previous studies that have found perceptual learning for L1 listeners of Dutch (e.g., Eisner & McQueen, 2005, 2006; Norris et al., 2003) . Therefore, to ensure that the experimental stimuli and procedure used in this study had the desired validity, Experiment 3-1b was replicated with a control group of native Dutch-speaking participants living in the Netherlands. This experiment is reported in section 3.3.4.1 below.

3.3.4. Control experiments

3.3.4.1. Experiment 3-2

3.3.4.1.1. Method

3.3.4.1.1.1. Participants

Thirty participants (19 females; aged 18-34 years, *M* = 23.1, *SD* = 4.2) were recruited from the participant pool of the Centre for Language Studies at the Radboud University Nijmegen, the Netherlands. They received a gift voucher in return for their participation. All participants were native speakers of Dutch and none reported any hearing problems. Participants' scores on the Dutch version of LexTALE (Lemhöfer & Broersma, 2012) were comparable to those of the Dutch emigrants of Experiment 3-1b, with a mean score of 92.5% (*SD* = 5.0, range: 76.3 – 100%). A further two participants' results were excluded from analysis as they grew up speaking languages other than Dutch. Written informed consent was obtained from all participants prior to the start of the experiment.

3.3.4.1.1.1.1. Stimulus materials

The stimulus materials used for this experiment were identical to those used for Experiment 3-1b (see sections 3.3.1.2).

3.3.4.1.1.1.2. Procedure

As in Experiment 3-1, participants were tested individually while seated in front of a computer screen in a sound-attenuated booth. The LexTALE task was presented in MATLAB (R2013b; The MathWorks, Inc.); all other computer tasks were conducted using DMDX (version 4.3.0.0; Forster & Forster, 2003). The order of the different stages of the experimental session can be seen in Table 3-4. Participants first completed the fricative pre-test and the vowel pre-test. They then continued with the LexTALE, the exposure phase and the post-test. At the end of the session, participants completed a brief language background questionnaire. There was no filler post-test, as there was no English session in the control experiment, so distraction from the purpose of the experiment was no longer necessary after the post-test. The same procedure as in Experiment 3-1b was followed for the tasks listed in Table 3-4 (see section 3.3.1.3). Auditory stimuli were presented over Sennheiser HD 215 headphones. The experimenter was a native speaker of Dutch, and all communication between the experimenter and participants was conducted in Dutch.

Table 3-4. Order of tasks within the testing session of Experiment 3-2.

	Experiment 3-2
(1)	fricative pre-test
	vowel pre-test
(2)	LexTALE
(3)	exposure
	fricative post-test
(4)	language background questionnaire

3.3.4.1.2. Results

3.3.4.1.2.1. Pre-test: Phonetic categorisation

Categorisation results from the fricative pre-test are shown in Figure 3-11. Steps on the /s/-side of the continuum (i.e., the left side) are clearly perceived as /s/ most of the time, while steps towards the opposite end of the continuum are most frequently perceived as /f/. The fricative that was perceived as the most ambiguous, on average, was step 25.

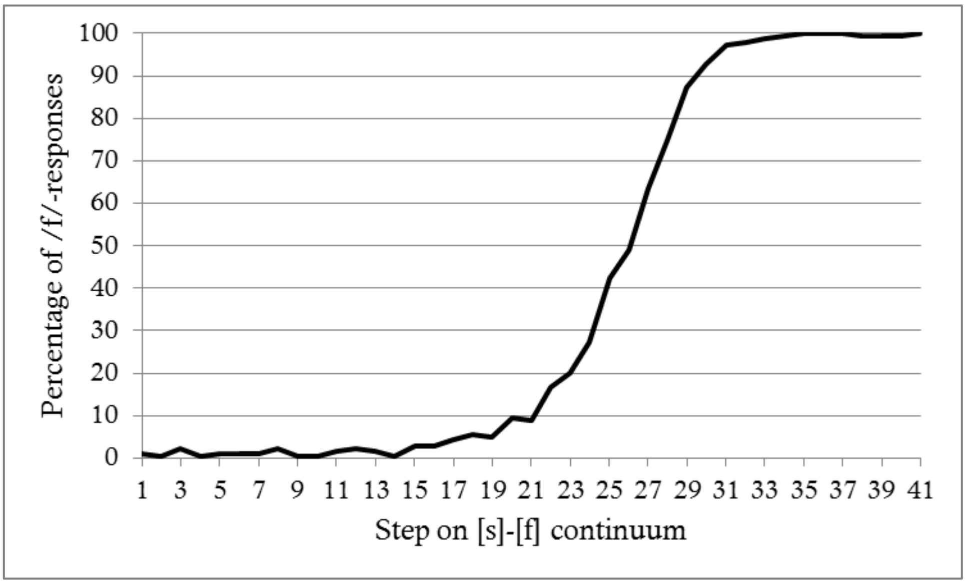

Figure 3-11. Mean percentage of /f/-responses to the 41-step continuum in the fricative pre-test of Experiment 3-2. Step 1 corresponds to natural /s/, step 41 to natural /f/.

As in Experiment 3-1b, the five ambiguous stimuli from the [ɛf]-[ɛs] continuum that were used during the phonetic categorisation task were selected based on a participant's own pre-test results and therefore varied from person to person. The ambiguous stimuli that were selected were those sounds that received approximately 10% (step A), 30% (step B), 50% (step C), 70% (step D) and 90% (step E) /f/-responses. Figure 3-12 shows the mean percentage of /f/-responses in the pre-test for these five steps, grouped by the exposure participants received in the subsequent lexical decision task. The two exposure groups do not differ from each other ($F(1, 28) = 0.84$, $p = .367$), so any categorisation differences that may be observed in the post-test cannot be due to selection of the ambiguous stimuli.

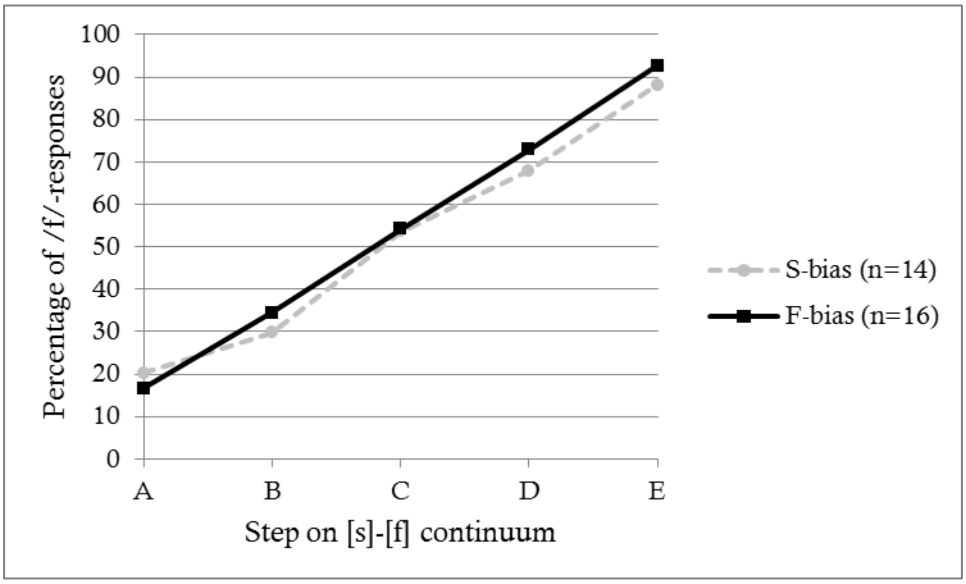

Figure 3-12. Mean percentage of /f/-responses to the five steps that were selected from the fricative pre-test of Experiment 3-2 to for use in the exposure and post-test phase. The solid black line shows participants who were later assigned to the f-bias group, and the dashed grey line shows participants in the s-bias group.

3.3.4.1.2.2. Exposure: Auditory lexical decision

As in Experiment 3-1b, all participants who accepted less than 50% of [?]-final items as words were excluded from further analysis. This was the case for two participants, who were both exposed to natural /s/-final words and ambiguous /f/-final words. As a result, data from 28 participants were included in the analysis, 14 per exposure condition.

Overall, participants that were exposed to the ambiguous fricative sound [?] in /f/-final words (the f-bias group) gave 'yes'-responses to 95.0% of the word filler items and 'no' responses to 98.3% of the non-word filler items. Participants who were exposed to the ambiguous fricative sound [?] in /s/-final words (the s-bias group) responded 'yes' to 94.3% of the word filler items and responded 'no' to 96.0% of the non-word filler items.

Table 3-5 shows listeners' responses to the fricative-final experimental items. Like in Experiment 3-1b, the ambiguous words presented to the f-bias group were rejected most often, with 'yes' responses to only 86.8% of these items. If the responses of the two excluded participants are included, this percentage goes down to 81.6%.

Table 3-5. Response times and percentage of correct responses to experimental items in Experiment 3-2. Response times are measured from target word onset.

	f-bias group		**s-bias group**	
	natural fricatives	ambiguous fricatives	natural fricatives	ambiguous fricatives
Mean % 'yes'	97.1	86.8	96.4	94.3
Mean RT 'yes' (in ms)	1118	1260	1216	1292

A repeated measures ANOVA by participant (F_1) but not by item (F_2) found an interaction between exposure group and fricative type $F_1(1,26) = 5.82$, $p = .023$, $\eta_p^2 = .18$; $F_2(1,38) = 3.45$, $p = .071$). Simple main effects analysis shows that this interaction is driven by the relatively poor acceptance of the ambiguous /f/-final words presented to listeners in the f-bias group. Listeners in this exposure group accepted significantly fewer words ending in an ambiguous fricative as existing words than listeners in the s-bias group ($p = .010$).

3.3.4.1.2.3. Post-test: Phonetic categorisation

Figure 3-13 shows the mean percentage of /f/-responses to all five ambiguous stimuli in the phonetic categorisation task. The perceptual learning effect is represented by the difference between the two lines. As expected, there was a main effect of the selected step from the fricative continuum ($F_1(4, 104) = 69.09$, $p < .001$, $\eta_p^2 = .73$). However, no effect of exposure bias was found ($F_1(1, 26) = 1.16$, $p = .291$), nor any interaction between step and exposure bias ($F_1(4,104) = 1.33$, $p = .262$). Since the percentages of /f/-responses from the two exposure groups appear to differ most on steps C and D, these steps were also analysed separately. Again, no effect of exposure bias was found, either for step C and D as a subcontinuum ($F(1, 26) = 2.69$, $p = .113$), or for step

C($t(26) = 1.49$, $p = .148$) or step D ($t(26) = 1.56$, $p = .131$) separately. Thus, listeners' fricative categorisation did not significantly differ depending on the exposure condition they received during the lexical decision task.

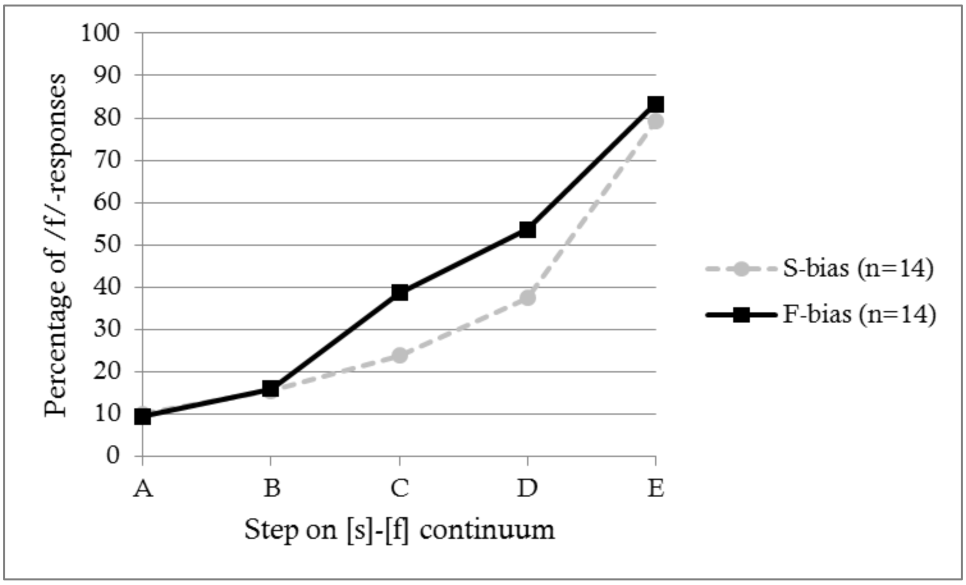

Figure 3-13. Mean percentage of /f/-responses in the fricative post-test of Experiment 3-2 for listeners in the f-bias and s-bias groups. Step A is the most /s/-like of the tested ambiguous stimuli, while step E is the most /f/-like.

3.3.4.1.3. Discussion

Experiment 3-2 was conducted to validate the stimuli and procedures of Experiment 3-1b. Validation was not successful, as the perceptual learning displayed by the Dutch control participants was not significant, in spite of previous studies that have demonstrated lexically-guided perceptual learning in Dutch with similar participant populations (e.g., Norris et al., 2003). The main difference between the experimental method used here, and that used by Norris et al. (2003) – and by many studies since (e.g., Clarke-Davidson et al., 2008; Eisner & McQueen, 2005; Kraljic & Samuel, 2005; Reinisch et al., 2013; Scharenborg et al., 2015; Sjerps & Mcqueen, 2010) – is the addition of a fricative pre-test. Despite the attempt to take away participants' focus from the /f/ and /s/ sounds by adding a vowel pre-test, completing a fricative pre-test may in some way have blocked perceptual learning[10]. A second control experiment was therefore conducted with participants from the same population, in which the pre-test was removed. This experiment thus consisted of an exposure and test phase only. If perceptual learning was indeed blocked by the fricative pre-test, its removal should see perceptual learning occur ‘as usual’ in Experiment 3-3.

3.3.4.2. Experiment 3-3

3.3.4.2.1. Method

3.3.4.2.1.1. Participants

Twenty-four participants (21 females; aged 18-36 years, M = 22.0, SD = 4.1) were recruited from the participant pool of the Centre for Language Studies at the Radboud University in Nijmegen, the Netherlands and received a gift voucher for their participation. None of the participants had previously participated in Experiment 3-2. All participants were native speakers of Dutch and none reported any hearing problems. Participants' scores on the Dutch version of LexTALE (Lemhöfer & Broersma, 2012) were similar to those of the listeners in Experiment 3-1b and Experiment 3-2, with a mean score of 92.0% (SD = 6.8, range: 75 – 100%). Written informed consent was obtained from all participants prior to the start of the experiment

3.3.4.2.1.2. Stimulus materials

The materials used here were the same as those used in Experiment 3-1b and Experiment 3-2. However, because of the absence of a pre-test in this control experiment, the ambiguous fricative sounds used in the exposure and post-test could not be selected on a participant by participant basis. Instead, the categorisation results

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[10] The results of Experiment 3-1a, however, suggest that perceptual learning occurs even despite the presence of a pre-test.

from the fricative pre-test of Experiment 3-2 were averaged to determine those five steps of the 41-step [f]-[s] continuum that had received approximately 10%, 30%, 50%, 70% and 90% /f/-responses, respectively. These steps (step 20, step 24, step 26, step 28, and step 30) were then used in the phonetic categorisation task for all participants in the present experiment. The step that received 50% /f/-responses (step 26) was used as the ambiguous fricative sound [?] in the exposure phase for all participants.

3.3.4.2.1.3. Procedure

The present experiment consisted of the tasks listed in Table 3-6 below. The procedure for individual part was the same as in Experiment 3-2 (see section 3.3.4.1.1.1.2), with the exception of the following: participants first completed the exposure phase, which was immediately followed by the fricative post-test. Participants then completed the LexTALE proficiency test (Lemhöfer & Broersma, 2012) and filled in a short language background questionnaire. There was neither fricative nor vowel pre-test.

Table 3-6. Order of tasks within the testing session of Experiment 3-3.

	Experiment 3-3
(1)	exposure
	fricative post-test
(2)	LexTALE
(3)	language background questionnaire

3.3.4.2.2. Results

3.3.4.2.2.1. Exposure: Auditory lexical decision

As in all previously reported experiments in this chapter, participants who accepted less than 50% of [?]-final items as words were excluded from further analysis. Thus, one participant's data were discarded. This participant was exposed to natural /s/-final words and ambiguous /f/-final words (f-bias group). Data from the remaining 23 participants were included in the analysis, with 13 listeners in the s-bias group and 10 in the f-bias group (due to an oversight during testing, one participant was assigned to the unintended exposure condition, leading to the imbalance).

Overall, listeners in the f-bias group (who were exposed to the ambiguous fricative sound [?] in /f/-final words) gave 'yes'-responses to 91.3% of the word filler items and 'no' responses to 95.3% of the non-word filler items. Listeners in the s-bias responded 'yes' to 93.7% of the word filler items and responded 'no' to 94.9% of the non-word filler items. Table 3-7 shows listeners' responses to the fricative-final experimental items. Like in Experiment 3-1b and Experiment 3-2, the ambiguous words presented to listeners in the f-bias group were most often rejected, with 'yes' responses to only 81.5% of these items. When the responses of the excluded participant are included, this percentage drops to 75.0%.

Repeated measures ANOVAs by participant (F_1) and by item (F_2) found an interaction between exposure group and fricative type $F_1(1,21) = 5.36$, $p = .031$, $\eta_p^2 = .20$; $F_2(1,38) = 6.39$, $p = .016$, $\eta_p^2 = .14$). Simple main effects analysis shows that this interaction is driven by the relatively poor acceptance of the ambiguous /f/-final words presented to listeners in the f-bias group. Listeners in this exposure group accepted significantly fewer words ending in an ambiguous fricative than listeners in the s-bias group ($p = .005$).

Table 3-7. Response times and percentage of correct responses to experimental items in Experiment 3-3. Response times are measured from target word onset.

	f-bias group		**s-bias group**	
	natural fricatives	ambiguous fricatives	natural fricatives	ambiguous fricatives
Mean % 'yes'	92.5	81.5	95.4	91.9
Mean RT 'yes' (in ms)	1038	1072	1075	1062

3.3.4.2.2.2. Post-test: Phonetic categorisation

Figure 3-14 shows the mean percentage of /f/-responses to all five ambiguous stimuli in the phonetic categorisation task.

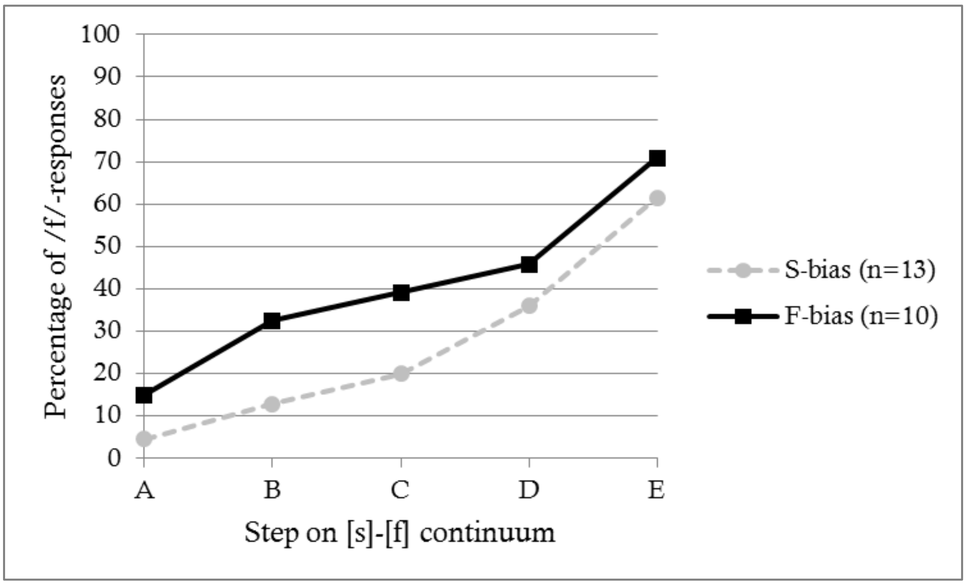

Figure 3-14. Mean percentage of /f/-responses in the fricative post-test of Experiment 3-3 for listeners in the f-bias and s-bias groups. Step A is the most /s/-like of the tested ambiguous stimuli, while step E is the most /f/-like.

The perceptual learning effect is represented by the difference between the two lines. There was a main effect of the selected step from the fricative continuum ($F_l(4, 84) = 40.01$, $p < .001$, $\eta_p^2 = .66$), but, as in the previous two experiments, no main effect of exposure bias ($F_l(1, 21) = 2.94$, $p = .101$), nor any interaction between step and exposure bias ($F_l(4, 84) = 0.61$, $p = .657$). Responses to steps B and C did not significantly differ between exposure groups either ($t(21) = 2.05$, $p = .053$, and $t(21) = 1.70$, $p = .103$, respectively). This indicates that there were no significant categorisation differences between listeners in the two exposure bias conditions.

3.3.4.2.3. Discussion

The purpose of the present control experiment was to determine whether the addition of a pre-test to the original perceptual learning paradigm devised by Norris et al.

(2003) (partially) blocks perceptual learning. If this is the case, removal of the pre-test should allow retuning of phoneme categories 'as usual'. This retuning did not occur in the current experiment, which suggests that the inclusion of a pre-test does not influence listeners' perceptual learning. The percentages of /f/-responses in the current control experiment were then compared to the results of the first control experiment. A mixed repeated-measures ANOVA, with fricative step (A-E) as the within-subjects factor, and exposure bias (f-bias and s-bias) and experiment (with and without pre-test) as between-subject factors did not show an effect of experiment ($F_1(1, 47) = 0.33$, $p = .569$), nor an interaction of exposure bias and experiment ($F_1(1, 47) = 0.43$, $p = .514$), which suggests that the exposure phase had the same effect on listeners in both experiments, regardless of whether or not they had previously completed a pre-test. The only significant interaction that was found was between fricative step and experiment, indicating that the two groups of control participants did not categorise the different fricative steps in the same way, which is not entirely surprising since listeners' categorisation of acoustic stimuli is known to be influenced by the range of stimuli presented (Brady & Darwin, 1978). Although all control participants were presented with an identical range of stimuli in the post-test (i.e., five selected steps from the original 41-step [ɛf]-[ɛs] continuum), by the time they completed the post-test, participants in Experiment 3-2 but not Experiment 3-3 had already been exposed in the pre-test to the entire 41-step [ɛf]-[ɛs] continuum. The range effect resulting from this previous exposure likely influenced phonetic categorisation in the post-test of Experiment 3-2.

While neither control experiment found evidence of perceptual learning, results from both experiments show a trend towards perceptual learning that suggests the control experiments may have been underpowered. Since it appears that listeners in

Experiment 3-3 did not behave differently from those in Experiment 3-2, data from both control experiments were collapsed and re-analysed. This re-analysis is described in section 3.3.4.3 below.

3.3.4.3. Re-analysis of combined control experiments

Data from 28 participants were included in the analysis of the phonetic categorisation post-test of Experiment 3-2. The analysis of the same task in Experiment 3-3 was carried out on data collected from 23 participants. Aggregating this data provides us with categorisation responses from 51 participants, 27 of whom were assigned to the s-bias group. Figure 3-15 shows the mean percentage of /f/-responses for this combined data set.

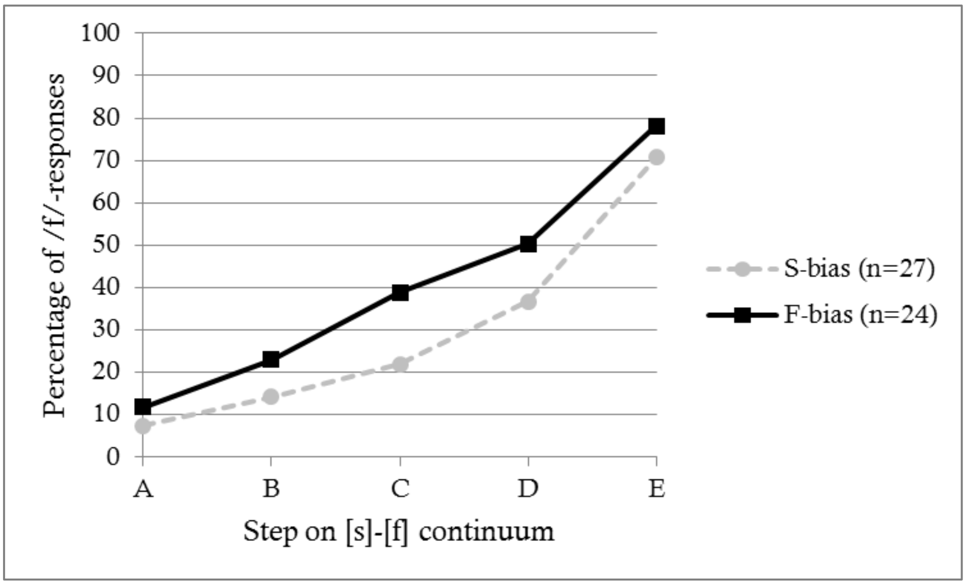

Figure 3-15. Mean percentage of /f/-responses for the aggregated data from the fricative post-tests of Experiments 3-2 and 3-3. Step A is the most /s/-like of the tested ambiguous stimuli, while step E is the most /f/-like.

A repeated-measures ANOVA confirms a significant main effect of step ($F_1(4, 196) = 106.28$, $p < .001$, $\eta_p^2 = .68$) and of exposure bias ($F_1(1, 49) = 4.17$, $p = .047$, $\eta_p^2 = .08$). This indicates that listeners in the f-bias group, who were trained to interpret the ambiguous fricative sound [?] as /f/, categorised significantly more tokens as /f/ than listeners in the s-bias group (who had learned to interpret the ambiguous fricative sound [?] as /s/). No interaction was found between step and exposure bias ($F_1(4,196) = 1.05$, $p = .384$). A comparison of responses to step C only (i.e. the most ambiguous step of the continuum) revealed a significant difference between listeners from the two bias groups ($t(49) = 2.32$, $p = .025$).

3.3.5. Discussion

Experiment 3-2 and 3-3 investigated whether the materials and procedures that were used in Experiment 3-1b could lead Dutch L1 listeners in the Netherlands to adjust the boundaries of their phoneme categories after exposure to an ambiguously pronounced fricative [?] in lexical contexts that favour interpretation of the ambiguous fricative as either as /f/ or as /s/. When analysed separately, neither Experiment 3-2 nor Experiment 3-3 provided evidence for this lexically guided perceptual learning. The number of participants in each experiment may not have supplied enough statistical power to reveal such effects. The combined data from Experiment 3-2 and 3-3, however, did show a perceptual learning effect [11]. Now that the control experiments have shown that the materials and procedures from Experiment 3-1b can be used to induce perceptual learning, several factors will briefly be discussed that may, at first glance, be assumed to have played a role in the flexibility loss found in the Dutch emigrant participants. It will become clear from the discussion below, however, that they do not explain the findings.

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[11] The fact that the control experiments lacked power and only found an effect of perceptual learning after their results had been combined may seem to suggest that Experiment 3-1b suffers from a similar power issue. Contrary to their training, however, listeners in Experiment 3-1b who were exposed to the ambiguous fricative [?] in /f/-final words (the f-bias group) appear to interpret that fricative as /f/ *less* often than listeners in the s-bias group (see Figure 3-9 on page 67). This makes it unlikely that the inclusion of additional participants would result in a significant perceptual learning effect in the expected (opposite) direction.

The first of these factors concerns the acoustic properties of the Dutch and English fricative phonemes used in the present series of experiments. While /f/ is spectrally similar in both languages, English /s/ typically contains more energy in the higher frequency regions than Dutch /s/ (Collins & Mees, 2003). After extended immersion in an English language environment, Dutch emigrants may have adapted to the acoustic characteristics of English /s/, leading to an adjusted perception of that phoneme in the L1. This, in turn, may have prevented potential perceptual learning effects from being revealed by the experimental paradigm that was used. The emigrants' categorisation of the Dutch [ɛf]-[ɛs] continuum during the pre-test was therefore compared to that of the native Dutch listeners in the Netherlands who were tested in the pilot, and in the pre-test of Experiment 3-2. Figure 3-16 displays the mean percentage of /f/-responses for these three participant groups and shows that the emigrants' categorisation of the Dutch [ɛf]-[ɛs] continuum was very similar to that of the native Dutch listeners still living in the Netherlands. It is therefore not likely that

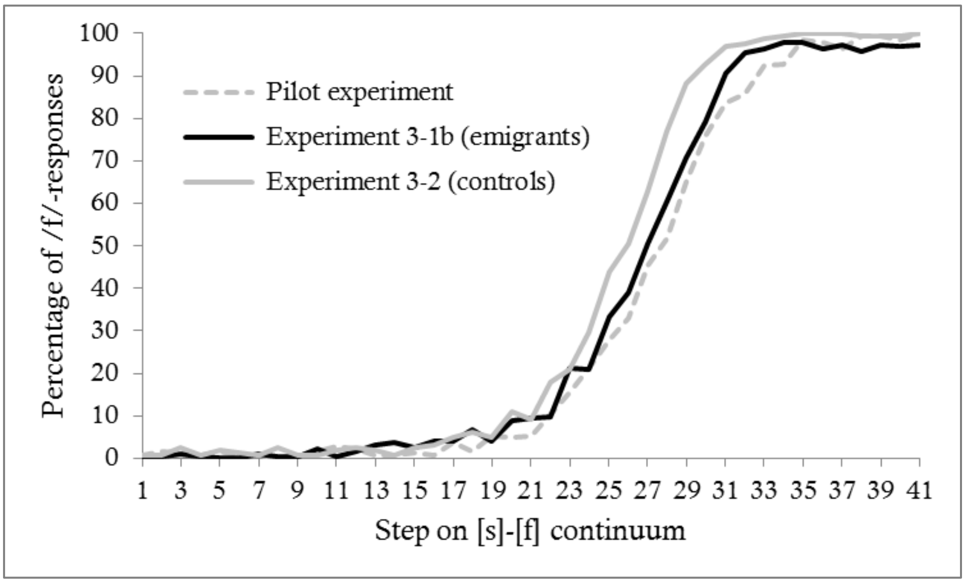

Figure 3-16. Mean percentage of /f/-responses to the 41-step continuum in the fricative pre-test of Experiments 3-1b and 3-2, and in the pilot of Experiment 3-1b. Step 1 corresponds to natural /s/, step 41 to natural /f/.

acoustic differences between Dutch and English /s/ have prevented us from finding perceptual learning effects in Experiment 3-1b.

Next, let us consider the relatively advanced age of the emigrants, who, with a mean age of 47.75 years, were older than the control participants, whose mean age was 22.6 years (refer back to sections 3.3.1.1, 3.3.4.1.1.1, and 3.3.4.2.1.1 for more details). Previous studies have found that perceptual learning is not restricted to younger adults but occurs in older adults as well (Scharenborg & Janse, 2013; Scharenborg et al., 2012; Scharenborg et al., 2015). This is supported by the fact that, in the present study, the same emigrants who did not show perceptual learning in L1 did retune their phoneme categories in L2 (Experiment 3-1a). Therefore, the emigrants' flexibility loss in L1 cannot be attributed to their higher age.

Another factor to consider, and not entirely unrelated to age, is listeners' hearing acuity. The continuum used in the present study was created from fricative sounds, which consist largely of high-frequency energy, and while the majority of the emigrant participants had normal hearing in the 4-8 kHz region (i.e., mean thresholds up to 25 dB HL), other participants suffered from mild to moderate hearing loss in the high-frequency area, with thresholds of up to 55 dB HL (see section 3.2.1.1). However, previous research has investigated perceptual learning effects in listeners whose hearing acuity varied and found no correlation between listeners' hearing sensitivity and the strength of perceptual learning (Scharenborg & Janse, 2013).

The final factor that should be considered is language proficiency. The experimental paradigm that was used in the current series of experiments relies on lexical information to induce perceptual learning. If a word is not present in a listener's mental lexicon, it cannot contribute towards disambiguation of the ambiguous fricative, leaving listeners with smaller lexicons with fewer opportunities to learn during the exposure phase. Since the emigrants who participated in Experiment 3-1b may be less proficient in Dutch than the control participants in Experiment 3-2 and 3-3, two different measures were used to compare proficiency and vocabulary size.

The first measure that allows a comparison of participants' relative vocabulary size is the mean percentage of correct responses to both words and non-words in the lexical decision task. Compared to listeners with a large vocabulary, listeners with a smaller vocabulary might recognise fewer words as such and/or erroneously accept more non-words as existing words. Table 3-8 shows the mean percentage of correct responses to the words (experimental items and fillers) and non-words (filler items only) presented in each Dutch exposure phase (reorganisation of percentages previously presented for Experiments 3-1b, 3-2 and 3-3 [in sections 3.3.2.2, 3.3.4.1.2.2, and 3.3.4.2.2.1, respectively]). Data for the two control experiments have been averaged into single values for all control participants. Repeated measures ANOVAs by participant (F_1) and by item (F_2) show no difference between the emigrants and the control participants (F_1 (1,78) = 0.70, p = .405; F_2 (1,146) = 0.19, p = .667).

Table 3-8. Mean percentage of correct responses to words and non-words in the lexical decision tasks of Experiment 3-1b, and of both control experiments (Experiments 3-2 and 3-3).

	words	**non-words**
Emigrants	94.5	96.0
Controls	93.2	96.2

The second measure that may be used to compare listeners' proficiency is the Dutch LexTALE scores (Lemhöfer & Broersma, 2012) that were collected from all participants. The distributions and means of these scores are displayed in Figure 3-17. On average, the emigrants whose data were included in the analysis of the post-test received a proficiency score of 92.2%, compared to a mean score of 92.0% for all included control participants. An independent-samples *t*-test confirms that, although they no longer live in an L1 environment, the emigrants are as proficient in Dutch as the control participants ($t(74) = 0.15$, $p = .883$). Both response accuracy and LexTALE proficiency scores suggest that emigrants and control participants had a similar amount of lexical information available to them to disambiguate the ambiguously pronounced fricative-final words they were exposed to.

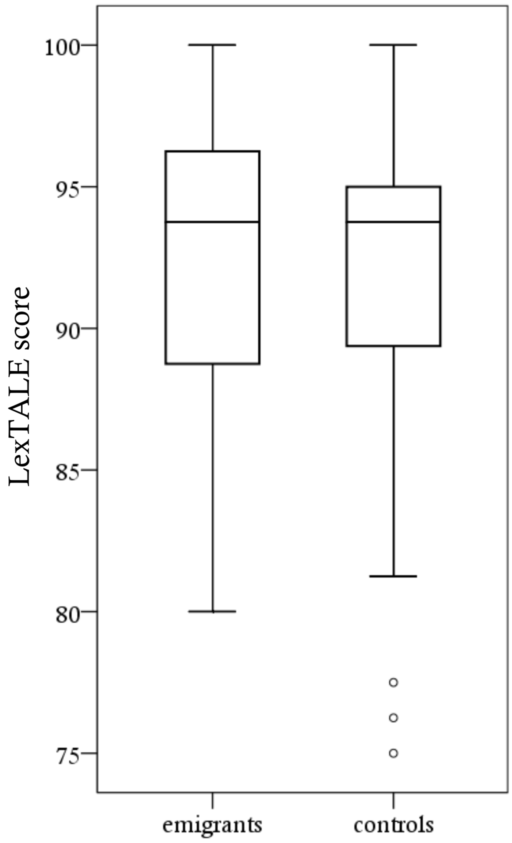

Figure 3-17. Distribution of Dutch LexTALE proficiency scores for emigrants and control participants in Experiments 3-1b, 3-2, and 3-3.

The discussion above suggests that the loss of phonetic flexibility displayed by the Dutch emigrants in the present experiment is unrelated to their age, hearing acuity or language proficiency. Instead, the loss of flexibility may most likely be attributed to the fact that the emigrants moved out of the L1 environment and into an L2 immersion environment. This is discussed in more detail in the next section, in which the findings of Experiment 3-1a and 3-1b are interpreted together.

3.4. General discussion

Experiments 3-1a and 3-1b examined lexically guided perceptual learning in listeners' L2 and L1, respectively. Experiment 3-1a found that, when listening to an unfamiliar Australian English speaker, Dutch emigrants in Australia use lexical knowledge to disambiguate ambiguously pronounced fricatives and retune their phoneme categories to accommodate for the idiosyncrasies in the new talker's speech. These results are in line with previous findings that L2 listeners adjust the boundaries of their phoneme categories to accommodate for novel pronunciations (Drozdova et al., 2014; Reinisch et al., 2013; Schuhmann, 2014) and suggest that nativeness in a language is not a prerequisite for perceptual learning.

When the same Dutch emigrants were exposed to ambiguously pronounced fricatives in their L1, Dutch, in Experiment 3-1b, no category retuning occurred. It appears that phonetic listening flexibility does not always remain available in a listener's L1 and this finding extends the literature on perceptual learning in an important way, as it suggests that – in addition to not being a prerequisite – nativeness in a language is also no guarantee for successful perceptual learning.

Although none of the participants of Experiment 3-1b lived in an L1 immersion environment, caution has to be exercised in concluding that immersion in a language is required for phonetic flexibility, as previous studies have found perceptual learning (for L2 listeners) in non-immersion environments (Drozdova et al., 2014; Schuhmann, 2014). It is proposed here that it may not be immersion as such that is required for phonetic flexibility, but variability in the speech input that listeners receive from regular exposure to new talkers, regardless of whether that is the result of immersion. Since perceptual learning is a mechanism that allows listeners to accommodate for idiosyncrasies in the speech of talkers they have never heard before, one may expect that listeners who do not regularly encounter new talkers no longer need this flexibility and lose it. The Dutch emigrants tested in the current study live in Australia and are therefore not only exposed to large quantities of speech input in the immersion language, English, they are also exposed to a great variability in that speech input, provided by both familiar and unfamiliar talkers on a daily basis. The emigrants are continuously required to make use of their phonetic flexibility in English to successfully understand what is being said. To many emigrants, a much smaller range of different talkers is available in Dutch (the non-immersion language) as speech input in Dutch may be limited to Skype calls with relatives in the Netherlands or occasional conversations with other Dutch emigrants. As a result, the need to draw upon their phonetic flexibility in Dutch arises much less frequently, and it appears that this may lead to the eventual loss or temporary suspension of this flexibility. The fact that the Dutch undergraduate students in Drozdova et al.'s (2014, 2015) studies showed perceptual learning in their L2 English despite the fact that they did not live in an English immersion environment can then also be explained by the amount of variability that they are exposed to in English in their daily lives. Although English is not one of the Netherlands' official languages, it is omnipresent in Dutch society, especially in the media. English-spoken television programmes are not dubbed but subtitled and thus provide a great amount of exposure to English, as do a number of English language television channels that are widely available, such as CNN and BBC. In addition, many university students in the Netherlands attend lectures in English. The German undergraduate students who participated in the studies by

Schuhmann (2014) may be similarly exposed to a large variability in their L2 English, although arguably to a slightly lesser extent than their Dutch peers. So, while the L2 listeners in the studies by Drozdova et al.(2014, 2015) and Schuhmann (2014) described above do not live in an L2 immersion environment, the range of talkers and the ensuing variability that they are continuously presented with in the L2 leads them to develop and maintain phonetic flexibility in that language.

To summarise, it is proposed that the range of talkers that a listener is exposed to in a particular language plays an important role in the development and maintenance of phonetic listening flexibility in that language, regardless of whether the language is the L1 or the L2. If this is the case, the loss of this flexibility is likely to be reversible and more research is needed on this issue. Future studies may test the L1 phonetic flexibility of remigrants (i.e., people who have returned to their country of origin after previous emigration), of emigrants who have just spent a holiday in their country of origin, or even provide emigrants with a ‘language boot camp’, consisting of large amounts of highly variable speech in the emigrants’ L1, prior to examining their L1 listening flexibility. The findings of this study also prompt the interesting question whether other aspects of L1 phonetic processing are malleable as well and may become L2-like. A study addressing this question is reported in Chapter 5. In Chapter 6, results from Experiment 3-1 are tested against measures of language dominance. First, however, the studies in Chapter 4 focus on the processes of lexical activation and competition in L1 and L2 listening and their potential flexibility.

Lexical Activation and Competition in L1 and L2 Listening

Chapter 4

Spoken-word recognition involves the activation of lexical candidates that overlap with parts of the speech input and the subsequent competition between these candidates. A word is recognised when only one lexical candidate remains and 'wins' the lexical competition process (for a review, see Eisner & McQueen, in press). Words that overlap with the onset of a spoken word (i.e., onset competitors) typically compete both earlier in time and more strongly for recognition than words that overlap with the offset (i.e., rhyme competitors; Allopenna, Magnuson, & Tanenhaus, 1998; McQueen & Viebahn, 2007). This onset-rhyme effect is due to fact that speech input unfolds over time and information about the intended words becomes available incrementally. Until the final segment of the spoken word *tower* arrives at the listener's ear, for instance, the onset competitor *towel* is a viable candidate for recognition, whereas the rhyme competitor *flower* mismatches from word onset and cannot start to compete (even weakly) for recognition until subsequent matching phonemes of the spoken word become available.

As has become clear from the discussion in Chapter 1, L2 listeners face many problems in spoken-word recognition that L1 listeners do not have to contend with. While these problems typically make L2 listening harder than L1 listening, to date little is known about how L1 and L2 lexical processing compare in one and the same listener. Does the activation and competition of lexical candidates occur in the same way in L2 listening as in L1 listening and do L2 listeners show an L1-like onset-rhyme effect? And do listeners who are dominant and highly proficient in L2 still show ‘normal’ lexical competition processes in their L1, or have these been affected by the shift in dominance? The experiments presented in this chapter address these questions, using the visual world paradigm (Allopenna et al., 1998; McQueen & Viebahn, 2007; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995; for a review, see Huettig, Rommers, & Meyer, 2011), a method that has proven to be very successful in capturing the time course of spoken word recognition and has been widely used to investigate lexical competition processes, not only in L1 but also in L2 listeners (e.g., Blumenfeld & Marian, 2007; Canseco-Gonzalez et al., 2010; Chambers & Cooke, 2009; Ju & Luce, 2004; Lagrou, Hartsuiker, & Duyck, 2013; Weber & Cutler, 2004).

In studies using the visual world paradigm, participants look at visual displays of pictures or written words presented on a computer screen (see Figure 4-1) while they hear spoken words or sentences. During the experiment, small cameras record participants’ eye movements.

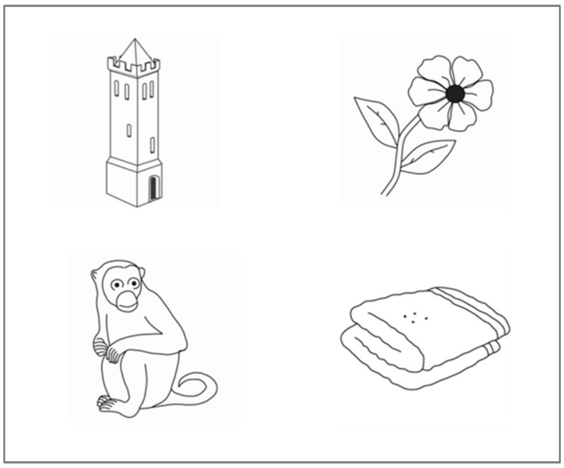

Figure 4-1. A visual display from an experiment using the visual world paradigm.

The pictures or words contained in each visual display are typically selected based on the way in which they are expected to generate recognition competitors for a critical word in the spoken stimulus. For instance, listeners who are instructed to ‘click on the tower' in Figure 4-1 not only activate the target word *tower* but are also expected to experience lexical competition from the onset competitor *towel* and the rhyme competitor *flower*. The strength and time course of this competition are reflected by the proportion of looks that each picture attracts. In this example, the picture of a monkey is a distractor item and serves as a baseline. Figure 4-2 visualises the lexical competition process and shows fixation proportions to each picture type after they have been averaged across participants and trials (based on fictitious data).

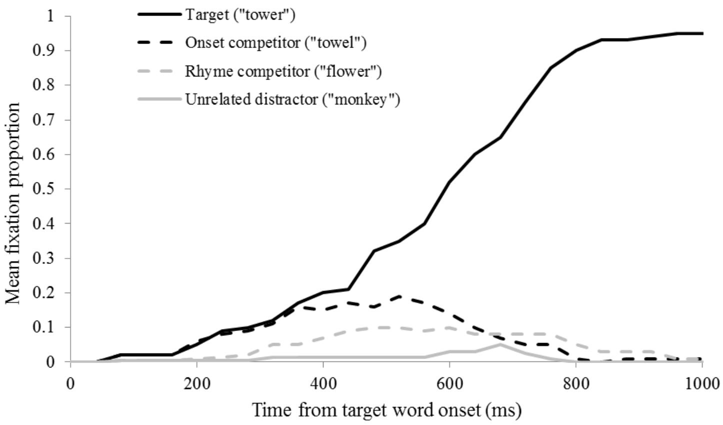

Figure 4-2. Mean proportion of looks to target, competitors, and distractor for a fictitious example experiment.

In normal listening situations more competition arises from onset competitors than from rhyme competitors and the onset competition occurs earlier in time, as illustrated by the dotted lines in Figure 4-2. However, recent evidence suggests that when listeners are faced with a speech signal that is less than perfect (e.g., because of a bad phone connection), parameters of lexical activation and competition may be adjusted to account for this imperfection (Brouwer, Mitterer, & Huettig, 2012; McQueen & Huettig, 2012). This way, mismatch between a lexical candidate and the incoming speech signal no longer necessarily leads to immediate de-activation of the candidate word. The studies that demonstrated this lexical flexibility examined spoken-word recognition in two situations in which listeners were exposed to imperfect speech signals. One of these studies used casual speech containing reduced word forms (Brouwer et al., 2012), while another (McQueen & Huettig, 2012) used speech that was occasionally distorted by noise. Both experiments were carried out in Dutch and used the visual world paradigm.

In Brouwer et al.'s (2012) study, participants listened to sentence-long fragments of casual speech while looking at visual displays containing four written words. Participants were instructed to click on the word that occurred in the spoken sentence. In some trials this target word was pronounced canonically (e.g., [bəneːdə] *beneden*, 'downwards'), while in other trials the target was a reduced form of the same word (e.g., [məneːə] instead of the canonical form [bəneːdə]). The visual display contained competitors both for the canonical and for the reduced form of the target word (e.g., [bənaːdeːlə] *benadelen*, 'to disadvantage' and [məneːr] *meneer*, 'mister', for the target *beneden*), as well as the target word [bəneːdə] and an unrelated distractor word. When listeners were exposed to canonical pronunciations only, they experienced more competition from the competitor for the canonical form of the target word than from the competitor for the reduced form of the target word. Listeners who heard both canonical and reduced pronunciations directed similar proportions of looks to both types of competitors, regardless of the actual pronunciation of the target word. This suggests that when speech contains many reduced word forms and therefore the likelihood of encountering reductions increases, listeners flexibly adjust by evaluating lexical candidates differently to allow for the imperfect acoustic information.

In McQueen and Huettig's (2012) eyetracking study, participants heard a Dutch sentence and saw four line drawings. They were not given any explicit tasks, but were merely asked to listen to the sentences without taking their eyes off the screen. In the experimental trials, none of the words from the spoken sentence were represented by the drawings (a 'target-absent' design; Huettig & Altmann, 2005). One of the drawings in each experimental trial, however, depicted either an onset competitor or a rhyme competitor for a critical word in the spoken sentence (e.g., *cirkel* 'circle' as onset competitor for the critical word *circus* 'circus' and *cent* 'cent' as rhyme competitor for *tent* 'tent'). The other three drawings were unrelated distractors. In the filler trials, the visual display indeed contained a drawing representing the critical word from the sentence. For one group of participants, bursts of noise would sometimes disrupt the spoken sentences (although never the critical word itself). A second group of participants served as a control group and heard sentences without any disruptions. Participants who heard the disrupted sentences looked more at rhyme competi-tors and less at onset competitors than the control participants, suggesting that the lexical competition process becomes more flexible when the probability that the acoustic information is distorted increases. There was no significant effect of the position of the noise within the words (i.e., word-initial or word-medial).

The two studies discussed above suggest that listeners flexibly adjust the parameters of lexical activation and competition when the speech signal becomes less reliable (lexical modulation). However, as both studies were conducted with L1 listeners, it is entirely unknown whether such lexical flexibility can be attained in L2 listening, or indeed whether it remains intact in the L1 for L2-dominant listeners. The experiments in this chapter were therefore modelled after McQueen and Huettig (2012) and Brouwer et al. (2012). The use of this paradigm not only allows a comparison of fundamental measures of lexical activation and competition patterns of onset and rhyme competitors in L1 and L2 listening, it also provides the additional opportunity to explore lexical modulation in L1 and L2.

Five experiments are described in this chapter. The main experiment, Experiment 4-1, was an extension of the study of McQueen and Huettig (2012), and, like Experiment 3-1, it was conducted with Dutch-English bilingual emigrants. The other four experiments were control experiments. Experiments 4-2 and 4-3 used the same task as the first experiment but were conducted with populations of young adult L1 listeners of English, and older adult L1 listeners of Dutch, respectively. A different task was used in Experiment 4-4, which was based on Brouwer et al.'s (2012) study and, again, tested older adult L1 listeners of Dutch. Finally, this same participant population was examined once more in Experiment 4-5, which was another adaptation of the study by McQueen and Huettig (2012).

4.1. Experiment 4-1

This experiment compared the lexical competition Dutch-English bilingual emigrants experience from onset and rhyme competitors in L1 and L2 listening. In addition, it explored whether these bilinguals adjust these competition processes when they listen to L1 and L2 in adverse listening conditions. Over two sessions, participants completed two sub-experiments, one in their L1 (Experiment 4-1a), and one in their L2 (Experiment 4-1b). The study by McQueen and Huettig (2012) that the present experiment was based on used noise as a between-subjects manipulation, presenting listeners either with clean speech only, or with sentences that all contained bursts of noise. Because of the expected difficulty in recruitment of Dutch emigrants and the expected participant variability within this population, a within-subject design was chosen for the present experiment. In both sub-experiments, all participants were therefore presented first with a baseline block of clean speech sentences, which was followed by a block in which all sentences contained bursts of noise. The experiments were thus constructed as a 2 × 2 × 2 within-subjects design, with competitor type (*onset* and *rhyme*), noise type (*clean speech* and *noise*) and language (*L1* and *L2*) as within-subject factors.

If the processes of lexical activation and competition are equivalent in L1 and L2 listening, similar looking patterns are expected for Experiments 4-1a and 4-1b. If, on the other hand, these processes are not equivalent, the emigrants' looking behaviour is expected to reflect this, and looking patterns should be different. If listeners adjust the way the aforementioned processes work in the face of unreliable speech signals, and do so similarly efficiently in L1 and L2 listening, weaker onset competition and stronger rhyme competition are expected in the noise conditions of Experiments 4-1a and 4-1b than in the clean speech conditions of these experiments. If lexical modulation does not occur when the emigrants listen to L1 or L2, looking patterns are predicted to be similar in the noise and in the clean speech conditions of Experiment 4-1a or 4-1b, respectively.

4.1.1. Method

4.1.1.1. Participants

Eighteen members of the Dutch immigrant community in the wider Sydney area (11 females and seven males; aged 27 – 73 years, M = 50.1, SD = 15.4) participated in both sessions of the experiment in exchange for a small reimbursement. Data from two additional participants were collected but discarded due to eyetracker calibration difficulties in both sessions, and one further participant's data were excluded from analysis because she did not complete the experiment. All participants were born and raised in the Netherlands, were native speakers of Dutch and had migrated to

Australia as adults (mean age at migration = 29.3 years, *SD* = 8.5, range: 18 – 52). The mean length of residence in Australia was 21.3 years (*SD* = 16.1). Participants' mean score on the Dutch version of LexTALE (Lemhöfer & Broersma, 2012) was 92.2% (*SD* = 5.8, range: 80 – 100), indicating that, despite migration to a predominantly English-speaking country, all participants still maintained high proficiency in their native Dutch. Participants' mean score on the English version of LexTALE was 94.1% (*SD* = 5.2, range: 83.8 – 100). None of the participants wore hearing aids in their daily life. For screening purposes, pure-tone air conduction thresholds were determined for all participants. Written informed consent was obtained from each participant at the start of session 1.

4.1.1.2. Stimulus materials

4.1.1.2.1. Materials for Experiment 4-1a – Dutch (L1)

Stimuli were based on and expanded from those used by McQueen and Huettig (2012) and consisted of 120 recorded Dutch sentences each containing a critical word (see Tables G-1 to G-3 in Appendix G). Sentences were constructed in such a way that the critical word was not easily predictable (e.g., *Het zag eruit als een paspoort, maar de tekst op de voorkant klopte niet*, "It looked like a passport but the text on the front was not right") and were spoken by a female native speaker of Dutch. They were read out with neutral intonation and the speaker was unaware of the presence or identity of any of the critical words. Each sentence was paired with a visual display containing four black-and-white line drawings (see Figure 4-3 for two example displays; a complete overview of all line drawings is provided in Tables G-4 to G-6 in Appendix G).

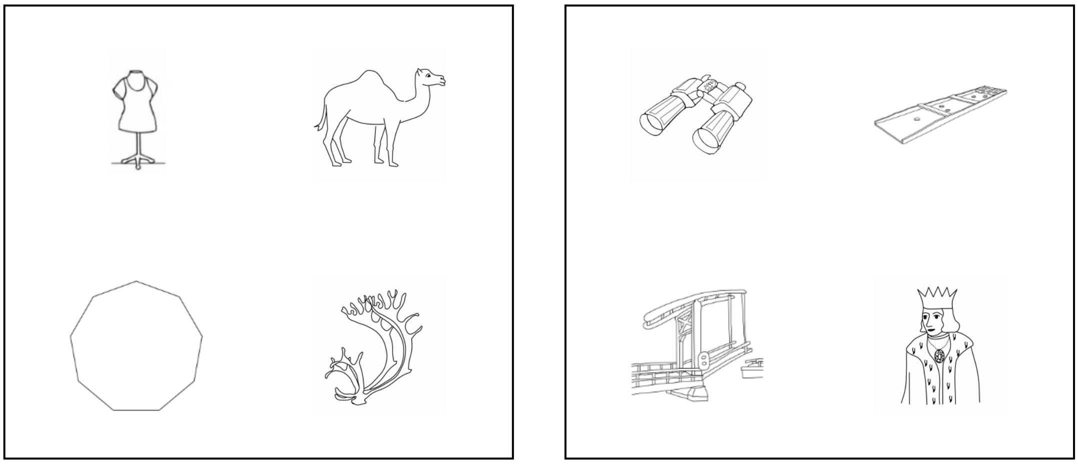

Figure 4-3. Visual displays from the onset-competitor condition (left) and rhyme-competitor condition (right) of Experiment 4-1a. The left panel contains a picture of a *paspop* ‘tailor's dummy’ (top left) as an onset competitor for the critical word *paspoort* ‘passport’, whereas the panel on the right contains the rhyme competitor *koning* ‘king’ (bottom right) for the critical word *honing* ‘honey’.

There were two types of experimental trials. The critical words were not represented by any of the drawings in these trials (a so-called 'target absent' design, described above and by Huettig and Altmann, 2005). Instead, the visual displays in those trials contained one phonological competitor for the critical word and three distractors that were phonologically and semantically unrelated. In the onset-competitor condition, the phonological competitor drawing depicted a word that overlapped at onset with the critical word (e.g., for the critical word *paspoort* ‘passport’, the onset competitor was *paspop* ‘tailor's dummy’; see Figure 4-3). Mean overlap for onset competitors was 3.8 phonemes, and mean word frequency of these competitors based on the CELEX lexical database (Baayen et al., 1995) was 10.3 per million words. In the rhyme-competitor condition, the competitor drawing depicted a word that had a rhyme overlap with the critical word and only differed in its first one or two phonemes (e.g., for the critical word *honing* ‘honey’, the rhyme competitor was *koning* ‘king’; see Figure 4-3). Rhyme competitors had a mean overlap of 3.2 phonemes and a mean CELEX word frequency of 51.8 per million words.

In addition to these two experimental conditions of 40 sentences each, there were 40 filler sentences, for which the visual displays contained a picture of the critical word itself, and three unrelated distractor pictures. As definite articles and adjectives are marked for gender in Dutch, it was ensured that in any given visual display all referents grammatically matched any articles and adjectives preceding the critical word in the spoken sentence, so that listeners could not make predictions based on the gender reflected by these articles and adjectives. In all conditions, competitor and distractor pictures were counterbalanced across four fixed positions on the screen and each sentence and visual display pair was presented once to each participant.

Activation of lexical candidates during spoken-word recognition in bi- or multilingual listeners is, as noted, not restricted to candidates from the language being spoken. Candidates from listeners' other languages can be co-activated (Spivey & Marian, 1999; Weber & Cutler, 2004) and this is especially the case for cognates (Blumenfeld & Marian, 2007). In visual world experiments, this co-activation affects the proportion of looks that referent pictures attract. Since all participants in the present study were at least bilingual, care was taken during stimulus selection to control for potential co-activation in Dutch and English. In trials containing a phonological onset or rhyme competitor that is a cognate in Dutch and English, this competitor was always paired with three distractors that were cognates in both languages as well. This was the case for 17 trials in the onset-competitor condition and for 13 trials in the rhyme-competitor condition. In addition, the distractors in each visual display were always phonologically unrelated to the competitor or target they occurred with, not only in the language of the experiment, but also in the other language. For example, the visual display shown in the left panel of Figure 4-3 contains a picture of the competitor *paspop* 'tailor's dummy'. The Dutch referents for the distractor images are *dromedaris*, *gewei*, and *achthoek* , whereas their English referents would be *camel*, *antlers*, and *octagon*. All of these referents are phonologically unrelated to the competitor *paspop*.

A preliminary picture naming experiment was carried out with native Australian-English speaking participants to establish the Australian-English referents for each line drawing. Details for this experiment are provided in Appendix H, which also includes a list of all line drawings and participants' responses. A particular distractor image was selected for inclusion in a visual display only if none of the responses for the image overlapped phonologically with the competitor or target item in the same display. So, for instance, the image depicting an ambulance could not be used as a distractor item for the target *kakkerlak* ([kɑkərlɑk], 'cockroach'), as it received the response *car* from one participant in the picture naming task. For reasons of feasibility, no picture naming pretest was carried out with native Dutch speakers. For a substantial number of line drawings, Dutch norms were already available as they were taken from the picture database of the Max Planck Institute for Psycholinguistics (either directly by the author, or by McQueen and Huettig, 2012, whose pictures were incorporated in the present study). The remaining distractor pictures were created based on images found on the internet, and checked by the author, who is a native speaker of Dutch, for possible phonological overlap with competitors or targets.

Stimulus sentences were recorded in a sound-attenuated booth at a sampling rate of 44.1 kHz using Adobe Audition. Subsequent selection, measurement and editing of the auditory stimuli was carried out using Praat (Boersma & Weenink, 2013). The amplitude of each sentence was root-mean-square (RMS) standardised by multiplying it by the ratio of the maximum RMS value of the entire set of sentences and the RMS value of the sentence itself. Subsequently two versions were created of each sentence. One version consisted of the original recording and this sentence was used in the baseline or clean speech condition. For the noise condition, a second version was created in which from two to four separate phonemes throughout each sentence were replaced with bursts of noise. As McQueen and Huettig (2012) found lexical modulation regardless of whether noise bursts were inserted in word-initial or word-medial position, noise was substituted for word-initial phonemes in half of the sentences and for word-medial phonemes in the other half of the sentences. Importantly, the bursts of noise were never inserted in the critical word, nor in the two words preceding and following the critical word, so that any differences in looking preference between the clean speech and the noise condition can only be attributed to a decrease in the reliability of the speech signal overall and not to decreased audibility of the critical word itself. The same radio noises were used as in McQueen and Huettig (2012), namely 42262_crk365_mobile_beep1.wav, 30335_ERH_radio_noise_2.wav and 495_skiptracer_RadioStatik3.wav from http://www.freesound.org, and radio_whitenoise.wav and whitenoise.wav from http://www.burninwave.com. The duration of each noise burst was adjusted individually, so that each burst replaced exactly one phoneme. Mean noise duration was 80.4 ms (*SD* = 35.2 ms) in the onset-competitor condition, 78.1 ms (*SD* = 31.3 ms) in the rhyme-competitor condition and sentences in the filler condition had a mean burst duration of 85.2 ms (*SD* = 34.5 ms). Overall mean noise duration was 81.2 ms (*SD* = 33.8, range: 11.2 – 214.1). Following McQueen and Huettig (2012), the amplitude of each noise burst was adjusted so that it corresponded to 80% of the average intensity (in dB) of the sentence it was inserted in. In each condition (onset-competitor, rhyme-competitor, and filler) there were 14 sentences containing two noise substitutions and 13 each with three and four substitutions. In each sentence, bursts were evenly divided over the sentence part that preceded the critical word and the part following it.

4.1.1.2.2. Materials for Experiment 4-1b – English (L2)

The stimulus materials for the English version of the experiment were constructed in parallel to those for the Dutch version (see Appendix I for an overview of all stimuli). Onset competitors had a mean overlap of 3.5 phonemes with the critical word in the spoken sentence and a mean CELEX word frequency of 16.7 per million words (Baayen et al., 1995), whereas mean overlap for rhyme competitors was 3.5 phonemes, and mean CELEX word frequency for these items was 20.2 per million words. Cognates occurred in 18 of the onset-competitor trials and in 14 trials of the rhyme-competitor condition. Unlike Dutch, English does not mark gender on its definite articles and adjectives. However, the form of English indefinite articles (*a*/*an*) depends on the onset of the word they precede. It was therefore ensured that visual displays for sentences in which the critical word was preceded by an indefinite article only contained pictures for which the referent matched the used article. This prevented listeners from making predictions based on the indefinite article.

The recorded sentences were spoken by a female native speaker of Australian English and were recorded, selected, measured and edited in the same way as the Dutch sentences. Mean noise duration was 90.9 ms (*SD* = 42.7 ms) for sentences in the onset-competitor condition, 90.3 ms (*SD* = 38.9 ms) for the rhyme-competitor condition and 91.4 ms (*SD* = 40.6 ms) for filler sentences. Overall mean noise duration was 90.9 ms (*SD* = 40.7, range: 19.5 – 256.0).

4.1.1.3. Procedure

All participants completed two experimental sessions, approximately three weeks apart (*M* = 18.3 days, *SD* = 4.7, range 12 – 29 days). During one session, all stimulus materials and tasks were in Dutch (the 'Dutch session'), while during the other session, they were in English (the 'English session'). Session order was counterbalanced across participants. The experimenter was a native speaker of Dutch who is fluent in English and the language that was spoken during each session depended on the participant's preference. For the majority of participants, this was Dutch. During the English session, several participants temporarily switched to speaking English immediately after completing an experimental task.

As shown in Table 4-1, the eyetracking task was followed in both sessions by the LexTALE proficiency test. In the first experimental session, participants' hearing sensitivity was assessed and participants completed a language background questionnaire. In the second session, there were no further tasks. Many of the emigrants who participated in the present experiment had previously also participated in the experiments reported in Chapter 3, so their language proficiency scores, hearing thresholds and language background information had already been collected. These participants were therefore not required to complete the LexTALE, the hearing assessment or the language background questionnaire for the present study.

Table 4-1. Order and duration of tasks in testing sessions 1 and 2 of Experiment 4-1.

	Session 1 – Language A	**Session 2 – Language B**	
(1)	eyetracking task	eyetracking task	(±20 min)
(2)	LexTALE	LexTALE	(±5 min)
(3)	pure-tone audiogram		(±8 min)
(4)	language background questionnaire		(±30 min)

The same experimental procedure was followed for both sessions of the experiment. Participants were tested individually in a sound-attenuated booth. They were seated in front of a computer screen at a comfortable viewing distance, with their head held in a fixed position by means of a chin and forehead rest. Participants' eye movements were recorded at a sampling rate of 1000 Hz (monocular) using an Eyelink 1000 Tower Mount system (SR Research, Ltd.). Auditory stimuli were presented over Beyerdynamic DT770 PRO headphones at a loud but comfortable level, kept constant for all participants. Written instructions were presented on the screen in the language of the experimental session and these were subsequently repeated orally by the experimenter and clarified if needed. As in McQueen and Huettig’s (2012) study, participants were given no explicit task, other than to listen to the sentences and to not take their eyes off the screen. Before the start of the experiment, the eyetracker was calibrated and validated using a 9-point calibration grid. After every five trials, an automatic drift check was carried out and, if required, calibration was repeated. At the start of each trial, a fixation cross was displayed in the centre of the screen. Participants were instructed to look at this cross until it disappeared. Once the fixation cross had disappeared, the visual display was shown for 1s. After this preview period the sentence would start playing while the display remained on the screen.

All participants were presented with all 120 sentence-display pairs in two blocks of 60, and each participant was presented with a different randomisation of the stimulus list. Sentences were counterbalanced across participants such that half of all participants heard the noise version of a sentence whereas the other half was presented with the clean-speech version of that sentence. There was no break between the baseline and the noise block and participants were not informed about the presence of noise in the second phase of the experiment.

Upon completion of the eyetracking task, participants who had not previously participated in the experiments reported in Chapter 3 completed the LexTALE (in both sessions and in the same language as the eyetracking experiment; Lemhöfer & Broersma, 2012), a hearing assessment and a language background questionnaire (in the first session only).

4.1.2. Results

4.1.2.1. Results of Experiment 4-1a – Dutch (L1)

Due to calibration difficulties data for one participant were excluded from analysis. Thus, data from seventeen listeners were included in the analyses reported in this section. To maintain integrity of the eyetracking data, trials with a track loss percentage greater than 30% were excluded from analysis. This was the case for 43 trials (out of a total of 2040 trials). Figure 4-4 shows the mean fixation proportions to competitors and distractors from the onset of the critical word for the onset- (top) and the rhyme-competitor condition (middle), and the mean fixation proportions to target and distractors for the filler trials (bottom). Proportions were calculated over 20 ms time bins and distractor proportions were averaged over three distractors.

As it is generally assumed that it takes around 200 ms to initiate an eye movement (Matin, Shao, & Boff, 1993), the earliest time windows used for analysis in visual world studies, including McQueen and Huettig (2012), begin at 200 ms after target word onset. For complete consistency with the analyses conducted by McQueen and Huettig it may therefore be argued that the present experiment should be analysed over a time interval starting at 200 ms after critical word onset. However, participants' looking patterns during the filler trials (remember that, unlike the experimental trials, each filler trial contained a spoken critical word that referred to one of the pictures in the visual display and was therefore considered a proper target

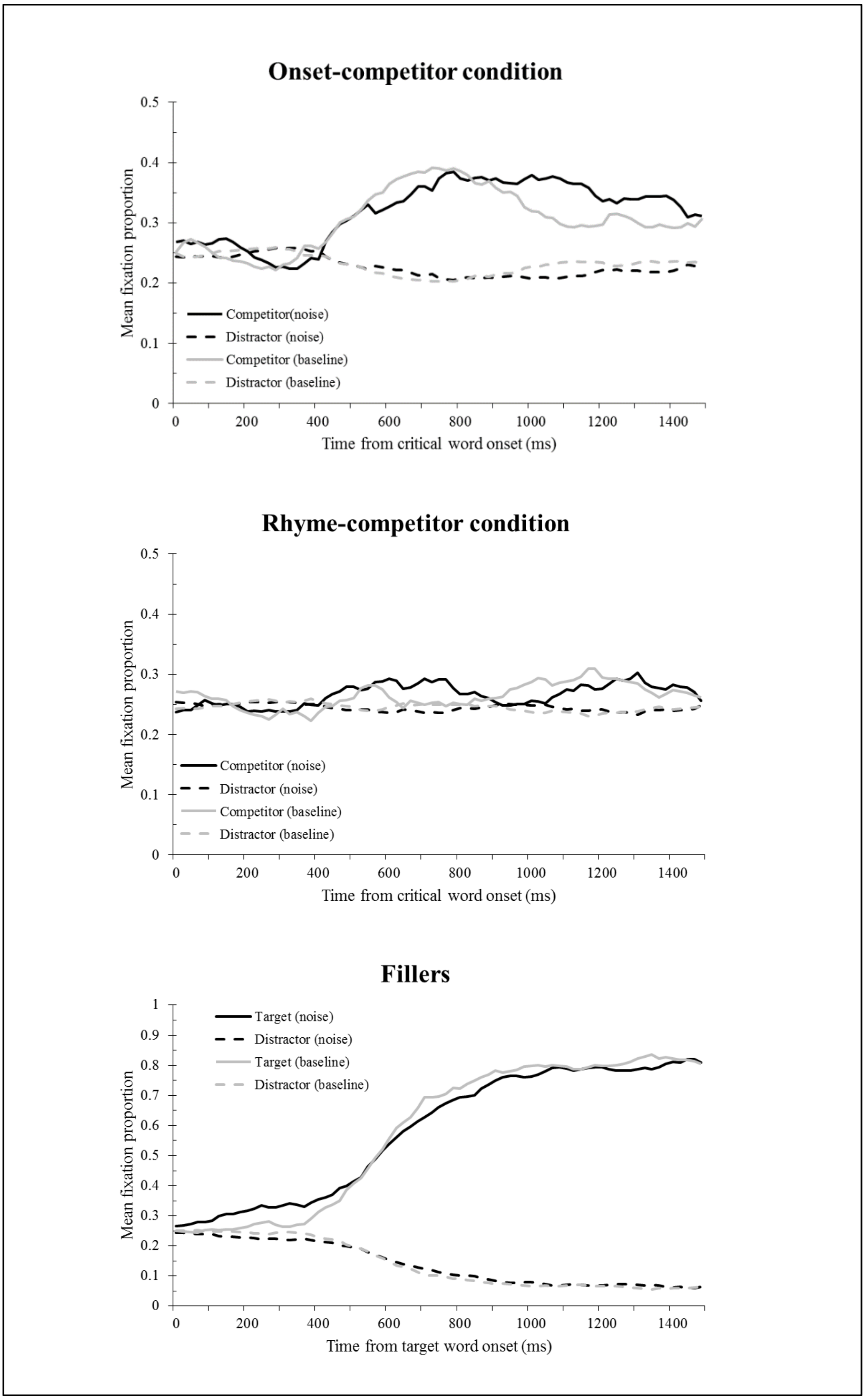

Figure 4-4. Mean fixation proportions for the onset-competitor condition (top), the rhyme-competitor condition (middle) and the fillers (bottom) of Experiment 4-1a. Fixations are plotted from critical word onset, for competitors and distractors, with the noise condition shown in black, and the baseline condition in grey.

word) suggest that a later analysis window may be more appropriate, as the lines representing the proportion of looks to the competitor and to the distractors do not start to diverge until around 300 ms after target word onset (see bottom panel of Figure 4-4). Therefore, the time window chosen for analysis had the same duration as that of McQueen and Huettig (2012), namely 600 ms, yet did not start until 300 ms after critical word onset.

First, competitor preference ratios were calculated for each type of competitor in both noise types. A competitor preference ratio higher than 0.5 indicates that of all looks to competitors and distractors over half were directed to the competitor picture and that the competitor picture therefore did in fact compete for recognition. Ratios were calculated by dividing the total number of competitor fixations in the analysis window by the sum of all competitor fixations and distractor fixations in the analysis window (see Figure 4-5).

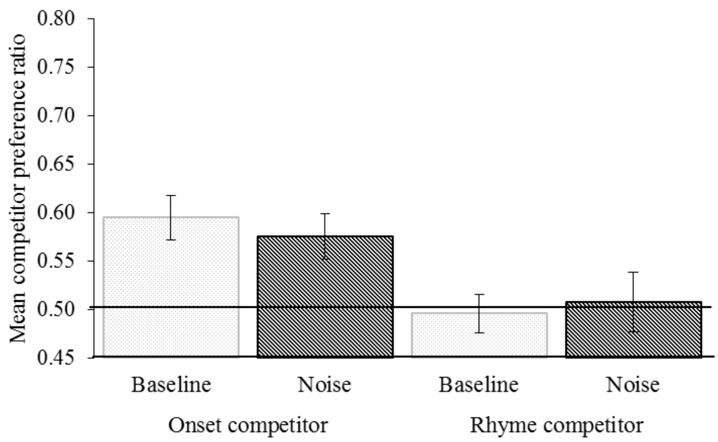

Figure 4-5. Mean competitor preference ratios in Experiment 4-1a for onset and rhyme competitors, in clean speech and in noise. Error bars represent standard errors of the means.

The number of distractor fixations was divided by three as each display contained three distractors and only one competitor picture. In a one-sample two-tailed *t*-test by participants (1) and by items (2), competitor preference ratios were compared to 0.5.

Onset competitors were fixated significantly more than distractors, both in the baseline condition (M_1 = 0.60, $t_1(16) = 4.21$, $p < .001$; M_2 = 0.57, $t_2(39) = 2.86$, p = .007), and in the noise condition (M_1 = 0.58, $t_1(16) = 3.22$, $p = .005$; M_2 = 0.55, $t_2(39)$ = 1.49, $p = .145$), but while this latter effect was significant by participants, it was not significant by items. Rhyme competitors, however, did not attract more looks than distractors in the baseline condition (M_1 = 0.50, $t_1(16) = 0.20$, $p = .842$; M_2 = 0.48, $t_2(39) = 0.71$, $p = .480$), or in the noise condition (M_1 = 0.51, $t_1(16) = 0.25$, $p = .805$; M_2 = 0.49, $t_2(39) = 0.43$, $p = .669$). This suggests that both in clean speech and in noise listeners experienced competition from onset competitors, but not from rhyme competitors.

To examine whether listeners' looking patterns had changed when there were noise bursts in the auditory stimuli, a time-course analysis was performed on competitor fixation proportions across competitor and noise types using weighted empirical logits (Barr, 2008) with linear mixed-effects regression models (LMER; Baayen, Davidson, & Bates, 2008). Separate regression analyses by participants and by items were conducted in R (2015), using the packages lme4 (Bates, Maechler, Bolker, & Walker, 2015) and lmerTest (Kuznetsova, Brockhoff, & Christensen, 2015). Although LMER models allow the inclusion of participants and items as crossed effects (thereby eliminating the need for separate by-participants and by-item analyses), this is typically not possible for experiments using the visual world paradigm due to the strong correlation that exists between individual fixations. In the present experiment, for example, fixations were registered once every millisecond, which means that the time interval between any two recorded fixations is much shorter than the time it would take listeners to move their eyes from one picture to another. As a result, the location of a fixation in a certain time sample strongly depends on the fixation location in the preceding and following time samples. To overcome this interdependence, competitor fixations can be aggregated into time bins. Aggregated fixations nested within participants can then be included in the by-participants analyses, while aggregated fixations nested within items can be included in the by-items analyses. Here, competitor fixations in each condition were aggregated into 50 ms time bins, both across participants and across items. Aggregated fixations were then transformed to empirical logits (Barr, 2008), including only fixations on competitor or distractor pictures in the total number of fixations for each time bin. Both Noise Type (with the clean speech or baseline condition coded as -0.5, and noise condition coded as 0.5) and Competitor Type (with onset competitors coded as -0.5 and rhyme competitors as 0.5) were entered into the models as fixed categorical predictors.[12] Time was added as a continuous fixed predictor. Random intercepts for participants and for aggregated fixations nested within participants were added to the by-participants model, and random intercepts were added for items and for aggregated fixations nested within items to the by-items model. Analyses started with a full random structure (Barr, Levy, Scheepers, & Tily, 2013), but as both models failed to converge with this structure, each model was simplified by removing any random slopes for fixed predictors that did not improve model fit. Results of the regression analysis are shown in Table 4-2.

[12] There are multiple ways to code categorical predictors for LMER models, some of which consider one predictor level to be the reference or baseline level and compare all other levels of the predictor against this baseline level. While this approach may seem a logical choice for the predictor Noise Type (as for this predictor, a proper baseline level exists), this is not the case for Competitor Type. For the present analysis, deviation coding was chosen, and the two levels of each of the fixed predictors were coded as 0.5 and -0.5, respectively. As a result, both levels of any given categorical predictor were compared to the grand mean for that predictor across all levels.

Table 4-2. Results of LMER analyses of competitor fixations in Experiment 4-1a.

Effect	**By-participants**			**By-items**		
	Est.[c]	SE	*t*-value	Est.[c]	SE	*t*-value
(Intercept)	-1.13	0.07	-15.50*	-1.07	0.08	-13.94*
Time	0.80[a]	0.21	3.72*	0.74[b]	0.20	3.64*
Noise Type	-0.07	0.14	-0.46	-0.04	0.14	-0.29
Competitor Type	-0.04	0.14	-0.29	0.01	0.15	0.07
Time * Noise Type	0.19	0.37	0.51	0.20	0.39	0.52
Time * Competitor Type	-1.04	0.37	-2.83*	-1.09	0.41	-2.67*
Noise Type * Competitor Type	0.09	0.29	0.31	0.09	0.29	0.32
Time * Noise Type * Competitor Type	0.12	0.74	0.16	0.13	0.78	0.16

* $p < .05$

[a] random slopes for participants and participants over aggregated items

[b] random slopes for items and items over aggregated participants

[c] Est. = estimated coefficient

As expected, the regression analysis shows a main effect of Time, indicating that, averaged across all conditions, competitors attracted increasingly more looks over the course of the critical time window. While the inclusion of Time in the regression models was necessary for a correct time-course analysis, this predictor in itself is not of interest here, since it is expected to be significant in all analyses. In the remainder of this chapter, main effects of Time will therefore no longer be mentioned. There is also a significant interaction between Time and Competitor Type. The β-value of -1.04 for this interaction indicates that the slope of fixations to onset competitors was steeper than the slope of fixations to rhyme competitors (since onset competitors were coded with -0.5). Crucially, no main effect of Noise Type was found, nor any interactions involving this fixed predictor. It therefore appears that the presence of noise bursts in the signal did not influence listeners' looking behaviour.

Nine participants completed Experiment 4-1a during the first testing session, while eight participants completed it in the second session. Additional LMER analyses that included session order as a fixed predictor did not reveal any order effects.

4.1.2.2. Results of Experiment 4-1b – English (L2)

Due to calibration difficulties data for two participants were excluded from analysis. Thus, data from sixteen listeners were included in the analyses reported in this section. Trials with a track loss percentage greater than 30% were again excluded from analysis. This was the case for 57 out of 1920 trials. Figure 4-6 shows the mean fixation proportions to the competitors and distractors from the onset of the critical word for the onset- (top) and the rhyme-competitor condition (middle), and the mean fixation proportions to the target and the distractors for the filler trials (bottom). Based on a visual inspection of these looking patterns, different analysis windows were selected for the onset-competitor and the rhyme-competitor condition. Onset-competitor trials were analysed from 300 – 900 ms, and the rhyme-competitor condition from 500 – 1100 ms after critical word onset. [13] Analyses were conducted as for Experiment 4-1a.

[13] For consistency with the analysis reported in section 4.1.2.1, an additional analysis was conducted with identical time windows for the onset-competitor and the rhyme-competitor condition. It provided no additional insights and is reported in Appendix J.

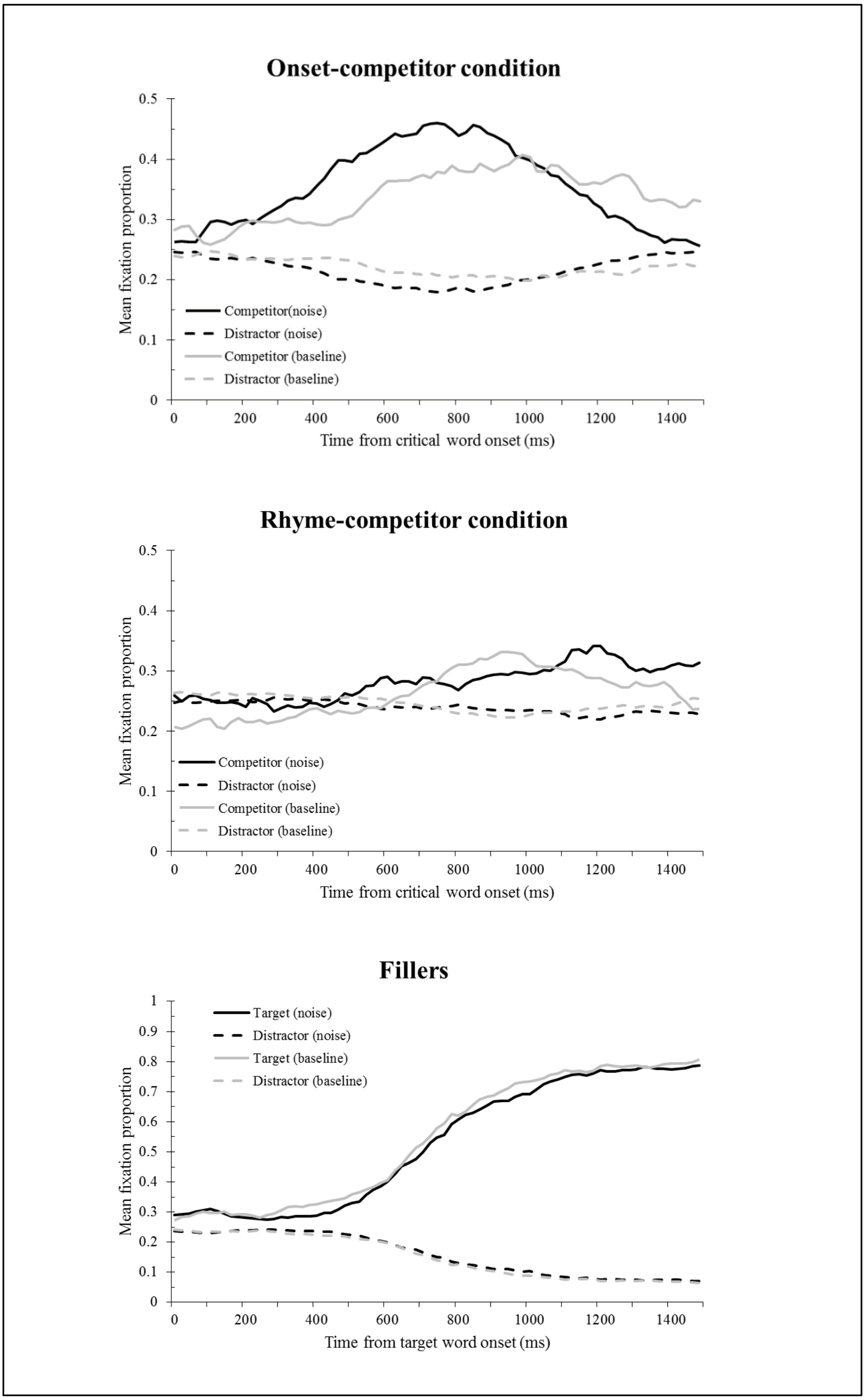

Figure 4-6. Mean fixation proportions for the onset-competitor condition (top), the rhyme-competitor condition (middle) and the fillers (bottom) of Experiment 4-1b. Fixations are plotted from critical word onset, for competitors and distractors, with the noise condition shown in black, and the baseline condition in grey.

Figure 4-7 shows competitor preference ratios per condition. A one-sample two-tailed *t*-test by participants (1) and by items (2) showed that onset competitors were fixated significantly more than distractors, both in the baseline condition (M_1 = 0.60, $t_1(15)$ = 3.62, p = .003; M_2 = 0.57, $t_2(39)$ = 2.49, p = .017), and in the noise condition (M_1 = 0.67, $t_1(15)$ = 6.46, p < .001; M_2 = 0.62, $t_2(39)$ = 3.35, p = .002). Rhyme competitors, on the other hand, did not attract significantly more looks than distractors, either in the baseline condition (M_1 = 0.54, $t_1(15)$ = 1.15, p = .268; M_2 = 0.51, $t_2(39)$ = 0.24, p = .814), or in the noise condition (M_1 = 0.53, $t_1(15)$ = 1.09, p = .293; M_2 = 0.50, $t_2(39)$ = 0.13, p = .895).

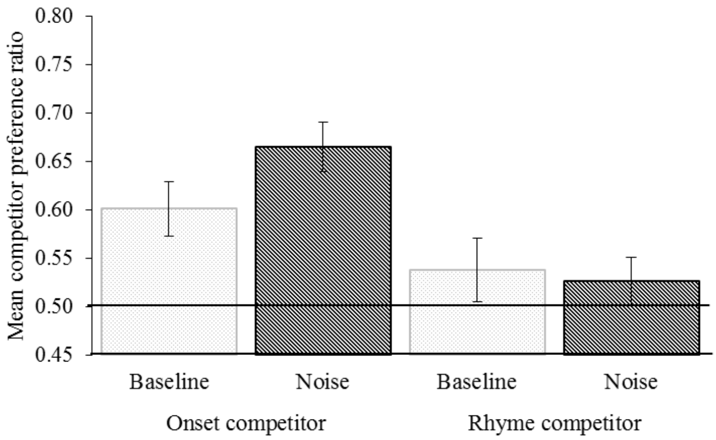

Figure 4-7. Mean competitor preference ratios in Experiment 4-1b for onset and rhyme competitors, in clean speech and in noise. Error bars represent standard errors of the means.

Table 4-3 shows the results of the linear mixed effects regression analysis of the time course of competitor fixations. There is a main effect of Competitor Type, which indicates that over the entire critical time window and averaged across both noise types, onset competitors attracted more looks than rhyme competitors (see the competitor preference ratios in Figure 4-7). This effect was significant only in the by-participants model. No other significant main effects or interactions were found. Importantly, as in Experiment 4-1a, listeners' looking behaviour showed no influence of the noise bursts in the auditory stimuli.

Table 4-3. Results of LMER analyses of competitor fixations in Experiment 4-1b.

Effect	**By-participants**			**By-items**		
	Est.[c]	SE	*t*-value	Est.[c]	SE	*t*-value
(Intercept)	-0.93	.08	-12.16*	-0.92	.08	-11.51*
Time	0.72[a]	.22	3.31*	0.70[b]	.21	3.26*
Noise Type	0.17	.15	1.13	0.18	.15	1.25
Competitor Type	-0.32	.15	-2.07*	-0.22	.16	-1.38
Time * Noise Type	-0.18	.40	-0.45	-0.16	.33	-0.48
Time * Competitor Type	-0.45	.40	-1.14	-0.56	.43	-1.31
Noise Type * Competitor Type	-0.20	.30	-0.67	-0.01	.29	-0.02
Time * Noise Type * Competitor Type	-0.50	.79	-0.64	-1.07	.67	-1.61

* $p < .05$
[a]random slopes for participants and participants over aggregated items
[b]random slopes for items and items over aggregated participants
[c] Est. = estimated coefficient

As in Experiment 4-1a, an additional LMER analysis was conducted to check whether the session in which participants completed the experiment influenced fixation patterns. No order effects were found.

4.1.2.3. Comparison of L1 and L2 competition

For a comparison of the lexical competition experienced in L1 and L2 listening, the baseline conditions of Experiments 4-1a and 4-1b were analysed together over a 1s time interval starting at 400 ms after critical word onset.[14] Figure 4-8 shows L1 and L2 competitor preference ratios per competitor condition for this time window. Paired *t*-tests showed that the strength of the onset competition listeners experienced did not significantly differ between L1 and L2 ($t(14) = 1.25$, $p = .231$). The strength of the rhyme competition did not significantly differ either ($t(14) = 0.72$, $p = .483$).

[14] Data from 17 L1 listeners and 16 L2 listeners (18 unique participants) were included in the reported comparisons. Analysis of data from only those 15 participants who completed both experiments yielded the same significant effects and interactions.

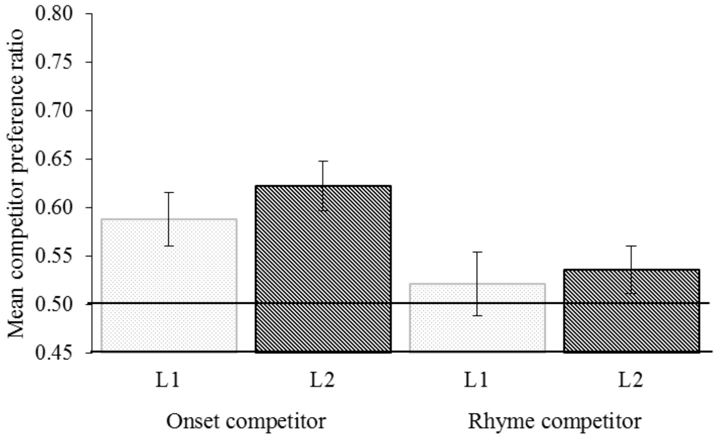

Figure 4-8. Mean competitor preference ratios in clean speech for the onset and rhyme competitor conditions of Experiments 4-1a (L1) and 4-1b (L2). Error bars represent standard errors of the means.

The time course of the fixations to onset and rhyme competitors in the baseline condition of both languages (see Figure 4-9) was analysed with an LMER model. This analysis used the same method as described for Experiments 4-1a and 4-1b but with Competitor Type (onset competitors coded as -0.5 and rhyme competitors as 0.5) and Language Type (L1 coded as -0.5 and L2 as 0.5) as the fixed categorical predictors. No by-items analysis was conducted, as items differed across language types. Results of the by-participants analysis are displayed in Table 4-4.

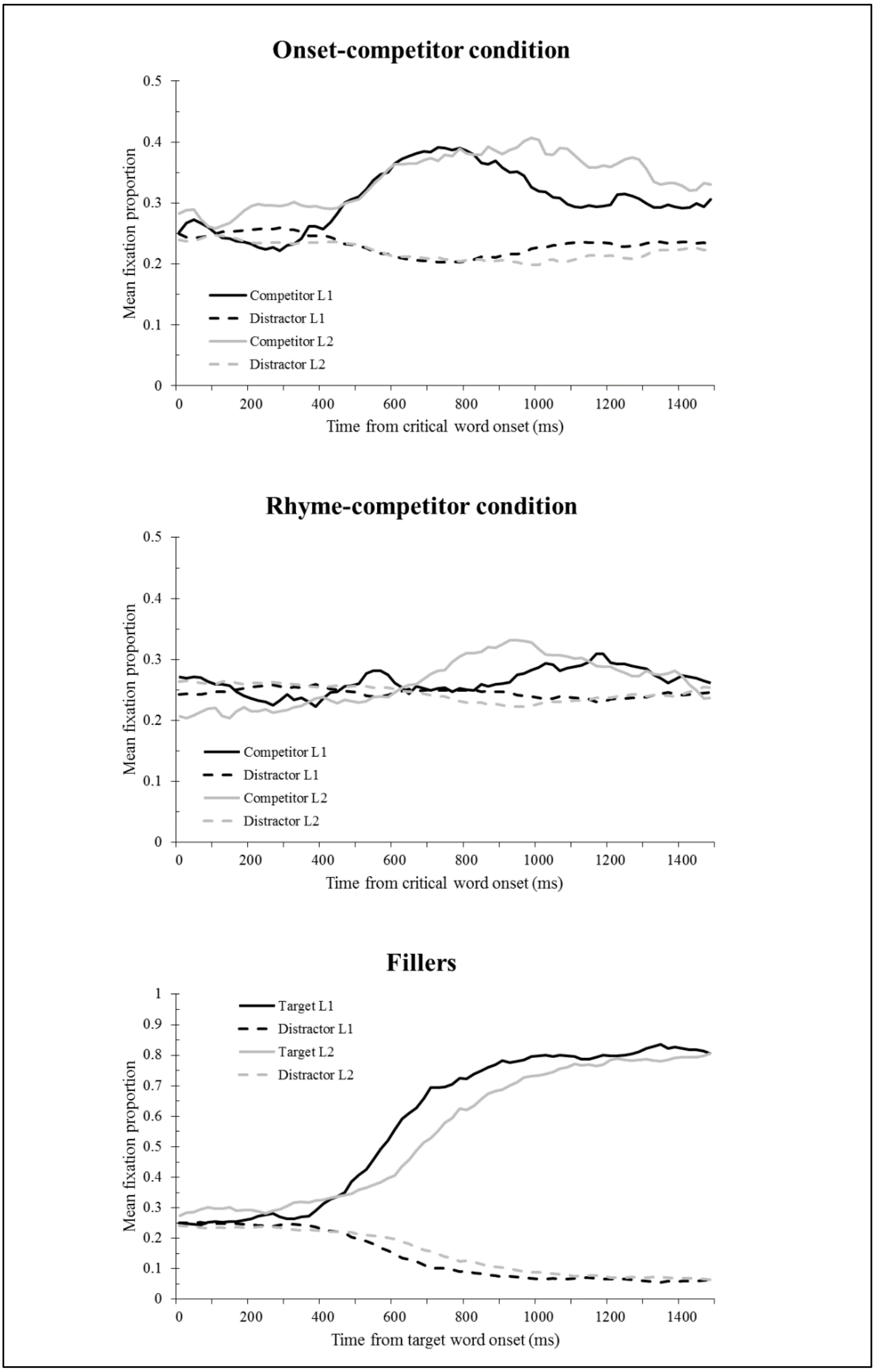

Figure 4-9. Mean fixation proportions in clean speech for the onset-competitor condition (top), the rhyme-competitor condition (middle) and the fillers (bottom) of Experiments 4-1a and 4-1b. Fixations are plotted from critical word onset, for competitors and distractors, with fixations from the L1 experiment shown in black, and fixations from the L2 experiment shown in grey.

Table 4-4. Results of LMER analyses of competitor fixations in the baseline conditions of Experiments 4-1a (L1) and 4-1b (L2).

Effect	By-participants		
	Est.[b]	SE	*t*-value
(Intercept)	-0.84	0.07	-12.26*
Time	0.16[a]	0.11	1.50
Competitor Type	-0.50	0.14	-3.70*
Language Type	0.01	0.05	0.28
Time * Competitor Type	0.31	0.20	1.53
Time * Language Type	0.19	0.09	2.19*
Competitor Type * Language Type	0.14	0.10	1.38
Time * Competitor Type * Language Type	-0.44	0.18	-2.50*

* $p < .05$

[a] random slopes for participants and participants over aggregated items

[b] Est. = estimated coefficient

The analysis shows a main effect of Competitor Type, with a β-value of -0.50 indicating that across both languages, onset competitors attracted more looks than rhyme competitors. The analysis also reveals a significant two-way interaction between Time and Language Type, which, with a β-value of 0.19, suggests that over time, fixation proportions are maintained longer in L2 than in L1. Finally, there is a three-way interaction between Time, Competitor Type and Language Type (β = -0.44), possibly capturing the fact that these maintained fixations affect the competitor types at different time points.

4.1.3. Discussion

In the present experiment, bilinguals' lexical competition in L1 and L2 listening was investigated. In addition, the question of whether bilinguals show lexical modulation when they listen to L1 and L2 in adverse listening conditions was examined. The findings suggest that Dutch-English bilingual emigrants experienced onset competition in L1 and L2 listening, and both in clean speech and in speech that is interrupted by bursts of noise. In neither language and in neither noise type, however, did rhyme competitors compete significantly more than unrelated distractors. Furthermore, a cross-language comparison of the clean speech condition found that although the overall levels of competition from onset and rhyme competitors are comparable across L2 and L1, the time course of this competition is not. In L2 listening onset competitors remain activated longer and rhyme competitors get activated earlier than in L1 listening. This is in line with findings from previous studies, which showed greater and longer-lasting lexical competition in L2 listening than in L1 listening (e.g., Broersma & Cutler, 2011; Weber & Cutler, 2004).

If Dutch emigrants adjust the way they evaluate lexical competitors when the speech signal is made less reliable with bursts of noise, whether it be in L1 or in L2 listening, a weaker onset-competitor and a stronger rhyme-competitor effect would be expected in the noise condition in comparison to the baseline (clean speech) condition for that language. No such evidence was found in either Experiments 4-1a or 4-1b. It would be premature, however, to interpret these results as an indication of the loss of lexical flexibility in L1 listening by emigrants or to conclude that lexical modulation does not occur in L2 listening. The reason for this caution is that only two studies to date have demonstrated lexical modulation (i.e., Brouwer et al., 2012, and McQueen & Huettig, 2012) and they share two possibly important characteristics: both studies were carried out in Dutch, and participants in both of these studies, as indeed in most studies of speech perception, were young adults, whereas the emigrant population tested here was considerably older (the youngest emigrant was 27, the oldest 73). In the second part of this chapter, several follow-up experiments are therefore reported to further investigate lexical modulation and assist in the interpretation of the findings of the present experiment.

4.2. Control experiments

4.2.1. Experiment 4-2

The present experiment was conducted to assess whether lexical modulation can be demonstrated in L1 listeners of English. If lexical modulation occurs in these listeners, weaker onset competition and stronger rhyme competition is expected in the noise condition compared to the clean speech condition.

4.2.1.1. Method

4.2.1.1.1. Participants

Twenty-five undergraduate students (five males) from Western Sydney University participated in return for course credit. All participants were native speakers of Australian English, aged 17–35 years (*M* = 21.4, *SD* = 4.2), with normal or corrected-to-normal vision. For screening purposes, pure-tone air conduction thresholds were determined for all participants. The mean threshold for the better ear (averaged over 0.5, 1, and 2 kHz) was 4.1 dB HL (range: -3.3 – 11.7, *SD* = 3.3) and high-frequency thresholds for the better ear (averaged over 4 and 8 kHz) ranged from -2.5 – 22.5 dB HL (*M* = 2.4, *SD* = 6.3). All participants therefore had normal hearing sensitivity. A further 18 participants' data were excluded from analysis for the following reasons: native languages other than English (*n* = 10), aged 35+ (*n* = 6), calibration difficulties (*n* = 1) and deafness (*n* = 1). Each participant provided written informed consent before the start of the experiment.

4.2.1.1.2. Stimulus materials

Stimulus materials were identical to those used for Experiment 4-1b (see section 4.1.1.2.2).

4.2.1.1.3. Procedure

The procedure was the same as in session 1 of Experiment 4-1 (see section 4.1.1.3), with the exception of the LexTALE, which was not included. After the eyetracking task, participants therefore only completed a hearing assessment and a language background questionnaire.

4.2.1.2. Results

Trials with a track loss percentage greater than 30% were excluded from analysis. This was the case for 23 out of 3000 trials. Figure 4-10 shows the mean fixation proportions to the competitors and distractors from the onset of the critical word for the onset- (top) and the rhyme-competitor condition (middle), and the mean fixation proportions to the target and the distractors for the filler trials (bottom). As before, proportions were calculated over 20 ms time bins and distractor proportions were averaged over three distractors. As in Experiment 4-1b, different analysis windows were selected for the onset-competitor and the rhyme-competitor condition based on a visual inspection of looking patterns (see Figure 4-10). Onset-competitor trials were once again analysed from 300 – 900 ms, whereas the window for the rhyme-competitor condition ran from 800 – 1400 ms after critical word onset.[15] Analyses were conducted in the same way as reported for Experiment 4-1 (see section 4.1.2).

[15] Analyses of identical time windows for the onset-competitor and the rhyme-competitor condition window are reported in Appendix K.

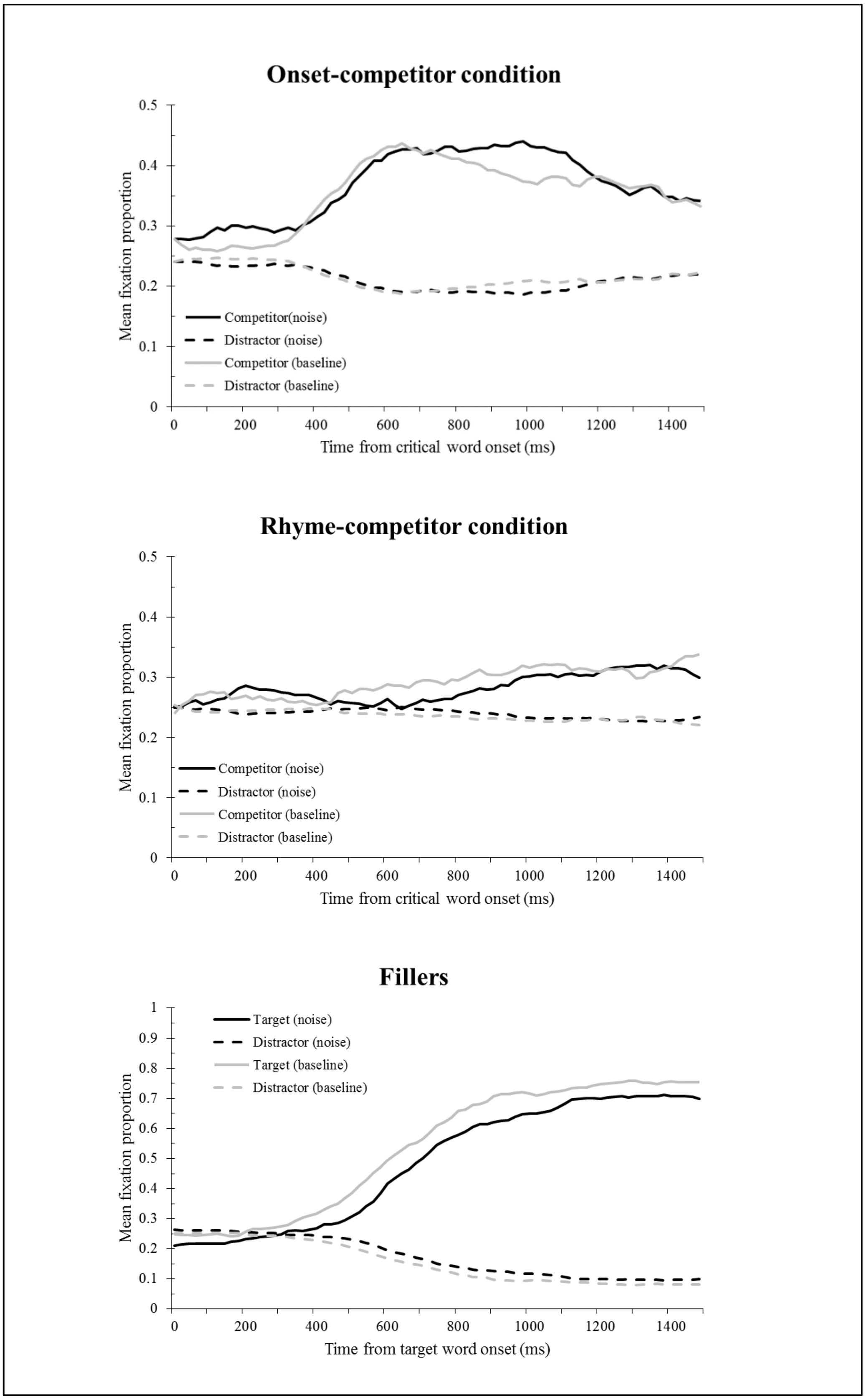

Figure 4-10. Mean fixation proportions for the onset-competitor condition (top), the rhyme-competitor condition (middle) and the fillers (bottom) of Experiment 4-2. Fixations are plotted from critical word onset, for competitors and distractors, with the noise condition shown in black, and the baseline condition in grey.

Figure 4-11 shows competitor preference ratios per condition. A one-sample two-tailed *t*-test by participants (1) and by items (2) showed that onset competitors were fixated significantly more than distractors, both in the baseline condition (M_1 = 0.63, $t_1(23) = 4.64$, $p < .001$; M_2 = 0.62, $t_2(39) = 4.79$, $p < .001$), and in the noise condition (M_1 = 0.65, $t_1(23) = 8.29$, $p < .001$; M_2 = 0.62, $t_2(39) = 5.08$, $p < .001$). Rhyme competitors also attracted more looks than distractors in the baseline condition (M_1 = 0.57, $t_1(23) = 3.16$, $p < .001$; M_2 = 0.55, $t_2(39) = 1.92$, $p = .063$), and in the noise condition (M_1 = 0.55, $t_1(23) = 2.67$, $p = .014$; M_2 = 0.53, $t_2(39) = 1.21$, $p = .235$), but while this latter effect was significant by participants, it was not by items. These results point to a strong onset-competitor effect and a later and weaker rhyme-competitor effect, both in noise and in clean speech.

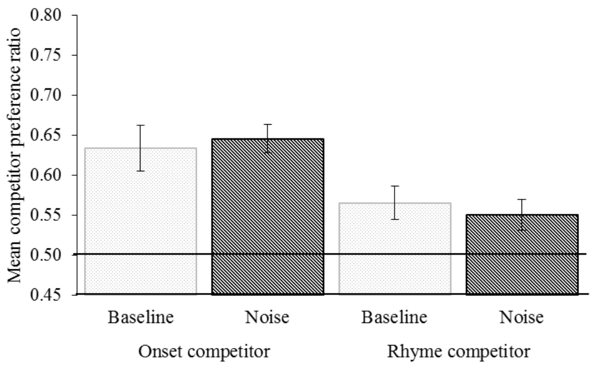

Figure 4-11. Mean competitor preference ratios in Experiment 4-2 for onset and rhyme competitors, in clean speech and in noise. Error bars represent standard errors of the means.

The results of the linear mixed effects regression analysis of the time course of competitor fixations are displayed in Table 4-5. As in Experiment 4-1a, there was a significant interaction between Time and Competitor Type. The β-value of -0.91 indicates that the slope of fixations to onset competitors was steeper than the slope of fixations to rhyme competitors. No main effect of Noise Type was found, nor any

Table 4-5. Results of LMER analyses of competitor fixations in Experiment 4-2.

Effect	By-participants			By-items		
	Est.[c]	SE	*t*-value	Est.[c]	SE	*t*-value
(Intercept)	-0.84	.06	-13.22*	-0.89	.08	-11.49*
Time	0.63[a]	.19	3.30*	0.70[b]	.16	4.39*
Noise Type	-0.13	.12	-1.07	-0.13	.13	-0.97
Competitor Type	-0.11	.12	-0.93	-0.13	.16	-0.85
Time * Noise Type	0.37	.30	1.23	0.32	.32	1.02
Time * Competitor Type	-0.91	.30	-3.02*	-0.83	.32	-2.60*
Noise Type * Competitor Type	-0.08	.24	-0.34	-0.07	.26	-0.27
Time * Noise Type *Competitor Type	0.06	.60	0.11	0.00	.64	0.01

* $p < .05$

[a]random slopes for participants and participants over aggregated items

[b]random slopes for items over aggregated participants

[c] Est. = estimated coefficient

interactions involving this predictor. It therefore once more appears that the occurrence of noise bursts in the signal did not influence listeners' looking behaviour.

4.2.1.3. Discussion

The present control experiment investigated whether young-adult L1 listeners of English adjust the parameters of lexical activation and competition when the reliability of the speech signal is decreased by occasional bursts of noise. If these young adults behave similarly to the native Dutch-speaking young adults in McQueen and Huettig (2012), a weaker onset-competitor and a stronger rhyme-competitor effect were predicted in the noise condition than in the baseline (clean speech) condition. Analysis confirmed previous findings of a strong onset-competitor effect and a weaker and later rhyme-competitor effect (as reported by, e.g., Allopenna et al., 1998), both in clean speech and in noise. No evidence was found, however, to suggest that listeners were affected by the presence of noise bursts. Overall, there was no significant difference between competitor fixations in noise and in clean speech, and the lack of interaction between noise type and competitor type indicates that listeners did not adjust their processing dynamics when they were faced with a less reliable speech signal. This matches the findings of Experiment 4-1b but not those of the study by McQueen and Huettig (2012).

4.2.2. Experiment 4-3

Unlike the participants in McQueen and Huettig (2012) and Brouwer et al. (2012), who were all young adults, the emigrants who participated in the present project ranged in age from mid-twenties to early-seventies. Extensive research on speech perception in aging listeners has shown that in adverse listening conditions, older listeners cope less well than younger listeners and that the disparity cannot be explained fully by hearing loss (Frisina & Frisina, 1997; Helfer & Staub, 2014). In particular, older adults may experience more difficulties suppressing lexical competitors due to the decline in inhibitory capacities that is arguably associated with aging (Robert & Mathey, 2007; Sommers & Danielson, 1999). Like younger adults, older listeners show a fairly strong onset-competitor effect and a rhyme-competitor effect that is smaller than the onset-competitor effect (e.g., Ben-David et al., 2011) but their ability to adjust competitor relationships under adverse conditions has not been investigated. The present control experiment was therefore conducted to investigate whether the emigrants' age may have prevented them from making adjustments to lexical competition processes. With a replication of Experiment 4-1a it was assessed whether native Dutch listeners in the Netherlands, aged 60 years and over, adjust the parameters of lexical activation and competition when the speech signal is occasionally interrupted by bursts of noise. Given that the saccadic motor system appears to be largely unaffected by aging (Pratt, Dodd, & Welsh, 2006), there is no reason to doubt that a visual world experiment was appropriate for this participant population,. The predictions for this experiment are the same as for Experiment 4-2.

4.2.2.1. Method

4.2.2.1.1. Participants

Twenty-two participants (11 males) from the participant pool of the MPI for Psycholinguistics in Nijmegen, the Netherlands, were paid for their participation in this study. Seven additional participants' results were excluded due to calibration difficulties. All participants were native speakers of Dutch, aged 62–85 years ($M = 69.8$, $SD = 6.5$), with normal or corrected-to-normal vision. For screening purposes, pure-tone air conduction thresholds were obtained for all participants. The mean threshold for the better ear (averaged over 0.5, 1, and 2 kHz) was 22.6 dB HL (range: 3.3 – 43.3, $SD = 12.8$). High-frequency thresholds for the better ear (averaged over 4, 6 and 8 kHz) ranged from 3.3 – 70.0 dB HL ($M = 38.3$, $SD = 24.2$). None of the participants wore hearing aids in their daily life. Informed consent was obtained from each participant prior to the start of the experiment.

4.2.2.1.2. Stimulus materials

All stimulus materials were identical to those used in Experiment 4-1a (see section 4.1.1.2), with the exception that several distractor pictures were exchanged across visual displays.[16]

4.2.2.1.3. Procedure

The procedure was the same as in session 1 of Experiment 4-1 (see section 4.1.1.3), with the following exceptions. Participants were seated in front of a computer screen

[16] For logistical reasons, all control experiments involving native Dutch listeners in the Netherlands (i.e., Experiments 4-3, 4-4 and 4-5) were conducted before Experiment 4-1. Some distractor pictures were exchanged between visual displays after Experiments 4-3 and 4-5 had been completed, because of the phonological overlap between their English referent (which was expected to be co-activated by the bilingual emigrants who participated in Experiment 4-1) and that of the competitor image.

at a viewing distance of 95 cm and auditory stimuli were presented over Sennheiser HD201 headphones. The LexTALE was not included.

4.2.2.2. Results

Again, trials with a track loss percentage greater than 30% (78 trials) were discarded. Figure 4-12 shows the mean fixation proportions to the competitors and distractors from the onset of the critical word for the onset- (top) and the rhyme-competitor condition (middle), and the mean fixation proportions to the target and the distractors for the filler trials (bottom). As in previous experiments, proportions were calculated over 20 ms time bins and distractor proportions were averaged over three distractors. Analysis windows were once more selected based on looking patterns (see Figure 4-12) and were the same as in Experiment 4-2. Thus analyses were conducted over a 600 ms time interval starting at 300 ms after critical word onset for the onset-competitor condition and at 800 ms for the rhyme-competitor condition. Analyses were conducted in the same way as reported for Experiments 4-1 and 4-2.

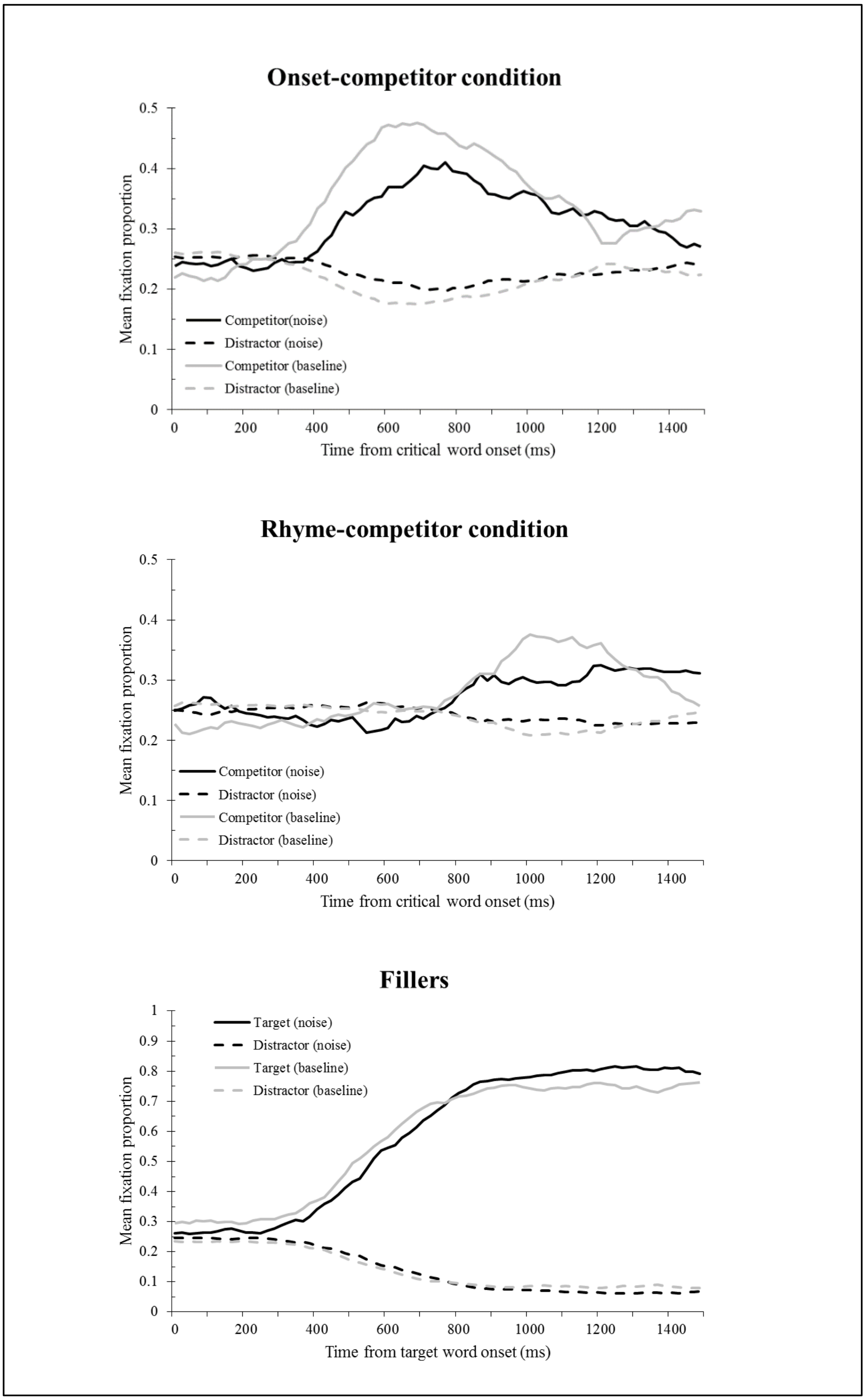

Figure 4-12. Mean fixation proportions for the onset-competitor condition (top), the rhyme-competitor condition (middle) and the fillers (bottom) of Experiment 4-3. Fixations are plotted from critical word onset, for competitors and distractors, with the noise condition shown in black, and the baseline condition in grey.

Figure 4-13 shows competitor preference ratios per condition. A one-sample two-tailed *t*-test by participants (1) and by items (2) revealed that in the baseline condition, both onset (M_1 = 0.67, $t_1(21) = 8.08$, $p < .001$; M_2 = 0.65, $t_2(39) = 6.62$, $p < .001$) and rhyme (M_1 = 0.59, $t_1(21) = 4.52$, $p <.001$; M_2 = 0.58, $t_2(39) = 3.18$, $p = .003$) competitors were fixated significantly more than distractors. In the noise condition, onset competitors were fixated significantly more than distractors (M_1 = 0.61, $t_1(21)$ = 4.34, $p < .001$; M_2 = 0.57, $t_2(39) = 2.54$, $p = .015$), whereas rhyme competitors were not (M_1 = 0.55, $t_1(21) = 1.94$, $p = .067$; M_2 = 0.54, $t_2(39) = 1.67$, $p = .102$).

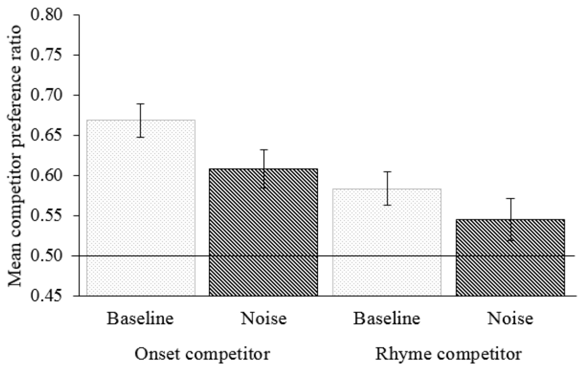

Figure 4-13. Mean competitor preference ratios in Experiment 4-3 for onset and rhyme competitors, in clean speech and in noise. Error bars represent standard errors of the means.

As in the previous experiments, the time course of competitor fixations was then analysed to determine whether listeners' looking patterns changed when noise bursts occurred in the spoken sentences. The results of the regression analyses are shown in Table 4-6. As in Experiments 4-1a and 4-2, there was a significant interaction between Time and Competitor Type with a negative β-value (-1.12) indicating that the slope of fixations to onset competitors was steeper than the slope of fixations to rhyme competitors. Noise Type was not significant as a main effect at an alpha rate of .05, but would be significant at a less conservative alpha rate of .10. While this differs from

Table 4-6. Results of LMER analyses of competitor fixations in Experiment 4-3.

Effect	**By-participants**			**By-items**		
	Est.[c]	SE	*t*-value	Est.[c]	SE	*t*-value
(Intercept)	-0.84	.08	-10.14*	-0.85	.08	-10.49*
Time	0.68[a]	.18	3.76*	0.74[b]	.19	3.89*
Noise Type	-0.27	.14	-1.92†	-0.22	.13	-1.72†
Competitor Type	0.05	.14	0.35	0.08	.16	0.50
Time * Noise Type	0.13	.36	0.35	0.02	.30	0.07
Time * Competitor Type	-1.12	.36	-3.10*	-1.16	.38	-3.07*
Noise Type * Competitor Type	0.07	.28	0.24	0.02	.26	0.07
Time * Noise Type * Competitor Type	0.15	.72	0.21	0.22	.60	0.37

* $p < .05$
† $p < .10$
[a] random slopes for participants and participants over aggregated items
[b] random slopes for items and items over aggregated participants
[c] Est. = estimated coefficient

the outcome of an F_1 x F_2 analysis of variance over collapsed fixation proportions for the entire analysis window that did show a main effect of Noise Type, this difference can be explained by the inclusion of random slopes for participants and items in the LMER models. By-participant and by-item models from which those random slopes have been removed do show a main effect of Noise Type, which indicates that variance contributed by participants and items was confounded with an effect of Noise Type in the models without random slopes for participants or items. Importantly, no interactions involving Noise Type and Competitor Type were found, suggesting once more that the occurrence of noise bursts in the signal did not influence listeners' looking behaviour.

Further, as participants' hearing acuity varied from normal hearing to mild-to-moderate hearing loss, it was checked whether hearing thresholds were related to the strength of the lexical competition participants experienced in the different conditions. The LMER model above was expanded to include listeners' hearing acuity as a fixed predictor, but neither thresholds averaged over 0.5, 1, and 2 kHz, nor mean thresholds for 4-8 kHz were significant predictors.

4.2.2.3. Discussion

The present control experiment investigated whether older Dutch listeners adjust the way they evaluate lexical competitors when the reliability of the speech signal is decreased by occasional bursts of noise. If older Dutch listeners behave like the young Dutch adults tested by McQueen and Huettig (2012), a weaker onset-competitor and a stronger rhyme-competitor effect would be expected in the noise condition than in the baseline (clean speech) condition. First, the results in the baseline condition confirmed previous findings of strong onset-competitor effects and smaller rhyme-competitor effects in young and older adults (e.g., Allopenna et al., 1998; Ben-David et al., 2011). This suggests normal efficiency of speech processing in older listeners. However, in the baseline condition, mean fixation proportions to both onset and rhyme competitors reached higher peaks (0.48 and 0.37 respectively) than those found by McQueen and Huettig (2012) for younger adults in the baseline condition. Fixation proportions in McQueen and Huettig (2012) peak around 0.34 for onset competitors and around 0.24 for rhyme competitors. This may indicate that, even in noise-free listening conditions, older listeners are more cautious than younger adults in eliminating competitors as potential lexical candidates. Alternatively, it could be the result of the decrease in inhibitory capacities that is generally associated with aging (e.g., Hasher & Zacks, 1988; Mattys & Scharenborg, 2014): older listeners may experience more difficulties suppressing competitors than younger adults.

In the noise condition, onset competitors did not compete for recognition as strongly as in the baseline condition. This replicates the findings by McQueen and Huettig (2012) and could indicate that the older listeners adjusted the parameters of lexical activation and competition. However, participants also experienced weaker competition from rhyme competitors in the noise condition than in the baseline condition, which speaks against such an adjustment, as listeners' increased uncertainty about the speech signal was expected to lead to an increased preference for rhyme competitors in noise. The fact that the older adults did not adjust their processing dynamics in this respect might be linked to the fact that rhyme competitors already attracted a high proportion of looks in the baseline condition. In order to compensate for age-related deficits, older adults may employ dynamic listening strategies in noise-free situations that are similar to those used by younger adults to adjust to noisy listening conditions. When the speech signal deteriorates, older listeners could already be operating at capacity and may therefore not adjust further to the changing listening conditions.

As participants with poorer-than-normal hearing thresholds were not excluded from this experiment, about half of all participants suffered from mild to moderate hearing loss. Even though the difference between the results of the present experiment and the study by McQueen and Huettig (2012) may be (partly) related to hearing differences between age groups, there was no correlation between the measured hearing thresholds and the levels of competition experienced, across these participants, so that this is unlikely to be the source of the difference in results.

In sum, contrary to previous findings for native Dutch-speaking younger adults by McQueen and Huettig (2012), there was no conclusive evidence to suggest that older native Dutch listeners adjust the parameters of lexical activation and competition when the speech signal becomes less reliable due to the presence of noise. If it is the case that older listeners already make this type of adjustments while processing speech in normal listening conditions, this appears to leave them without extra resources of this kind to fall back on when listening conditions become difficult.

4.2.3. Experiment 4-4

The experiments reported in this chapter so far were all based on McQueen and Huettig (2012) and used noise bursts to decrease the reliability of the speech signal. While the mean duration of these bursts (81.2 ms) was well above the gap detection thresholds reported for older listeners (Lister, Roberts, & Lister, 2011; Snell, 1997; Snell & Frisina, 2000), the older participants may have had difficulties perceiving the noise bursts that were used to make the speech signal less reliable. A new visual world control experiment was therefore constructed, based on Brouwer et al. (2012), which used casually articulated reduced speech instead of noise to suggest the decreased reliability of the speech signal. This should overcome any potential problems older listeners may experience perceiving noise bursts.

As discussed at the start of this chapter (see page 92), the study by Brouwer et al. (2012) consisted of a series of eye-tracking experiments in which participants listened to sentence fragments while looking at visual displays containing four written words. Participants were instructed to click on a target word that occurred in the spoken fragment. In certain trials this target word was pronounced canonically (e.g., [bəneːdə] *beneden*, 'downwards'), while other trials contained a reduced pronunciation (e.g., [məneːə] instead of the canonical form [bəneːdə]). Each visual display contained both a competitor for the canonical form of the target word (e.g., [bənaːdeːlə] *benadelen*, 'to disadvantage') and a competitor for the reduced form of the target word (e.g., [məneːr] *meneer*, 'mister'), as well as the target word and a phonologically unrelated distractor. In one experiment, all target words were pronounced canonically, but the speech style of the sentence fragments varied as they were either taken from a corpus of spontaneous casual speech or consisted of carefully pronounced laboratory speech. In another experiment, all fragments consisted of spontaneous casual speech, with some target words pronounced canonically while the pronunciation of other target words was reduced. When listeners were exposed to canonical pronunciations only, the competitor for the canonical form of the target word competed more for recognition than the competitor for the reduced form of the target word. Listeners who heard both canonical and reduced pronunciations directed similar proportions of looks to both types of competitors, regardless of the actual pronunciation of the target word. This suggests that when speech contains many reduced word forms and therefore the likelihood of encountering reductions increases, the dynamics of the spoken word recognition processes change to allow for the imperfect acoustic information.

The above conclusions were drawn across multiple experiments, so here conditions from Brouwer et al. (2012) were combined into a single experiment with a within-subjects design. The first half of the experiment, block 1, served as a baseline, during which participants were exposed to casually pronounced sentence fragments containing canonically pronounced target words (henceforth referred to as *canonical speech*) intermixed with carefully articulated fragments of laboratory-style speech (*lab speech*) that also contained canonically pronounced target words. During the second half of the experiment, block 2, listeners again heard fragments of canonical speech. This time, however, these fragments were combined with fragments of casually pronounced speech containing reduced pronunciations of the target words (*reduced speech*). Thus, target words in canonical speech fragments were pronounced canonically throughout the entire experiment, yet the speech style of the trials by which they were surrounded was manipulated and changed from reliable lab speech in block 1 to less reliable, reduced speech in block 2. A comparison across blocks of competitor fixations for canonical speech trials then shows whether listeners adjust the way they evaluate lexical competitors based on the quality and reliability of the overall speech input they receive. If they do, reduced form competitors in the canonical speech trials should attract more fixations in block 2 than in block 1, as listeners will take into consideration the frequent speech reductions in the surrounding fragments in block 2. If listeners do not adjust to the reliability of the speech signal, looking patterns in blocks 1 and 2 are expected to resemble one another.

4.2.3.1. Method

4.2.3.1.1. Participants

Twenty-nine older adults (15 males) with an average age of 67.8 years (*SD* = 4.5; range: 62 – 79 years) were recruited from the participant pool of the MPI for Psycholinguistics in Nijmegen, the Netherlands, and paid for their participation in this study. Data from a further 15 participants were excluded from analysis due to calibration difficulties (*n* = 10), hearing aids (*n* = 2), tinnitus (*n* = 1), cataract (*n* = 1), and failure to complete the experiment (*n* = 1). All included participants were native speakers of Dutch with normal or corrected-to-normal vision and none wore hearing aids in daily life. For screening purposes, pure-tone air conduction thresholds were collected for all participants. The mean threshold for the better ear (averaged over 0.5, 1, and 2 kHz) was 17.6 dB HL (range: 3.3 – 40, *SD* = 9.6). High-frequency thresholds for the better ear (averaged over 4 – 8 kHz) ranged from 3.3 – 65 dB HL (*M* =35.7, *SD* = 18.6). Written informed consent was obtained from each participant prior to the start of the experiment.

4.2.3.1.2. Stimulus materials

All auditory and visual stimulus materials were taken from Brouwer et al. (2012). Auditory stimuli consisted of casually pronounced sentence fragments of spontaneous speech from the Spoken Dutch Corpus (Oostdijk, 2000) and carefully pronounced fragments that were recorded in a laboratory setting. The fragments taken from the Spoken Dutch Corpus fell into one of two speech style conditions. The canonical speech stimuli each contained a target word that was realised canonically, whereas for stimuli in the reduced speech style, at least one of the phonemes in each target word had been substituted or omitted. All target words occurred in both the canonical and the reduced speech condition. The context for each target word, however, differed between conditions, since all sentence fragments were natural utterances selected from a corpus of spontaneous speech. The stimuli in the lab speech style consisted of re-recorded versions of the canonical speech fragments. In total, 32 experimental target words each occurred in three sentence fragments (once in canonical speech, once in reduced speech, and once in lab speech). In addition, there were 32 filler fragments, each containing a unique target word. Of these filler fragments, eight were reduced speech, eight were lab speech and 16 were canonical speech. For full technical details about the creation of the auditory stimuli, see Brouwer et al. (2012).

Each target word was matched with a visual display containing four written words displayed in the four quadrants of the screen (see Figure 4-14). In the experimental trials, each display contained the target word, an unrelated distractor word, and two competitors that were phonologically related to the target word. The written target word (e.g., *positie* ‘position’) was always a word that also occurred in the spoken sentence fragment, while the distractor was phonologically unrelated to the target word (e.g., *naburig* ‘neighbouring’). Of the two competitors, the so-called canonical form competitor had a greater onset overlap with the canonical pronunciation of the target word than with the reduced form (e.g., *poseren* ‘to pose’, [poːzeːrə] as a competitor for the canonical pronunciation [poːziʦi]), whereas the reduced form competitor overlapped more with the onset of the reduced pronunciation of the target word than with the canonical pronunciation (e.g., *psyche* ‘psyche’, [psixə] as a competitor for the reduced pronunciation [psiʦi]).

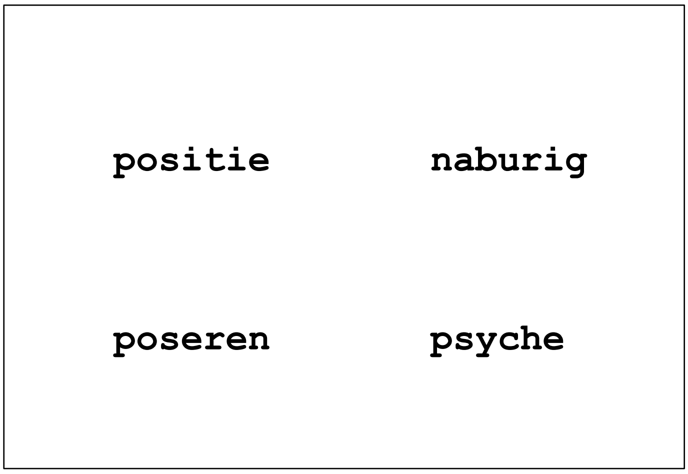

Figure 4-14. Example of a visual display as used in Experiment 4-4.

Visual displays for the filler trials were also made up of three phonologically related words and one unrelated word. In the filler trials, however, it was this unrelated word that was the target word occurring in the sentence fragment. This was done to prevent participants from developing a strategy whereby they simply ignored all unrelated words. Four counterbalanced experimental lists were created, with individual randomisations for each participant. Each experimental list started with three practice trials, which were the same for all participants. These were followed by two 32-trial blocks. The first block contained 16 sentence fragments that were spoken in a canonical casual speech style. These fragments were intermixed with 16 sentence fragments in laboratory speech style. The second block again consisted of 16 sentence fragments in a canonical casual speech style, intermixed with 16 fragments in reduced casual speech style. Half of the items of each speech style in each speech block were experimental items, the other half were filler items. No participant was presented with a target word and matching visual display more than once throughout the experiment, regardless of speech style. In total, there were 67 trials per experimental list.

4.2.3.1.3. Procedure

Participants were tested individually in a sound-attenuated booth. They were seated in front of a computer screen at a viewing distance of 95 cm, with their head held in a fixed position by means of a chin and forehead rest. Participants' eye movements were recorded using an Eyelink 1000 Tower Mount system (SR Research, Ltd.) at a sampling rate of 1000 Hz (monocular). The auditory stimuli were presented over Sennheiser HD201 headphones. Before the start of the experiment, the eyetracker was calibrated and validated using a 9-point calibration grid. After every five trials, an automatic drift check was carried out and, if required, another calibration was done as well. At the start of each trial, a fixation cross was displayed in the centre of the screen. The four written words were displayed on the computer screen at the start of each trial for 2500 ms. After this preview period, the sentence fragment was presented. As in Brouwer et al. (2012), participants were instructed to click on the word on the screen that occurred in the spoken sentence they heard.

4.2.3.2. Results

4.2.3.2.1. Accuracy and response times

Table 4-7 shows participants’ responses for the different speech styles in Block 1 and 2 and their response times for trials with correct responses. Response times were measured from target word offset. Participants correctly clicked on the target word in 97.2% of all experimental trials and in 99.5% of all filler trials. Participants’ accuracy for the critical canonical speech trials did not significantly differ across blocks (F(1, 28) = 0, p = 1), nor did response times for canonical speech trials in which participants correctly identified the target word (F(1, 28) = 1.51, p = .229).

Table 4-7. Mean percentage of correct mouse click responses and mean response times for correct trials in Experiment 4-4.

	Block 1		**Block 2**	
	Canonical speech	Laboratory speech	Canonical speech	Reduced speech
Target	99.6%	100%	99.6%	89.7%
Canonical competitor	0.4%	0	0.4	6.9%
Reduced competitor	0	0	0	2.6%
Distractor	0	0	0	0.9%
RT in ms (SD) for correct trials only	1455 (424)	1342 (785)	1361 (306)	1998 (822)

4.2.3.2.2. Eye movements

As in Brouwer et al. (2012), trials in which participants did not click on the target word were excluded from eye movement analysis. Thus, two trials of the canonical casual condition, and 24 trials of the reduced casual condition were excluded. No trials had to be excluded due to track loss. Figure 4-15 shows the mean fixation proportions to the target, both competitor types and the distractor from target word onset for the experimental trials of each speech type in Block 1 (left panels) and Block 2 (right panels). Proportions were averaged over 20 ms bins. The analysis reported in this section focuses on the canonical speech trials (top left and top right), as these are the trials for which a difference in looking patterns is expected to be found if listeners adjust their lexical competition processes in response to decreased reliability of the speech signal. The analysis window selected for the present experiment started at 200 ms after target word onset and lasted for 600 ms. This is the same time interval that was used by Brouwer et al. (2012).

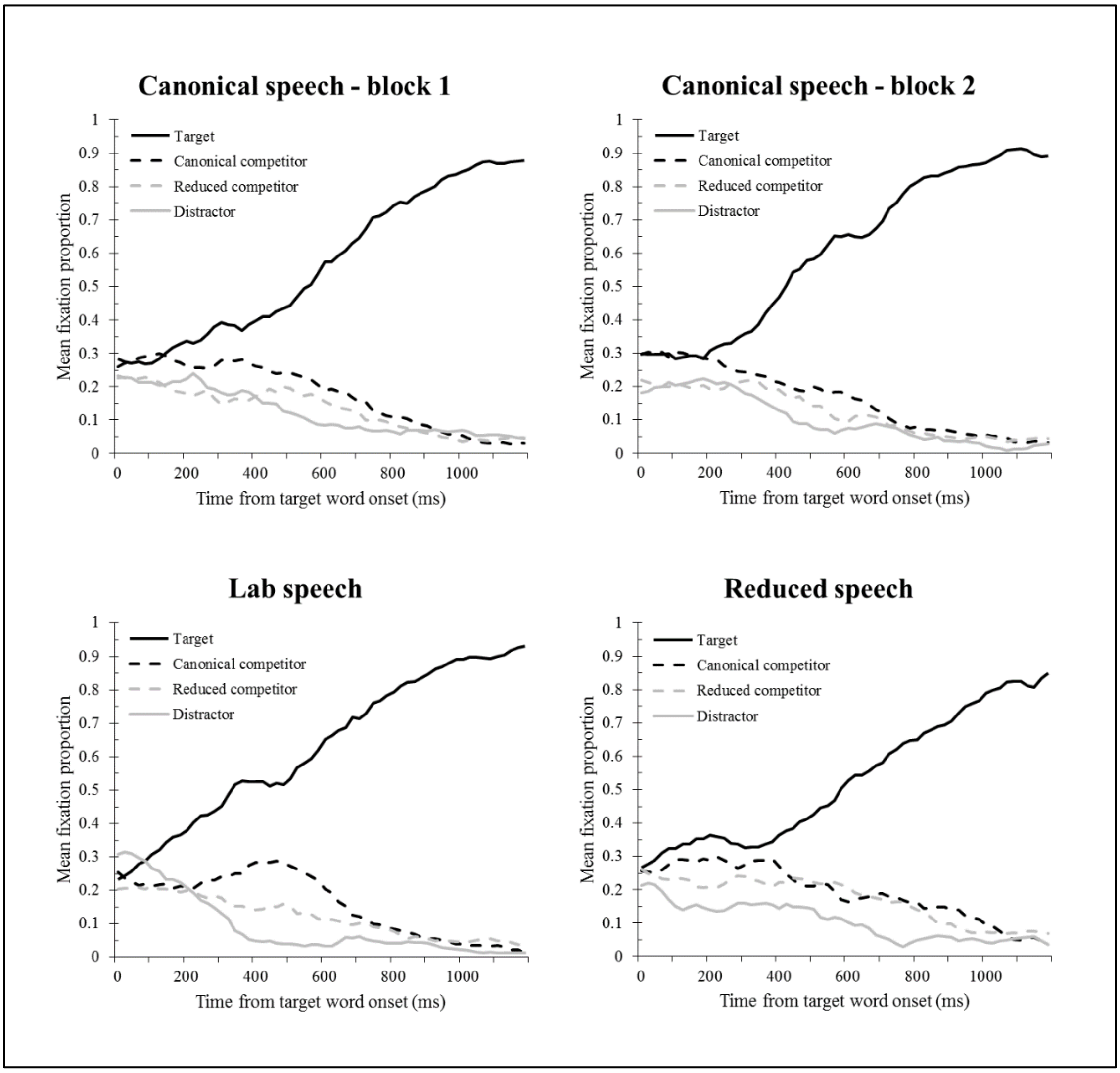

Figure 4-15. Mean fixation proportions of Experiment 4-4 by speech type. Fixations from Block 1 are shown on the left; fixations from Block 2 are displayed on the right.

First, as in the previous experiments, competitor preference ratios were calculated (see Figure 4-16). The mean number of fixations to canonical and reduced form competitors was divided by the sum of the competitor mean and distractor fixations. A competitor preference ratio greater than 0.5 thus indicated that on average the competitors attracted over half of all looks that were not directed at the target (i.e., the competitors indeed competed for recognition). One-sample two-tailed *t*-tests by participants (1) and by items (2) showed significant competition from canonical and reduced competitors in Block 1 (M_1 = 0.59, $t_1(28) = 3.27$, $p = .003$; M_2 = 0.62, $t_2(31) = 3.27$, $p = .003$) and in Block 2 (M_1 = 0.61, $t_1(28) = 3.79$, $p < .001$; M_2 = 0.63, $t_2(31) = 3.11$, $p = .004$).

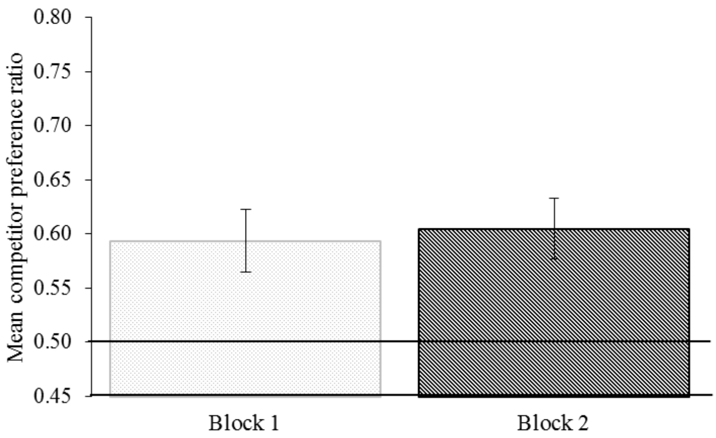

Figure 4-16. Competitor preference ratios for the canonical speech trials in Block 1 and Block 2 of Experiment 4-4. Error bars represent standard errors of the means.

To investigate the time course of competition effects across blocks, two of the measures analysed by Brouwer and colleagues were selected: (a) mean fixation proportion for both competitors minus fixation proportion to the distractor, and (b) fixation proportion for the canonical competitor minus fixation proportion for the reduced competitor. Like competitor preference ratios, Measure A provides an indication of whether the competitor words attracted more looks than the distractor item and did, in fact, compete for recognition, whereas Measure B tells us which competitor drives any lexical competition effects Measure A may reveal. As in Brouwer et al. (2012), both measures were analysed using empirical logits (Barr, 2008) and linear mixed-effects regression models (LMER; Baayen et al., 2008). Separate LMER analyses by participants and by items were conducted in R (2015), using the same packages as before. For each speech condition, looks to each picture type (target, canonical competitor, reduced competitor and distractor) were aggregated into 50 ms time bins, both across participants and across items. Aggregated fixations were then transformed to empirical logits (Barr, 2008). Measure A and B were derived from the empirical logits. Added Speech Type was entered into the model as a fixed categorical predictor, with Lab Speech (i.e., canonical speech trials that were mixed with lab speech trials) coded as -0.5 and Reduced Speech (i.e., canonical speech trials that were mixed with reduced speech trials) as 0.5. Time was added as a continuous fixed predictor. Random intercepts for participants and for aggregates nested within participants were added to the by-participants model, and random intercepts were added for items and for aggregates nested within items to the by-items model. Since models for both measures of competition failed to converge with a full random structure, each model was simplified by removing any random slopes for fixed predictors that did not improve model fit.

The results of the regression analysis of overall competition (i.e., Measure A), as displayed in Table 4-8, show no main effects or interactions, indicating that listeners did not experience significantly different levels of overall competition for canonical speech stimuli, regardless of whether the fragments in the surrounding trials consisted of lab speech or of reduced speech.

Table 4-8. Results of LMER analyses of overall competition in the canonical speech trials in Experiment 4-4.

Effect	**By-participants**			**By-items**		
	Est.[c]	SE	*t*-value	Est.[c]	SE	*t*-value
(Intercept)	0.32	0.46	0.71	0.15	0.43	0.35
Time	1.65[a]	1.44	1.14	1.99[b]	1.34	1.49
Added Speech Type	0.70	0.65	1.09	0.71	0.66	1.07
Time * Added Speech Type	-3.62	1.81	-2.00[†]	-2.97	1.91	-1.56

[*] $p < .05$
[†] $p < .10$
[a] random slopes for participants and participants over aggregated items
[b] random slopes for items and items over aggregated participants
[c] Est. = estimated coefficient

Table 4-9 displays the results of the regression analysis of Measure B, which consists of the difference between the proportion of fixations to the canonical form competitors and the reduced form competitors. Importantly, no main effects nor interactions were found, which indicates that there was no significant difference across blocks in the contribution that each competitor type made to the overall competitor effect.

Table 4-9. Results of LMER analyses of the specificity of the competition effect in the canonical speech trials in Experiment 4-4.

Effect	By-participants			By-items		
	Est.[c]	SE	*t*-value	Est.[c]	SE	*t*-value
(Intercept)	0.87	0.49	1.80	0.46	0.67	0.68
Time	-0.44[a]	1.32	-0.33	-0.20[b]	1.62	-0.12
Added Speech Type	-0.49	0.91	-0.54	-1.19	0.83	-1.44
Time * Added Speech Type	1.74	2.58	0.68	2.20	2.81	0.78

* $p < .05$
† $p < .10$
[a] random slopes for participants and participants over aggregated items
[b] random slopes for items and items over aggregated participants
[c] Est. = estimated coefficient

4.2.3.3. Discussion

Like Experiment 4-3, the present experiment examined whether older listeners adjust the way lexical competitors are evaluated when the speech signal is less reliable. Since the older participants in Experiment 4-3 may have had difficulties perceiving the noise bursts that were used to make the speech signal less reliable, and therefore may have failed to notice its decreased reliability, the present experiment did not rely on the insertion of noise. Instead, as in Brouwer et al. (2012), casually articulated reduced speech was used to suggest a decrease in reliability of the speech signal. If, like the young adults in Brouwer et al. (2012), older listeners adjust the parameters of lexical competition based on the overall probability of reduced pronunciations in the speech input, stronger competition from reduced form competitors and weaker competition from canonical form competitors was predicted for fragments of canonical speech when these fragments were mixed with fragments of reduced speech (block 2) than when they were combined with fragments of lab speech (block 1). No such effects were found. The strength of overall competition that listeners experienced was similar in both blocks of the experiment, and both competitor types contributed to a similar degree to the overall competition in each block. Summing up, there was no evidence to suggest that older listeners make adjustments to the way they evaluate lexical competitors when the speech signal contains many reduced pronunciations and therefore appears to be less reliable. This result confirms findings of Experiment 4-3.

4.2.4. Experiment 4-5

As all experiments reported thus far in this chapter had a within-subjects design, while the studies by McQueen & Huettig (2012) and Brouwer et al. (2012) used a between-subjects design, this final control experiment examined the importance of a between-subjects design for the demonstration of lexical modulation. Experiment 4-1a (which also functioned as Experiment 4-3 and had a within-subjects design) was changed to a between-subjects design and tested another group of older native-Dutch speaking adults.[17] Again, the predictions are the same as for Experiment 4-2.

4.2.4.1. Method

4.2.4.1.1. Participants

Thirty-two participants (17 females) from the participant pool of the MPI for Psycholinguistics in Nijmegen, the Netherlands, participated in exchange for a small payment. None of them had previously participated in Experiment 4-3. All

[17] Note that Experiment 4-5 was conducted before any of the other experiments reported in this chapter and this determined the choice of a participant population consisting of older adults.

participants were native speakers of Dutch, aged 60 – 84 years (*M* = 67.5, *SD* = 5.5), with normal or corrected-to-normal vision. For screening purposes, pure-tone air conduction thresholds were obtained for all participants. The mean threshold for the better ear (averaged over 0.5, 1, and 2 kHz) was 17.0 dB HL (range: 3.3 – 40.0, *SD* = 8.5). High-frequency thresholds for the better ear (averaged over 4 – 8 kHz) ranged from 10.0 – 65.0 dB HL (*M* = 40.5, *SD* = 16.9). None of the participants wore hearing aids in daily life. Written informed consent was obtained from each participant prior to the start of the experiment.

4.2.4.1.2. Stimulus materials

A subset of the stimulus materials of Experiment 4-3 (25 sentences and their matching visual displays from each condition) was used for the present experiment. Thus the number of trials in each condition was identical to that used in McQueen and Huettig (2012). Sentences were selected so that in each condition there were nine sentences containing two noise substitutions and eight each with three and four substitutions. (See section 4.1.1.2.1 for a detailed description of the creation of the stimuli.) Mean overlap was 4.1 phonemes for onset competitors and 3.3 for rhyme competitor items. Mean word frequency based on the CELEX lexical database (Baayen et al., 1995) was 6.3 per million words for onset competitors and 35.4 for rhyme competitors. The original recording of each sentence was used in the clean speech or baseline condition, while the sentences with inserted bursts of noise were used in the noise condition. Mean noise duration was 82.3 ms (*SD* = 35.4 ms) in the onset-competitor condition, 79.3 ms (*SD* = 30.5 ms) in the rhyme-competitor condition and sentences in the filler condition had a mean burst duration of 86.1 ms (*SD* = 32.6 ms). Overall mean noise duration was 82.6 ms (*SD* = 32.9, range: 11.2 – 214.1). As in Experiment 4-3, each sentence and visual display pair was presented once to each participant.

4.2.4.1.3. Procedure

The same testing procedure was followed as in Experiment 4-3 (see section 4.2.2.1.3), with the exception of the following: participants were randomly assigned to either the clean speech or the noise condition and each participant was presented with all 75 sentence-display pairs from that condition, in randomised order.

4.2.4.2. Results

As before, trials with a track loss percentage greater than 30% (10 trials out of 2400) were excluded from analysis. Figure 4-17 shows the mean fixation proportions to the competitors and distractors from the onset of the critical word for the onset- (top) and the rhyme-competitor condition (middle), and the mean fixation proportions to the target and the distractors for the filler trials (bottom), again calculated over 20 ms time bins and with distractor proportions averaged over three distractors. Based on looking patterns (see Figure 4-17) the same windows as in Experiment 4-1a were selected for analysis, which ran from 300 – 900 ms after critical word onset for both onset and rhyme-competitor conditions.[18] Analyses were conducted in the same way as reported for Experiments 4-1, 4-2, and 4-3.

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[18] As for previous experiments in this chapter, analyses of a different time interval can be found in Appendix L.

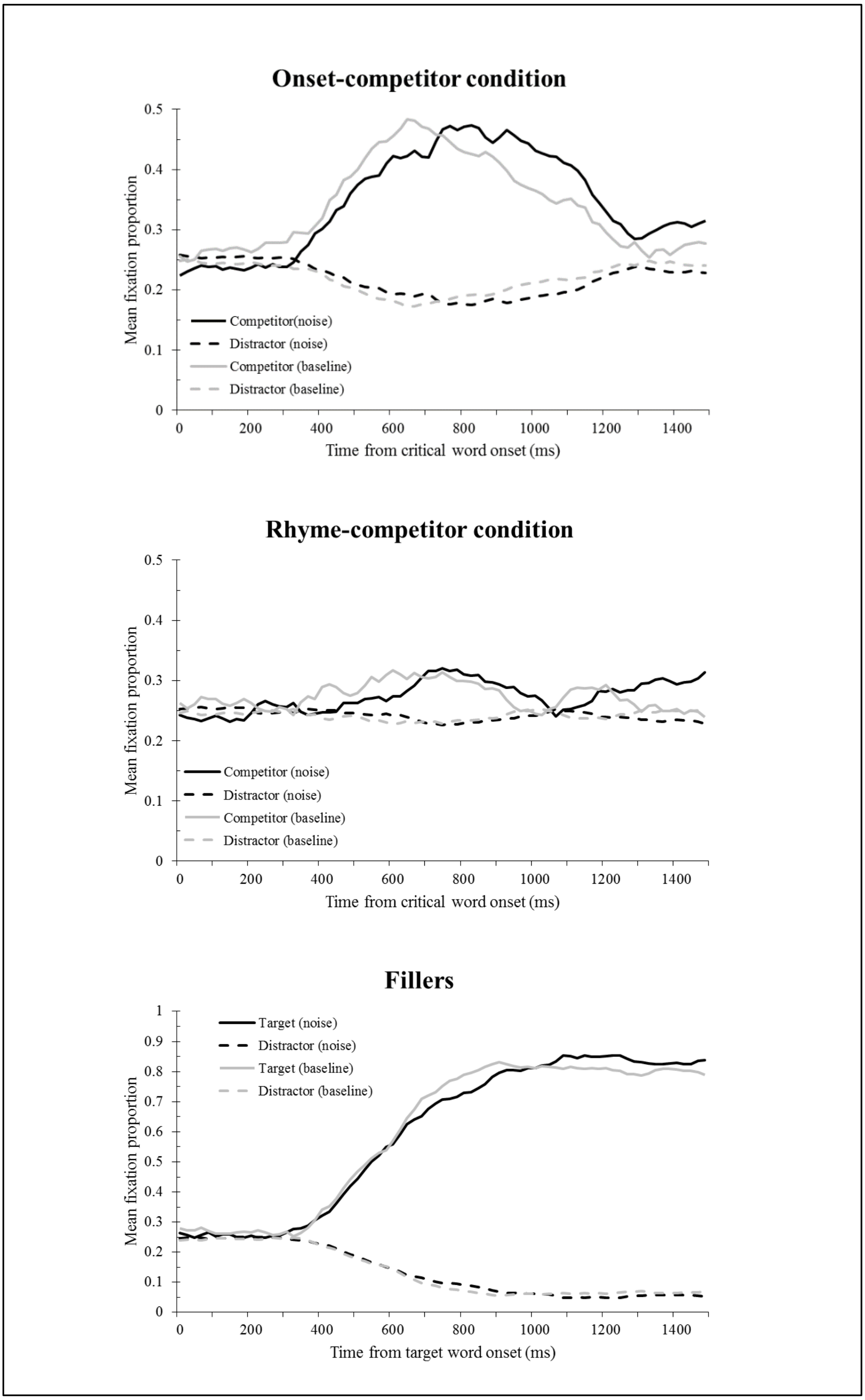

Figure 4-17. Mean fixation proportions for the onset-competitor condition (top), the rhyme-competitor condition (middle) and the fillers (bottom) of Experiment 4-5. Fixations are plotted from critical word onset, for competitors and distractors, with the noise condition shown in black, and the baseline condition in grey.

Figure 4-18 displays competitor preference ratios per condition. One-sample two-tailed *t*-tests by participants (1) and by items (2) showed that onset competitors were fixated significantly more than distractors in both the baseline condition ($M_1 = 0.67$, $t_1(15) = 9.67$, $p < .001$; $M_2 = 0.65$, $t_2(24) = 5.88$, $p < .001$) and the noise condition ($M_1 = 0.65$, $t_1(15) = 7.78$, $p < .001$; $M_2 = 0.64$, $t_2(24) = 6.11$, $p < .001$). While rhyme competitors attracted more looks than distractors in the baseline condition (this effect is significant across participants but misses significance over items) ($M_1 = 0.55$, $t_1(15) = 2.44$, $p = .028$; $M_2 = 0.53$, $t_2(24) = 0.88$, $p = .389$), they did not in the noise condition ($M_1 = 0.52$, $t_1(15) = 1.09$, $p = .293$; $M_2 = 0.52$, $t_2(24) = 0.88$, $p = .390$). These results support the findings of Experiment 4-3 and suggest that older listeners experience onset competition in clean speech and in noise, yet experience competition from rhyme competitors only in clean speech.

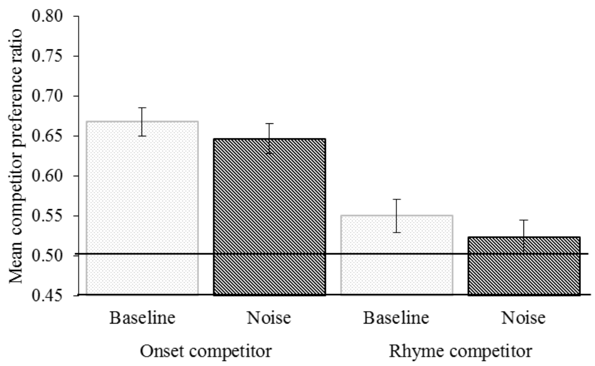

Figure 4-18. Mean competitor preference ratios in Experiment 4-5 for onset and rhyme competitors, in clean speech and in noise. Error bars represent standard errors of the means.

Next, the time course of competitor fixations was analysed, using the method described in section 4.1.2.1. Table 4-10 shows the results of the regression analysis. As in Experiments 4-1a, 4-2 and 4-3, the regression analysis shows a significant interaction between Time and Competitor Type, with a negative *β*-value (-0.98), and no main effect of Noise Type, nor any interactions involving this predictor. It therefore appears that once again the occurrence of noise bursts in the signal did not influence listeners' looking behaviour.

Table 4-10. Results of LMER analyses of competitor fixations in Experiment 4-5.

Effect	By-participants			By-items		
	Est.[c]	SE	*t*-value	Est.[c]	SE	*t*-value
(Intercept)	-0.95	.06	-16.10*	-0.96	.09	-10.62*
Time	0.97[a]	.18	5.48*	0.99[b]	.24	4.11*
Noise Type	-0.21	.12	-1.82†	-0.22	.13	-1.67
Competitor Type	-0.21	.12	-1.77†	-0.20	.18	-1.09
Time * Noise Type	0.41	.35	1.17	0.52	.36	1.46
Time * Competitor Type	-0.98	.35	-2.77*	-0.99	.48	-2.05*
Noise Type * Competitor Type	0.07	.23	0.28	0.13	.26	0.49
Time * Noise Type * Competitor Type	-0.30	.71	-0.42	-0.19	.76	-0.27

* $p < .05$
† $p < .10$
[a] random slopes for participants over aggregated items
[b] random slopes for items and items over aggregated participants
[c] Est. = estimated coefficient

4.2.4.3. Discussion

The present control experiment assessed whether a between-subjects design may be essential in demonstrating evidence of lexical modulation, since Experiments 4-1 to 4-4 failed to provide any such evidence using a within-subjects design. If the older participants adjust the parameters of lexical activation and competition when the reliability of the speech signal is decreased by occasional bursts of noise, a weaker onset-competitor and a stronger rhyme-competitor effect were expected in the noise condition than in the baseline (clean speech) condition. As in Experiment 4-3, a strong onset-competitor effect and a weaker rhyme-competitor effect were found in both the baseline and the noise condition, which suggests that older listeners are as efficient in processing speech as younger adults. Mean fixation proportions to onset and rhyme competitors in the baseline condition peak at 0.48 and 0.32 respectively, which corresponds to peaks found in Experiment 4-3 and is considerably higher than fixation proportions reported by McQueen and Huettig (2012) for young adults. This supports the previously proposed explanation that older listeners may already be operating at capacity in clean speech conditions and therefore do not further adjust their processing dynamics when the speech signal becomes less reliable.

In sum, the present experiment confirms findings for older adults from Experiments 4-3 and 4-4, and once more shows that, in contrast to previous findings for younger adult listeners by McQueen and Huettig (2012) and Brouwer et al. (2012), older listeners do not appear to adjust the way lexical competitors are evaluated when they are exposed to a speech signal that is less reliable. As suggested for Experiment 4-3, older listeners may already make these adjustments in normal listening conditions, and may therefore not adjust further when listening conditions become difficult.

4.3. General discussion

The experiments reported in this chapter examined lexical competition of onset and rhyme competitors in L1 and L2 listening. They also explored whether bilinguals show lexical modulation when they listen to L1 and L2 in adverse listening conditions. Table 4-11 provides an overview of all experiments and their findings. Further implications of this set of experiments will be brought together with those of the other lines of investigation in the final chapter of this dissertation. Results will also be tested against measures of dominance in Chapter 6. In the interim, however, tentative conclusions may be drawn with regard to three issues. They are described in the sections below and involve lexical competition in L1 and L2 listening (section 4.3.1), lexical modulation (section 4.3.2), and older listeners (section 4.3.3).

Table 4-11. Overview of experiments and findings reported in Chapter 4

Exp.	**Target language**	**Listeners**	**Age**	**Design**	**Manipulation**	**Competition?**				**Lexical modulation?**
						baseline		**noise**		
						onset	**rhyme**	**onset**	**rhyme**	
4-1a	Dutch	emigrants	mixed	within-subject	noise bursts	✓		✓		–
4-1b	English	emigrants	mixed	within-subject	noise bursts	✓		✓		–
4-2	English	controls	<35	within-subject	noise bursts	✓	✓	✓	✓	–
4-3	Dutch	controls	60+	within-subject	noise bursts	✓	✓	✓		–
4-4	Dutch	controls	60+	within-subject	speech reductions	n/a	n/a	n/a	n/a	–
4-5	Dutch	controls	60+	between-subject	noise bursts	✓	✓			–

4.3.1. Lexical competition in L1 and L2 listening

Experiment 4-1 found that processes of lexical activation and competition in bilinguals pattern largely parallel in L1 and L2 listening. Listeners in this experiment experienced substantial onset competition but no significant rhyme competition in their L1 and L2, regardless of whether they were presented with clean speech or with speech that was interrupted by bursts of noise. However, the time course of lexical activation in L1 and L2 listening differed; activation of onset competitors lasted longer and activation of rhyme competitors started earlier in L2 than in L1. This difference suggests that listeners have more difficulties suppressing lexical candidates in their L2, which has also been found by previous studies (e.g., Weber & Cutler, 2004).

The lack of rhyme competition that bilinguals experience in the baseline condition is in contrast with the rhyme-competitor effects that are typically found for L1 listeners. They also disagree with findings for L2 listening by Shin, Bauman, MacPhee, and Zevin (2015), who conducted a mouse-tracking study in which American L1 listeners and Korean L2 listeners of English were asked to click on one of two pictures that were presented on the computer screen simultaneously. The non-target picture was either an onset competitor, a rhyme competitor, or an unrelated distractor. Analysis of mouse movement trajectories revealed robust onset and rhyme competition for L2 listeners that was no different from that experienced by the L1 participants. In contrast to Experiment 4-1, however, only two pictures were presented on the screen at a time, and listeners were familiarised with the pictures prior to the mouse-tracking task. The potentially most important difference between Shin et al.'s (2015) study and Experiment 4-1, however, lies in the participant populations tested. The Korean L2 listeners were 9.4 years old on average when they moved to the United States. This is considerably younger than the participants of Experiment 4-1, who were all at least 18 years of age at the time of emigration. The Korean participants may therefore be expected to show more native-like listening behaviour than the Dutch emigrants. The lack of rhyme competition found in Experiment 4-1 cannot be the result of the materials that were used in the present study, as the materials from Experiments 4-1a and 4-1b did invoke significant rhyme competition in L1 listeners in Experiments 4-3 and 4-2, respectively. It may not be attributed to the bilinguals' higher age either, as older listeners in Experiments 4-3 and 4-5 were found to experience rhyme competition as well. It is therefore tentatively concluded that (a) rhyme competition effects in L1 listening seem to weaken or disappear for listeners who live in an L2 immersion environment where they predominantly use the L2, and (b) even highly proficient L2 listeners do not appear to exhibit the rhyme competition pattern typically found in L1 listeners.

The great resemblance that was found between L1 and L2 lexical competition suggests that the bilingual participants used lexicon-appropriate processing for each of their languages. However, Dutch and English differ in the lexical processes that are typically used by L1 listeners of each language. In Chapter 5, an experiment is therefore reported that focuses on a particular aspect of lexical processing (i.e., the use of suprasegmental stress cues during word recognition) and investigates whether the strategies bilinguals use in L2 listening originate from their L1 or have been adapted to better match the requirements of their L2.

4.3.2. Lexical modulation

The experimental paradigm used in Experiment 4-1 not only allowed us to compare the lexical competition processes that occur in L1 and L2 listening, the choice for this paradigm also provided an opportunity to explore whether lexical modulation effects are characteristic of L1 listening, or whether such flexibility is also available to L2 listeners. While bilinguals in Experiment 4-1 did not adjust the way they evaluated lexical competitors when speech signal reliability decreased, either in their L1 or in their L2, this finding appears unrelated to the language profile of these listeners as Experiments 4-2, 4-3, 4-4, and 4-5 also found no evidence of lexical modulation, regardless of whether speech reliability was decreased by the insertion of noise bursts in the signal or by a high prevalence of speech reductions. It must therefore be concluded that the lexical modulation effects found by McQueen and Huettig (2012) and Brouwer et al. (2012), which were very weak indeed, may not be replicable. As a between-subjects design was used for both of these studies, the adjustments in processing dynamics these studies demonstrated may have to be attributed to individual differences in participants or to other artefacts, rather than to a decrease in speech signal reliability.

4.3.3. Older listeners

Although it was not the main focus of this chapter, the investigation of lexical modulation in older listeners yielded interesting results. Findings from Experiments 4-3 and 4-5 suggest that older listeners process clean speech with normal efficiency. Similarly to competition effects typically found in young adults (e.g., Allopenna et al., 1998; McQueen & Viebahn, 2007), both onset and rhyme competitors compete for recognition, and onset competitors do so earlier and more strongly than rhyme competitors. Compared to the young adults in the study by McQueen and Huettig (2012), however, older listeners in the studies reported here seemed to experience stronger competition from both competitor types. While this difference should be interpreted with caution, as it is based on a comparison of different (albeit very similar) experiments, it may be linked to the fact that older adults typically have a larger vocabulary than younger adults, which increases the number of available lexical candidates (Ramscar, Hendrix, Shaoul, Milin, & Baayen, 2014 ; Verhaeghen, 2003). Furthermore, it has been argued that inhibitory capacities decline with age, which may negatively affect older listeners' ability to suppress lexical competitors (Revill & Spieler, 2012; Robert & Mathey, 2007; Sommers, 1996; Sommers & Danielson, 1999). Stronger competition for older than for younger adults has previously been shown for both rhyme competitors (Ben-David et al., 2011) and onset competitors (Mercier, 2013; but see Ben-David et al., 2011). When older listeners were presented with speech that was occasionally interrupted by bursts of noise, onset and rhyme competitors were not activated as strongly as in clean speech. This finding confirms evidence from Ben-David et al.'s (2011) study, who found a similar pattern of weakened competition for older listeners when they were presented with speech in speech spectrum noise.

Language-specific Listening Strategies

Chapter 5

As noted, listeners with different L1s differ in respect to the strategies that they apply during spoken-word recognition to make this process more efficient. Listeners process speech with strategies that are tailored to their L1 and typically apply these strategies to L2 listening as well. The findings from Chapters 3 and 4, however, suggest that speech processing strategies may be malleable – for instance, L1 strategies may change when listeners move out of the L1 immersion environment. The question was therefore asked whether listeners who live in an L2 environment, such as the Dutch emigrants that participated in the experiments described in Chapters 3 and 4, still apply listening strategies that are founded on their L1, or whether they have adopted strategies more appropriate to the L2. This is an interesting question, since previous research on L2 speech segmentation has found that language dominance may affect which segmentation strategies listeners apply but not for all types of listener. In a study with French-English and English-French early bilinguals, for instance, Cutler et al. (1992) found that French-dominant listeners were flexible and used syllable-based segmentation strategies when listening to French but abandoned them when listening to English (which L1 listeners do not segment based on syllables either; Cutler, Mehler, Norris, & Segui, 1986). English-dominant listeners, on the other hand, did not show this flexibility: they did not use syllable-based strategies for the segmentation of either English or French (but see Kearns, 1994, for a different result).

Although Dutch and English are closely related and highly similar languages, there are nonetheless some known differences in the strategies listeners of each language use for the exploitation of acoustic cues. In this chapter, two experiments are reported, each of which examines one of these listening strategies. The first experiment in this chapter, Experiment 5-1, focuses on a phonetic strategy, namely the exploitation of formant transitions for fricative identification. Experiment 5-2 assesses the use of a lexical listening strategy that concerns the use of lexical stress in word recognition.

5.1. Experiment 5-1

5.1.1. Introduction

At the phonetic level, listeners differ, for instance, in the extent to which they make use of formant transitions to facilitate their identification of fricatives. L1 listeners of English, Spanish and Polish (whose L1 phoneme inventories each contain perceptually confusable fricatives) use these cues to a larger degree than L1 listeners of Dutch and German, whose L1 only contains spectrally distinct, phonetically non-confusable fricatives (Wagner et al., 2006). Listeners in the study by Wagner et al. (2006) were presented with spoken non-words, such as *dotafi* and *pilufesa*, and had to respond as quickly as possible whenever they heard a certain target fricative; this task is called phoneme monitoring. In one block the target fricative was /f/, in another /s/, and items differed in whether or not formant transitions in the surrounding vowels were consistent with the target fricative. Inconsistent transitions were created by cross-splicing (e.g., the /f/ from *dotafi* was spliced into a token of *dotasi* to replace the /s/); items with consistent transitions contained an identity-spliced fricative taken from another recording of the same non-word. Overall, English, Spanish and Polish listeners, but not German and Dutch listeners, were both slower and less accurate in their response to fricatives in inconsistent than in consistent contexts, suggesting that phonetic processing was impeded by the mismatching formant transitions. Furthermore, differences existed between English, Spanish, and Polish listeners as to which fricatives were affected. Polish listeners were most affected by mismatching formant transitions preceding /s/, whereas Spanish and English listeners appeared to pay more attention to formant transitions for the identification of /f/. Wagner et al. (2006) attributed the asymmetric pattern of results to the similarly asymmetric make-up of the fricative inventories in English, Spanish, and Polish. In English and Spanish, there are no fricatives that are confusable with /s/, yet /f/ shows great spectral similarity to and is highly confusable with /θ/(Miller & Nicely, 1955). This confusability may increase the usefulness of formant transitions in distinguishing /f/ from /θ/. The Polish fricative inventory shows the opposite pattern from English and Spanish, with three fricatives that are phonetically confusable with /s/ and none that are confusable with /f/.

In the context of the present research project, the demonstrated difference between Dutch and English listeners is particularly interesting. While Dutch listeners are sensitive to formant transitions on the auditory level (i.e, they rate fricatives with consistent formant transitions as better examples than those with mismatching transitions; Wagner et al., 2006), and thus, in principle, have these cues at their disposal, they tend to ignore them in fricative identification. As suggested by Wagner and colleagues, Dutch listeners may simply not need these cues to distinguish between the spectrally-distinct, phonetically non-confusable fricatives in their L1 phoneme inventory. English listeners, on the other hand, pay attention to formant transitions for the identification of both /f/ and /s/, yet they appear to do so slightly more for /f/.

Here, the study by Wagner et al. (2006) was replicated with listeners from the same bilingual population that participated in Experiments 3-1 and 4-1. The experiment allowed for an examination of the strategies these listeners use for the exploitation of formant transitions. If these listeners still behave like listeners of their L1, they are expected to ignore formant transitions and identify fricatives in a misleading context and fricatives in a consistent context with similar accuracy and speed. However, if they have acquired listening strategies that are more appropriate to their L2, these listeners should pay attention to formant transitions and are expected to respond slower and less accurately to fricatives that occur in a misleading context, potentially with the same asymmetry displayed by the English listeners in Wagner et al.'s study.

5.1.2. Method

5.1.2.1. Participants

Twenty participants were recruited from the Dutch immigrant community in the wider Sydney area (12 females and eight males; aged 27 – 73 years, $M = 51.1$, $SD = 14.9$) and were paid for their participation in the experiment. All participants were native speakers of Dutch, who grew up in the Netherlands and had migrated to Australia as adults (mean age at migration: 28.8 years, $SD = 8.25$, range: 18 – 52). Their mean length of residence in Australia was 22.25 years ($SD = 15.77$). All participants had normal hearing and normal or corrected-to-normal vision and each participant provided written informed consent prior to the start of the experiment.

5.1.2.2. Materials

Stimulus materials were a subset of those used by Wagner et al. (2006) and consisted of 100 recorded non-words of three or four syllables (e.g., *dotafi* and *pilufesa*). All items were non-words in both Dutch and English and were spoken by a male native speaker of Spanish. This choice was intended to prevent listeners from selectively applying a language-specific listening strategy based on the speaker's perceived accent. Stimuli were presented in two blocks that each contained 15 experimental items, 15 target-present fillers, and 15 target-absent fillers. All experimental items and all target-present fillers in a block contained the same target fricative. In one block, this was /f/, in the other /s/. In the experimental items the target always occurred in the final syllable, whereas in the target-present fillers, it always occurred in the penultimate syllable. No other fricatives than /f/ or /s/ were used in any of the stimuli. Ten additional stimuli with the target phoneme /m/were selected for use in the practice block. There were two versions of each experimental item, one in which the formant transitions were consistent with the target fricative (the identity-spliced items) and one in which they were misleading (the cross-spliced items). Fricatives in the identity-spliced items were taken from another token of the same non-word (e.g., the /f/ from *dotafi* was put into another token of *dotafi*), while the cross-spliced items combined a target fricative with the context of the other fricative (e.g., the /f/ from *dotafi* replaced the /s/ in *dotasi*). Half of the participants were presented with eight identity-spliced items and seven cross-spliced items per block, while the other half heard the other splicing version of these non-words and was thus presented with eight cross-spliced items and seven identity-spliced items. Order of blocks was counterbalanced across participants, and listeners were never presented with a non-word more than once.

5.1.2.3. Procedure

Participants were tested individually in a sound-attenuated booth. Auditory stimuli were presented over Beyerdynamic DT770 PRO headphones at a comfortable sound level, kept constant for all participants. Participants were instructed to press the space bar as soon as they heard the target phoneme. Instructions were provided in Dutch written on the computer screen and were subsequently repeated and if necessary clarified orally by the experimenter. Each trial started with a beep to alert participants that they were about to hear the next non-word, which was played 100 ms after the beep and was followed by a 2000 ms timeout interval. The inter-trial interval was 600 ms. At the start of each block, written instructions informed listeners which phoneme was the target for that block. The target phoneme was written in large uppercase font in the middle of the computer screen and remained on the screen throughout the entire block. Responses were made with the dominant hand using the space bar.

5.1.3. Results

Analyses were conducted for listeners' detection accuracy as well as response times. Table 5-1 shows the mean percentage of detected targets. It also displays mean response times for trials in which targets were correctly detected, for both fricative types and both splicing types. If listeners paid attention to formant transitions, detection accuracy should be lower and response latencies should be higher in the cross-spliced than in the identity-spliced conditions.

Table 5-1. Mean percentage of detected targets, and mean response times for correct detections of /s/ and /f/ in the cross-splicing and identity-splicing conditions of Experiment 5-1. Absolute number of detected targets and the total number of trials are shown in parentheses.

Fricative	Splicing	Mean percentage of detected targets	Mean RT
/s/	identity-spliced	97.3% (146/150)	569.24
	cross-spliced	98.0% (147/150)	602.48
/f/	identity-spliced	100% (150/150)	580.12
	cross-spliced	96.7% (145/150)	568.64

5.1.3.1. Response accuracy

The false alarm rate (i.e., how often did listeners detect a fricative that was not present in the stimulus) for the filler trials was only 1.6% (9 out of 580 trials, caused by eight different participants). A repeated-measures ANOVA by participant (F_1) and by item (F_2) on the percentage of correct detections found no main effect of splicing ($F_1(1, 19) = 1.07$, $p = .315$; $F_2(1, 28) = 0.82$, $p = .374$), or of fricative ($F_1(1, 19) = 0.37$, $p = .548$; $F_2(1, 28) = 0.25$, $p = .623$), nor any interaction between splicing and fricative ($F_1(1, 19) = 2.57$, $p = .125$; $F_2(1, 28) = 1.84$, $p = .186$).

5.1.3.2. Response times

Response times were measured from frication onset, as determined by Wagner et al. (2006). As there were no trials with a response time under 150 ms (the lower limit used by Wagner et al. for the inclusion of trials), no trials were excluded from the response time analysis. A repeated-measures ANOVA by participant (F_1) and by item (F_2) found no effect of splicing ($F_1(1, 19) = 1.32$, $p = .265$; $F_2(1, 28) = 0.64$, $p = .431$), or of fricative ($F_1(1, 19) = 0.40$, $p = .535$; $F_2(1, 28) = 0.58$, $p = .455$), nor any interaction between splicing and fricative ($F_1(1, 19) = 3.07$, $p = .096$; $F_2(1, 28) = 2.30$, $p = .141$).

5.1.4. Discussion

This experiment investigated the strategies that Dutch-English bilinguals use for fricative identification and asked whether these strategies have become similar to those deployed by native listeners of the L2 (i.e., involve the exploitation of information provided by formant transitions), or whether listeners have remained L1-like in their behaviour (ie. ignore such cues). Results show that listeners are not slower (nor faster) in detecting the fricatives /f/ and /s/ in a misleading context (the cross-splicing condition) than in a coherent context (the identity-splicing condition). This is exactly the result observed with Dutch L1 listeners by Wagner et al. (2006).This suggests that when it comes to the use of formant transitions for fricative identification, listeners in this experiment still apply strategies from their L1. No evidence was found to suggest that they have adopted strategies that would be more appropriate to their L2.

It should be noted, however, that the English listeners that participated in the original study by Wagner et al. (2006) were speakers of British English, whereas the Dutch emigrants' L2 is Australian English. It has not yet been established whether listeners of these two English dialects exploit formant transitions in the same way. As listeners of American English have also been shown to be sensitive to formant transitions (K. S. Harris, 1958), and the fricative inventory of all three English dialects contains the same phonemes, there is no reason to assume that Australian-English listeners would behave differently from British-English or American-English listeners. Furthermore, preliminary results from an ERP experiment with Australian listeners (Baldacchino, Peter, & Cutler, 2016) show that, on a neural level, these listeners appear to be sensitive to misleading formant transitions for /f/ but not for /s/. A replication of Experiment 5-1 with a control group of Australian English listeners could provide evidence for this. Unfortunately, such a replication was not possible within the scope of this dissertation.

5.2. Experiment 5-2

5.2.1. Introduction

Experiment 5-1 demonstrated that listeners who live in an L2 environment seem to apply L1 and not L2 listening strategies when it comes to the use of phonetic cues such as formant transitions. This raises the question which strategies they employ with respect to lexical cues. In the framework of this dissertation, with Dutch and English as participants' L1 and L2, suprasegmental stress cues provide an interesting opportunity to address this question, since Dutch listeners have been found to use such cues more efficiently for word recognition than English listeners (Cooper et al., 2002). In a two-alternative forced choice task Cooper and colleagues presented both Dutch L2 listeners and English L1 listeners with truncated fragments of English words and asked them to identify the word from which they were taken. So, listeners would hear, for instance, the fragment *ro-* and decided whether it formed the beginning of *robot* or *robust*. The word pairs that were provided as response options always consisted of words with opposing stress patterns (*RObot* versus *roBUST*), providing listeners with the opportunity to base their decisions on the stress cues available in the truncated word fragment. Interestingly, Dutch L2 listeners performed more accurately than English L1 listeners. Cooper et al. explained this finding by looking at the frequency of occurrence of speech fragments that are ambiguous on a segmental level yet can be disambiguated when suprasegmental stress patterns are taken into account. In English, such fragments occur relatively infrequently, whereas in Dutch they occur more commonly. This means that there is a greater benefit for Dutch listeners than for English listeners to make use of suprasegmental stress cues during spoken-word recognition, which leads native speakers of both languages to develop listening strategies in which this information is weighted differently. The Dutch listeners in the study by Cooper et al. appear to have benefited from the inappropriate application of their L1 strategies to L2 listening and, as a result, were more accurate than the English L1 listeners.

The present experiment set out to address the following questions: do Dutch listeners who live in an English L2 environment (i.e., listeners from the same population of Dutch emigrants tested Experiments 3-1, 4-1 and 5-1) employ their L1 strategies in L2 listening and use suprasegmental stress cues for word recognition, despite the lack of benefits these cues provide? Or have they abandoned the L1 strategies in favour of strategies more appropriate for the L2, the language of their environment? To answer the questions posed above, a replication of Experiment 3 from Cooper et al.'s (2002) study was carried out with Dutch emigrants living in Australia and compared their identification accuracy to that of the Dutch L2 listeners and English L1 listeners tested by Cooper and colleagues. If the emigrants use L1 strategies for the exploitation of stress cues, their accuracy is predicted to be high and resemble that of the Dutch L2 listeners in Cooper et al. If, on the other hand, the emigrants have stopped using stress cues as they are not useful for the L2, accuracy is predicted to be lower than that of Cooper et al.'s Dutch listeners and more similar to the accuracy of the English listeners in that study.

5.2.2. Method

5.2.2.1. Participants

Participants were the same twenty Dutch emigrants who participated in Experiment 5-1.

5.2.2.2. Materials

Stimulus materials were taken from Experiment 3 of Cooper et al. (2002) and consisted of truncated recordings of 21 pairs of English words, spoken by a male native speaker of Australian English (see Appendix M). Words in each pair differed in their stress pattern, so that one word always had primary stress on the first syllable (e.g., *robot*), whereas primary stress for the other word fell on the second syllable (e.g., *robust*). The first syllable for words of the latter type always contained a full vowel. Each word was truncated at the end of the first syllable and was recorded in two different sentence contexts, resulting in a total of 84 spoken word fragments, that were each presented twice (168 trials). In conformity with the study by Cooper et al., different pseudo-randomised stimulus lists were created for all participants, and fragments from the same word pair never occurred in successive trials.

5.2.2.3. Procedure

Participants were tested individually in a sound-attenuated booth. Auditory stimuli were presented over Beyerdynamic DT770 PRO headphones at a comfortable sound level, kept constant for all participants. Instructions were provided in English written on the computer screen and were subsequently repeated and clarified orally (in Dutch) by the experimenter. Participants were instructed to listen carefully to each word fragment and decide whether the fragment they heard formed the beginning of the word displayed on the left of the screen or of that on the right. The screen position (left or right) of the word that was the correct response was counterbalanced across presentations of the same word fragment. At the start of each trial, the response words were displayed on the computer screen for a preview period of 2000 ms. Subsequently, the truncated word fragment was played and participants gave their response. There was no time-out period and the next trial started 500 ms after a response was received. Participants responded using the shift keys, pressing the left shift key to select the word printed on the left of the screen and the right shift key to choose the word printed on the right.

5.2.3. Results

Figure 5-1 shows the results of the present experiment (on the right) as well as results for the two listener groups from Experiment 3 of Cooper et al.'s (2002) study. One trial had a response time of less than 100 ms and was therefore excluded from all analyses reported below.

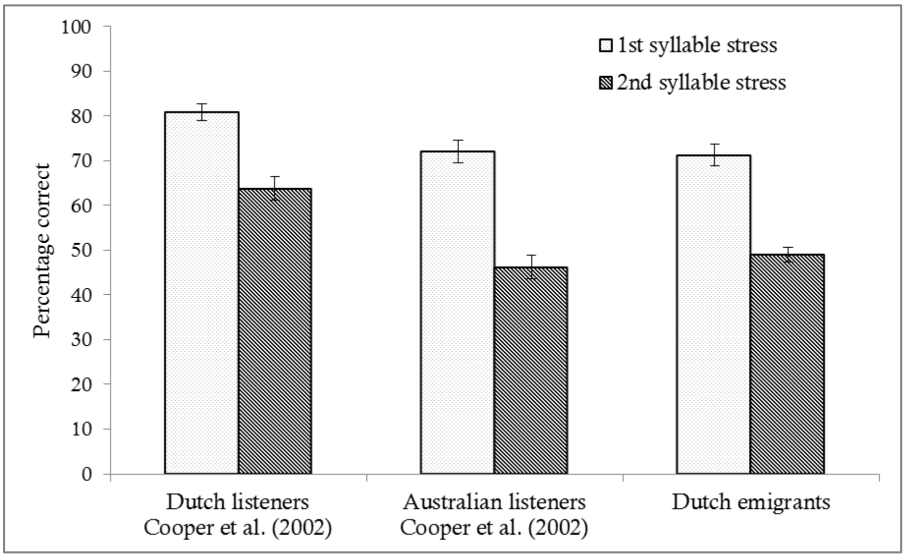

Figure 5-1. Mean percentage of correct responses from Cooper et al. (2002; left and middle panels) and from Experiment 5-2 (right panel). Error bars represent standard errors.

In 61.1% of all trials, participants judged a word with first-syllable stress to be the source of the fragment they had heard. This percentage is very similar to the first-syllable-stress judgments made by the L2 (57.5%) and L1 listeners (62.5%) in Cooper et al.'s study. Listeners correctly assigned 72.3% (*SD* = 10.8) of fragments from words with first-syllable stress, and 49.0% (*SD* = 7.7) of fragments from words with second-syllable stress. Overall, listeners correctly identified the source word for 60.2% of truncated fragments. This percentage was compared to the accuracy of the L2 (72.3%) and L1 listeners (59.2%) from the study by Cooper and colleagues in a one-way analyses of variance, which showed a significant main effect of listener group ($F(2,65) = 18.39$, $p < .001$, $\eta_p^2 = .36$). A Bonferroni-corrected post-hoc comparison revealed that the emigrants' accuracy was significantly different from that of the Dutch-native L2 listeners from Cooper et al. ($p < .001$) but not from the accuracy of the English-native L1 listeners ($p = 1$). This suggests that the emigrants no longer use suprasegmental stress cues as successfully as their compatriots who remained in the Netherlands. Following Cooper et al., participants' judgments for all items with second-syllable stress were then compared to chance level (i.e., 50%) with a binomial test. While the Dutch L2 listeners in the study by Cooper et al. performed significantly better than chance, this was not the case for the emigrants, who performed neither better nor worse than chance level ($z = -0.78$, $p = .435$).

5.2.4. Discussion

This experiment examined the strategies that are used for the exploitation of suprasegmental stress cues in L2 spoken-word recognition by highly proficient L2 listeners who are immersed in the L2 language environment. The aim was to test whether native Dutch-speaking emigrants in Australia employ their L1 strategies when listening to the L2, English, or whether these strategies are abandoned in favour of strategies more appropriate for the immersion language, English. Results clearly show that Dutch emigrants do not use suprasegmental information to the same extent as Dutch L2 listeners living in the Netherlands and that their exploitation of this information is more in line with that of English L1 listeners. This suggests that when an L1 listening strategy fails to provide listeners with increased processing efficiency for the L2 it may be abandoned in favour of a strategy more suitable for the language in question.

The question remains whether listeners in this experiment have lost their sensitivity to suprasegmental stress cues and the L1 strategy thus no longer interferes with L2 listening, or whether they have become more adept at suppressing the L1 listening strategy when listening to L2 speech as it is inappropriate in such situations. In other words, is it a matter of inability to use the L1 strategy, or an experience-induced abandonment? This latter view is in line with the findings of Cutler et al. (1992), who observed that French-dominant French-English early bilinguals appropriately segmented French speech based on syllables, yet were also able to suppress this strategy when listening to English, a language for which syllable-based segmentation is not appropriate. To determine which of these two interpretations is the most likely, further research is needed. A version of the current experiment with Dutch materials, for instance, could assess which strategies these same listeners use in L1 listening; can they 'turn on' the ability to exploit suprasegmental cues for L1 listening or has it really disappeared? Unfortunately, it was not feasible to conduct such an experiment in the present project.

5.3. General discussion

The two experiments reported in this chapter examined the use of L1 listening strategies by listeners who live in an L2 immersion environment. Experiment 5-1 focused on phonetic processing and showed that Dutch emigrants in Australia still apply listening strategies from their L1; they ignored formant transitions for fricative identification in much the same way as Dutch native listeners in the Netherlands do and did not apply the strategies used by native English listeners. In contrast, findings of Experiment 5-2, which investigated the use of suprasegmental lexical stress information, showed that the same Dutch emigrants do not appear to have behaved in parallel to native Dutch listeners in the Netherlands but instead appear to have applied a strategy more appropriate to the language of their environment, the L2.

The strategies examined in this chapter do not each apply to the same level of speech processing (i.e., one is phonetic, the other lexical), and it cannot be ruled out that this difference may underlie the contrast in the findings. Alternatively, the fact that stimuli in Experiment 5-2 were in English may have encouraged listeners to use L2-appropriate listening strategies. In Experiment 5-1, stimuli were non-words in L1 and L2 and were recorded by a native speaker of Spanish, which did not bias listeners towards strategies from either L1 or L2.

However, there is an alternative explanation for the difference in the findings of the two experiments reported here. Since native Dutch listeners typically make more use of suprasegmental information than native English listeners, findings of Experiment 5-2 suggest that emigrants have either lost their sensitivity to this information or have succeeded in ignoring it. In Experiment 5-1, on the other hand, adopting the listening strategies that are typically employed by L1 listeners of English requires Dutch emigrants to incorporate formant transitions into the way they identify fricatives. This involves acquiring a new listening skill, which might be harder than losing or ignoring one.

Summing up, the results reported in this chapter suggest that some but not all L1 listening strategies are retained. Listeners living in an L2 immersion environment appear to lose or suppress those strategies that are redundant for the L2, while they seem to experience more difficulties when changing strategies involves acquisition of a new skill. And like the data of the experiments in previous chapters of this dissertation, the data of Experiments 5-1 and 5-2 lend themselves very well to an investigation with respect to the effects of language dominance. In Chapter 6, therefore, there will be a discussion of whether the results are correlated with listeners' language dominance.

Further research is needed to determine whether the processing levels of the strategies involved played a role in the findings of these experiments. This issue could be addressed, for instance, by examining which listening strategies are used by native English-speaking emigrants in the Netherlands (i.e., listeners with the reverse language history from the participants in the current project), although it may be difficult to find sufficient English speakers in the Netherlands who predominantly speak Dutch. Experiment 5-1 and a Dutch version of Experiment 5-2 may be used for this purpose. As mentioned earlier, English L1 listeners typically exploit formant transitions for the identification of fricatives, yet ignore suprasegmental stress when segmenting speech. According to the 'loss versus acquisition' account proposed here, English emigrants would be predicted to behave like Dutch listeners on the phonetic level but not the lexical level. If, on the other hand, the processing level is important, the opposite may be expected; they may behave like Dutch listeners on the lexical and not the phonetic level. It may also be interesting to replicate Experiment 5-1 with Polish emigrants whose L2 is English or Dutch. In the original study by Wagner et al. (2006), both Polish and English were found to make use of formant transitions for fricative identification, but Polish listeners did so to a larger degree for /s/ than for /f/, a pattern that mirrored that of the English listeners. The 'loss versus acquisition' explanation would predict that Polish emigrants in a Dutch L2 environment would stop using the cues provided by formant transitions. Polish emigrants in an English L2 environment may increase their use of such cues for the identification of /f/, as they, in principle, already possess the skill to exploit these cues for identification of /s/, and may decrease their use for identification of /s/ as it is redundant in their L2 English.

Language Dominance II: Effects in Speech Processing

Chapter 6

In Chapter 2, three measures were introduced to determine participants' language dominance. In this chapter the experimental results are reanalysed to determine whether these measures of language dominance correlate with, and hence might offer some explanation of, the experimental results reported in this dissertation. To begin with, the three measures were compared with one another. Table 6-1 provides an overview of all Dutch emigrants who participated in one or more of the experiments reported in this dissertation, and their language dominance on the self-report measure, the L1-use measure, and the proficiency-based (LexTale score) measure. This overview shows that only few participants had the same language dominance on all measures. While agreement across all three measures was fair[19] (Fleiss' $\kappa = 0.23$), there was no indication of a single underlying commonality: self-report and proficiency-based dominance showed moderate agreement (Cohen's $\kappa = 0.54$), as did self-report and L1-use dominance (Cohen's $\kappa = 0.43$), but agreement between proficiency-based and L1-use dominance was poor (Cohen's $\kappa = 0.08$).

The fact that self-reported language dominance agrees to a similar extent with both of the other dominance measures may reflect participants' interpretation of the question

[19] Agreement between multiple raters (here: measures of language dominance) can be determined with the kappa statistic. Cohen's κ is used to measure agreement between two raters (Cohen, 1960); Fleiss' κ is used when there are more than two raters (Fleiss, 1971). Interpretation of κ-values according to Landis and Koch (1977) is as follows: $\kappa < 0$ – poor; $0.00 \leq \kappa \leq 0.20$, slight; $0.21 \leq \kappa \leq 0.40$, fair; $0.41 \leq \kappa \leq 0.60$, moderate; $0.61 \leq \kappa \leq 0.80$, substantial; $0.81 \leq \kappa \leq 1.00$, almost perfect.

Table 6-1. Language dominance of included participants in Experiments 3-1, 4-1, 5-1, and 5-2 on the self-report, the profiency-based, and the L1-use measure.

Participant	**Dominance measures**			**Exp. participated in**		
	Self-report	Proficiency	L1-use	3-1	4-1	5-1 & 5-2
1	L1	L1	neither	✓	✓	✓
2	*L2*	neither	*L2*	✓	✓	✓
3	*L2*	*L2*	neither	✓	–	–
4	L1	L1	*L2*	✓	–	–
5	L1	L1	L1	✓	✓	✓
6	*L2*	*L2*	L1	✓	✓	✓
7	L1	L1	L1	✓	✓	✓
8	*L2*	*L2*	L1	✓	✓	✓
9	L1	L1	neither	✓	–	–
10	*L2*	*L2*	*L2*	✓	✓	✓
11	L1	L1	L1	✓	–	–
12	L1	*L2*	*L2*	✓	✓	✓
13	*L2*	L1	*L2*	✓	✓	✓
14	L1	*L2*	L1	✓	✓	✓
15	L1	*L2*	L1	✓	✓	✓
16	L1	L1	L1	✓	–	–
17	L1	*L2*	L1	✓	✓	✓
18	*L2*	*L2*	neither	✓	✓	✓
19	*L2*	*L2*	L1	✓	–	–
20	L1	*L2*	L1	✓	–	–
21	*L2*	*L2*	*L2*	✓	✓	✓
22	*L2*	*L2*	L1	✓	–	–
23	L1	L1	L1	✓	–	–
24	*L2*	neither	*L2*	✓	✓	✓
25	*L2*	*L2*	*L2*	✓	✓	✓
26	*L2*	*L2*	*L2*	✓	✓	✓
27	*L2*	*L2*	neither	✓	✓	✓
28	L1	L1	*L2*	✓	✓	✓
29	L1	L1	L1	✓	–	–
30	L1	L1	L1	✓	–	–
31	*L2*	L1	neither	✓	–	–
32	*L2*	*L2*	neither	–	✓	✓

that was used to determine their self-reported dominance. When asked which language they considered to be the dominant one, some participants may have interpreted this as their most proficient language, while others may have based their answer on the frequency of language use.

This chapter has the following structure. First, section 0 describes the dependent variables from Experiments 3-1, 4-1, 5-1, and 5-2 that were used to determine whether the experimental results correlate with listeners' language dominance. Section 6.2 examines whether these variables correlate with listeners' self-reported language dominance. Subsequently, section 6.3 reports a similar investigation for the proficiency-based measure of dominance. Then, in section 6.4, language dominance according to listeners' self-reported L1 use is tested against the experimental results. This chapter concludes with a discussion of the findings (section 6.5).

6.1. What was measured per experiment

In the next sections, each dominance measure is tested against the results of the experiments reported in Chapters 3, 4, and 5. First, however, in this section, the dependent variables that were used from each of these experiments are described. One variable was selected per experiment. For more details about each experiment, please refer to its respective experimental chapter, as no further description of the experiments is provided in this chapter.

6.1.1. Experiment 3-1 – Perceptual learning

As the perceptual learning effect in Experiment 3-1 depends on a comparison of phonetic categorisation results across two exposure groups, a transformation of participants' responses was required before potential correlations with language dominance could be investigated. Thus, percentages of "learning-consistent responses" (Scharenborg & Janse, 2013) were calculated for each participant for steps A-E of the fricative post-test. This measure allows a direct comparison of the strength of the perceptual learning effect for all listeners regardless of exposure group. Listeners in the f-bias group were exposed to the ambiguous fricative [?] in f-final words and were expected to have learned to interpret the ambiguous sound as /f/. For this group, all f-responses were therefore recoded as learning-consistent. Listeners in the s-bias group, on the other hand, should have learned to interpret the ambiguous sound as /s/ and therefore had all s-responses recoded as learning-consistent.

6.1.2. Experiment 4-1 – Lexical activation and competition

Eyetracking data from the baseline condition only were analysed with an LMER model following the same procedure as described in section 4.1.2.1. Time, Competitor Type (with onset competitors coded as -0.5 and rhyme competitors as 0.5) and Language Dominance (with L1 coded as -0.5 and L2 as 0.5) were entered as predictors, and analyses were conducted by participants only. The same analysis windows were used as reported in sections 4.1.2.1 and 4.1.2.2.[20]

6.1.3. Experiment 5-1 – Use of formant transitions for fricative identification

Since the overall number of missed targets in the phoneme-monitoring task was extremely low (12 out of 600 targets), response times and not miss rates were used as the dependent variable from Experiment 5-1.

6.1.4. Experiment 5-2 – Use of suprasegmental stress for word recognition

Overall identification accuracy was used as the dependent variable from Experiment 5-2.

[20] Additional analyses were conducted for each dominance measure over a 1s time interval from 400-1400 ms from critical word onset. This is the same analysis window that was used for the cross-language comparison for experiment 4-1. These analyses provided no further insights and are reported in Appendix N and Appendix O.

6.2. Measuring language dominance I: Self-report

6.2.1. Does the self-report measure explain the perceptual learning results?

6.2.1.1. Experiment 3-1a (L2)

Eleven participants reported that they felt more dominant in their L2, while the remaining 15 indicated they felt more dominant in their L1. Figure 6-1 shows the mean percentage of learning-consistent responses for steps A-E for these two participant groups. While at first glance it may seem that the L1-dominant and not the L2-dominant listeners gave the most learning-consistent responses across all five steps, a repeated-measures ANOVA revealed no significant difference between dominance groups ($F(1, 24) = 0.36$, $p = .552$), nor a main effect of step, nor any interaction between step and language dominance. When only step C was considered, which is the most ambiguous of the fricatives sounds and may therefore be expected to attract the most learning-consistent responses, again no significant effect of language dominance was found ($t(24) = 0.67$, $p = .507$).

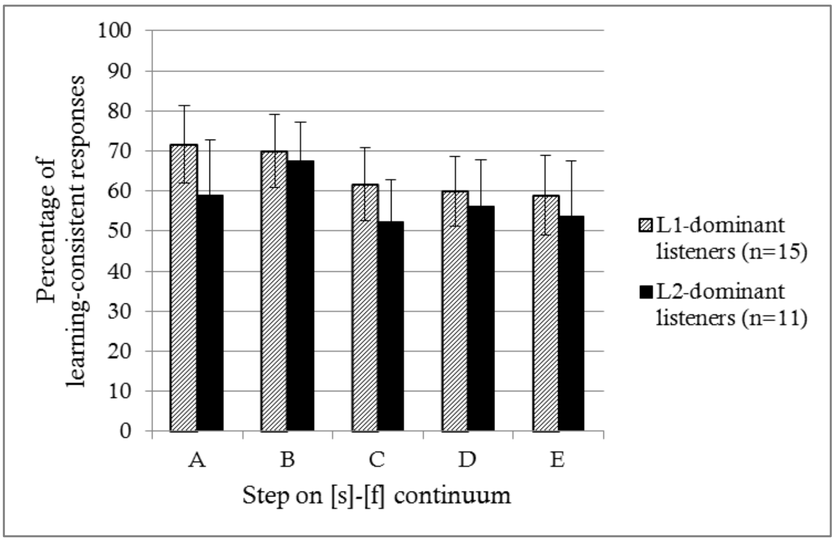

Figure 6-1. Mean percentage of learning-consistent responses in Experiment 3-1a according to participants' self-reported language dominance. Step A is the most /s/-like of the tested ambiguous stimuli, while step E is the most /f/-like. Error bars represent standard errors of the means.

6.2.1.2. Experiment 3-1b (L1)

Fifteen participants were classed as L2-dominant and 14 as L1-dominant. Mean percentages of learning-consistent responses for these two subgroups are displayed in Figure 6-2. As in Experiment 3-1a, statistical analyses found no main effect of language dominance ($F(1, 27) = 1.10$, $p = .305$), nor a main effect of step, nor any interaction between step and language dominance. Responses to step C did not significantly differ between groups either ($t(27) = 0.30$, $p = .769$). Listeners' phoneme category retuning thus appears unrelated to their self-reported language dominance.

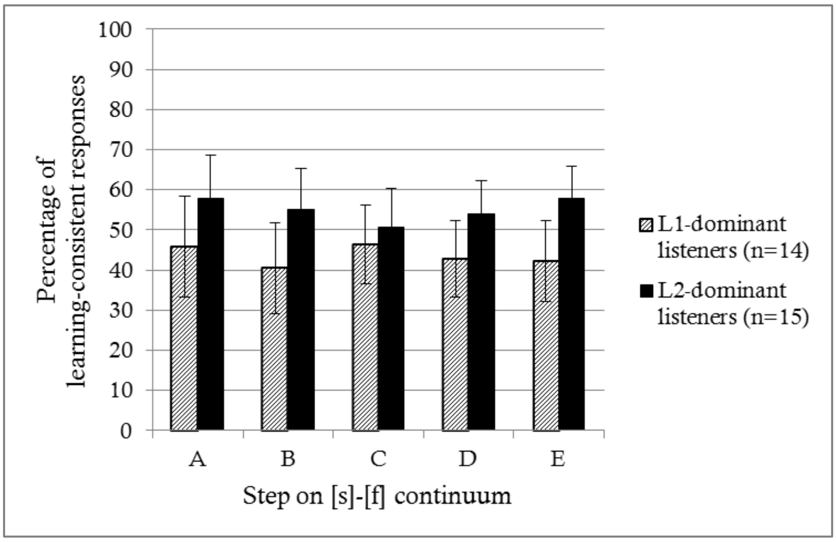

Figure 6-2. Mean percentage of learning-consistent responses in Experiment 3-1b according to participants' self-reported language dominance. Step A is the most /s/-like of the tested ambiguous stimuli, while step E is the most /f/-like. Error bars represent standard errors of the means.

6.2.2. Does the self-report measure explain the patterns of lexical activation and competition?

Results of the LMER analyses of Experiments 4-1a and 4-1b with regard to self-reported language dominance are shown in Table 6-2 and Table 6-3, respectively. No significant main effects or interactions involving language dominance were found. Additional analysis of competitor preference ratios revealed no links between these ratios and listeners' language dominance either.

Table 6-2. Results of LMER analysis of competitor fixations in Experiment 4-1a (L1) for self-reported language dominance.

Effect	By-participants		
	Est.[b]	SE	*t*-value
(Intercept)	-1.09	0.09	-12.60*
Time	0.65[a]	0.29	2.27*
Competitor Type	-0.06	0.16	-0.37
Language Dominance	-0.04	0.17	-0.24
Time * Competitor Type	-1.11	0.57	-1.93†
Time * Language Dominance	0.55	0.57	0.96
Competitor Type * Language Dominance	-0.29	0.31	-0.93
Time * Competitor Type * Language Dominance	0.00	1.14	0.00

* $p < .05$

† $p < .10$

[a] random slopes for participants over aggregated items

[b] Est. = estimated coefficient

Table 6-3. Results of LMER analysis of competitor fixations in Experiment 4-1b (L2) for self-reported language dominance.

Effect	By-participants		
	Est.[b]	SE	*t*-value
(Intercept)	-1.01	0.10	-10.58*
Time	0.79[a]	0.23	3.37*
Competitor Type	-0.20	0.15	-1.32
Language Dominance	0.09	0.19	0.47
Time * Competitor Type	-0.22	0.40	-0.55
Time * Language Dominance	0.08	0.47	0.16
Competitor Type * Language Dominance	-0.27	0.31	-0.88
Time * Competitor Type * Language Dominance	-0.35	0.81	-0.44

* $p < .05$

[a] random slopes for participants and participants over aggregated items

[b] Est. = estimated coefficient

6.2.3. Does the self-report measure explain the extent to which formant transitions are used for fricative identification?

On the self-report measure, eight participants were classified as L1-dominant, and 12 as L2-dominant. Mean response times for these subgroups are shown in Figure 6-3. A repeated-measures ANOVA revealed a significant three-way interaction between self-reported language dominance, splicing, and fricative ($F(1,18) = 10.40$, $p = .005$, $\eta_p^2 = .37$), yet no main effects or two-way interactions for any of the sub-components of this

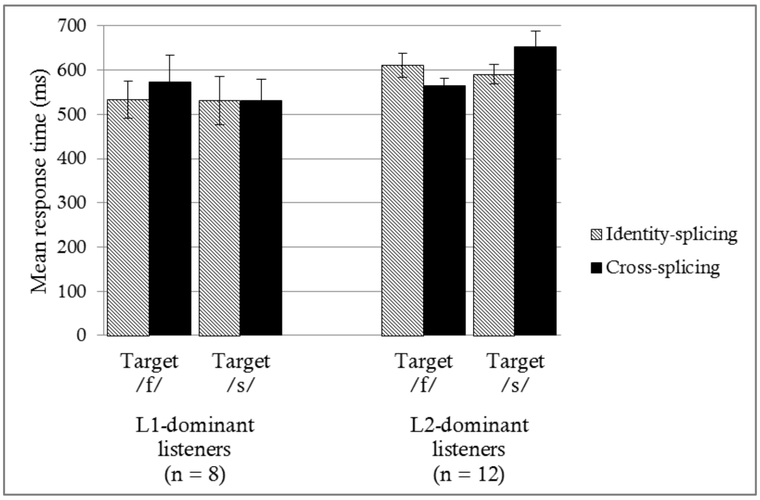

Figure 6-3. Mean response times for /f/ and /s/ in the identity- and cross-splicing conditions of Experiment 5-1, split according to participants' self-reported language dominance. Error bars represent standard errors of the means.

interaction were significant. It is highly likely that this three-way interaction is a spurious finding and it would not be observed with larger numbers of participants in each dominance group. Note that whatever difference underlies this interaction, it is certainly not that only L2-dominant participants show the effect previously found for native speakers of English (much longer RTs for cross-spliced /f/ only), as Figure 6-3 shows.

6.2.4. Does the self-report measure explain the patterns of suprasegmental stress exploitation for word recognition?

As participants were the same as in Experiment 5-1, again, eight participants were classified as L1-dominant, and 12 as L2-dominant. No significant difference was found between the overall identification accuracy of the dominance subgroups ($t(18) = 1.10$, $p = .287$).

6.3. Measuring language dominance II: Proficiency

6.3.1. Does the proficiency measure explain the perceptual learning results?

6.3.1.1. Experiment 3-1a (L2)

On the proficiency-based measure of language dominance, 13 participants were considered L1-dominant and 17 were L2-dominant. Two participants achieved an identical proficiency score in English and in Dutch and were excluded from classification as dominant in either language on this measure. Percentages of learning-consistent responses for the two dominance subgroups are shown in Figure 6-4. Once more, statistical analysis found no main effect of language dominance on listeners' category retuning, not across step A-E ($F(1, 22) = 2.36$, $p = .139$), nor for step C alone ($t(22) = 1.38$, $p = .182$); and again, no main effect of step nor any interaction between step and language dominance was found. The pattern of data displayed in Figure 6-4 nevertheless appears to be different for the language dominance subgroups, so responses for the two exposure groups within each language dominance group were examined to investigate whether the difference in patterns may be driven by listeners' exposure bias. This was not the case.

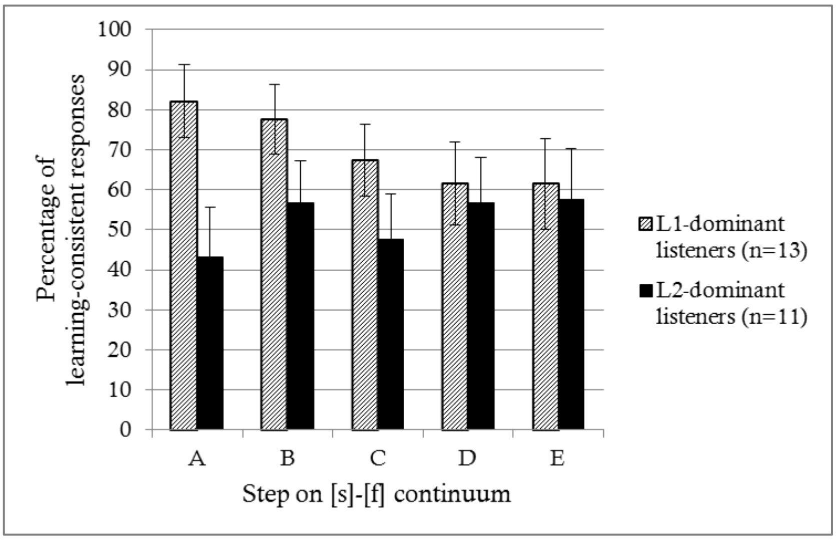

Figure 6-4. Mean percentage of learning-consistent responses in Experiment 3-1a according to listeners' proficiency-based language dominance. Step A is the most /s/-like of the tested ambiguous stimuli, while step E is the most /f/-like. Error bars represent standard errors of the means.

6.3.1.2. Experiment 3-1b (L1)

Thirteen participants were L1-dominant on the proficiency-based measure, and 14 were L2-dominant. Two participants were classified as not dominant in either language. Figure 6-5 shows the mean percentage of learning-consistent responses for the L2-dominant and L1-dominant participants. Once again, statistical analysis failed to reveal any main effects of language dominance either for all steps ($F(1, 25) = 0.98$, $p = .332$) or for step C only ($t(25) = 0.94$, $p = .355$), and no main effect of step nor any interaction between step and language dominance were found.

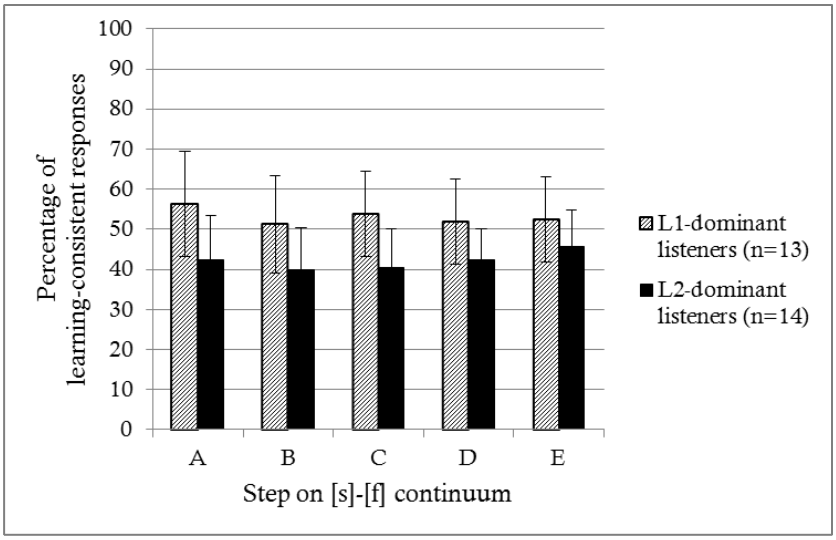

Figure 6-5. Mean percentage of learning-consistent responses in Experiment 3-1b according to listeners' proficiency-based language dominance. Step A is the most /s/-like of the tested ambiguous stimuli, while step E is the most /f/-like. Error bars represent standard errors of the means.

6.3.2. Does the proficiency measure explain the patterns of lexical activation and competition?

Table 6-4 and Table 6-5 show the results of the LMER analyses of Experiments 4-1a and 4-1b, respectively, for the proficiency-based measure of language dominance. Again, no significant main effects or interactions involving language dominance were found, and no correlations were revealed by additional analysis of competitor preference ratios either.

Table 6-4. Results of LMER analysis of competitor fixations in Experiment 4-1a (L1) for proficiency-based dominance.

Effect	By-participants		
	Est.[b]	SE	*t*-value
(Intercept)	-1.15	0.09	-12.45*
Time	0.72[a]	0.32	2.25*
Competitor Type	-0.05	0.18	-0.26
Language Dominance	0.24	0.18	1.30
Time * Competitor Type	-0.91	0.64	-1.43
Time * Language Dominance	0.44	0.64	0.69
Competitor Type * Language Dominance	0.02	0.35	0.07
Time * Competitor Type * Language Dominance	-1.08	1.27	-0.85

* $p < .05$

[a] random slopes for participants and participants over aggregated items

[b] Est. = estimated coefficient

Table 6-5. Results of LMER analysis of competitor fixations in Experiment 4-1b (L2) for proficiency-based dominance.

Effect	By-participants		
	Est.[b]	SE	*t*-value
(Intercept)	-1.02	0.10	-10.44*
Time	0.66[a]	0.24	2.76*
Competitor Type	-0.19	0.20	-0.97
Language Dominance	0.12	0.20	0.63
Time * Competitor Type	-0.31	0.48	-0.65
Time * Language Dominance	0.34	0.48	0.70
Competitor Type * Language Dominance	0.09	0.39	0.23
Time * Competitor Type * Language Dominance	0.26	0.95	0.28

* $p < .05$

[a] random slopes for participants over aggregated items

[b] Est. = estimated coefficient

6.3.3. Does the proficiency measure explain the extent to which formant transitions are used for fricative identification?

On the proficiency-based measure, five participants were classified as L1-dominant, and 13 as L2-dominant. Two participants were classified as not dominant in either language. Figure 6-6 shows mean response times for the L1-dominant and L2-dominant subgroups. A repeated-measures ANOVA found no significant main effects or interactions.

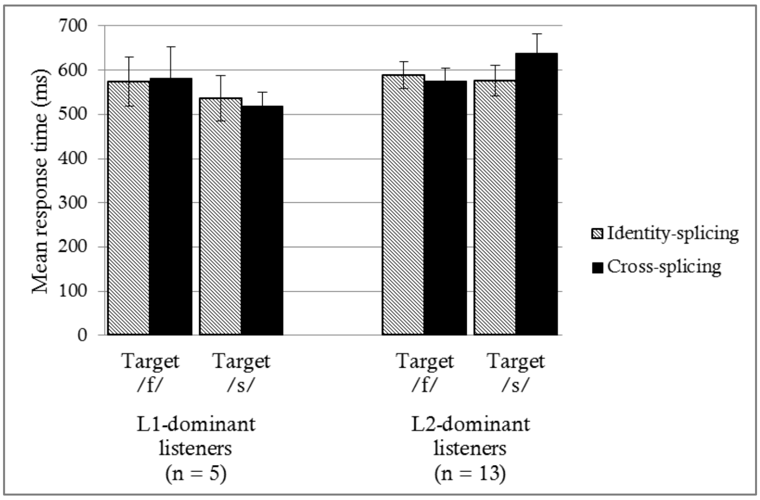

Figure 6-6. Mean response times for /f/ and /s/ in the identity- and cross-splicing conditions of Experiment 5-1, split according to participants' proficiency-based language dominance. Error bars represent standard errors of the means.

6.3.4. Does the proficiency measure explain the patterns of suprasegmental stress exploitation for word recognition?

As in Experiment 5-1, five participants were classified as L1-dominant on the proficiency-based measure, and 13 as L2-dominant. Two participants were classified as not dominant in either language. Again, no significant difference was found in overall identification accuracy ($t(16) = 1.65$, $p = .118$).

6.4. Measuring language dominance III: Use of L1

6.4.1. Does the L1-use measure explain the perceptual learning results?

6.4.1.1. Experiment 3-1a (L2)

On the final measure of language dominance, 11 participants were classified as L1-dominant and nine as L2-dominant. Six participants were classified as not dominant in either language. Percentages of learning-consistent responses for the resulting dominance subgroups are shown in Figure 6-7. As before, statistical analyses show that the subgroups did not significantly differ in the percentage of learning-consistent responses (no main effect of dominance; $F(1, 18) = 0.60$, $p = .448$), suggesting that

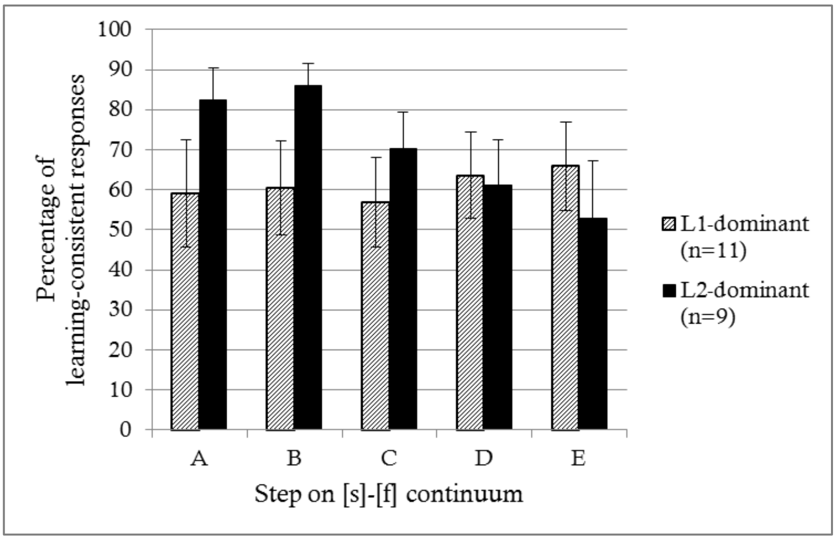

Figure 6-7. Mean percentage of learning-consistent responses in Experiment 3-1a according to listeners' L1-use language dominance. Step A is the most /s/-like of the tested ambiguous stimuli, while step E is the most /f/-like. Error bars represent standard errors of the means.

language dominance has no effect on listeners' category retuning. In addition, no main effect of step was found, nor was there any interaction between step and language dominance. An analysis on step C only also found no effect of dominance ($t(18) = 0.92$, $p = .371$).

While the interaction between language dominance and step was not significant, it may be nevertheless be informative to consider the data separately for the two exposure conditions, as the response pattern in Figure 6-7 seems to suggest a difference between the language dominance subgroups. So, as before, it was examined whether this may be driven by exposure bias (see Figure 6-8). Although participant numbers were low, the response pattern shown in the top panel of Figure 6-8 suggests that the L2-dominant listeners in the f-bias group better learned to interpret the ambiguous fricative they were exposed to as /f/ than the L1-dominant listeners in the same exposure group, which may point towards an effect of language dominance in the expected direction. Of the listeners in the s-bias exposure group, however, the L1-dominant listeners appear to show more learning-consistent responses for steps C-E than the L2-dominant participants (bottom panel of Figure 6-8).

There may be an explanation for this unexpected pattern, related to the realisation of the phoneme /s/ in Dutch and English. English /s/ is typically realised as a sharper sibilant (i.e., containing more high-frequency energy) than Dutch /s/ (Collins & Mees, 2003). Thus, both the ambiguous fricative sound used during the exposure phase of Experiment 3-1a (step C), and the tested steps towards the /f/-end of the continuum (steps D and E) may have borne more resemblance to Dutch /s/ than English /s/ and therefore have led to more learning-consistent responses (from L1-dominant listeners).

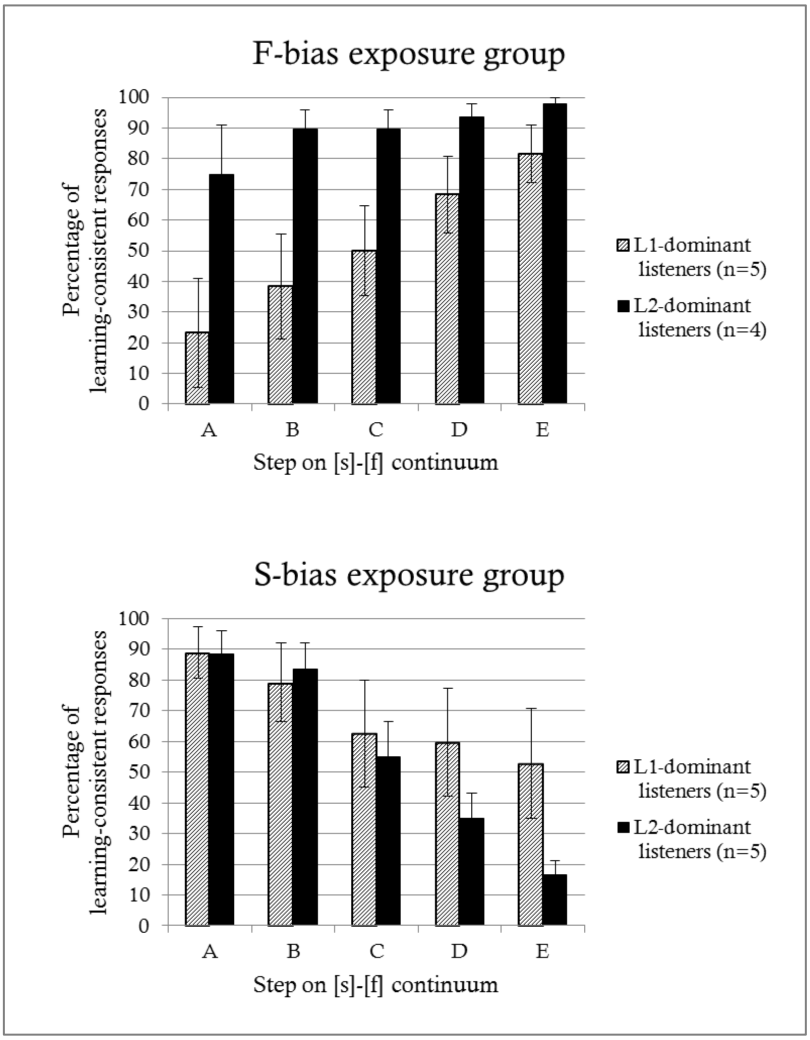

Figure 6-8. Mean percentage of learning-consistent responses for the f-bias group (top panel) and s-bias group (bottom panel) of Experiment 3-1a, split by listeners' L1-use language dominance. Step A is the most /s/-like of the tested ambiguous stimuli, while step E is the most /f/-like. Error bars represent standard errors of the means.

6.4.1.2. Experiment 3-1b (L1)

In Experiment 3-1b, 14 participants were classified as L1-dominant and nine as L2-dominant, while six were classified as not dominant in either language. Percentages of learning-consistent responses for the resultant subgroups are shown in Figure 6-9; again, no significant effects were found either for responses to all five steps ($F(1, 21) = 0.65$, $p = .428$), or for step C only ($t(21) = 0.37$, $p = .712$). There was also no main effect of step, and no significant interaction of step and language dominance.

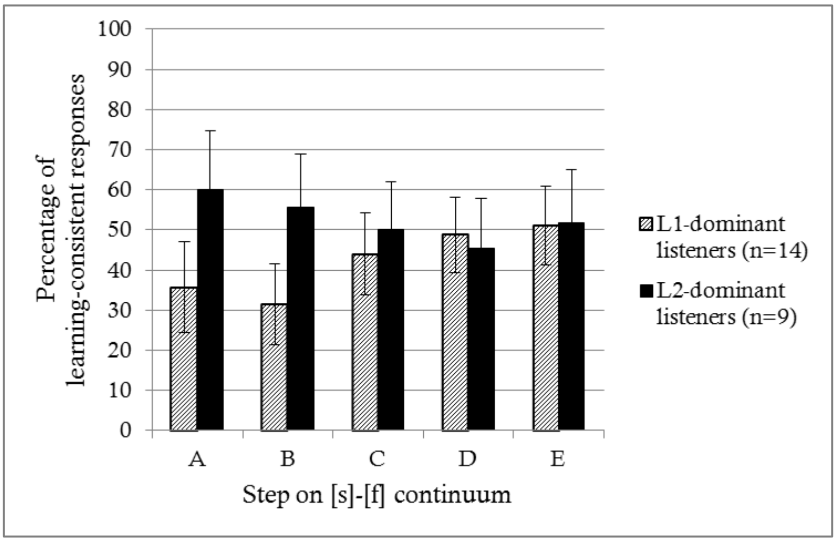

Figure 6-9. Mean percentage of learning-consistent responses in Experiment 3-1b according to listeners' L1-use language dominance. Step A is the most /s/-like of the tested ambiguous stimuli, while step E is the most /f/-like. Error bars represent standard errors of the means.

6.4.2. Does the L1-use measure explain the patterns of lexical activation and competition?

Like the previous measures, the final measure of dominance (L1-use) was unrelated to the levels of lexical competition that listeners experienced in Experiments 4-1a and 4-1b. Neither LMER analyses (see Table 6-6 and Table 6-7) nor additional analyses of competitor preference ratios showed any significant main effects or interactions involving language dominance.

Table 6-6. Results of LMER analysis of competitor fixations in Experiment 4-1a (L1) for L1-use language dominance.

Effect	**By-participants**		
	Est.[b]	SE	*t*-value
(Intercept)	-1.13	0.08	-14.15*
Time	0.80[a]	0.26	3.13*
Competitor Type	0.05	0.15	0.31
Language Dominance	-0.24	0.16	-1.49
Time * Competitor Type	-1.23	0.40	-3.10*
Time * Language Dominance	0.24	0.51	0.46
Competitor Type * Language Dominance	-0.21	0.31	-0.67
Time * Competitor Type * Language Dominance	1.57	0.79	1.99†

* $p < .05$

† $p < .10$

[a] random slopes for participants and participants over aggregated items

[b] Est. = estimated coefficient

Table 6-7. Results of LMER analysis of competitor fixations in Experiment 4-1b (L2) for L1-use language dominance.

Effect	**By-participants**		
	Est.[b]	SE	*t*-value
(Intercept)	-0.98	0.10	-10.25*
Time	0.70[a]	0.23	2.99*
Competitor Type	-0.15	0.16	-0.98
Language Dominance	0.09	0.19	0.48
Time * Competitor Type	-0.31	0.42	-0.75
Time * Language Dominance	0.17	0.47	0.36
Competitor Type * Language Dominance	-0.39	0.31	-1.26
Time * Competitor Type * Language Dominance	-0.27	0.84	-0.32

* $p < .05$

[a] random slopes for participants and participants over aggregated items

[b] Est. = estimated coefficient

6.4.3. Does the L1-use measure explain the extent to which formant transitions are used for fricative identification?

Based on their usage of L1, seven participants were classified as L1-dominant, and nine as L2-dominant, while four participants were classified as not dominant in either language. Mean response times for the two dominance groups are displayed in Figure 6-10. As for the previous measures of language dominance, a repeated-measures ANOVA revealed no significant main effects or interactions.

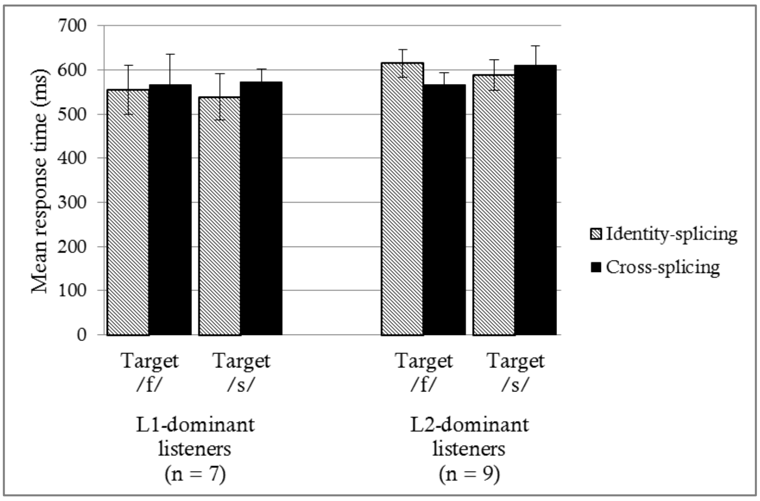

Figure 6-10. Mean response times for /f/ and /s/ in the identity- and cross-splicing conditions of Experiment 5-1, split according to participants' L1-use language dominance. Error bars represent standard errors of the means.

6.4.4. Does the L1-use measure explain the patterns of suprasegmental stress exploitation for word recognition?

As in the previous experiment, seven participants were classified as L1-dominant, and nine as L2-dominant. Four participants were classified as not dominant in either language. An independent-samples *t*-test comparing mean accuracy did not reveal a significant difference between the two dominance subgroups ($t(14) = 1.82$, $p = .090$). However, the L2-dominant group contained one outlier whose overall identification accuracy was more than two standard deviations above the group mean. With the scores of this outlier removed from the data, the same test does show a significant difference in that L2-dominant listeners were less accurate than L1-dominant listeners ($t(13) = 2.78$, $p = .016$).

Similarly, a Spearman rank-order correlation between the L1-use measure and identification accuracy (see Figure 6-11) narrowly misses significance when data from all participants are included ($r = .43$, $p = .057$) but reaches significance when the score of the aforementioned outlier (marked in black in Figure 6-11) is removed ($r = .54$, $p = .016$).

While exercising caution in interpreting a single significant result among so many null results for the dominance measures, it is important to note that this significant difference is indeed in the direction predicted for dominance measures: the task was completed in the L2, and the L2-dominant group shows a greater resemblance to the results previously observed for English listeners. There are two interpretations that could be offered for this result: firstly, it may be the case that as listeners use their L2 more frequently (which is a likely though not necessary consequence of decreased L1 use), they may become more adept at suppressing the L1 listening strategies when listening to L2 speech as they are not appropriate in such situations; secondly, when demand for the L1 listening strategy decreases as a result of a decline in L1 use, listeners may lose their sensitivity to suprasegmental stress cues and as a result, the L1 strategy no longer interferes with L2 listening. In either case, the result is that L2-dominant listeners resemble the native speakers of their L2.

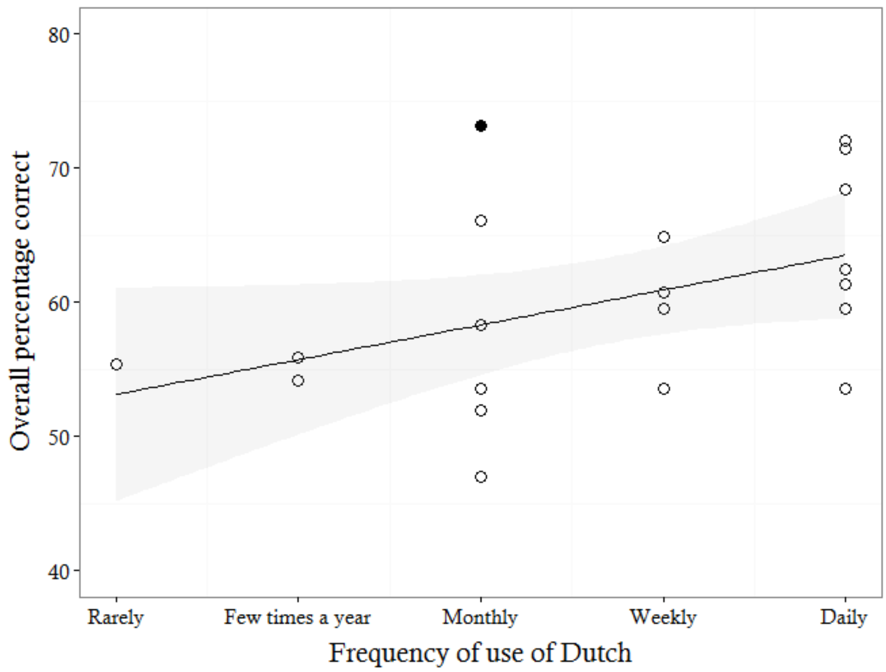

Figure 6-11. Overall percentage of correctly identified word fragments in Experiment 5-2 by listeners' frequency of L1 use.

6.5. Discussion

A comparison of the three measures of language dominance defined in Chapter 2 suggests that self-reported and proficiency-based dominance did not effectively predict listeners' behaviour in L1 and L2 speech processing at all. In the case of the proficiency-based measure, it is of course possible that ceiling effects may have contributed to the measure's lack of effectiveness, since all of the participants were highly proficient in both L1 and L2. Self-report measures, as was suggested above, may have been influenced by different assumptions on the part of the participants.

The L1-use measure may be a more promising predictor, at least to judge by the findings of Experiment 5-2. Testing of additional participants would help to strengthen this tentative conclusion. Indeed, it seems that much larger participant numbers are needed in any case for a more conclusive investigation of the role of language dominance. Unfortunately, this was not possible within the scope of this dissertation. While it was possible to recruit a substantial group of Dutch emigrants for Experiment 3-1, over one third were unable to return to our lab to participate in Experiments 4-1, 5-1, and 5-2. Moreover, several of the older emigrants wore (reading) glasses that made calibration of the eyetracker extremely difficult and resulted in a further reduction in participant numbers for Experiment 4-1. As a result of these rather disappointing circumstances it became unlikely that the experiments would have sufficient power to test effects of language dominance. Had a conclusive effect of dominance been found in any of the experiments, it may have been possible to derive an individual measure of language dominance for each participant based on their performance in that experiment. Results of the other experiments may then have been interpreted in light of this measure.

Returning once more to the measure of language use, it should be noted that this measure was quite crude, and was based solely on participants' self-reported frequency of L1 use; frequency of L2 use was not explicitly taken into account. All participants are resident in the L2-using country and use their L2 in work and social situations; but there may nevertheless be an underlying range of more to less actual use. The language-use measure may thus have been a stronger predictor if both L1 and L2 use had been separately considered, and also if a more sensitive scale had been implemented. Furthermore, participants were asked in the language background questionnaire (see Appendix A) how often they used Dutch 'nowadays'. With hindsight, a question specifically probing language use in the week or fortnight preceding the testing session may have provided more pertinent language use information, since a few participants mentioned they had Dutch visitors at the time of testing, or had visited the Netherlands themselves shortly before participating, and it is not certain that the resulting increase in L1 use was reflected in their responses to the questionnaire.

Finally, it is important to note that Dutch and English are closely related languages that resemble one another in multiple aspects of linguistic structure, and many of the processing strategies used by their L1 listeners have been shown to be alike (e.g., Akker & Cutler, 2003; Cutler & Norris, 1988; Vroomen et al., 1996). Thus, dominance may not greatly affect L1 and L2 processing in the specific case of Dutch-English bilinguals, making it difficult to find any evidence of language dominance effects in a study such as this. Future studies with bilinguals whose languages are less similar than Dutch and English may shed more light on the effects that language dominance has on speech processing.

General Discussion and Conclusions

Chapter 7

This final chapter starts with a summary of the arguments made in the introductory chapters of this dissertation, and of the findings of the subsequent experimental chapters (section 7.1). The summary is followed by a discussion of what these findings tell us about the influence of language use on speech processing (section 7.2), the acquisition and loss of listening skills (section 7.3), and the processes of lexical activation and competition in L1 and L2 listening (section 7.4). Section 7.5 discusses the limitations of the present research project and suggests directions for future research. Final conclusions are drawn in section 7.6.

7.1. Summary

The way we listen to language is shaped by the properties of our L1. While L1 listening is generally efficient and effortless, L2 listening is typically less efficient and much harder by comparison, since listening strategies are attuned to the L1 and may not always be appropriate for the L2. But how do L1 and L2 listening compare in listeners who predominantly use the L2 in daily life, such as emigrants? And what are the effects of language dominance on these processes, if any? This dissertation addressed these questions by investigating several phonetic and lexical aspects of L1 (Dutch) and L2 (English) speech processing in Dutch emigrants in Australia, and relating the experimental results to the emigrants' language dominance.

Chapter 1 started with an account of the properties of L1 listening and the way it is tailored to the properties of the L1. From this discussion it became clear that, for instance, the size and the makeup of a language's phoneme inventory determine how its listeners recognise sounds, the rhythmic structure of a language influences what cues listeners use for speech segmentation, and the presence or absence of lexical stress in a language affects the way words are recognised. This tailoring makes L1 listening optimally efficient and provides listeners with, for instance, the flexibility to adjust to unfamiliar talkers. The review then turned to L2 listening and showed that the efficiency of L1 listening appears to come at a cost for L2 listening, because listeners tend to apply their L1 listening strategies to L2 listening as well, regardless of whether this is appropriate or not.

Chapter 2 summarised the literature on L1 listening in adult emigrants, and discussed the concept of language dominance . It also contained an overview of the ways language dominance has been operationalised in the literature, and presented the three measures of language dominance that were used in this dissertation.

In Chapter 3, the lexically guided perceptual learning paradigm was used to test listeners' adaptability to an unfamiliar talker's fricative pronunciation in the L1 (Experiment 3-2) and the L2 (Experiment 3-1). Emigrants were exposed to words containing an ambiguous fricative sound between /f/and /s/, and subsequently tested on their categorisation of a set of ambiguous fricatives taken from the same [f]-[s] continuum. The lexical context in which the ambiguous fricative occurred during exposure allowed listeners to draw upon their lexical knowledge to disambiguate ambiguously pronounced fricative sounds, and adjust the boundaries of their phoneme categories accordingly (Norris et al., 2003). Results showed that Dutch emigrants flexibly adapted to the ambiguous pronunciation in L2. Interestingly, however, the same listeners made no such adjustments in their L1. The pattern of results suggests that variability in the speech input listeners are exposed to on a daily basis may be essential for maintaining this type of phonetic flexibility, and that even L1 flexibility may disappear or be temporarily suspended when variability is not available.

The experiments in Chapter 4 were based on the visual world paradigm and compared processes of lexical activation and competition in L1 (Experiment 4-1) and L2 (Experiment 4-2) listening. In these experiments, emigrants listened to spoken sentences and looked at displays of line drawings presented on a computer screen, during which their eye movements were continuously recorded with an eyetracker. Each display contained a picture whose referent was either an onset or a rhyme competitor for a critical word in the spoken sentence. Comparison of looking patterns revealed a great resemblance between lexical activation and competition in L1 listening and in L2 listening. In both languages, onset competitors competed similarly strongly for recognition. Neither L1 nor L2 listening, however, displayed the rhyme competition that is typically found for L1 listeners who live in an L1 environment. These findings suggest that bilingual listeners living in an L2 environment use lexicon-appropriate processing for their L1 and their L2, albeit with different patterns of lexical competition than L1 listeners of each language who live in an L1 environment.

The studies in Chapter 5 addressed two types of acoustic cues that are known to be exploited differently by Dutch and English listeners, and assessed which strategies were used by these Dutch emigrants. Experiment 5-1 focused on the use of formant transitions for fricative identification and was based on a study by Wagner et al. (2006). Participants completed a phoneme-monitoring task in which they heard non-words and pressed a button as soon as they heard /f/ (in one block) or /s/ (in another block). The context in which these fricatives occurred was manipulated so that formant transitions in the surrounding vowels either matched or mismatched the target fricative. Results showed that the emigrants were unaffected by this manipulation, as they ignored the cues to fricative identity that are provided by formant transitions. That is, their performance was similar to that of the Dutch listeners in the Netherlands of Wagner et al., but unlike that of the English listeners in that study. This suggested the emigrants applied their L1 listening strategy and had not adopted a strategy more appropriate to their L2.

Experiment 5-2 concerned the exploitation of suprasegmental stress cues for word recognition and replicated an experiment by Cooper et al. (2002) and. Emigrants heard the beginning of an English word (e.g., *ro-*) and decided which of two written words (e.g., *robot* and *robust*) was the source of this fragment. Written word pairs always consisted of words with contrasting stress patterns, so that stress cues from the truncated word fragment may be used to facilitate word recognition, a strategy that is typically employed more successfully by Dutch listeners than by English listeners, even for English speech (Cooper et al., 2002). In this case the results showed that Dutch emigrants' use of suprasegmental stress cues closely resembled that of the English but not the Dutch listeners from Cooper et al., suggesting that emigrants had abandoned their L1 strategy in favour of a strategy more appropriate for the L2. Combined results from Experiments 5-1 and 5-2 suggested that Dutch emigrants seemed to abandon a lexical L1 strategy that did not benefit them in L2 listening, whereas they may continue to use a phonetic L1 strategy in a situation when the use of an L2 strategy would require them to acquire a new skill.

The experimental results from Chapters 3, 4, and 5 were tested against three measures of language dominance in Chapter 6. This revealed no significant effects of language dominance. In spite of the fact that this investigation would have benefited from a greater number of participants, tentative conclusions regarding the influence of language dominance may be drawn. The findings suggest that L1 listening processes are flexible and may be shaped by predominant use of the L2. Results of Experiment 3-1 point towards the importance of language usage for maintaining phonetic adaptability in a language. This importance is reinforced by the trend that was found in Experiment 5-2, which suggests that listeners with less frequent L1 use have a greater tendency to behave in an L2-like manner and ignore suprasegmental stress cues in L2 than listeners who use their L1 more often. Furthermore, if language dominance is defined by language usage, one may argue that although the language dominance of the Dutch emigrants who participated in the present studies varied from person to person on the measures collected and assessed in Chapter 6, all of the participants may have been effectively L2 dominant. That is, if dominance may be considered as not an absolute but, rather, a relative condition, then it is certain that none of the participants were as L1 dominant as typical L1 listeners of Dutch in the Netherlands. Accordingly, all could be considered to some extent L2 dominant. The assumption that, as a group, the emigrants were all L2 dominant would then imply that the findings reported here may be linked to participants' language dominance after all.

Together, the findings from Experiments 3-1, 4-1, 5-1, and 5-2 provide important insights into three aspects of L1 and L2 listening, namely the influence of language use on speech processing, the acquisition and loss of listening skills, and the processes of lexical activation and competition. In the following three sections, these points will be discussed in turn.

7.2. The importance of language use

Adding to a large body of literature showing the sensitivity of speech comprehension and production to linguistic experience (e.g., Chang, 2012; MacKain, Best, & Strange, 1981), the findings reported in this dissertation suggest that language use and exposure change the way listeners process speech whenever this is within the range of the listeners' capabilities. This is in agreement with previous work (e.g., Chang, 2012)from various fields of research that used a range of different paradigms. Several studies have shown, for instance, that experience with a regional accent of the L1 makes phonetic processing of speech in that accent easier. For instance, in one such study (Impe, Geeraerts, & Speelman, 2008) Belgian and Dutch L1 listeners completed a Dutch lexical decision task in which they heard words with various Flemish accents as well as words with a Netherlandic-Dutch pronunciation. While listeners from the Netherlands – who are generally unfamiliar with Flemish-accented Dutch – were significantly slower to respond to Flemish-accented words than to words with a Netherlandic-Dutch accent, Belgian listeners – who are regularly exposed to the varieties of Dutch spoken in the Netherlands – processed words spoken in either accent with similar efficiency. Evidence of such experience-based adjustment is also available from studies in other languages, such as French (lexical decision; Floccia, Goslin, Girard, & Konopczynski, 2006), Japanese (gating; Otake & Cutler, 1999) and English (goodness ratings for synthesized vowels; Evans & Iverson, 2004; primed lexical decision; Sumner & Samuel, 2009). Experience also affects L1 processing of foreign-accented speech, as shown in a cross-modal priming study by Witteman et al. (2013), who found larger priming effects in German-accented Dutch for Dutch listeners who had extensive experience with this accent than for listeners who had limited experience with it.

In addition, effects of experience have also been shown for L2 listening (Hanulíková & Weber, 2011; Leikin, Ibrahim, Eviatar, & Sapir, 2009). Hanulíková and Weber (2011) conducted an eyetracking study with German and Dutch L2 listeners of English, focussing on the recognition of words that contained a mispronunciation of /θ/. In speech production, this English phoneme is often replaced by /s/ by German speakers, whereas Dutch speakers often pronounce it as /t/. Hanulíková and Weber (2011) found that both listener groups were able to interpret both mispronunciations, but recognised words more easily when the mispronunciation was consistent with the listeners' own accent. In Leikin et al.'s (2009) study, which made use of the gating task, late Russian-Hebrew and late Arabic-Hebrew bilinguals required less information to recognize L2 Hebrew words when these words were spoken by a native speaker of Hebrew or by a native speaker of the participants' own L1 (i.e., with an accent that was familiar to participants) than when words were pronounced with an unfamiliar accent (i.e., American, Russian – for the Arabic-Hebrew bilinguals, and Arabic – for the Russian-Hebrew bilinguals). Together, these studies show that experience with foreign- or regional-accented speech changes the ease with which this speech is processed, in both L1 listening and in L2 listening.

Tremblay (2009) conducted a discrimination task with English non-words to investigate the perception of lexical stress by Canadian-French L2 listeners (i.e., listeners whose L1 does not have lexical stress). This experiment showed a positive correlation between listeners' L2 use and their ability to perceive lexical stress, but failed to demonstrate a link between this ability and the length of time listeners had spent in an L2 immersion environment (i.e. a community speaking their L2). Participants in Tremblay's study were no longer in such an immersion environment at the time of testing, which led Tremblay to propose that continuous variability in the language listeners are exposed to may play an important role. Listeners who did not use the L2 often after leaving the immersion environment may thus have suffered from a lack of variability, and this may have deleteriously affected their ability to perceive lexical stress. This reasoning matches the explanation proposed for the findings of Experiment 3-1 in section 3.4, which suggested that variability in the language listeners are exposed to may be essential for the development and maintenance of phonetic listening flexibility.

When it comes to the use of language-specific listening strategies, the results are consistent with evidence from previous work suggesting that L2 listeners use L2-appropriate strategies in some cases but not others. Looking at L2 speech segmentation strategies in particular, a word-spotting study by Weber and Cutler (2006) showed that although highly proficient German L2 listeners of English had become sensitive to phonotactic constraints from the L2 and used them to segment L2 speech, they were also affected by L1 phonotactic constraints that were not useful for L2 segmentation. Hanulíková, Mitterer, and McQueen (2011) likewise used a word-spotting task to assess the segmentation strategies of highly proficient Slovak L2 listeners of German. They demonstrated that these listeners appropriately abandoned their L1 strategies regarding the use of fixed stress as a cue to word segmentation, but employed L1-based strategies for the exploitation of phonotactic probabilities. And as discussed in Chapter 5, Cutler et al. (1992) found that early French-English bilinguals used (language-appropriate) syllable-based segmentation for French and abandoned this strategy when listening to English, whereas early English-French bilinguals never used syllable-based strategies for either language.

An excursion into the field of written language processing provides further evidence of the influence of immersion in L2 on the processing strategies used by bilinguals. In an eyetracking study, Dussias and Sagarra (2007) investigated the strategies that Spanish-English bilingual readers use to resolve relative-clause attachment ambiguities in their L1 Spanish. This is the type of ambiguity that occurs in sentences such as "An armed robber shot the sister of the actor who was on the balcony". Spanish and English L1 readers differ in the way they typically interpret the phrase "who was on the balcony" (i.e., whether it refers to "the sister" or to "the actor"). Dussias and Sagarra compared the L1 reading strategies used by Spanish monolinguals, Spanish-English bilinguals living in the United States (i.e., immersed in the L2), and non-immersed bilinguals living in Spain. They found that the non-immersed bilinguals used the same parsing strategies as their monolingual compatriots, but that the bilinguals living in the United States resolved the ambiguity in a way that was more appropriate to their L2 than to their L1. This showed once more that immersion, and extensive experience with the L2 in consequence, may change the way language is processed.

The importance of language use, both for L1 and L2 listening, is also supported by evidence from language production studies. For instance, in a study on intonation imitation, D'Imperio and German (2015) asked speakers of Singaporean English to imitate sentences spoken in American English, which has a different prosodic structure from Singaporean English. Results from this study suggest that the amount of American English participants were exposed to in daily life may be positively correlated with their ability to imitate the prosody of the American-English sentences. Another study examined the prosodic rhythm of Korean L2 speakers of English using a delayed sentence-repetition task (Trofimovich & Baker, 2006). The English-likeness of speakers' timing was found to correlate with their amount of L2 use. That is, syllable duration for speakers who used L2 more often was more stress-timed (i.e., more L2-appropriate), than that of speakers with infrequent L2 use, whose speech was more syllable-timed (i.e., more appropriate to the speakers' L1). Finally, Sancier and Fowler (1997) report a case study of L1 and L2 speech production by a Brazilian Portuguese-English late bilingual. This bilingual lived in the United States (i.e., in an L2 immersion environment) and was recorded speaking her L1 and L2 immediately before and after a 2.5-month stay in Brazil (i.e., the L1 environment). Sentence pairs consisting of one sentence from each set of L1 recordings were subsequently presented to Brazilian L1 listeners, who were asked to indicate which sentence of the pair had a stronger American accent. The L1 speech recorded prior to the bilingual's trip to Brazil was judged to have a stronger accent than the recordings that were made immediately after the trip. This was confirmed by acoustic measurements of the speaker's voiceless stops /p/ and /t/ in L1 and L2: these phonemes were produced in a more L2-like manner before the speaker's trip to Brazil and in a more L1-like form immediately after that trip. Since speech production and speech perception are highly related, the fact that language use appears to influence production means that it is highly likely to be also affecting speech perception.

This section discussed the importance of language use and exposure for L1 and L2 speech processing, and showed how the findings reported in this dissertation can be situated in the broader literature. The next section focuses on the acquisition and loss of listening skills.

7.3. Acquisition and loss of listening skills

In the discussion section of Chapter 5 it was hypothesised that losing or ignoring an existing listening skill may be more easily accomplished than the acquisition of a new skill. This account is also consistent with existing literature. Consider the findings from a study on the use of suprasegmental stress by French L2 listeners of Spanish

(Dupoux, Sebastián-Gallés, Navarrete, & Peperkamp, 2008). As noted, Spanish is a language with free lexical stress, and L1 listeners of Spanish use stress cues for word recognition. French, on the other hand, does not have lexical stress, so these cues are not available to listeners of French. Using a non-word sequence recall task, and a lexical decision task, Dupoux and colleagues found that even listeners who had lived in a Spanish-speaking country for several years (4.3 years on average) had not become sensitive to lexical stress and did not use stress cues to facilitate lexical access in L2 listening.

Another study that provides support for this hypothesis focused on cross-dialectal differences in the exploitation of acoustic cues. Scott and Cutler (1984) examined the phonological rule of flapping, and the cues it provides to syntactic structure, and showed that listeners can acquire a certain sensitivity to phonetic cues that are useful in a non-native (immersion) dialect but not in the native dialect. Flapping (i.e., the realisation of /t/ or /d/ as [ɾ] in certain intervocalic contexts) occurs in American but not British English and cannot occur across major syntactic boundaries. This means it is available as a potential cue to the syntactic structure of an utterance. Scott and Cutler showed that American-English listeners indeed exploited this segmental information. British-English listeners in Britain, who are not exposed to flaps in their native dialect of English, did not. Interestingly, however, British-English listeners who had lived in the United States for several years did make use of the cues provided by the presence of a flap, although not to the same extent as American-English listeners. Since Scott and Cutler's study involved the use of a cue from the L1, one may expect the British expatriates in that experiment to have adopted the appropriate listening strategy more readily than the Dutch participants in Experiment 5-1 of this project, for whom the exploitation of formant transitions for fricative identification involved a strategy from the L2. This was indeed the case. However, the British listeners in Scott and Cutler's experiment did not exploit the cues provided by flaps as efficiently as American-English listeners, which suggests that acquiring new sensitivity to phonetic cues can be difficult even in the L1.

The aforementioned studies thus support the hypothesis that acquisition of a new listening skill may be harder than losing an existing skill. That is, the use of L2 listening strategies may be more difficult when this involves the exploitation of cues that are absent or not attended to in the L1 than when it involves losing an existing skill. Next, in section 7.4, the discussion turns to the results from Experiment 4-1, which investigated lexical activation and competition in L1 and L2 listening.

7.4. Lexical activation and competition

Experiment 4-1 was based on an eyetracking study that had demonstrated L1 listeners' adaptability to changes in speech signal reliability (i.e., McQueen & Huettig, 2012), in the hope of further comparing this type of flexibility in L1 versus L2 listening. However, the studies described in Chapter 4 found no evidence of such lexical modulation, either in Dutch emigrants or in various groups of control participants. One possible conclusion is that the effects found by McQueen and Huettig (2012) and Brouwer et al. (2012) may have been too weak to allow replication, and may have to be attributed to individual differences between participants or to as yet unidentified task-specific factors. However, the malleability of the processes of lexical activation and competition has attracted a lot of attention recently, with studies investigating this topic, for instance, from a neurophysiological perspective (Hödl & Iverson, 2016), with speech in noise (Brouwer & Bradlow, 2015), and with a training-test paradigm (Kapnoula & McMurray, 2016). It is thus to be hoped that this uncertainty will be cleared up by further findings in the very near future.

Results from Experiment 4-1 suggest that Dutch emigrants in Australia experienced no significant rhyme competition either in L1 listening or in L2 listening. This contrasts with the rhyme competition that L1 listeners of Dutch and of English typically experience. In particular, the lack of rhyme competition experienced by the emigrants in L1 listening may be linked to evidence from speech production studies suggesting that increased L2 proficiency, as well as immersion in L2, inhibit the activation and retrieval of L1 words (e.g., Guo, Liu, Misra, & Kroll, 2011; Levy, McVeigh, Marful, & Anderson, 2007; Linck, Kroll, & Sunderman, 2009; see van Hell & Tanner, 2012, for a review), and in particular the processing of their phonological forms (Levy et al., 2007).

This inhibition account does not, however, explain the lack of rhyme competition in L2 listening. A hypothesis based on working memory (WM) may explain not only the lack of rhyme competition demonstrated in L1 listening but also the lack of this competition in L2 listening. First, there is evidence to suggest that listeners may have lower WM span in L2 listening than in L1 listening (Service, Simola, Metsänheimo, & Maury, 2002). Second, spoken-word recognition is not language-selective. Lexical candidates from the L1 are activated during L2 listening, and, at least in proficient listeners in an immersion situation, so are L2 candidates during L1 listening (e.g., Blumenfeld & Marian, 2013; Lagrou, Hartsuiker, & Duyck, 2011; Marian & Spivey, 2003; Weber & Cutler, 2004). Due to this co-activation of cross-language competitors, bilinguals may activate greater numbers of competitors – and thus use more WM resources – in both L1 and L2 listening than monolingual listeners of either language. MacDonald, Just, and Carpenter (1992) found that readers with larger WM capacities (as measured by a reading-span task) were slower to resolve temporary syntactic ambiguities than readers with lower WM capacities. They proposed that readers with a greater WM entertained alternative representations of the ambiguity longer than the lower WM readers, who they thought were quicker to discard the less likely representations. Drawing a parallel with the activation of lexical candidates during spoken-word recognition, this may suggest that monolingual listeners – whose WM only has to store lexical competitors from a single language – have sufficient WM capacity available to hold in consideration both onset and rhyme competitors. Bilinguals, on the other hand, whose WM is filled with competitors from multiple languages, may not. Due to the temporal nature of speech, onset competition typically occurs earlier than rhyme competition. Thus, by the time rhyme competitors start overlapping with the incoming speech signal a large part of bilingual listeners' WM resources is already in use by activated onset competitors from the L1 and L2. Following a reasoning parallel to that of MacDonald et al. (1992), this may mean that bilinguals are quicker to discard rhyme competitors – which are less likely lexical candidates than onset competitors – than monolingual listeners and thus do not show the levels of rhyme competition in L1 and L2 listening that are typical for L1 listeners of either language. In addition, the findings that the WM capacity span appears to be smaller in L2 listening already, and that L2 immersion may lead to inhibited activation and retrieval of L1 phonological word forms may further contribute to a reduction of rhyme competition. More research is recommended to explore this hypothesis further, perhaps with pupillometry to use pupil dilation as a measure of listeners' working memory use.

The next section of this chapter contains a discussion of the limitations of the present project, and suggestions for future research.

7.5. Limitations and future directions

The studies reported in this dissertation come with several limitations. The first and most important of these limitations concerns the concept of language dominance. A recurring problem concerning this concept – which has undoubtedly affected previous studies as well as the project reported in this dissertation – is the circularity that is inevitably encountered when attempting to develop a method to determine a person's language dominance. Experimental outcomes or aspects of bilinguals' language background (e.g., proficiency, or language usage) may be found to correlate with one another and may therefore appear a useful measuring tool of language dominance. However, this overlooks the fact that the usefulness of such a tool is based on the very same definition it is meant to operationalise. Take, for example, a hypothetical study that assesses participants' language dominance by means of a fluency test, and subsequently finds a relation between this dominance and participants' response times on a lexical decision task. Interpreting this finding as support for the appropriateness of the fluency test as a measure of language dominance then disregards the fact that this is true only if the fluency was an appropriate measure of dominance to start with.

In this dissertation, three different measures were used to capture participants' language dominance, yet no conclusive evidence was found to indicate that any of these measures were related to the experimental results reported here. Furthermore, only few participants were assigned the same dominance label on all three measures. This further illustrates the difficulties that may arise when one attempts to determine bilinguals' language dominance. More research is strongly recommended in this area, as a clear and agreed-upon definition and operationalisation of language dominance will greatly benefit future studies involving this concept.

A related limitation of the present project pertains to the size of the participant sample. The choice of Dutch emigrants in Australia unfortunately made it difficult to recruit large numbers of participants. Since all emigrants were relatively L2 dominant, and variability was thus small, a greater sample size may have increased the chances of bringing to light any potential effects of language dominance.

The project reported in this dissertation was the first study since Cutler et al.'s syllable monitoring experiments (1992) to compare L1 and L2 listening within the same listeners. While, at least from a practical perspective, this approach may be more complicated than between-listener comparisons, it certainly deserves wider adoption. It is therefore encouraging to see studies such as that by Litcofsky, Tanner, and van Hell (2015), who carried out a within-subject comparison of bilinguals' speech production and written language processing in L1 and L2. Furthermore, it would certainly be interesting to see within-listener comparisons in bilingual listeners whose L1 and L2 share fewer characteristics than Dutch and English, which, as noted, are related to one another, and very similar in many aspects. One such project is currently underway at our lab (see Cutler et al., 2015 for the first results), and more research of this kind could prove very fruitful.

To further explore potential links between listeners' working memory and their processes of lexical activation and competition, it may prove useful for future studies to take into account various measures of participants' working memory capacity, such as verbal memory span.

7.6. Conclusion

At the start of this dissertation, the question was asked how L1 and L2 speech processing compare in listeners who are immersed in the L2 and for whom the L2 may have become the more dominant language. The studies reported here are the first to make this comparison for several aspects of speech processing within the same listeners. They showed that the L1 and L2 processes of lexical activation and competition resemble one another to a considerable degree. Moreover, they demonstrated that although the way we listen to language is, in principle, tailored to favour processing of our L1, this may be altered by extensive use of an L2 which imposes other demands upon spoken-language processing. Acoustic cues that are attended to in L1 listening may be ignored in L2 listening if their exploitation does not improve L2 processing efficiency. It may be harder for listeners, however, to add to their processing repertoire the use of cues that are typically ignored in listening to their L1. Finally, the results of the present studies demonstrate (hearteningly) that listeners are able to adapt to unfamiliar pronunciations in L2 listening. Importantly, and less encouragingly however, this adaptability may decrease in L1 listening when insufficient exposure to the L1 is available.

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Appendix A

Questionnaires used for Experiments 3-1, 4-1, 5-1, and 5-2

Taalachtergrondvragenlijst

Proefpersoonnummer:

Datum:

Deze vragenlijst is bedoeld om een beeld te krijgen van uw taalachtergrond. Er bestaan geen goede of foute antwoorden! De vragenlijst bestaat uit 86 vragen, maar het kan zijn dat niet alle vragen op u persoonlijk betrekking hebben (bijvoorbeeld wanneer u gevraagd wordt naar het taalgebruik van uw kinderen, maar u heeft geen kinderen). In dat geval kunt u de vraag overslaan. Mochten er onduidelijkheden zijn, dan kunt u natuurlijk altijd om een toelichting vragen.

1. Geboortedatum: ______________________________

2. Geslacht: ❑ man ❑ vrouw

3. Bent u rechts- of linkshandig?

❑ rechtshandig
❑ linkshandig

4. Bent u dyslectisch?

❑ ja
❑ nee

5. Heeft u problemen met uw gehoor?
❑ ja
❑ nee
Zo ja, geeft u alstublieft een toelichting.

____
____
____

6. Heeft u problemen met uw gezichtsvermogen die niet verholpen zijn met een bril of contactlenzen?
❑ ja
❑ nee
Zo ja, geeft u alstublieft een toelichting.

____
____
____

7. Waar bent u geboren?

Dorp/stad: ______________________________________

Provincie: ______________________________________

Land: ____

8. Welke talen werden er gesproken in het huis waar u opgegroeid bent? (bijvoorbeeld door ouders, voogd, grootouders, oppas of andere familieleden)

____

9. Welke taal beschouwt u als uw moedertaal? _____________________________

10. Wat is de moedertaal van uw ouders?

Moeder: ______________________________________

Vader: ______________________________________

11. Welke talen spreekt u vloeiend en begrijpt u moeiteloos?

1. ________________________
2. ________________________
3. ________________________
4. ________________________

12. Welke talen heeft u op school als vreemde taal geleerd?

1. ________________________ Aantal jaar _____ Vanaf (leeftijd) ________
2. ________________________ Aantal jaar _____ Vanaf (leeftijd) ________
3. ________________________ Aantal jaar _____ Vanaf (leeftijd) ________
4. ________________________ Aantal jaar _____ Vanaf (leeftijd) ________

13. Welke ta(a)l(en) heeft u buiten school om geleerd en hoe heeft u die geleerd?

____

____

____

____

____

14. Sprak u voor uw vertrek naar Australië standaard-Nederlands of een dialect?

❑ standaard-Nederlands
❑ een dialect, namelijk ______________________________________

15. Wat is het hoogste schoolniveau dat u in Nederland heeft afgerond?

❑ lagere school/basisschool
❑ middelbare school, niveau ______________________________________
❑ beroepsonderwijs, namelijk ________________________________
❑ universiteit, opleiding: ______________________________________

16. Heeft u in Australië verdere scholing gevolgd?

❑ ja, gedurende ____ jaar. Type opleiding: ________________________________
❑ nee

17. Wat is uw huidige nationaliteit?

❑ Australisch
❑ Australisch en Nederlands
❑ Nederlands

18. In welk jaar bent u naar Australië verhuisd? _______

19. Waarom bent u geëmigreerd en waarom naar Australië in het bijzonder?

❑ baan
❑ partner
❑ baan van partner
❑ anders, namelijk ____
____
____

20. In welke landen heeft u langer dan 6 maanden gewoond?

____________________________ van ________________ tot ________________
____________________________ van ________________ tot ________________
____________________________ van ________________ tot ________________
____________________________ van ________________ tot ________________
____________________________ van ________________ tot ________________
____________________________ van ________________ tot ________________

21. Welke talen sprak u al **vóórdat** u in Nederland naar school ging?

❑ Nederlands
❑ Nederlands en een andere taal, namelijk ______________________________
❑ alleen een andere taal, namelijk ______________________________

22. Had u ooit Engelse lessen gehad voor u naar Australië kwam? (hiermee wordt bedoeld in een educatieve omgeving: dat kan op school zijn of elders)

❑ nee
❑ ja, 0-1 maanden
❑ ja, 2-3 maanden
❑ ja, 4-6 maanden
❑ ja, 7-12 maanden
❑ ja, langer dan 1 jaar, namelijk _______ jaar

23. Wat is uw huidige beroep? Indien u gepensioneerd bent, wat was dan uw laatste beroep? ____

24. Indien u meerdere beroepen heeft gehad, geef deze dan in chronologische volgorde aan.

1.______________________________ van ______________ tot ______________
2.______________________________ van ______________ tot ______________
3.______________________________ van ______________ tot ______________
4.______________________________ van ______________ tot ______________

25. Heeft u in Australië ooit lessen genomen om uw Nederlandse taalbeheersing op te frissen?

❑ ja, in (jaar) _______ gedurende _______ maanden, _______ uur per week
❑ nee

26. Bent u wel eens teruggeweest naar Nederland sinds u in Australië woont?

❑ nooit
❑ zelden
❑ regelmatig, elke paar jaar
❑ regelmatig, 1-2 keer per jaar
❑ regelmatig, 3-5 keer per jaar
❑ regelmatig, meer dan 5 keer per jaar

27. Indien u heeft aangegeven nog wel eens terug te gaan naar Nederland: wat is de reden voor zo'n bezoek? (u kunt hier meerdere mogelijkheden aankruisen)

❑ vanwege een dringende familieaangelegenheid (zoals een bruiloft of begrafenis)

❑ voor mijn werk
❑ om familie te bezoeken
❑ een andere reden, namelijk: ________________________________

28. Woont u wel eens een kerkdienst bij in Australië?

❑ nee, nooit; ga verder met vraag 30
❑ ja, af en toe
❑ ja, regelmatig

29. Indien u heeft geantwoord dat u wel eens een kerkdienst bijwoont: in welke taal wordt de dienst over het algemeen gehouden?

❑ Engels
❑ Nederlands
❑ Engels en Nederlands
❑ anders, namelijk: ______________________

30. Hoe was uw Engelse taalvaardigheid voordat u naar Australië verhuisde?

	1	2	3	4	5	6	7	8	9	
zeer slecht	○	○	○	○	○	○	○	○	○	uitstekend

31. Hoe is uw Engelse taalvaardigheid op dit moment?

	1	2	3	4	5	6	7	8	9	
zeer slecht	○	○	○	○	○	○	○	○	○	uitstekend

32. Hoe was uw Nederlandse taalvaardigheid voordat u naar Australië verhuisde?

1	2	3	4	5	6	7	8	9
○	○	○	○	○	○	○	○	○
zeer slecht								uitstekend

33. Hoe is uw Nederlandse taalvaardigheid op dit moment?

1	2	3	4	5	6	7	8	9
○	○	○	○	○	○	○	○	○
zeer slecht								uitstekend

34. Hoe vaak spreekt u tegenwoordig Nederlands?

❑ zelden
❑ een paar keer per jaar
❑ maandelijks
❑ wekelijks
❑ dagelijks

35. Hoe belangrijk vindt u het dat uw Nederlands op niveau blijft?

❑ onbelangrijk
❑ tamelijk onbelangrijk
❑ niet erg belangrijk
❑ belangrijk
❑ zeer belangrijk

36. Voelt u zich meer één met de Australische of de Nederlandse cultuur?

❑ met de Australische
❑ met beide, maar vooral met de Australische
❑ met beide culturen evenveel
❑ met beide, maar vooral met de Nederlandse
❑ met de Nederlandse

37. Voelt u zich prettiger als u Nederlands spreekt of als u of Engels spreekt?

❑ Engels
❑ Nederlands
❑ geen voorkeur

38. Licht alstublieft uw antwoord op de vorige vraag toe: waarom voelt u zich prettiger bij één van beide talen of waarom heeft u geen voorkeur?

____
____
____
____

39. Wat is uw huidige burgerlijke staat?

❑ getrouwd/samenwonend
❑ gescheiden
❑ weduwe/weduwnaar
❑ met partner, niet samenwonend
❑ alleenstaand; ga verder met vraag 46

40. Met welke ta(a)l(en) is uw (wijlen/ex-) partner opgegroeid?

❑ Nederlands
❑ Engels
❑ anders, namelijk ________________________

41. Wat was voor uw (wijlen/ex-) partner de reden om naar Australië te komen?

❑ baan
❑ partner
❑ baan van partner
❑ niet van toepassing, mijn (wijlen/ex-) partner is in Australië geboren; ga verder met vraag 43
❑ anders, namelijk ____
____
____

42. In welk jaar is uw (wijlen/ex-) partner naar Australië gekomen? _______

43. Waar heeft u uw (wijlen/ex-) partner ontmoet?

❑ in Nederland
❑ in Australië
❑ ergens anders, namelijk in ________________________

44. Welke ta(a)l(en) gebruikt(e) u meestal om met uw (wijlen/ex-) partner te praten?

❑ uitsluitend Engels
❑ zowel Nederlands als Engels, maar meestal Engels
❑ evenveel Nederlands als Engels
❑ zowel Nederlands als Engels, maar meestal Nederlands
❑ uitsluitend Nederlands
❑ anders, namelijk ________________________

45. Welke ta(a)l(en) gebruikt(e) uw (wijlen/ex-) partner meestal om met u te praten?

❑ uitsluitend Engels
❑ zowel Nederlands als Engels, maar meestal Engels
❑ evenveel Nederlands als Engels
❑ zowel Nederlands als Engels, maar meestal Nederlands
❑ uitsluitend Nederlands
❑ anders, namelijk ________________________

46. Heeft u kinderen?

❑ nee; ga verder met vraag 57
❑ ja, ik heb ____ kind(eren) van ____________________ jaar oud

47. Welke ta(a)l(en) gebruikt u meestal als u met uw kinderen praat?

❑ uitsluitend Engels
❑ zowel Nederlands als Engels, maar meestal Engels
❑ evenveel Nederlands als Engels
❑ zowel Nederlands als Engels, maar meestal Nederlands
❑ uitsluitend Nederlands
❑ anders, namelijk _______________________

48. Welke ta(a)l(en) gebruiken uw kinderen meestal als ze met u praten?

❑ uitsluitend Engels
❑ zowel Nederlands als Engels, maar meestal Engels
❑ evenveel Nederlands als Engels
❑ zowel Nederlands als Engels, maar meestal Nederlands
❑ uitsluitend Nederlands
❑ anders, namelijk _______________________

49. Hoe belangrijk vindt u het dat uw kinderen Nederlands kunnen spreken en begrijpen?

❑ onbelangrijk
❑ tamelijk onbelangrijk
❑ niet erg belangrijk
❑ belangrijk
❑ zeer belangrijk

50. Heeft u kleinkinderen?

❑ nee; ga verder met vraag 53
❑ ja, ik heb ____ kleinkind(eren) van ____________________ jaar oud

51. Welke ta(a)l(en) gebruikt u meestal als u met uw kleinkinderen praat?

❑ uitsluitend Engels
❑ zowel Nederlands als Engels, maar meestal Engels
❑ evenveel Nederlands als Engels
❑ zowel Nederlands als Engels, maar meestal Nederlands
❑ uitsluitend Nederlands
❑ anders, namelijk _______________________

52. Welke ta(a)l(en) gebruiken uw kleinkinderen meestal als ze met u praten?

- ❑ uitsluitend Engels
- ❑ zowel Nederlands als Engels, maar meestal Engels
- ❑ evenveel Nederlands als Engels
- ❑ zowel Nederlands als Engels, maar meestal Nederlands
- ❑ uitsluitend Nederlands
- ❑ anders, namelijk ________________________

53. Moedigt u uw kinderen aan om Nederlands te gebruiken?

- ❑ nee, nooit
- ❑ ja, af en toe
- ❑ ja, vaak

54. Hebben uw kinderen wel eens opfrislessen Nederlands gevolgd (bijvoorbeeld door middel van zaterdagklasjes)?

- ❑ ja
- ❑ nee

55. Corrigeert u het Nederlands van uw kinderen wel eens?

- ❑ nooit
- ❑ zelden
- ❑ af en toe
- ❑ regelmatig
- ❑ zeer vaak

56. Indien uw kinderen geen Nederlands spreken of begrijpen: vindt u dat jammer?

- ❑ helemaal niet jammer
- ❑ niet jammer
- ❑ een beetje jammer
- ❑ heel erg jammer
- ❑ geen mening

57. Hoe vaak heeft u contact met vrienden en familie in Nederland?

- ❑ nooit
- ❑ zelden
- ❑ af en toe
- ❑ regelmatig
- ❑ zeer vaak

58. Hoe onderhoudt u contact met vrienden en familie in Nederland? (u kunt meerdere mogelijkheden aankruisen)

- ❑ telefoon
- ❑ Skype
- ❑ brieven

❑ e-mail
❑ anders, namelijk ________________________

59. Welke ta(a)l(en) gebruikt u om in contact te blijven met vrienden en familie in Nederland?

❑ uitsluitend Engels
❑ zowel Nederlands als Engels, maar meestal Engels
❑ evenveel Nederlands als Engels
❑ zowel Nederlands als Engels, maar meestal Nederlands
❑ uitsluitend Nederlands
❑ anders, namelijk ________________________

60. Hoe belangrijk vindt u de rol die de Nederlandse taal speelt bij het in stand houden van de relatie tussen u en uw directe familie?

❑ zeer onbelangrijk
❑ onbelangrijk
❑ niet belangrijk en niet onbelangrijk
❑ belangrijk
❑ zeer belangrijk
❑ geen mening

61. Spreekt u over het algemeen meer Nederlands of meer Engels met uw vrienden en kennissen in Australië?

❑ alleen Engels
❑ beide, maar meer Engels
❑ evenveel Nederlands als Engels
❑ beide, maar meer Nederlands
❑ alleen Nederlands

62. Wat is de moedertaal van het merendeel van uw vrienden en kennissen in Australië? (Dit hoeft niet dezelfde taal te zijn als die waarin u met hen communiceert.)

❑ Engels
❑ Nederlands
❑ evenveel Engels als Nederlands
❑ een andere taal, namelijk ________________________

63. Hoe heeft u het merendeel van deze mensen ontmoet?

❑ via een Nederlandse club of organisatie
❑ via wederzijdse vrienden/kennissen
❑ via het werk of via de school van de kinderen
❑ op een andere manier, namelijk ____

64. Vul in onderstaande tabel alstublieft de vijf personen in met wie u het meeste contact heeft. Dit kunnen mensen in Nederland, in Australië of in een ander land zijn. Deze tabel geeft ons meer inzicht in uw dagelijkse taalgebruik. Vul alstublieft voor elke persoon alle kolommen in, behalve als de persoon een familielid is. In dat geval kunt u de laatste kolom overslaan.

Persoon	In welk land woont deze persoon?	Welke taal spreekt u met hem/haar?	Wat is uw relatie met hem/haar?	Hoe lang kent u deze persoon al?	Hoe hebt u deze persoon ontmoet?
1					
2					
3					
4					
5					

65. Vul alstublieft in in welke mate u Nederlands (tabel 1) en Engels (tabel 2, z.o.z.) spreekt in de hieronder beschreven situaties, door een kruisje te zetten in het desbetreffende vakje. Indien een bepaalde situatie niet op u van toepassing is (als u bijvoorbeeld geen partner of huisdieren heeft), dan mag u die regel open laten.

Ik spreek Nederlands					
	altijd	vaak	regelmatig	af en toe	nooit
Met mijn partner					
Met familie					
Met vrienden					
Tegen huisdieren					
Op het werk					
In de kerk					
In winkels					
Op clubs of verenigingen					

Ik spreek Engels					
	altijd	vaak	regelmatig	af en toe	nooit
Met mijn partner					
Met familie					
Met vrienden					
Tegen huisdieren					
Op het werk					
In de kerk					
In winkels					
Op clubs of verenigingen					

66. Bent u (ooit) lid (geweest) van een Nederlandse vereniging of organisatie in Australië?

❑ nee
❑ ja, ik ben momenteel lid van: ____________________________ (naam vereniging) sinds _______________________ (start van lidmaatschap)
❑ ja, ik ben lid geweest van: _______________________________ (naam vereniging) van _______________________ tot ____________________ (lidmaatschapsperiode)

67. Hebt u wel eens heimwee naar Nederland?

❑ nee
❑ ja; wat ik dan het meeste mis is/zijn: _____________________________________
____
____

68. Luistert u wel eens naar Nederlandstalige liedjes?

❑ ja, elke dag
❑ ja, een aantal keer per week
❑ ja, een aantal keer maand
❑ ja, een aantal keer per jaar
❑ ja, eens per jaar of minder
❑ nee

69. Kijkt u wel eens naar Nederlandstalige televisieprogramma's?

❑ ja, elke dag
❑ ja, een aantal keer per week
❑ ja, een aantal keer maand
❑ ja, een aantal keer per jaar
❑ ja, eens per jaar of minder
❑ ik zou het graag willen, maar ik kan ze niet ontvangen
❑ nee

70. Luistert u wel eens naar Nederlandstalige radioprogramma’s?

❑ ja, elke dag
❑ ja, een aantal keer per week
❑ ja, een aantal keer maand
❑ ja, een aantal keer per jaar
❑ ja, eens per jaar of minder
❑ ik zou het graag willen, maar ik kan ze niet ontvangen
❑ nee

71. Leest u wel eens Nederlandstalige kranten, boeken of tijdschriften?

❑ ja, elke dag
❑ ja, een aantal keer per week
❑ ja, een aantal keer maand
❑ ja, een aantal keer per jaar
❑ ja, eens per jaar of minder
❑ ik zou het graag willen, maar ik kan er niet aankomen
❑ nee

72. Bezoekt u wel eens Nederlandstalige internetpagina's?

❑ ja, elke dag
❑ ja, een aantal keer per week
❑ ja, een aantal keer maand
❑ ja, een aantal keer per jaar
❑ ja, eens per jaar of minder
❑ ik zou het graag willen, maar ik heb geen toegang tot internet
❑ nee

73. Indien u heeft ingevuld dat u niet naar Nederlandstalige liedjes of radioprogramma's luistert, dat u geen Nederlandstalige lectuur leest en niet naar Nederlandstalige televisieprogramma's kijkt of Nederlandstalige internetpagina's bezoekt: licht alstublieft toe **waarom** u dat niet doet.

____

____

____

____

____

____

74. Denkt u dat uw Nederlandse taalvaardigheid is veranderd sinds uw vertrek naar Australië?

❑ ja, ik denk dat mijn Nederlands slechter is geworden
❑ nee
❑ ja, ik denk dat mijn Nederlands beter is geworden

75. Denkt u dat de mate waarin u Nederlands gebruikt, veranderd is sinds uw vertrek naar Australië?

- ❑ ja, ik denk dat ik nu minder Nederlands gebruik
- ❑ nee, ik denk dat ik nu net zo vaak Nederlands gebruik als vantevoren
- ❑ ja, ik denk dat ik nu meer Nederlands gebruik

76. Voelt u zich wel eens ongemakkelijk als u Nederlands praat tegen een Nederlander die nooit voor langere tijd in het buitenland heeft gewoond?

- ❑ ja, soms
- ❑ ja, altijd
- ❑ nee, nooit; ga verder met vraag 78

77. Indien u de vorige vraag met ja heeft beantwoord: voelt u zich ook ongemakkelijk als u Nederlands praat met een Nederlander die, net als u, al langere tijd in Australië woont?

- ❑ ja, dat maakt niets uit, dan voel ik me net zo ongemakkelijk
- ❑ nee, dan voel ik me minder ongemakkelijk

78. Ziet u zichzelf als tweetalig? Met andere woorden: vindt u dat u even goed bent in het Nederlands als het Engels?

- ❑ ja
- ❑ nee, mijn Engels is beter
- ❑ nee, mijn Nederlands is beter
- ❑ ik weet het niet, want ____

79. Kunt u mensen beter plaatsen wat betreft hun maatschappelijke positie/status wanneer ze Nederlands praten of wanneer ze Engels praten?

- ❑ Nederlands
- ❑ Engels
- ❑ maakt geen verschil
- ❑ ik weet het niet, want ____

80. Wat vindt u ervan als mensen (bijv. toeristen) een sterk Nederlands accent hebben als zij Engels praten?

- ❑ ik erger mij daaraan, want ____
- ❑ ik heb daar geen problemen mee

81. Wat vindt u ervan als Nederlanders die al langere tijd in het buitenland wonen een sterk Engels accent hebben als zij Nederlands praten?

- ❑ ik erger mij daaraan, want ____
- ❑ ik heb daar geen problemen mee

82. Welke taal beschouwt u als uw dominante taal?

❑ Nederlands
❑ Engels

83. Bent u van plan om ooit weer terug te verhuizen naar Nederland?

❑ ja, ooit zou ik wel weer terug willen naar Nederland
❑ nee, ik wil nooit meer terug naar Nederland
❑ ik heb daar nooit zo over nagedacht

84. Indien u heeft aangegeven nooit meer terug te willen keren naar Nederland, licht alstublieft toe wat uw redenen hiervoor zijn: ______________________________

____
____
____
____

85. Als u terugkijkt, denkt u dan dat u de juiste beslissing heeft genomen om naar Australië te verhuizen?

❑ ja
❑ nee, als ik opnieuw moest kiezen, zou ik niet naar Australië zijn gegaan, omdat:

____
____

❑ ik weet het niet, omdat: ____

____
____

86. U bent aan het einde gekomen van deze vragenlijst. Is er tot slot nog iets dat u wilt toevoegen of opmerken? (over het onderzoek, over uw houding tegenover de Engelse of Nederlandse taal of over de vragenlijst zelf)

____
____
____
____
____
____
____
____

the MARCS institute

University of Western Sydney
Bringing knowledge to life

Language background questionnaire

Participant number:

Date:

This questionnaire is intended to provide an impression of your language background. There are no right or wrong answers! There are 86 questions in this questionnaire. It is important to note that not all questions may apply to you personally. Should you think that a certain question does not apply to you (for example when you are asked about the language use of your children and you don't have any children), you may cross out the number in front of that particular question and move on to the next. If you don't understand a certain question, please do not hesitate to ask me.

1. Date of birth: ____________________________

2. Sex: ❑ male ❑ female

3. Are you right-handed or left-handed?

❑ right-handed
❑ left-handed

4. Are you dyslexic?

❑ yes
❑ no

5. Do you have any hearing problems?
❑ yes
❑ no

If yes, please describe the nature of the problem.

____
____
____

6. Do you have any vision problems that are **not** corrected by glasses or contact lenses?

❑ yes
❑ no

If yes, please describe the nature of the problem.

____
____
____

7. Where were you born?

Village/Town: ____________________________________

Province/State : __________________________________

Country: ____________________________________

8. When you were a child, what languages were spoken in your home? (for example, by parents, guardians, grandparents, nannies or relatives)

____

9. What language do you consider your native language? ______________________

10. What is your parents' native language?

Mother: ____

Father: ____

11. What languages do you speak fluently and understand without effort?

1. ________________________
2. ________________________
3. ________________________
4. ________________________

12. What language(s) did you study as a foreign language in school?

1. _______________ Number of years _____ Starting at the age of ______
2. _______________ Number of years _____ Starting at the age of ______
3. _______________ Number of years _____ Starting at the age of ______
4. _______________ Number of years _____ Starting at the age of ______

13. What language(s) did you learn outside of school and how did you learn them?

____

____

____

____

____

14. When you lived in the Netherlands, did you speak standard Dutch or a dialect?

❑ standard Dutch
❑ a dialect, namely _______________________________________

15. What is the highest level of education you completed in the Netherlands?

❑ primary school
❑ high school, level _______________________________________
❑ professional education, namely _________________________________
❑ university, degree: _______________________________________

16. Have you pursued further education while living in Australia?

❑ yes, for _______ years. Type of education: _________________________________
❑ no

17. What is your current nationality?

❑ Australian
❑ Australian and Dutch
❑ Dutch

18. In what year did you move to Australia? _______

19. Why did you emigrate and why to Australia in particular?

❑ job
❑ partner
❑ partner's job
❑ other, namely ____
____
____

20. In which countries have you lived for more than 6 months?

___________________________ from _______________ to _______________
___________________________ from _______________ to _______________
___________________________ from _______________ to _______________
___________________________ from _______________ to _______________
___________________________ from _______________ to _______________
___________________________ from _______________ to _______________

21. What language(s) had you already acquired **before** you started school in the Netherlands?

❑ Dutch
❑ Dutch and another language, namely _____________________________
❑ only another language, namely _____________________________

22. Did you attend any English classes before coming to Australia? (in an educational environment, like a school or some similar institution)

❑ no
❑ yes, for 0-1 month
❑ yes, for 2-3 months
❑ yes, for 4-6 months
❑ yes, for 7-12 months
❑ yes, for more than 1 year, namely for _______ years

23. What is your current profession? If you are retired, what was your last profession before retirement?

____

24. If you have had multiple professions, please list them in chronological order.

1. _____________________________ from ____________ until ______________
2. _____________________________ from ____________ until ______________
3. _____________________________ from ____________ until ______________
4. _____________________________ from ____________ until ______________

25. Have you ever attended Dutch heritage classes while living in Australia?

❑ yes, in (year) _______ for the period of _____ months, for _____ hours a week
❑ no

26. Have you ever been back to the Netherlands since you moved to Australia?

❑ never
❑ rarely
❑ regularly, every few years
❑ regularly, 1-2 times a year
❑ regularly, 3-5 times a year
❑ regularly, more than 5 times a year

27. If you have indicated that you have been back to the Netherlands, please indicate the reason(s) for such a visit (you may tick more than one box).

❑ because of urgent family matters (such as a wedding or a funeral)
❑ for my job
❑ to visit relatives
❑ another reason, namely: _________________________________

28. Do you ever attend church in Australia?

❑ no, never; continue with question 30
❑ yes, sometimes
❑ yes, regularly

29. If you have indicated you go to church, please indicate in which language the services are generally held.

❑ English
❑ Dutch
❑ English and Dutch
❑ other, namely: _______________________

30. How do you rate your English language proficiency before you moved to Australia?

1	2	3	4	5	6	7	8	9
○	○	○	○	○	○	○	○	○
very poor								excellent

31. How do you rate your English language proficiency at present?

1	2	3	4	5	6	7	8	9
○	○	○	○	○	○	○	○	○
very poor								excellent

32. How do you rate your Dutch language proficiency before you moved to Australia?

	1	2	3	4	5	6	7	8	9	
	○	○	○	○	○	○	○	○	○	
very poor										excellent

33. How do you rate your Dutch language proficiency at present?

	1	2	3	4	5	6	7	8	9	
	○	○	○	○	○	○	○	○	○	
very poor										excellent

34. How often do you speak Dutch nowadays?

❑ rarely
❑ a few times a year
❑ monthly
❑ weekly
❑ daily

35. How important do you feel it is that you maintain your Dutch?

❑ unimportant
❑ relatively unimportant
❑ not very important
❑ important
❑ very important

36. Do you feel more at home with Dutch or with Australian culture?

❑ with Australian culture
❑ with both, but more with Australian culture
❑ with both cultures equally
❑ with both, but more with Dutch culture
❑ with Dutch culture

37. Do you feel more comfortable speaking Dutch or speaking English?

❑ English
❑ Dutch
❑ no preference

38. Please elaborate on your answer to the question above. Why do you feel more comfortable speaking either Dutch or English or why do you not have any preference?

____

____

____

39. What is your current marital status?

❑ married/living together
❑ separated/divorced
❑ widow/widower
❑ with partner, not living together
❑ single; continue with question 46

40. With what language(s) was your (ex/late) partner brought up?

❑ Dutch
❑ English
❑ other, namely ________________________

41. Why did your (ex/late) partner come to Australia?

❑ job
❑ partner
❑ partner's job
❑ not applicable, my (ex/late) partner was born in Australia; continue with question 43
❑ other, namely ____
____
____

42. In what year did your (ex/late) partner come to Australia? _______

43. Where did you meet your (ex/late) partner?

❑ in the Netherlands
❑ in Australia
❑ somewhere else, namely in ________________________

44. What language(s) do/did you mostly use when talking to your (ex/late) partner?

❑ only English
❑ both Dutch and English, but mostly English
❑ both Dutch and English, equally often
❑ both Dutch and English, but mostly Dutch
❑ only Dutch
❑ other, namely ________________________

45. What language(s) does/did your (ex/late) partner mostly use when talking to you?

❑ only English
❑ both Dutch and English, but mostly English
❑ both Dutch and English, equally often
❑ both Dutch and English, but mostly Dutch
❑ only Dutch
❑ other, namely ________________________

46. Do you have any children?

❑ no; continue with question 57
❑ yes, I have ____ children and they are ____________________ years old

47. What language(s) do you mostly use when talking to your children?

❑ only English
❑ both Dutch and English, but mostly English
❑ both Dutch and English, equally often
❑ both Dutch and English, but mostly Dutch
❑ only Dutch
❑ other, namely _______________________

48. What language(s) do your children mostly use when talking to you?

❑ only English
❑ both Dutch and English, but mostly English
❑ both Dutch and English, equally often
❑ both Dutch and English, but mostly Dutch
❑ only Dutch
❑ other, namely _______________________

49. How important do you feel it is that your children can speak and understand Dutch?

❑ unimportant
❑ relatively unimportant
❑ not very important
❑ important
❑ very important

50. Do you have any grandchildren?

❑ no; continue with question 53
❑ yes, I have ____ grandchildren and they are ____________________ years old

51. What language(s) do you mostly use when talking to your grandchildren?

❑ only English
❑ both Dutch and English, but mostly English
❑ both Dutch and English, equally often
❑ both Dutch and English, but mostly Dutch
❑ only Dutch
❑ other, namely _______________________

52. What language(s) do your grandchildren mostly use when talking to you?

❑ only English
❑ both Dutch and English, but mostly English
❑ both Dutch and English, equally often
❑ both Dutch and English, but mostly Dutch
❑ only Dutch
❑ other, namely ________________________

53. Do you encourage your children to speak Dutch?

❑ no, never
❑ yes, sometimes
❑ yes, often

54. Have your children ever attended Dutch heritage classes (Saturday classes for example)?

❑ yes ❑ no

55. Do you ever correct your children's Dutch?

❑ never
❑ rarely
❑ sometimes
❑ regularly
❑ very often

56. If your children do not speak or understand Dutch, do you regret that?

❑ not at all
❑ not much
❑ a bit
❑ very much
❑ no opinion

57. How often are you in touch with friends and relatives in the Netherlands?

❑ never
❑ rarely
❑ sometimes
❑ regularly
❑ very often

58. How do you keep in touch with friends and relatives in the Netherlands? (you may tick more than one box)

❑ telephone
❑ Skype
❑ letters

❑ e-mail
❑ another way, namely ________________________

59. What language(s) do you use to keep in touch with friends and relatives in the Netherlands?

❑ only English
❑ both Dutch and English, but mostly English
❑ both Dutch and English, equally often
❑ both Dutch and English, but mostly Dutch
❑ only Dutch
❑ other, namely ________________________

60. How important do you consider the role of Dutch in maintaining the relationship between you and your immediate family?

❑ very unimportant
❑ unimportant
❑ not important and not unimportant
❑ important
❑ very important
❑ no opinion

61. In general, do you speak more Dutch or more English with your friends and acquaintances in Australia?

❑ only English
❑ both, but more English
❑ as much Dutch as English
❑ both, but more Dutch
❑ only Dutch

62. What is the native language of the majority of your friends and acquaintances in Australia? (This does not have to be the same language that you use to communicate with them.)

❑ English
❑ Dutch
❑ equal English and Dutch
❑ another language, namely ________________________

63. How did you meet most of these people?

❑ through a Dutch club or organisation
❑ through mutual friends/acquaintances
❑ through work or through the children's school
❑ another way, namely ____

64. In the table below, please list the five people that you are most frequently in touch with (regardless of whether they live in the Netherlands, in Australia or somewhere else). This will provide some further insight into your daily language use. Please fill out all columns for each person but feel free to leave the last column empty if the person is a relative.

Person	In what country does this person live?	What language do you speak with him/her?	What is your relationship with him/her?	How long have you known this person?	How did you meet this person?
1					
2					
3					
4					
5					

65. Please indicate in the tables below to what extent you use Dutch (table 1) and English (table 2, p.t.o.) in the situations listed. Simply tick the appropriate box. If a certain situation is not applicable to you (for example, if you don't have a partner or any pets), please leave that row empty.

I speak Dutch					
	always	often	regularly	every now and then	never
With my partner					
With relatives					
With friends					
To pets					
At work					
In church					
In shops					
At clubs or organisations					

I speak English					
	always	often	regularly	every now and then	never
With my partner					
With relatives					
With friends					
To pets					
At work					
In church					
In shops					
At clubs or organisations					

66. Are you/have you ever been a member of a Dutch club or organisation in Australia?

❑ no
❑ yes, I have been a member of:
______________________________ (name of the organisation)
from ____________ to ____________ (period of membership)
❑ yes, I am currently a member of:
______________________________ (name of the organisation)
and have been since _______________ (start of membership)

67. Do you ever get homesick (as in, missing the Netherlands)?

❑ no
❑ yes; what I miss most in those situations is/are: ____________________
____

68. Do you ever listen to songs in Dutch?

❑ yes, daily
❑ yes, several times a week
❑ yes, several times a month
❑ yes, several times a year
❑ yes, once a year or less
❑ no

69. Do you ever watch television programmes in Dutch?

❑ yes, daily
❑ yes, several times a week
❑ yes, several times a month
❑ yes, several times a year
❑ yes, once a year or less
❑ I would love to, but I do not have access to them
❑ no

70. Do you ever listen to radio programmes in Dutch?

❑ yes, daily
❑ yes, several times a week
❑ yes, several times a month
❑ yes, several times a year
❑ yes, once a year or less
❑ I would love to, but I do not have access to them
❑ no

71. Do you ever read Dutch newspapers, books or magazines?

❑ yes, daily
❑ yes, several times a week
❑ yes, several times a month
❑ yes, several times a year
❑ yes, once a year or less
❑ I would love to, but I do not have access to them
❑ no

72. Do you ever visit websites that are in Dutch?

❑ yes, daily
❑ yes, several times a week
❑ yes, several times a month
❑ yes, several times a year
❑ yes, once a year or less
❑ I would love to, but I do not have internet access
❑ no

73. If you have indicated that you never listen to Dutch songs or radio programmes, nor read Dutch newspapers, books or magazines and that you don’t watch Dutch television programmes nor visit Dutch websites, please indicate why you don't.

____
____
____
____
____
____
____

74. Do you think your Dutch language proficiency has changed since you moved to Australia?

❑ yes, I think my Dutch has deteriorated
❑ no
❑ yes, I think my Dutch has improved

75. Do you think your frequency of using Dutch has changed since you moved to Australia?

❑ yes, I think I use less Dutch now
❑ no, I think I use Dutch as often now as I did before I moved to Australia
❑ yes, I think I use more Dutch now

76. Do you ever feel uncomfortable when speaking Dutch to a Dutch person who has never lived abroad for a considerable amount of time?

❑ yes, sometimes
❑ yes, always
❑ no, never; continue with question 78

77. If you have answered yes to the question above: do you also feel uncomfortable speaking Dutch with someone who, like you, has lived in Australia for a long time?

❑ yes, it does not make a difference, I feel equally uncomfortable
❑ no, I feel less uncomfortable

78. Do you see yourself as bilingual? In other words, do you think you are as proficient in Dutch as in English?

❑ yes
❑ no, I'm more proficient in English
❑ no, I'm more proficient in Dutch
❑ I don't know, because ______________________________

79. Are you better at guessing a person's social position/status when they speak Dutch or when they speak English?

❑ Dutch
❑ English
❑ no difference
❑ I don't know, because ______________________________

80. How do you feel when Dutch people (e.g., tourists) speak English with a heavy Dutch accent?

❑ that annoys me, because ______________________________
❑ I don't have any problems with that

81. How do you feel when Dutch people who have lived abroad for a long time speak Dutch with a heavy English accent?

❑ that annoys me, because ______________________________
❑ I don't have any problems with that

82. Which language do you consider to be your dominant language?

❑ Dutch
❑ English

83. Do you intend to ever move back to the Netherlands?

❑ yes, I would eventually like to move back to the Netherlands
❑ no, I never want to return to the Netherlands
❑ I have never really given it much thought

84. If you have indicated that you do not intend to ever move back to the Netherlands, please explain why you feel that way:

____
____
____
____
____

85. Looking back, do you think you made the right decision in moving to Australia?

❑ yes
❑ no, I would not do it again if I had to make the choice again, because:___________
____
____

❑ I don't know, because: ____
____
____

86. You have come to the end of this questionnaire. Are there any additional comments you would like to add? (This can be anything from language-related comments to remarks about the questionnaire or research itself.)

____
____
____
____
____
____
____
____

Appendix B

Results of extra post-tests Experiment 3-1

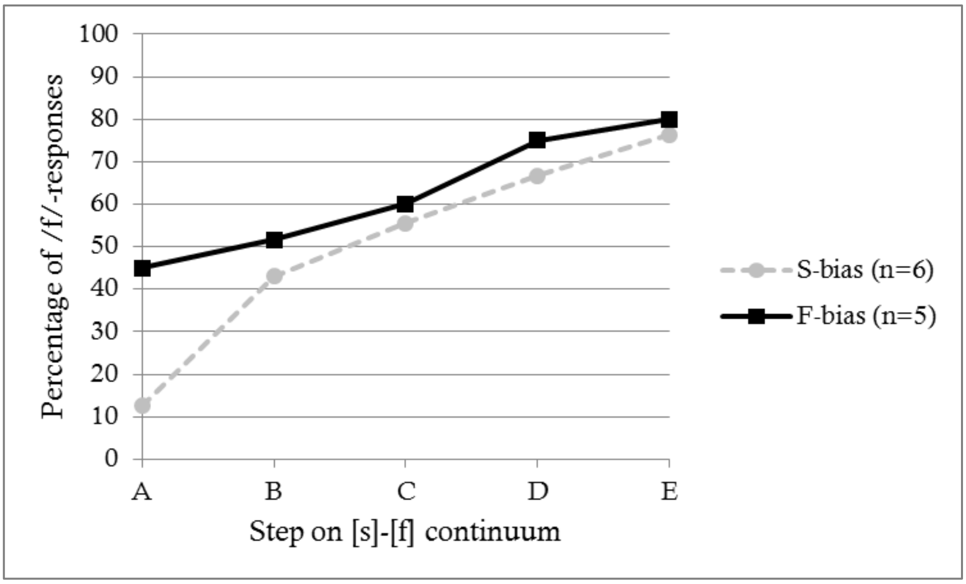


Figure B-1. Mean percentage of /f/-responses in the extra post-test of Experiment 3-1a for listeners in the f-bias and s-bias groups. Step A is the most /s/-like of the tested ambiguous stimuli, while step E is the most /f/-like.

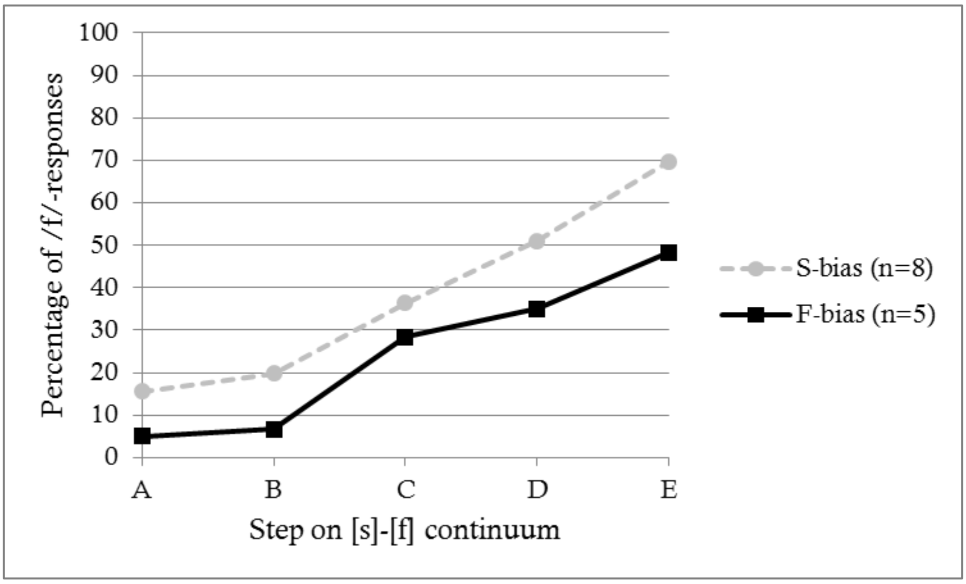


Figure B-2. Mean percentage of /f/-responses in the extra post-test of Experiment 3-1b for listeners in the f-bias and s-bias groups. Step A is the most /s/-like of the tested ambiguous stimuli, while step E is the most /f/-like.

Appendix C

Phonetic categorisation pilot for Experiment 3-1a

Participants

Twenty undergraduate students (four males) who were enrolled in introductory psychology courses at Western Sydney University participated in this experiment in exchange for course credit. All participants were native speakers of Australian English, aged 17-33 years ($M = 19.3$; $SD = 3.4$), and none had any native languages other than Australian English. Written informed consent was obtained from each participant prior to the start of the experiment.

Materials

The materials used in this pilot consisted of all 41 steps of the [ɛf]-[ɛs] continuum that was constructed for Experiment 3-1a.

Procedure

Participants were tested individually or in pairs in a sound-dampened room. Auditory stimuli were presented over Sennheiser HD 280 headphones. The pilot experiment was conducted with DMDX 4.3.0.0 (Forster & Forster, 2003) and consisted of six blocks, during each of which participants were presented once with all 41 steps of the [ɛf]-[ɛs] continuum, in random order, and were asked to categorise the final sound of each token as either /f/ or /s/.

Results

Categorisation results from the pilot experiment are shown in Figure C-1, with step 1 of the continuum, which was a natural /s/, on the far left, and step 41, which was a natural /f/, on the far right.

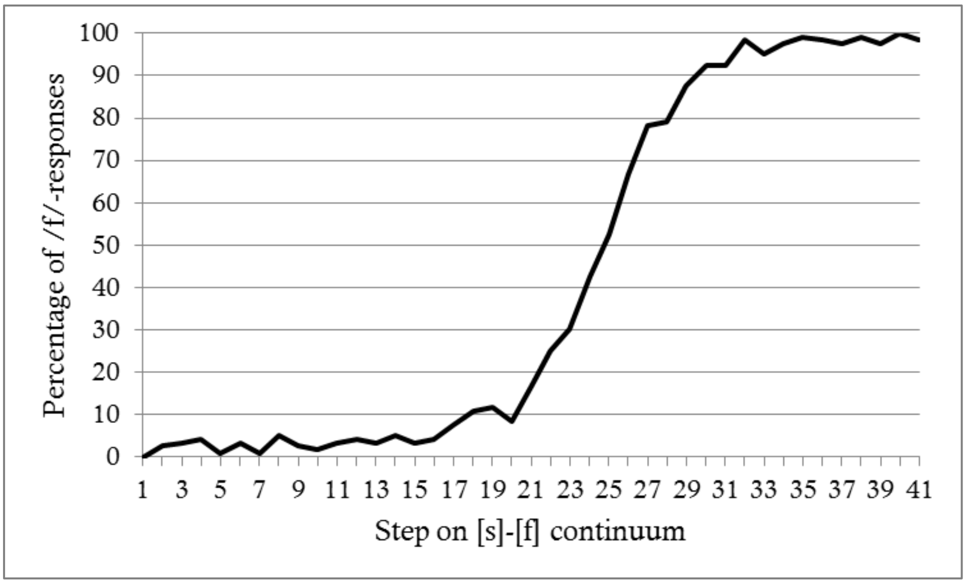


Figure C-1. Mean percentage of /f/-responses to the 41-step continuum in the pilot for Experiment 3-1a.Step 1 corresponds to natural /s/, step 41 to natural /f/.

Steps on the /s/-side of the continuum are clearly perceived as [s] most of the time, while steps towards the opposite end of the continuum are most frequently perceived as [f]. Step 25 is the most ambiguous step for the native Australian-English speaking participants of this pilot experiment.

Appendix D

Stimuli from the lexical decision task of Experiment 3-1a

/f/-final words	/s/-final words
aloof	across
autograph	awareness
beef	bias
behalf	bliss
belief	crease
bulletproof	dress
dandruff	embrace
debrief	entice
dwarf	eyewitness
earmuff	harass
enough	hideous
handcuff	immerse
laugh	necklace
loaf	noose
midwife	pierce
plaintiff	promise
proof	remorse
rough	replace
whooping-cough	twice
wildlife	unless

Appendix E

Phonetic categorisation pilot for Experiment 3-1b

Participants

Twenty participants (seven males) were recruited from the participant pool of the Max Planck Institute for Psycholinguistics in Nijmegen, the Netherlands. They received a small payment in return for their participation. All participants were native speakers of Dutch, aged 18-79 years (M = 44.2; SD = 25.2), and none had any native languages other than Dutch. Each participant provided their written informed consent prior to the start of the experiment.

Materials

The materials used in this pilot consisted of all 41 steps of the [ɛf]-[ɛs] continuum that was constructed for Experiment 3-1b.

Procedure

Participants were tested individually in a sound-dampened booth. Auditory stimuli were presented over Sennheiser HD 280 headphones. The pilot experiment was conducted with DMDX (version 4.3.0.0; Forster & Forster, 2003) and consisted of six blocks, during each of which participants were presented once with all 41 steps of the [ɛf]-[ɛs] continuum, in random order, and were asked to categorise the final sound of each token as either /f/ or /s/.

Results

Categorisation results from the pilot experiment are shown in Figure E-1, with a natural /s/ on the far left side of the x-axis and a natural /f/ on the far right. Steps on the /s/-side of the continuum are clearly perceived as [s] most of the time, while steps towards the opposite end of the continuum are most frequently perceived as [f]. Step 28 is the most ambiguous step for the native Dutch-speaking participants of this pilot experiment.

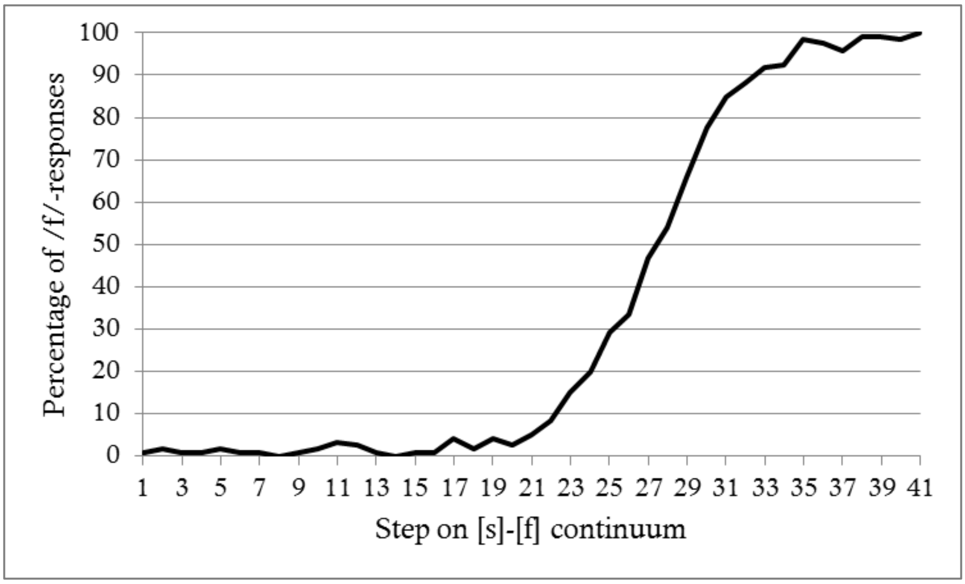


Figure E-1. Mean percentage of /f/-responses to the 41-step continuum in the pilot for Experiment 3-1b.Step 1 corresponds to natural /s/, step 41 to natural /f/.

Appendix F

Stimuli from the lexical decision task of Experiment 3-1b

/f/-final words	/s/-final words
aanhef (beginning)	ananas (pineapple)
achterneef (great nephew)	anijs (aniseed)
autokerkhof (wrecking yard)	appelmoes (apple sauce)
braaf (honest)	bekentenis (confession)
doolhof (maze)	bordes (steps)
dreigbrief (threatening letter)	collectebus (collecting box)
educatief (educational)	doctorandus (doctoral candidate)
hartedief (darling)	gedachteloos (thoughtless)
landbouwbedrijf (farm)	geitenkaas (goat's cheese)
loopgraaf (trench)	gemeentehuis (town hall)
middenrif (diaphragm)	hagedis (lizard)
onderlijf (lower body)	hakmes (machete)
ongeloof (disbelief)	krijs (scream)
operatief (surgically)	lerares (teacher)
ophef (fuss)	matroos (sailor)
praalgraf (mausoleum)	naaldbos (pine forest)
proef (test)	nis (niche)
recreatief (recreational)	pedagogisch (pedagodical)
rentetarief (interest rate)	pimpelmees (blue tit)
tortelduif (turtle dove)	relaas (account)

Appendix G
Stimulus materials from Experiment 4-1a

Table G-1. Sentences from the onset-competitor condition of Experiment 4-1a. Critical words are marked in bold.

	Sentence
1	Er ontstond verwarring in de groep over de **agenda** die verdwenen was
2	Mijn vriendin wist niet dat een **bacterie** niet hetzelfde is als een virus
3	In de spellingstoets stond het woord **blikopener** en niemand had het fout
4	Hij gaf toe dat er inderdaad geen **bloed** meer in zijn overhemd zat na het wassen
5	De buurvrouw zei dat er een **circus** in de stad zou komen
6	Hij vroeg wat het woord **diabolo** betekende, omdat hij het niet kende
7	Zoals ze al verwacht hadden, bleef de **dobber** doodstil op het water liggen
8	Hij had een schilderij van een **duiventil** in een park aan de muur hangen
9	Na een paar uur vonden we de **hagelslag** die mijn broertje wilde hebben
10	De jongen hoopte dat hij de **held** mocht spelen in de voorstelling van zijn theaterclub
11	Toen ik opkeek, zag ik een **kakkerlak** over de vensterbank lopen
12	Ze keken allemaal naar de **kers** die vertrapt op de stoep lag
13	Hij wist zeker dat zijn vriendin de **klok** die hij gekocht had erg mooi zou vinden
14	De man keek om zich heen en zag een **kompas** op de grond liggen
15	Toen we vertrokken, vergaten we de **krans** die we cadeau wilden geven
16	Ze had laatst nog een plaatje van een **krokus** gezien op internet
17	Gisteren had mijn broertje een **kruisbes** geplukt, maar hij vond hem niet lekker
18	Ik was er van overtuigd dat er geen **lepra** meer voorkwam in de Westerse wereld
19	Midden in de garage zag ik een **matras** waarop iemand lag te slapen
20	Hij vroeg zich af wat het nut van de **paraplu** was, omdat die kapot was
21	Hij keek aandachtig naar de **parkeermeter** en stopte er toen geld in
22	Het zag eruit als een **paspoort,** maar de tekst op de voorkant klopte niet
23	Het was haast niet te zien dat er een **pepernoot** achter de boekenkast lag
24	Het jongetje had moeite met de spelling van het woord **pyjama,** daarom vroeg hij om hulp
25	Misschien had ik de **rolschaats** die in de gang lag beter op kunnen ruimen
26	De journalist vond dat het een **scheldwoord** was, maar zijn baas was het er niet mee eens
27	Iedereen keek goed naar de **schilder** die bezig was een aquarel te maken
28	Vanuit de achtertuin kun je een **schoolplein** zien met een schommel en een klimrek
29	De man keek erg verbaasd toen hij een **slipcursus** voor zijn verjaardag kreeg
30	Hij had altijd al eens een **stacaravan** willen huren voor een weekendje weg
31	De buurman probeerde de **steiger** te verstevigen met een paar extra lagen hout
32	De vrouw kocht een **stemvork** met een gouden handvat
33	De stotteraar had moeite met het woord **strippenkaart,** dat hij slecht kon uitspreken
34	Pas geleden schreef ze een werkstuk over een **synagoge,** waarvoor ze een acht kreeg
35	Mijn collega wilde net de **telefoon** oppakken, toen die begon te rinkelen
36	Hij droomde die nacht over een **telefooncel** waar hij niet meer uit kon
37	In die brief stond het woord **thermoskan** helaas niet goed geschreven
38	Na enige aarzeling koos ze de **vliegenmepper** met de groene streep
39	Het meisje hoopte dat ze de **vorm** van het standbeeld goed onthouden had
40	Toen mijn neefje vorig jaar een **zwaard** kreeg, wilde hij het overal mee naartoe nemen

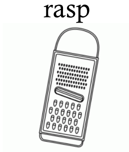
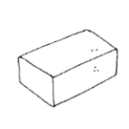
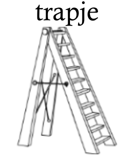
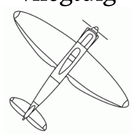
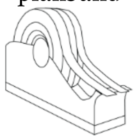
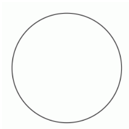
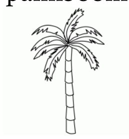
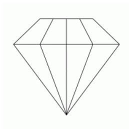
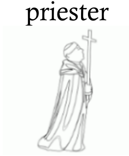
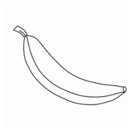
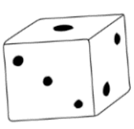
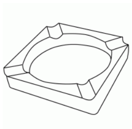
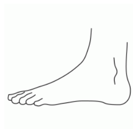
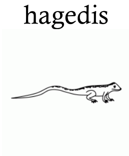
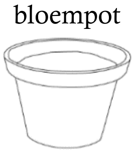
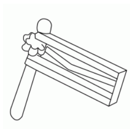
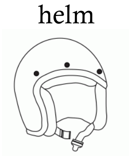
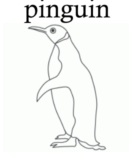
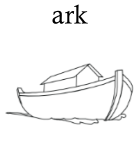
Table G-2. Sentences from the rhyme-competitor condition of Experiment 4-1a. Critical words are marked in bold.

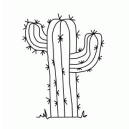
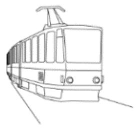
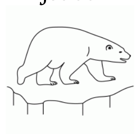
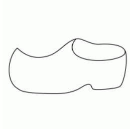
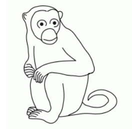
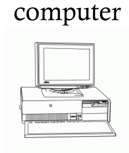
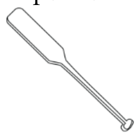
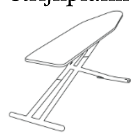
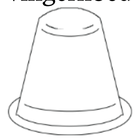
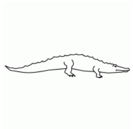
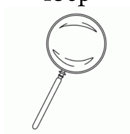
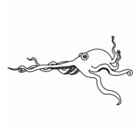
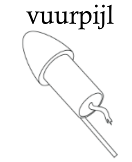
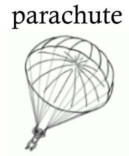
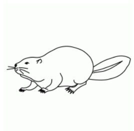
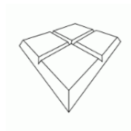
	Sentence
41	Hij las het woord **borst** verkeerd, omdat hij zijn lenzen niet in had
42	Hij had nog nooit van z'n leven een **cent** uit de negentiende eeuw gezien
43	Toen ze het gebouw in keek, zag ze de **damp** die uit de keuken kwam
44	Aandachtig bekeken ze de **dolk** die in het museum hing
45	Ze was op zoek naar een **draad** om mee te borduren
46	De voor- en de achterkant van het **fort** zijn de afgelopen jaren volledig gerestaureerd
47	Met grote letters schreef de leraar het woord **fruit** op het schoolbord, zodat iedereen het goed kon zien
48	Ze bekeek eerst de **gids** toen ze op zoek was naar een leuke film
49	Hij realiseerde zich dat een **golf** zijn hele zandkasteel zou kunnen wegspoelen
50	Ze vroeg of ik nog een ander woord voor **graan** kende misschien
51	De nieuwe buren praten nog steeds over de **haard** van hun dromen
52	Toen ze zich omdraaide, zag ze de **hond** op het vloerkleed liggen
53	Ze kwam er achter dat de **honing** bijna op was en bestelde een nieuwe voorraad
54	Uiteindelijk bleek dat de **kabel** van zijn beeldscherm kwijt was
55	Vol enthousiasme beschreef hij de **kamer** die hij geschilderd had
56	Aan de onderkant van de **kluit** zaten tientallen pissebedden verstopt
57	Mijn vriendin is erg blij met de **kruik** die ze van haar moeder heeft gekregen
58	Gisteren zag iedereen de **laars** die ik in de steeg naast de bakker had gevonden
59	Als ik jou was, zou ik een **laken** van puur katoen kopen
60	Telkens weer wist het plaatje van de **lans** zijn aandacht te trekken
61	De tekening van een **mand** met fruit was erg goed gelukt
62	Hij merkte op dat de **massa** mensen in de winkelstraat erg luidruchtig was
63	Ik was verbaasd dat de **mast** zo lang bleek te zijn
64	Ze vertelden een lang verhaal over een **paard** dat weggelopen was
65	Toen ik beter keek, zag ik een **park** in de verte verschijnen
66	Hij was al begonnen om een **perk** vol bloemen aan te leggen naast de nieuwe oprit
67	Ik hoop dat ik ergens een **plank** kan vinden om mijn knutselwerk af te maken
68	Hij dacht direct aan een **riool** toen zijn leraar over ratten begon te praten
69	Het jongetje dacht niet dat hij de **slag** snel te pakken zou krijgen, maar hij bleef stug doorzwemmen
70	Ze wilde niet dat haar **speen** afgepakt werd, dus ze begon hard te krijsen
71	Ik had niet door dat er geen **suiker** meer in huis was toen ik koekjes wilde bakken
72	Hij was erg blij dat de **toets** nog een paar weken uitgesteld werd
73	Hij zocht een ander woord voor **varen,** maar hij kon niks bedenken
74	Tegen het einde van de middag was het **veld** eindelijk beschikbaar voor de voetballers
75	Ik zag laatst een **vest** op straat liggen dat iemand verloren had
76	Van dichtbij zagen ze dat het **vlot** toch niet zo stevig was als ze hadden gedacht
77	Het jongetje koos een **wafel** in plaats van een pannenkoek
78	Ik won het spelletje door het woord **wraak** in het midden van het speelbord te leggen
79	Het meisje hoopte dat er geen **zand** meer in de groente zat
80	Ze bestudeerde de **zegel** die op de envelop geplakt zat

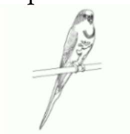
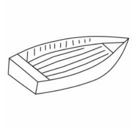
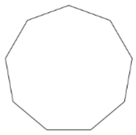
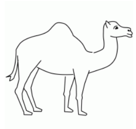
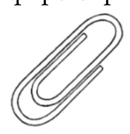
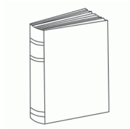
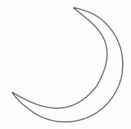
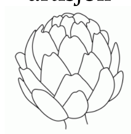
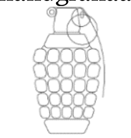
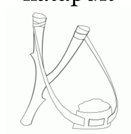
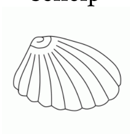
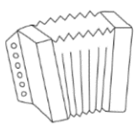
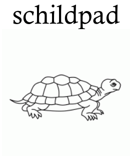
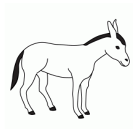
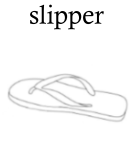
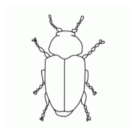
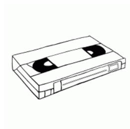
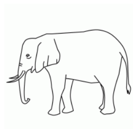
Table G-3. Filler sentences from Experiment 4-1a. Target words are marked in bold.

	Sentence
81	Na enige aarzeling pakte ze de **aardappel** en besloot ze dan maar puree te maken
82	Midden op de vloer lag een **asperge** die al bijna verrot was
83	Met verbazing vertelde ze over de **boom** die omgewaaid was door de harde wind
84	Voorzichtig verplaatste hij de **cake** naar de andere kant van het aanrecht
85	Ze kochten toch maar geen **champagne,** omdat die duurder dan gepland was
86	Uiteindelijk besloot ze de **citroen** te gebruiken om de saus meer smaak te geven
87	Hij moest hard lachen om de **cowboy** die hij over straat zag lopen
88	Tijdens het spelletje tekende hij een **deegroller** en het werd meteen geraden
89	ze praatte aan een stuk door over de **eekhoorn** die in haar achtertuin zat
90	De spreekbeurt van mijn nichtje ging over de **egel** die ze vorige week in de tuin gezien had
91	Ze hoopte dat er op het **eiland** goede medische voorzieningen zouden zijn
92	Ineens schoot haar te binnen dat ze geen **emmer** meer onder het lek in de douche had gezet
93	Je zag niet aan haar dat ze de **fluitketel** met heet water eigenlijk een beetje eng vond
94	We moesten lang zoeken naar de **gieter** voordat we hem eindelijk vonden
95	Mijn buurmeisje toonde haar vader de **glijbaan** en vroeg of hij mee ging spelen
96	Ik heb er schoon genoeg van dat de **haan** van de buren me zo vroeg wakker maakt elke ochtend
97	Na veel overleg besloten ze om een **haas** te bestellen bij de slager om de hoek
98	In het tijdschrift stond een foto van een **harnas** uit de vroege Middeleeuwen
99	Mijn collega's waren aan het praten over het **hoefijzer** dat ze op het strand gevonden hadden
100	Hij was verdrietig omdat hij het **horloge** van zijn opa verloren had
101	Aan de muur hing een foto van een **kanon** met een klein kindje er boven op
102	Na een paar uur zagen we het **kasteel** aan de horizon verschijnen
103	In een doos vond ze een **kleed** dat ze kon gebruiken voor haar toneelstuk
104	Hij maakte zich zorgen om zijn **koffer**, omdat er breekbare spullen in zaten
105	Uiteindelijk kocht de vrouw het **konijn** om het aan haar kleinkind te geven
106	Ze vertelde geestdriftig over de **ooievaar** die uit de dierentuin ontsnapt was
107	Ze toonde haar man de **paddestoel,** waarna hij van schrik een gil gaf
108	Ze beweerden dat ze een **papegaai** hadden zien vliegen in de duinen
109	Het meisje probeerde om de **pauw** van dichterbij te bekijken, maar ze was te laat
110	Eén van de buren wilde graag een **picknick** voor de hele straat organiseren
111	Ik had het woord **pleister** helemaal onderaan op mijn lijstje staan
112	Toen het meisje de **pop** in de etalage zag liggen, was ze meteen verkocht
113	Op straat volgden we een gesprek over de **robot** die de buren hadden gezien
114	Toen ze de schuur in keek, zag ze een **schroef** op de werkbank liggen
115	We gingen weg maar vergaten de **sleutel** van het vakantiehuisje terug te geven
116	Vanuit de verte zagen ze de **ster** nog even oplichten en toen verdween hij uit het zicht
117	De man kocht uiteindelijk geen **tuba** maar een drumstel voor zijn zoon
118	Iemand vroeg me of ik de **vaas** al aan de buren teruggegeven had
119	Een paar maanden geleden is de **vijver** om de hoek door vrijwilligers schoongemaakt
120	Ze vroeg haar collega of hij de **vlinder** die langs vloog ook zo mooi vond

Table G-4. Pictures from the onset-competitor condition of Experiment 4-1a. Sentence numbers correspond to those listed in Table G-1.

Sentence	Critical word	Competitor	Distractor	Distractor	Distractor
1	agenda	agent 	rasp 	auto 	zuil 
2	bacterie	baksteen 	doolhof 	hobbelpaard 	flamingo 
3	blikopener	bliksem 	achtbaan 	schilderij 	toren 
4	bloed	bloem 	trapje 	vliegtuig 	plakband 
5	circus	cirkel 	palmboom 	baby 	bloes 
6	diabolo	diamant 	priester 	sigaret 	banaan 
7	dobber	dobbelsteen 	asbak 	vingerafdruk 	kraag 
8	duiventil	duivel 	fotomodel 	ballon 	voet 
9	hagelslag	hagedis 	bloempot 	ratel 	fakkel 
10	held	helm 	microscoop 	pinguin 	ark 

Sentence	Critical word	Competitor	Distractor	Distractor	Distractor
11	kakkerlak	cactus 	megafoon 	tram 	cello 
12	kers	kerstboom 	spiegel 	ijsbeer 	trommel 
13	klok	klomp 	pan 	aap 	typemachine 
14	kompas	computer 	racket 	bad 	peddel 
15	krans	krant 	gehaktmolen 	strijkplank 	vingerhoed 
16	krokus	krokodil 	loep 	vinger 	anker 
17	kruisbes	kruisboog 	pakje 	ventilator 	inktvis 
18	lepra	lepel 	zeilboot 	vrachtschip 	tovenaar 
19	matras	matroos 	kraal 	vuurpijl 	gordijn 
20	paraplu	parachute 	bever 	hoorn 	chocolade 

Sentence	Critical word	Competitor	Distractor	Distractor	Distractor
21	parkeermeter	parkiet 	wol 	boot 	taco 
22	paspoort	paspop 	gewei 	achthoek 	dromedaris 
23	pepernoot	paperclip 	zebra 	boek 	maan 
24	pyjama	piano 	artisjok 	tijger 	handgranaat 
25	rolschaats	rolstoel 	katapult 	muts 	schep 
26	scheldwoord	schelp 	accordeon 	karaf 	pistool 
27	schilder	schildpad 	pet 	wekker 	boterham 
28	schoolplein	schoorsteen 	vrachtauto 	aansteker 	ezel 
29	slipcursus	slipper 	tooi 	kever 	bladmuziek 
30	stacaravan	stapelbed 	vuilnisbak 	videoband 	olifant 

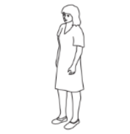
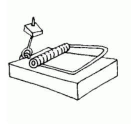
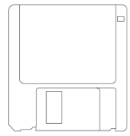
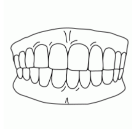
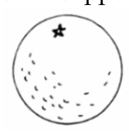
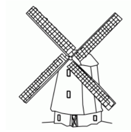
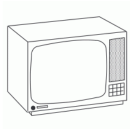
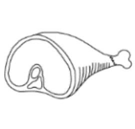
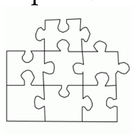
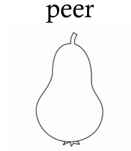
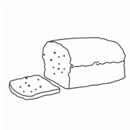
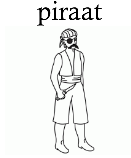
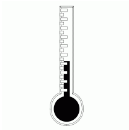
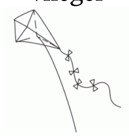
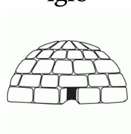
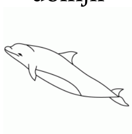
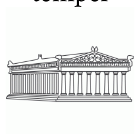
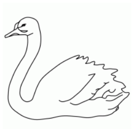
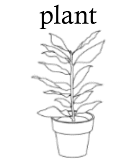
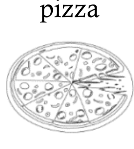
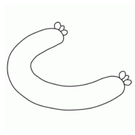
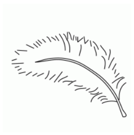
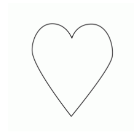
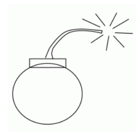
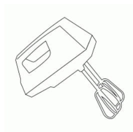
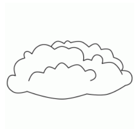
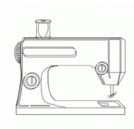
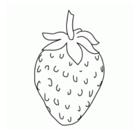
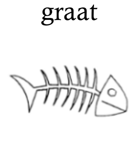
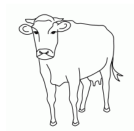
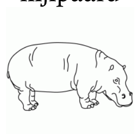
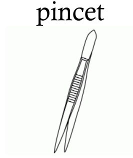
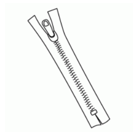
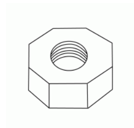
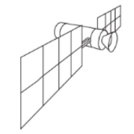
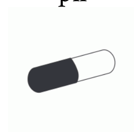
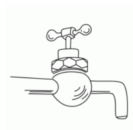
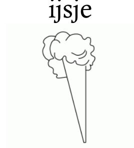
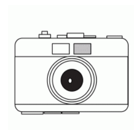
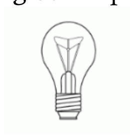
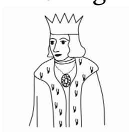
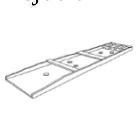
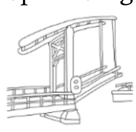
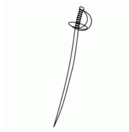
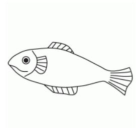
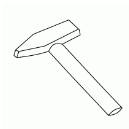
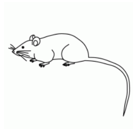
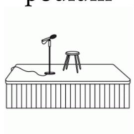
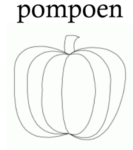
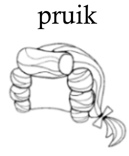
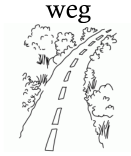
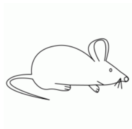
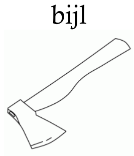
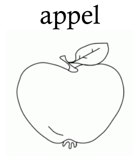
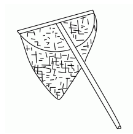
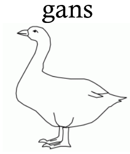
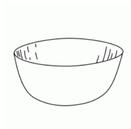
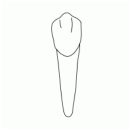
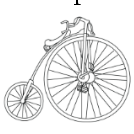
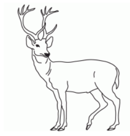
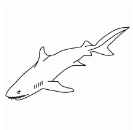
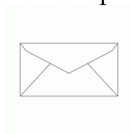
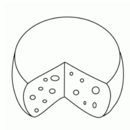
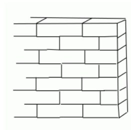
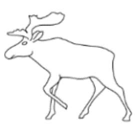
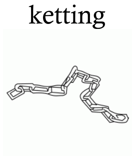
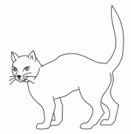
Sentence	Critical word	Competitor	Distractor	Distractor	Distractor
31	steiger	stijgbeugel 	regen 	vrouw 	muizenval 
32	stemvork	stempel 	gasbrander 	diskette 	garde 
33	strippenkaart	strik 	mes 	gebit 	houweel 
34	synagoge	sinaasappel 	kies 	trechter 	molen 
35	telefoon	televisie 	ham 	puzzel 	peer 
36	telefooncel	telescoop 	dokter 	brood 	piraat 
37	thermoskan	thermometer 	bel 	soldaat 	hamster 
38	vliegenmepper	vlieger 	tuinslang 	kluis 	huifkar 
39	vorm	vork 	iglo 	dolfijn 	tempel 
40	zwaard	zwaan 	hoed 	plant 	pizza 

Table G-5. Pictures from the rhyme-competitor condition of Experiment 4-1a Sentence numbers correspond to those listed inTable G-2.

Sentence	Critical word	Competitor	Distractor	Distractor	Distractor
41	borst	worst 	veer 	arend 	tas 
42	cent	tent 	dubbeldekker 	hart 	oester 
43	damp	lamp 	roos 	bom 	mixer 
44	dolk	wolk 	naaimachine 	wasknijper 	aardbei 
45	draad	graat 	koe 	kampvuur 	kandelaar 
46	fort	bord 	nijlpaard 	standbeeld 	pincet 
47	fruit	bruid 	neus 	pijp 	rails 
48	gids	rits 	moer 	slak 	kooi 
49	golf	wolf 	satelliet 	pil 	beker 
50	graan	kraan 	ijsje 	fototoestel 	vogelhuisje 

Sentence	Critical word	Competitor	Distractor	Distractor	Distractor
51	haard	baard 	trompet 	jongen 	keu 
52	hond	mond 	boomstam 	gloeilamp 	fles 
53	honing	koning 	verrekijker 	sjoelbak 	ophaalbrug 
54	kabel	sabel 	vleugel 	eikel 	vis 
55	kamer	hamer 	meloen 	rat 	schoen 
56	kluit	fluit 	stethoscoop 	podium 	pompoen 
57	kruik	pruik 	weg 	stier 	fiets 
58	laars	kaars 	muis 	bijl 	appel 
59	laken	baken 	giraf 	oven 	net 
60	lans	gans 	kom 	verfroller 	kleerhanger 

Sentence	Critical word	Competitor	Distractor	Distractor	Distractor
61	mand	tand 	velocipede 	hert 	blikje 
62	massa	kassa 	haai 	zaag 	wandelstok 
63	mast	kast 	portemonnee 	luier 	vleermuis 
64	paard	taart 	rugzak 	wastafel 	envelop 
65	park	hark 	gewichtheffer 	kaas 	muur 
66	perk	kerk 	steekwagen 	eland 	jager 
67	plank	bank 	ketting 	stofzuiger 	tornado 
68	riool	viool 	kat 	koorddanser 	locomotief 
69	slag	vlag 	knol 	mossel 	kam 
70	speen	teen 	jas 	grasmaaier 	ligstoel 

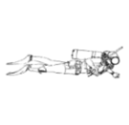
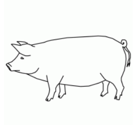
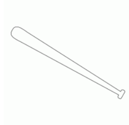
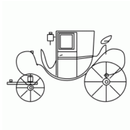
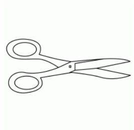
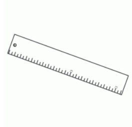
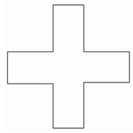
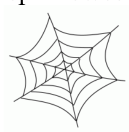
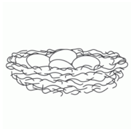
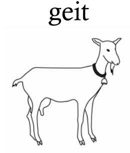
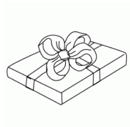
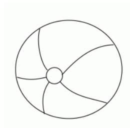
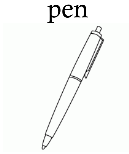
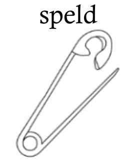
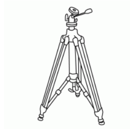
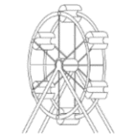
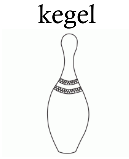
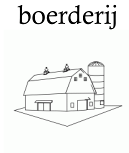
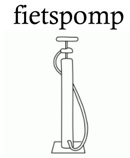
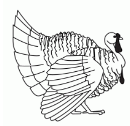
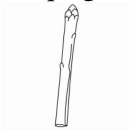
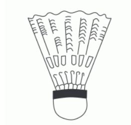
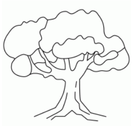
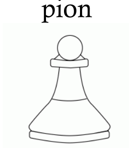
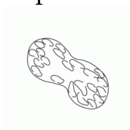
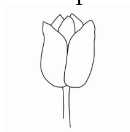
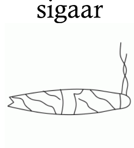
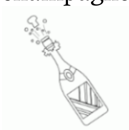
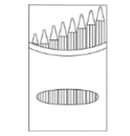
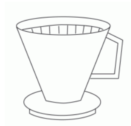
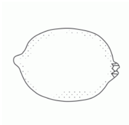
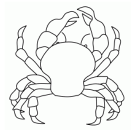
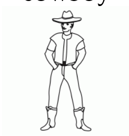
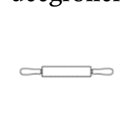
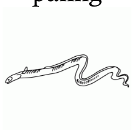
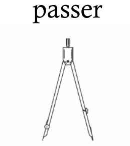
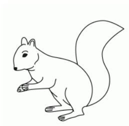
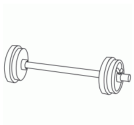
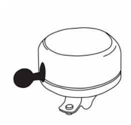
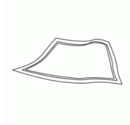
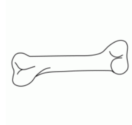
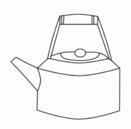
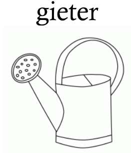
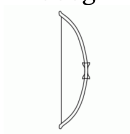
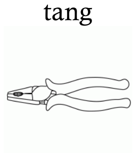
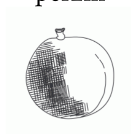
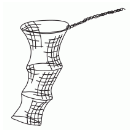
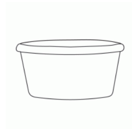
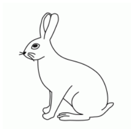
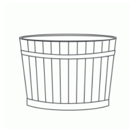
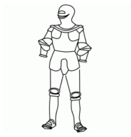
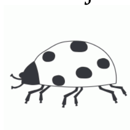
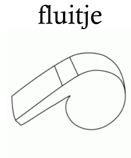
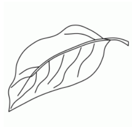
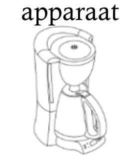
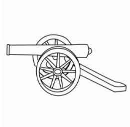
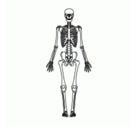
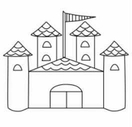
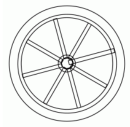
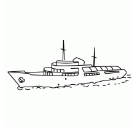
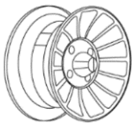
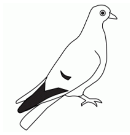
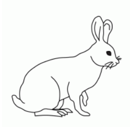
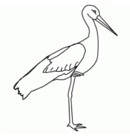
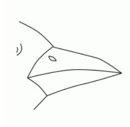
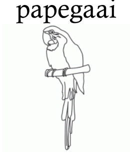
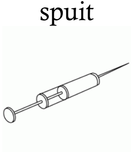
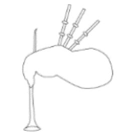
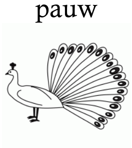
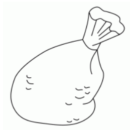
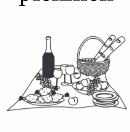
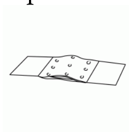
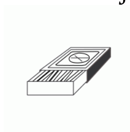
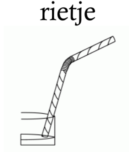
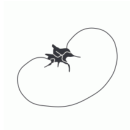
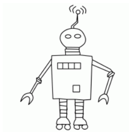
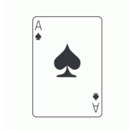
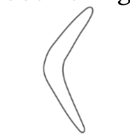
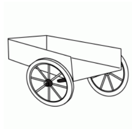
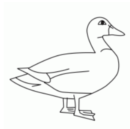
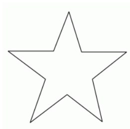
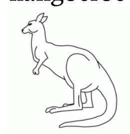
Sentence	Critical word	Competitor	Distractor	Distractor	Distractor
71	suiker	duiker 	bolderkar 	varken 	knuppel 
72	toets	koets 	boter 	schaar 	bij 
73	varen	garen 	aanrecht 	kopje 	liniaal 
74	veld	geld 	ei 	kruis 	spinneweb 
75	vest	nest 	orgel 	geit 	toilet 
76	vlot	slot 	geweer 	bureau 	kado 
77	wafel	tafel 	helikopter 	bal 	pen 
78	wraak	draak 	veiligheids- speld 	statief 	reuzenrad 
79	zand	hand 	toiletpapier 	beer 	grammofoon 
80	zegel	kegel 	boerderij 	fietspomp 	galg 

Table G-6. Filler pictures from Experiment 4-1a. Sentence numbers correspond to those listed in Table G-3.

Sentence	Target word	Target	Distractor	Distractor	Distractor
81	aardappel	aardappel 	rok 	kalkoen 	tak 
82	asperge	asperge 	gitaar 	boeddha 	shuttle 
83	boom	boom 	pion 	pinda 	hooivork 
84	cake	cake 	venkel 	tulp 	sigaar 
85	champagne	champagne 	kwast 	kleurdoos 	koffiefilter 
86	citroen	citroen 	tuinstoel 	karateka 	krab 
87	cowboy	cowboy 	fruitschaal 	bus 	fontein 
88	deegroller	deegroller 	paling 	passer 	kruiwagen 
89	eekhoorn	eekhoorn 	mond-harmonica 	halter 	fietsbel 
90	egel	egel 	sproeier 	brommer 	bureaustoel 

Sentence	Target word	Target	Distractor	Distractor	Distractor
91	eiland	eiland 	doek 	meetlint 	bot 
92	emmer	emmer 	sinterklaas 	moeder 	hulst 
93	fluitketel	fluitketel 	naald 	hijskraan 	engel 
94	gieter	gieter 	boog 	knots 	step 
95	glijbaan	glijbaan 	tang 	mug 	perzik 
96	haan	haan 	fuik 	bak 	waaier 
97	haas	haas 	tobbe 	eierdoos 	boekenkast 
98	harnas	harnas 	lieveheers-beestje 	rietpluim 	flipper 
99	hoefijzer	hoefijzer 	infuus 	wijnglas 	fluitje 
100	horloge	horloge 	blad 	koffiezet-apparaat 	wapen 

Sentence	Target word	Target	Distractor	Distractor	Distractor
101	kanon	kanon 	donut 	hooiberg 	skelet 
102	kasteel	kasteel 	wiel 	t-shirt 	schip 
103	kleed	kleed 	bidon 	velg 	driewieler 
104	koffer	koffer 	tol 	duif 	zeeppompje 
105	konijn	konijn 	huis 	penseel 	pennenblik 
106	ooievaar	ooievaar 	mijter 	sla 	kapstok 
107	paddestoel	paddestoel 	hengel 	snavel 	druiven 
108	papegaai	papegaai 	spuit 	doedelzak 	tube 
109	pauw	pauw 	vijzel 	zak 	handdoek 
110	picknick	picknick 	kok 	voetbal 	deur 

Sentence	Target word	Target	Distractor	Distractor	Distractor
111	pleister	pleister 	kurketrekker 	luciferdoosje 	rietje 
112	pop	pop 	nier 	zonnebank 	kachel 
113	robot	robot 	mol 	kaart 	boemerang 
114	schroef	schroef 	kar 	gezin 	ton 
115	sleutel	sleutel 	eend 	komkommer 	friet 
116	ster	ster 	kangoeroe 	hyacint 	kabouter 
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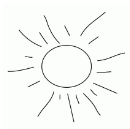
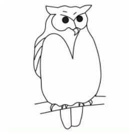
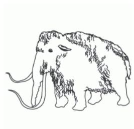
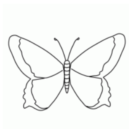
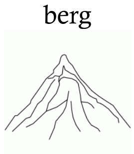
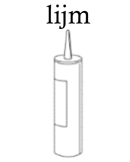
118	vaas	vaas 	slee 	zon 	uil 
119	vijver	vijver 	granaatappel 	mammoet 	sfinx 
120	vlinder	vlinder 	berg 	lijm 	kruk 

Appendix H

Picture naming task for Experiment 4-1

Participants

Thirty-seven native English-speaking undergraduate students (30 females and 7 males, age 18-56 years; $M = 24.1$, $SD = 9.3$) from Western Sydney University participated in this experiment in exchange for course credit for an introductory psychology course. Written informed consent was provided by each participant prior to the start of the experiment.

Stimulus materials

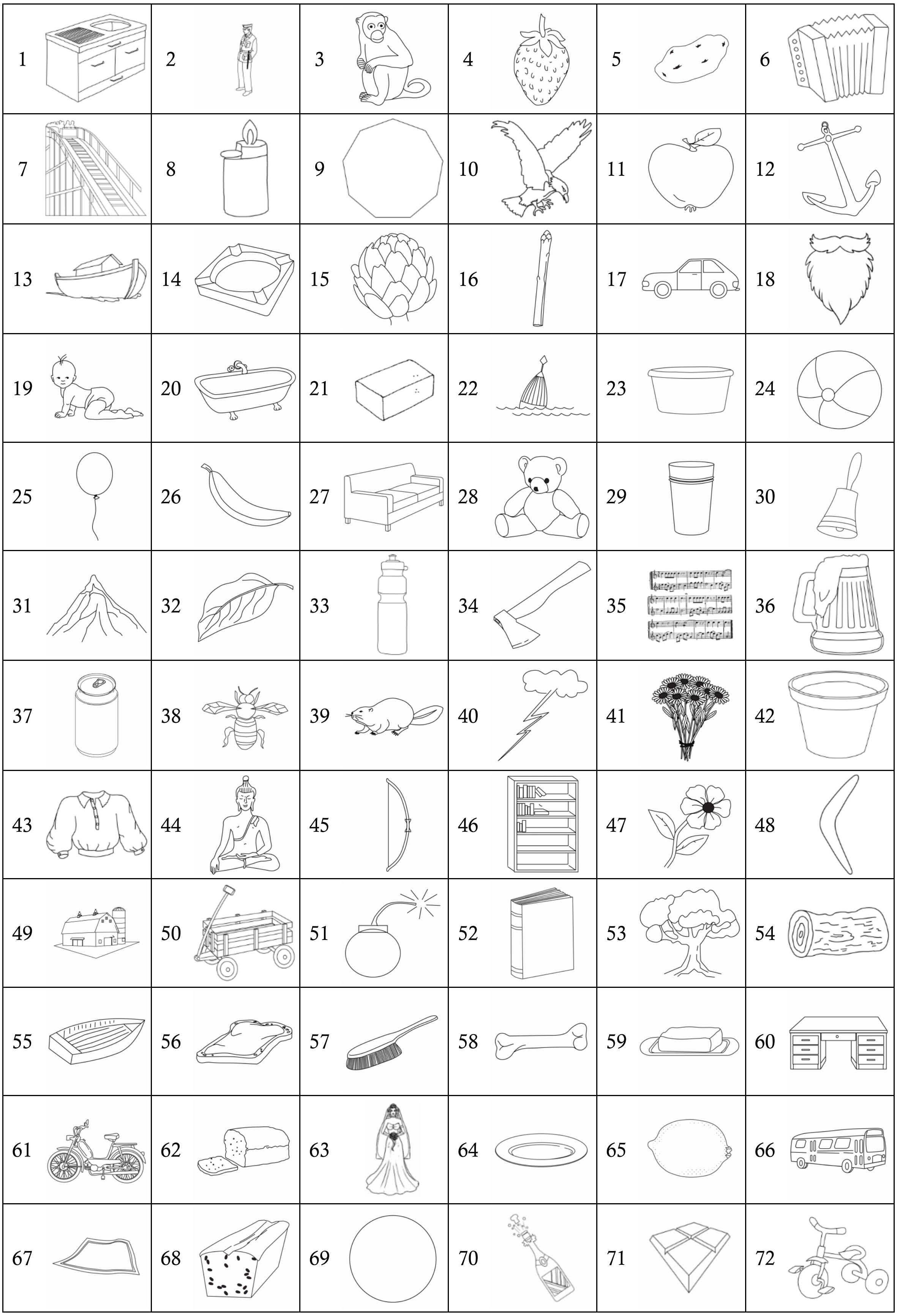
Stimuli consisted of the 960 black and white line drawings that were used in Experiment 4-1 (see Table H-1). All pictures were 210x210 pixels in size. The task of naming 960 pictures was expected to take around two hours, so two experimental lists of 480 pictures each were created to reduce the duration of the pre-test to one hour. Participants were randomly assigned to either of the two lists, so that all pictures were named by 18 or 19 people.

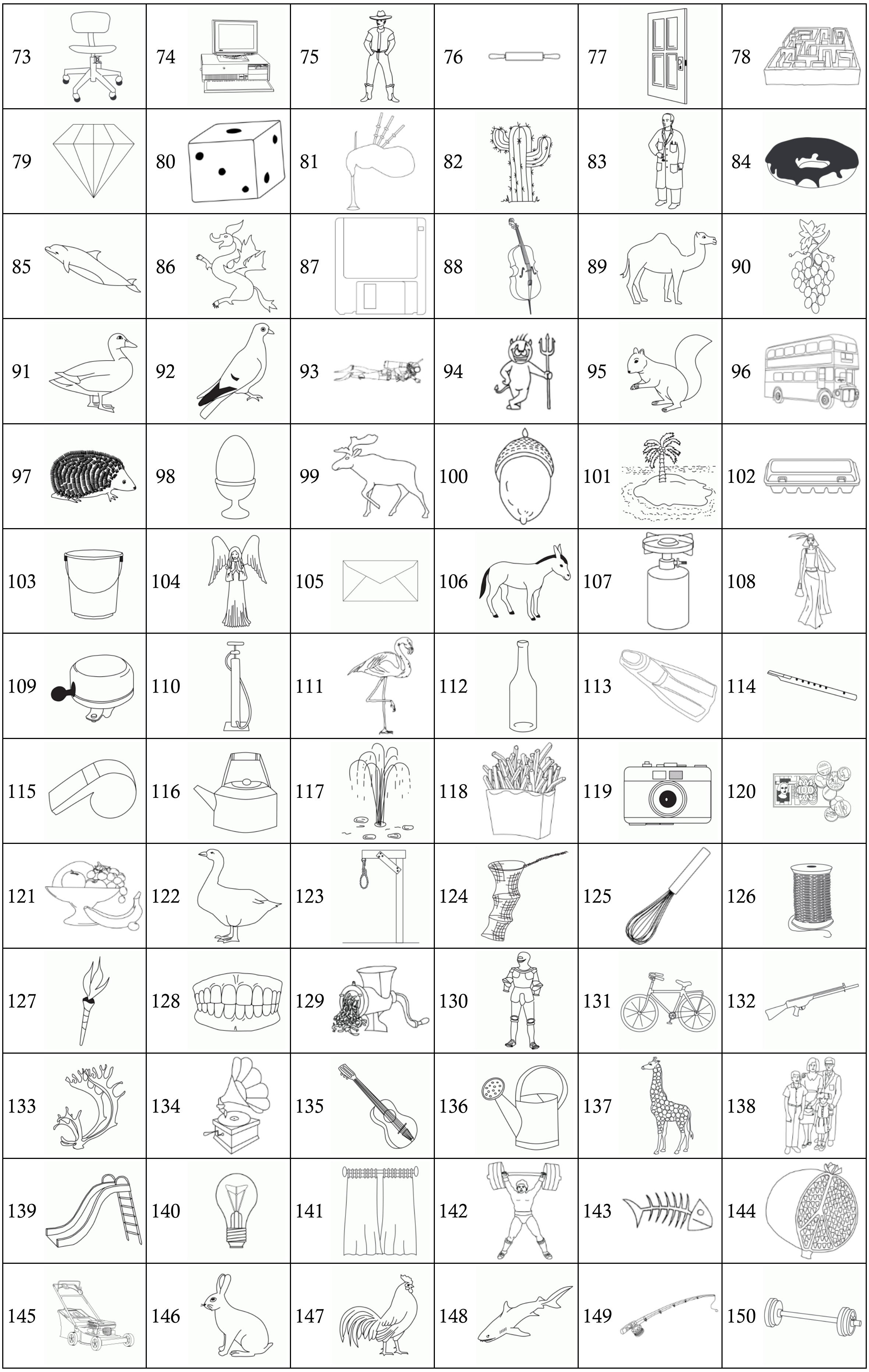
Procedure

Up to three participants were tested simultaneously in a quiet room. Each participant was presented with a picture on a computer screen and was instructed to name the picture using the keyboard. After a participant had entered their response the next picture would appear, until all 480 pictures had been named. The experiment lasted about one hour. Upon completion of the experiment, each participant filled out a short language background questionnaire.

Participants' responses are listed in Table H-2.

Table H-1. Pictures presented for naming in the picture naming task for Experiment 4-1. Picture numbers correspond to those listed in the table of responses (Table H-2).

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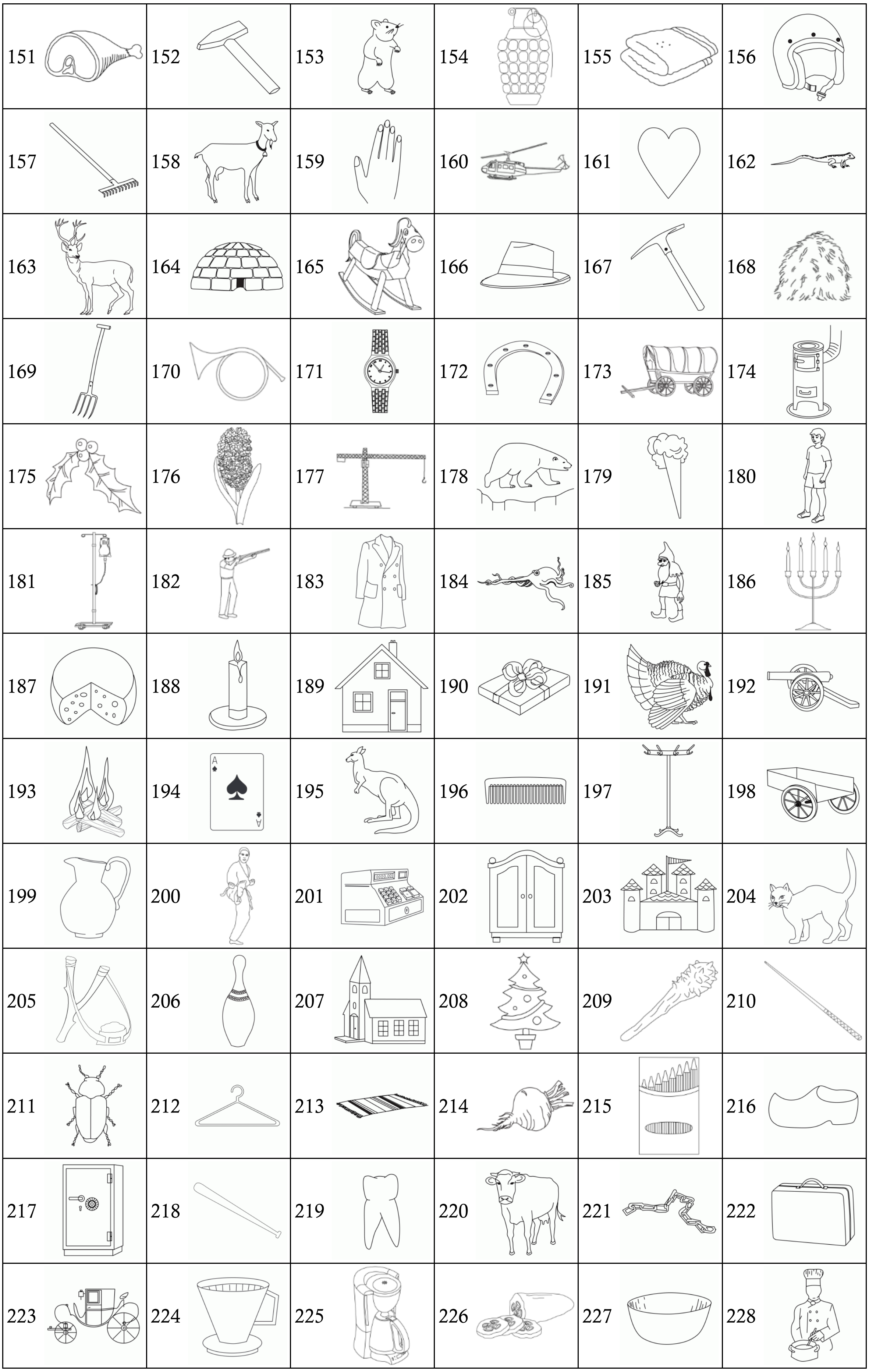
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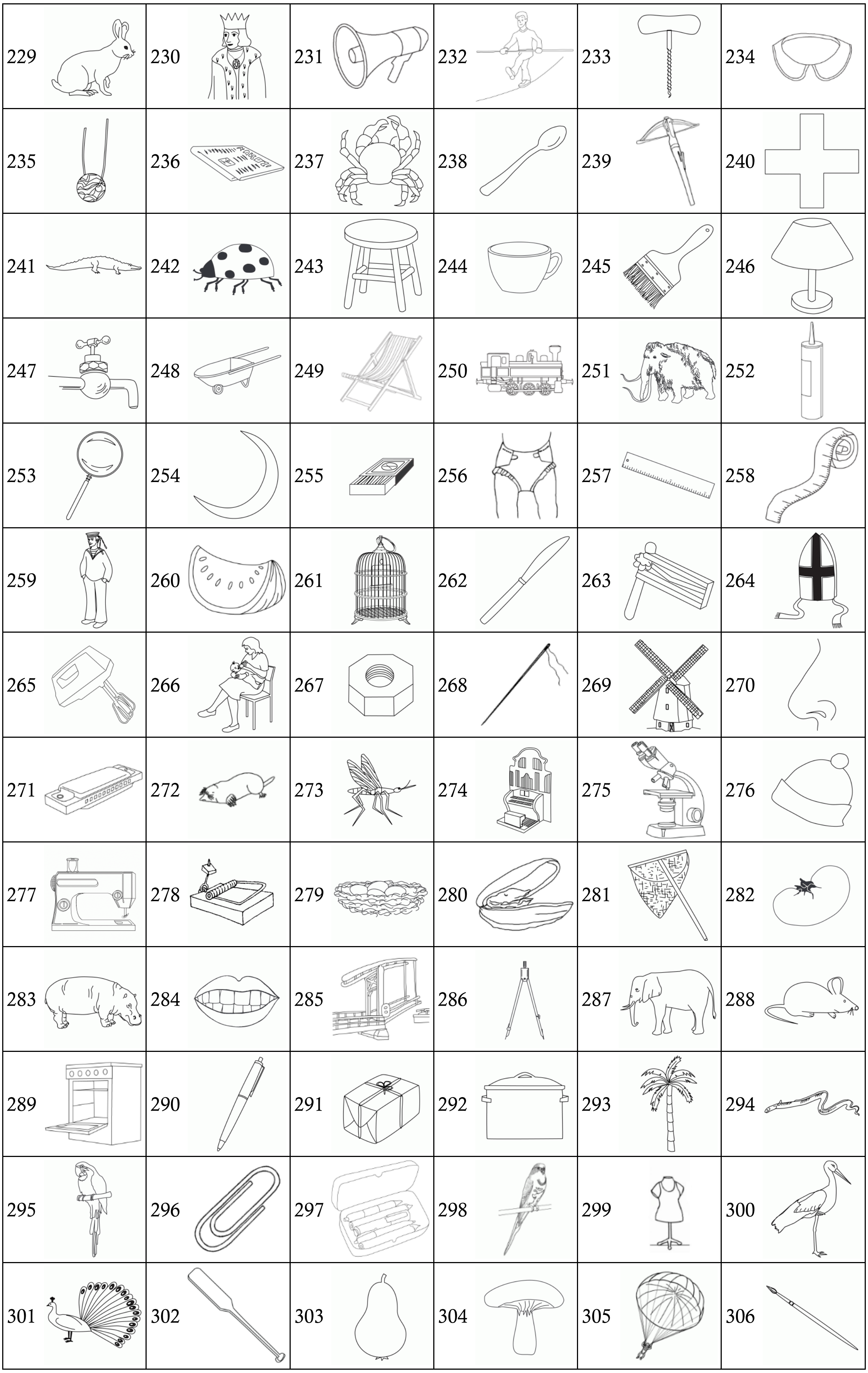
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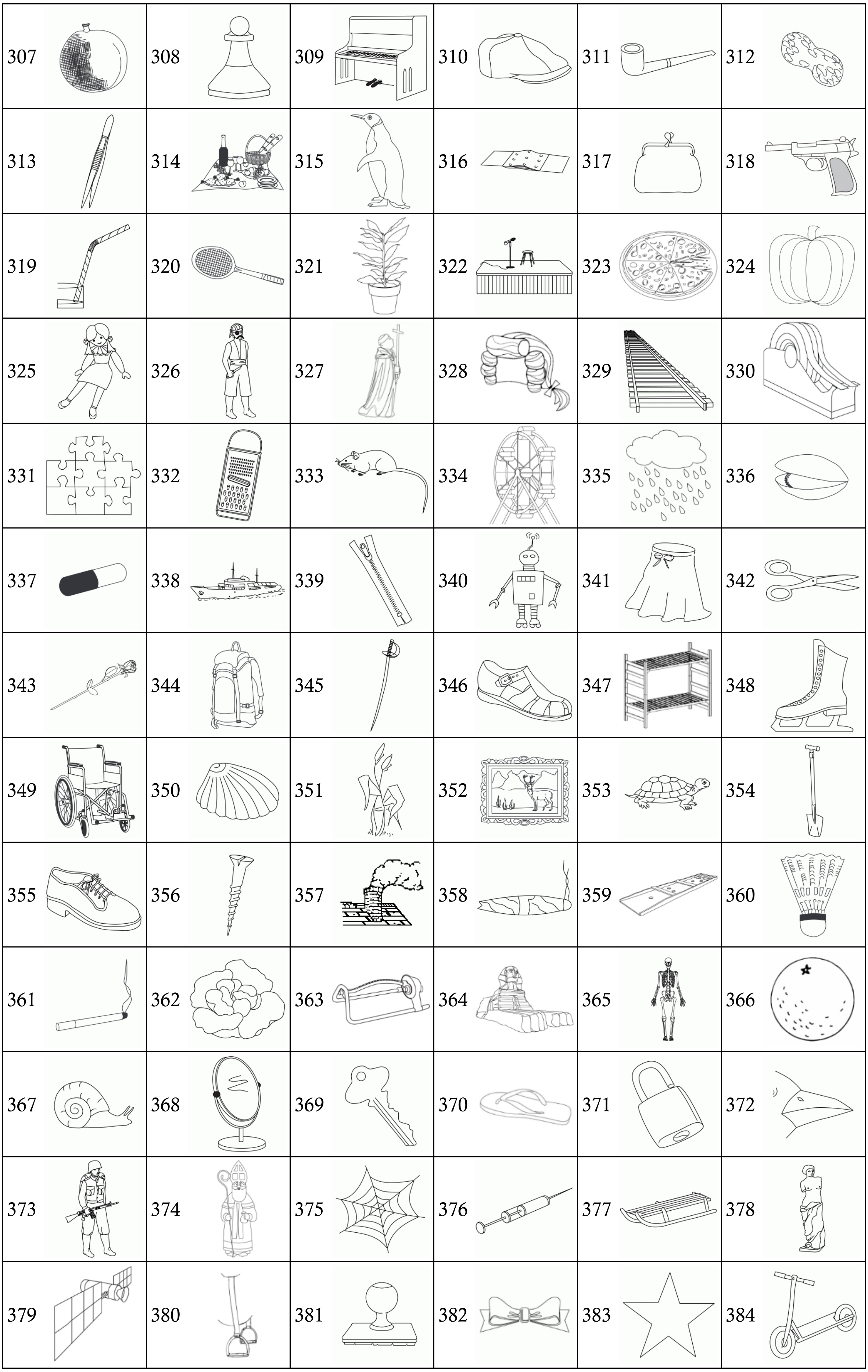

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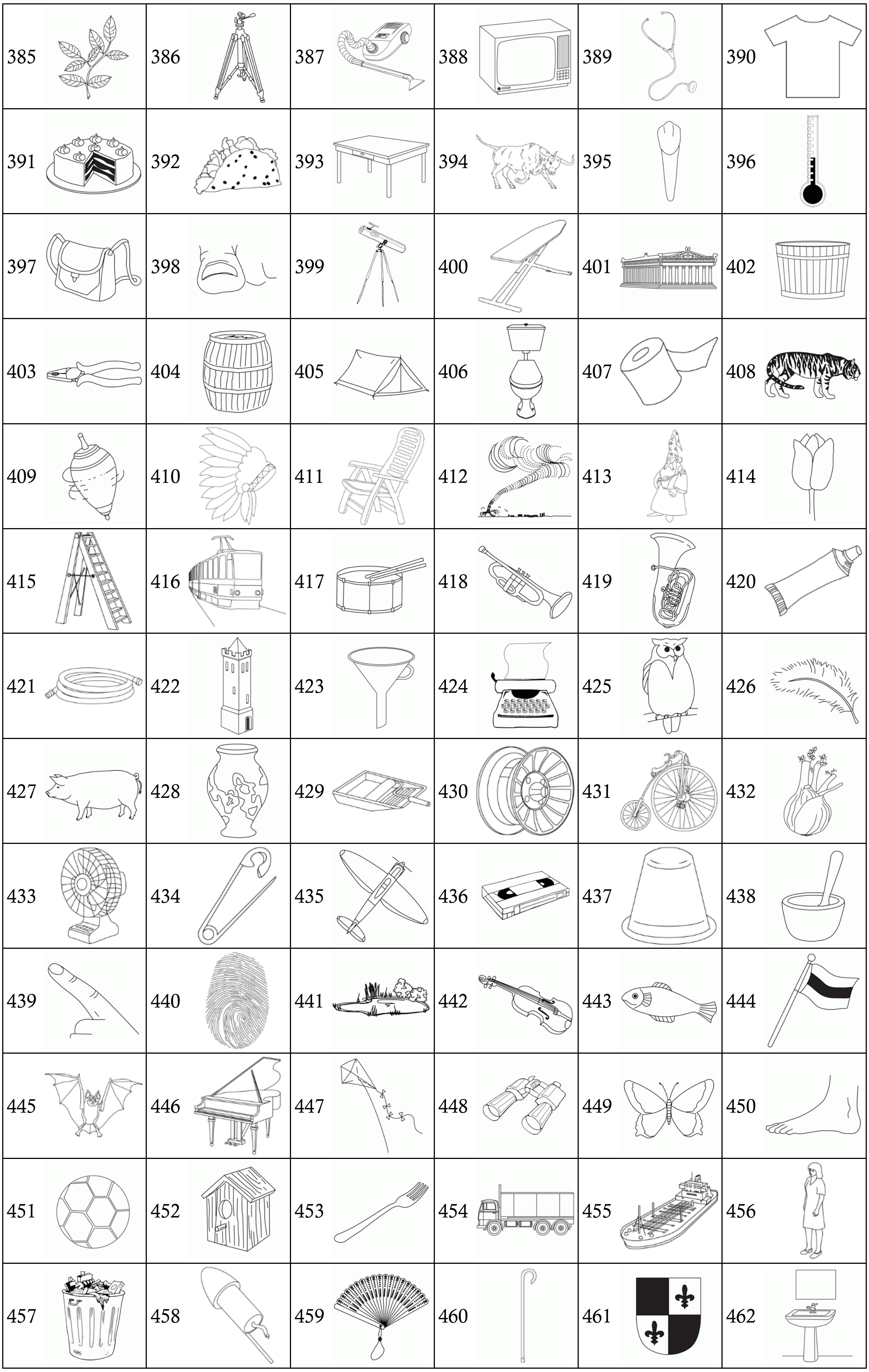
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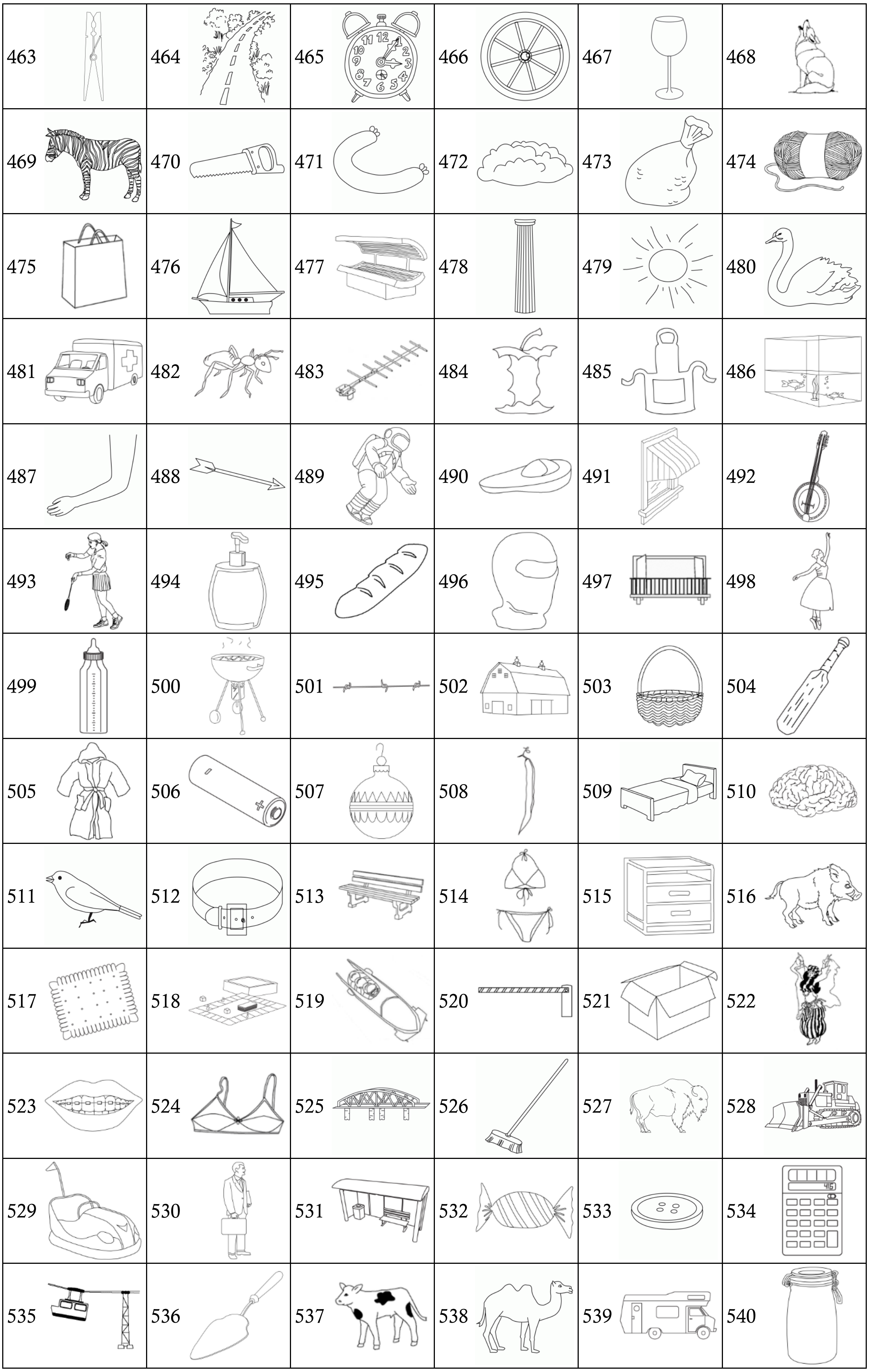

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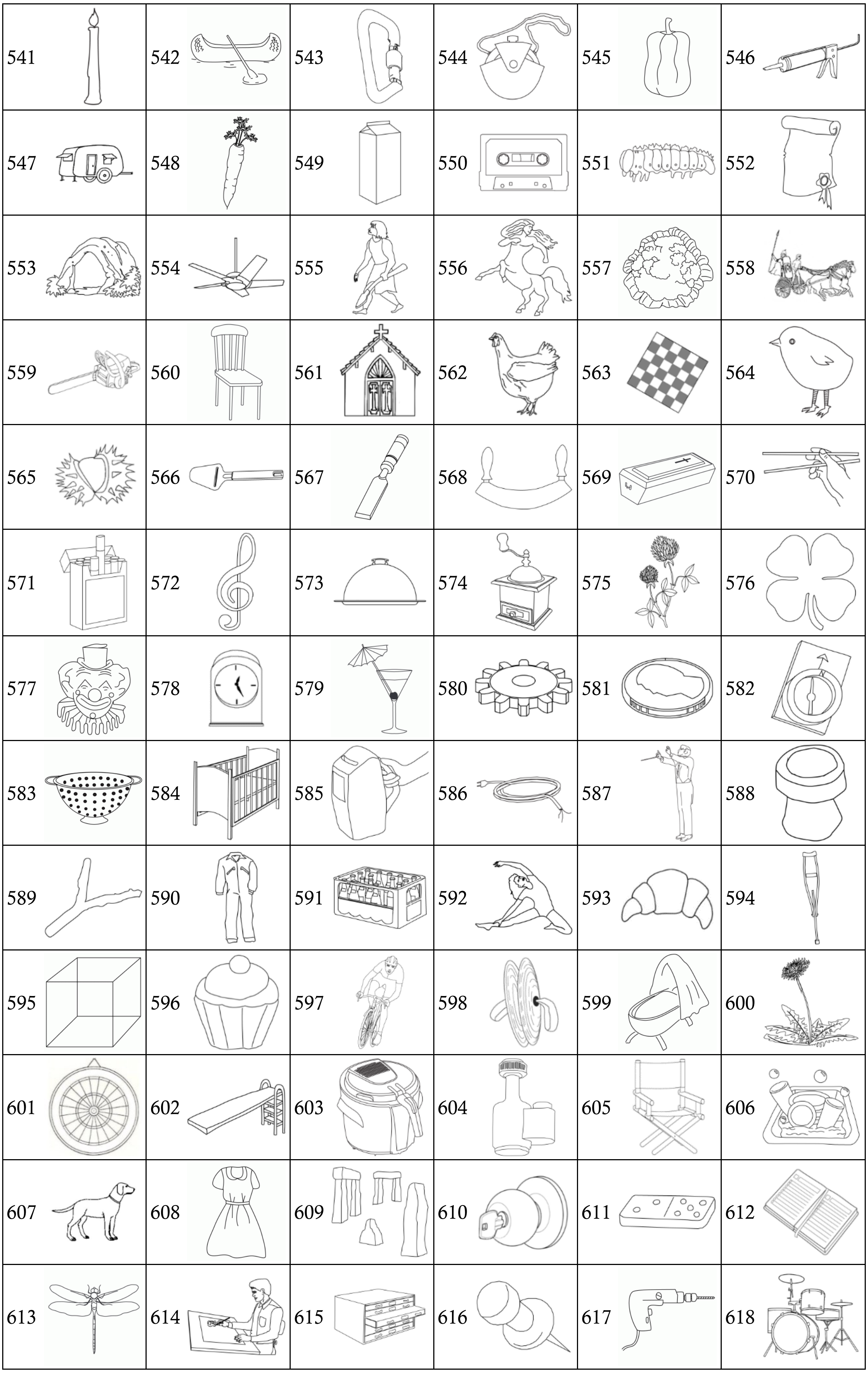
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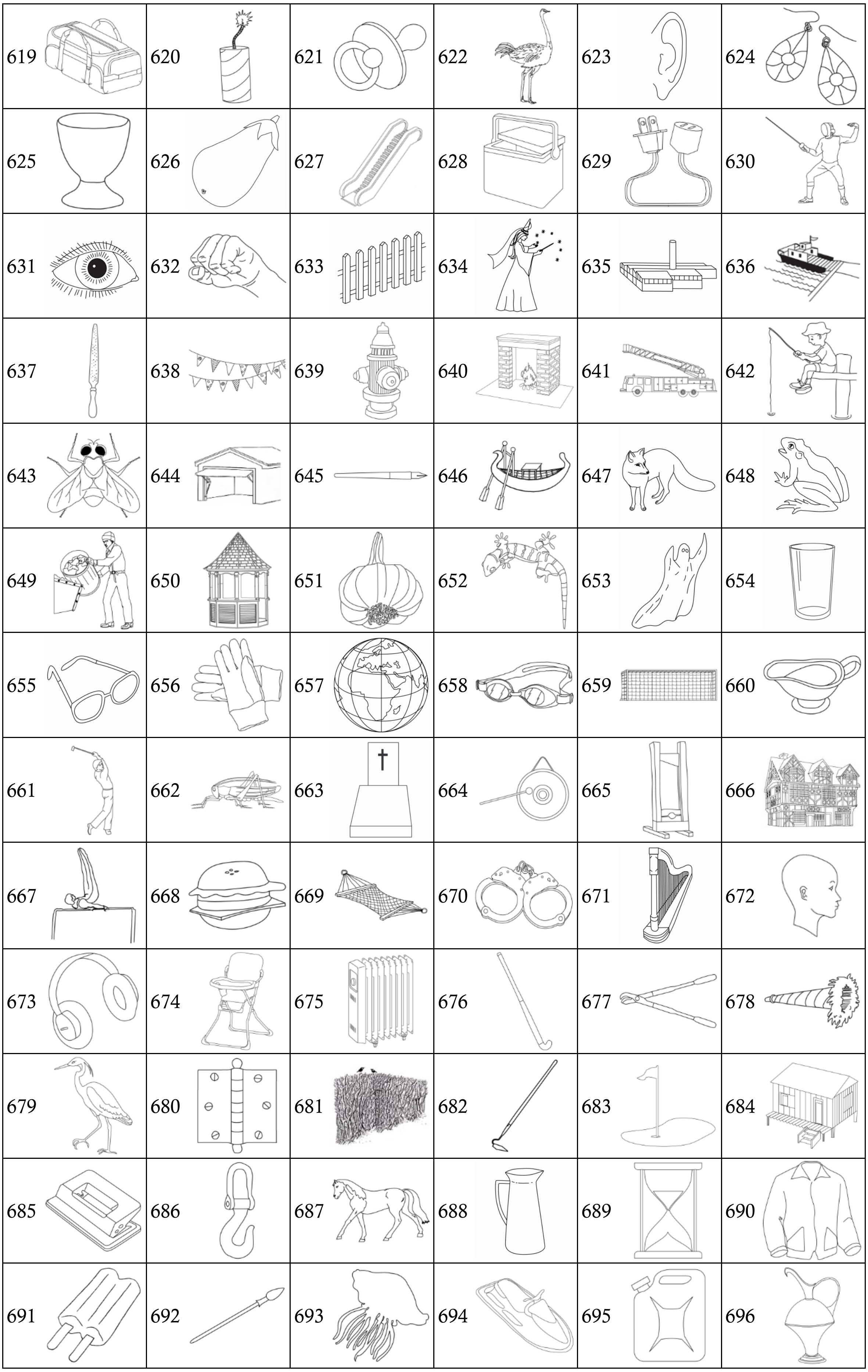
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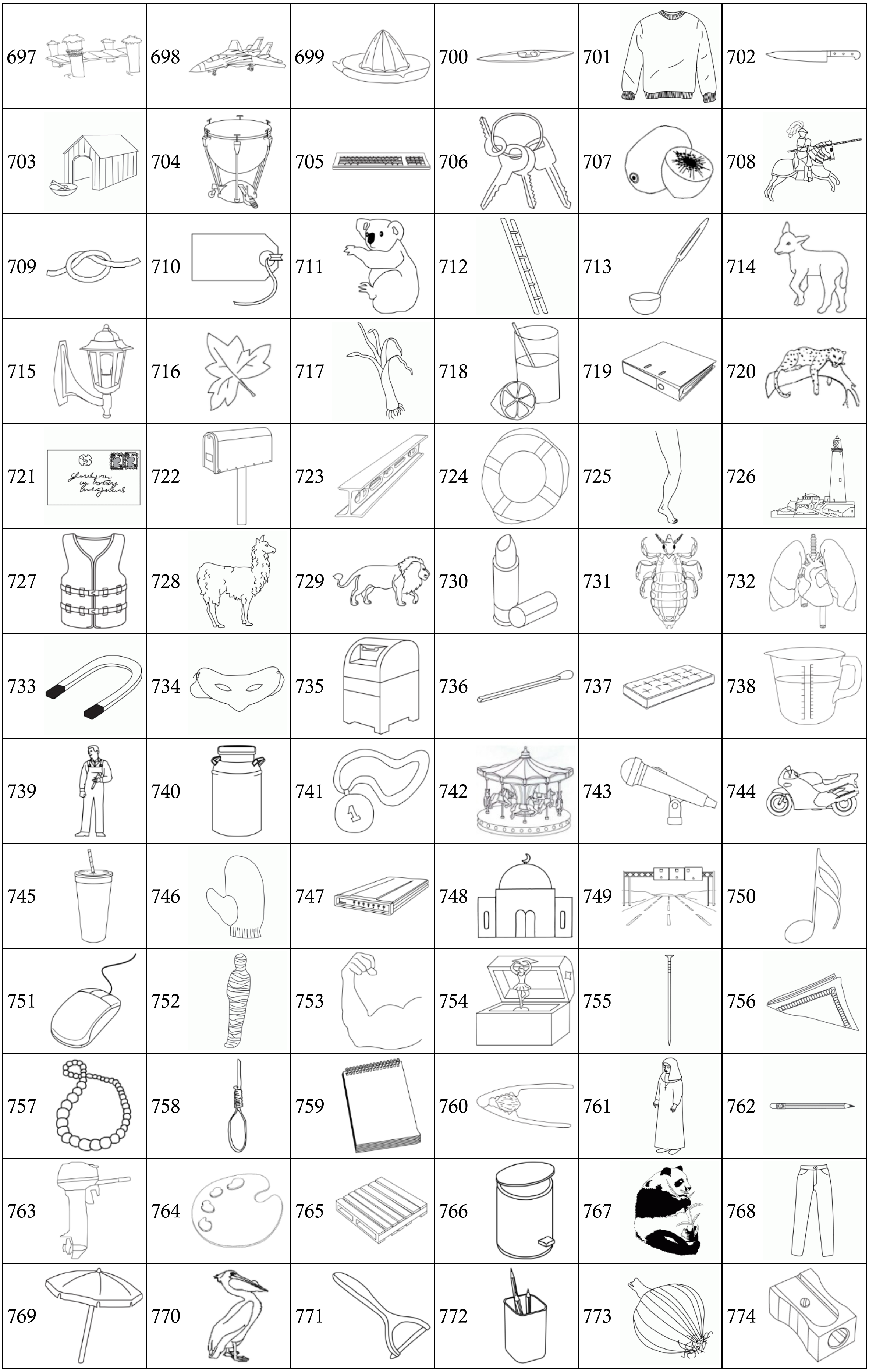
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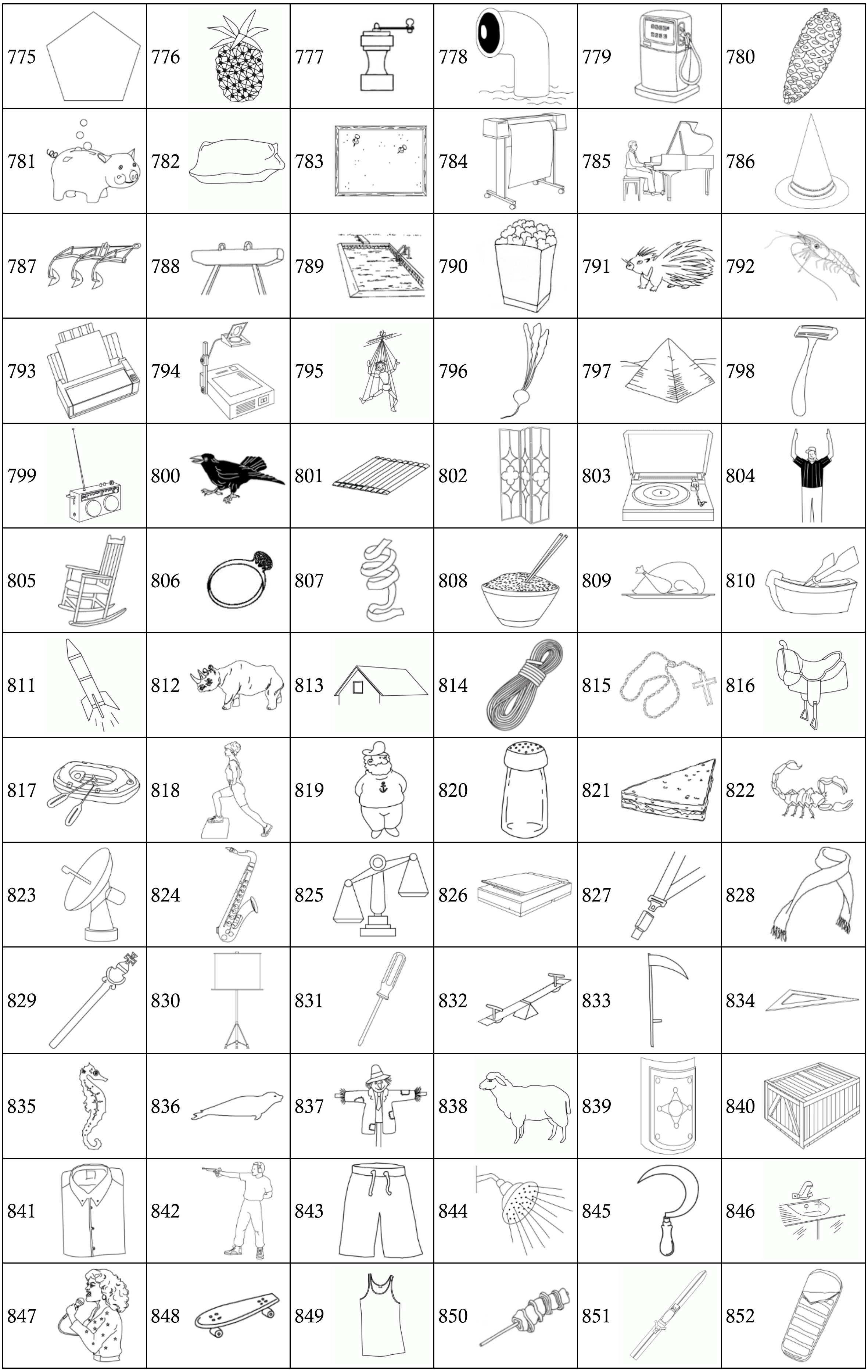
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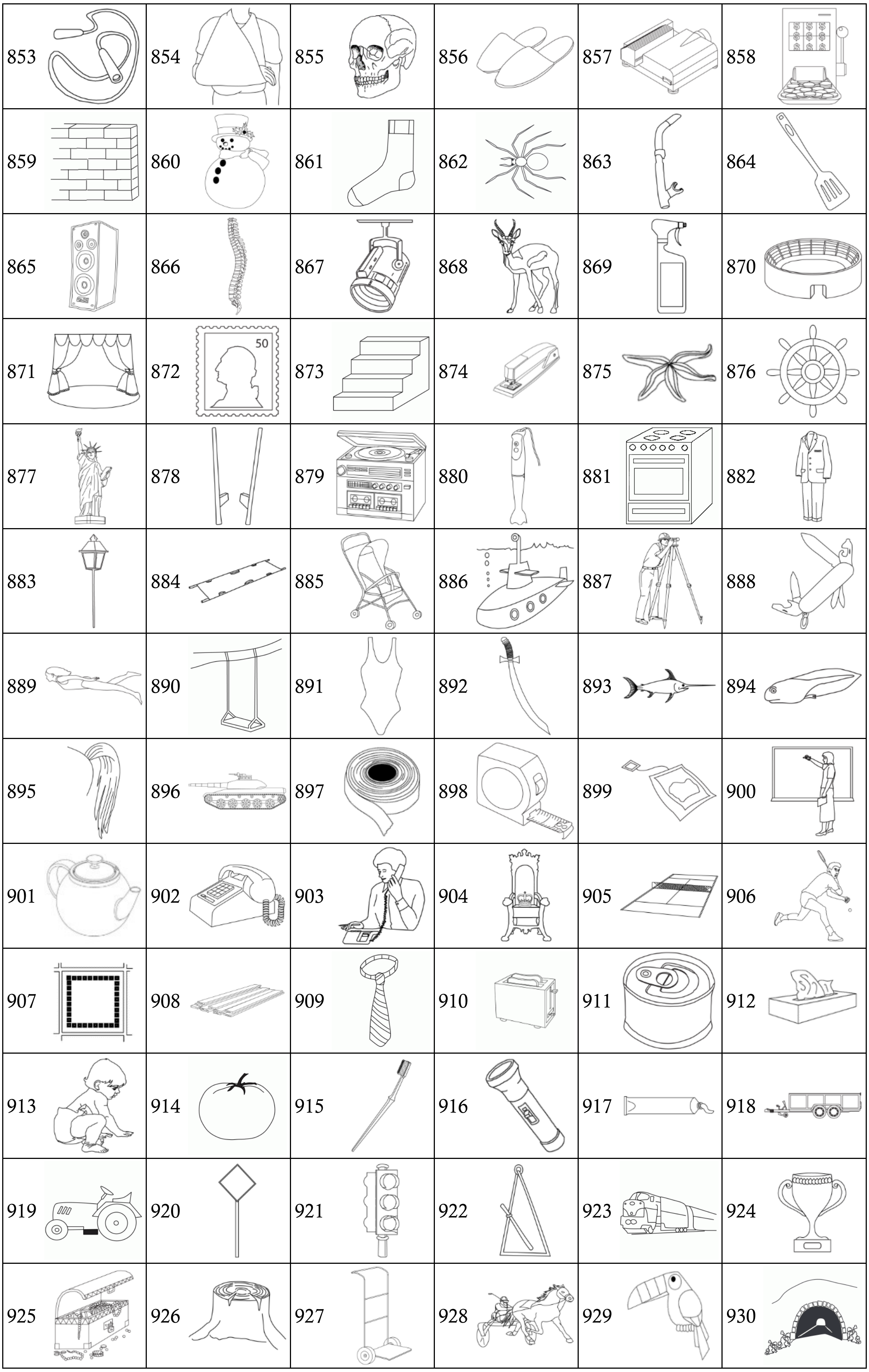

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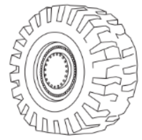
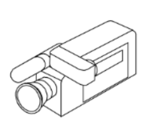
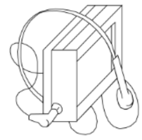
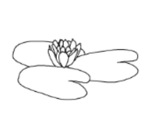
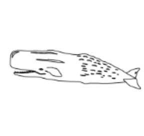
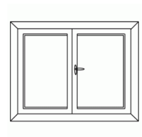
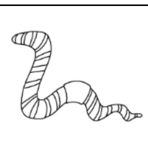
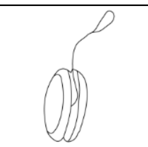
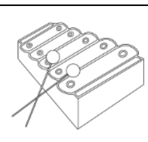
931 	932 	933 	934 	935 	936 
937 	938 	939 	940 	941 	942 
943 	944 	945 	946 	947 	948 
949 	950 	951 	952 	953 	954 
955 	956 	957 	958 	959 	960 

Table H-2. Responses to pictures presented in the picture naming task for Experiment 4-1.Picture numbers correspond to those listed in Table H-1.

Picture	Response (frequency)	Picture	Response (frequency)
1	basin (1) bathroom sink (1) bathroom vanity (1) kitchen bench (2) kitchen draws (1) kitchen sink (4) kitchen sink cabinet (1) sink (7)	2	[blank] (1) army officer (2) officer (3) police (2) policeman (4) police officer (5) soldier (1)
3	chimp (1) monkey (17)	4	[blank] (1) strawberry (17)
5	cookie (1) pond (1) potato (14) potatoes (1) shit (1)	6	[blank] (2) accordion (9) musical (1) musical instrument (5) music player (1)
7	circus ride (1) rollercoaster (17)	8	candle (1) lighter (17)
9	hexagon (5) nonagon (3) octagon (6) shape (3) sign (1)	10	bird (1) crow (1) eagle (14) hawk (1) sea eagle (1)
11	[blank] (1) apple (16) tomato (1)	12	[blank] (1) anchor (16) sinker (1)
13	ark (4) boat (12) noahs ark (2)	14	ashtray (15) cylinder (1) smoke tray (1) well (1)
15	artichoke (5) bud (1) bud of a flower (1) choko (1) flora (1) flower (5) gymea lily (1) plant (1) seed (1) waratah (1)	16	[blank] (1) artichoke stem (1) asparagus (6) asparagus (1) bark (1) branch (1) log (1) stick (5) twig (2)
17	car (16) small car (2)	18	beard (18)

Picture	Response (frequency)	Picture	Response (frequency)
19	baby (15) baby crawling (1) crawling baby (1) toddler (1)	20	bath (6) bathtub (11) tub (1)
21	[blank] (1) bar (1) block (2) brick (7) butter (1) cheese (1) eraser (1) rectangle (1) rubber (1) soap (1) cube of cheese (1)	22	boat (1) buoy (11) buoyant (1) floating beacon (1) floaty (1) floater (1) vessel (1) water (1)
23	bowl (11) bucket (4) plant pot (1) tub (2)	24	ball (7) basketball (1) beach ball (10)
25	balloon (18)	26	banana (18)
27	lounge (12) couch (4) sofa (2)	28	bear (6) teddy (1) teddy bear (11)
29	bear (6) teddy (1) teddy bear (11)	30	bell (17) hand bell (1)
31	mountain (18)	32	leaf (18)
33	[blank] (1) bottle (4) drink bottle (3) water bottle (10)	34	axe (15) axes (1) hammer (1) sledgehammer (1)
35	[blank] (1) musical notes (2) music (5) music notes (6) music sheets (1) reading music (1) scoresheet (1) sheet music (1)	36	beer (12) beer in a mug (1) beer mug (1) beer stein (1) mug (1) pint of beer (1) stein (1)
37	can (14) can of drink (1) drink can (1) ring pull can (1) soda can (1)	38	[blank] (1) bee (11) bug (2) fly (2) wasp (2)

Picture	Response (frequency)	Picture	Response (frequency)
39	[blank] (1) beaver (10) chipmunk (1) otter (1) rat (2) squirrel (3)	40	lightning bolt (2) lightning (11) lightning strike (1) storm (1) thunder (2) thundercloud (1)
41	bunch of daisies (1) bunch of flowers (4) flower (2) flowers (9) posy (1) sunflowers (1)	42	bucket (2) flowerpot (3) plant pot (1) pot (9) pot plant (3)
43	blouse (9) jacket (2) ladies blouse (1) long shirt (1) shirt (3) top (1) womans shirt (1)	44	[blank] (1) buddhist (2) buddha statue (1) buddha (6) hindu (1) man (1) meditation (1) meditator (2) religious statue (1) statue (1) yogi (1)
45	archery (1) arrow (1) bow (14) crossbow (2)	46	[blank] (1) bookcase (3) bookshelf (13) shelving (1)
47	flower (17) poppy (1)	48	[blank] (2) boomerang (16)
49	[blank] (1) barn (6) factory (4) farm (1) farmhouse (2) farm shed (1) house (1) mill (1) shed (1)	50	[blank] (1) carrier (1) cart (6) pull cart (1) pushcart (1) trailer (2) tray (1) wagon (2) wheelbarrow (1) wheel cart (1) wheelie box (1)
51	bomb (18)	52	book (18)
53	[blank] (1) large tree (1) tree (16)	54	log (15) wood (3)

Picture	Response (frequency)	Picture	Response (frequency)
55	boat (10) dingy (2) lifeboat (1) raft (1) rowboat (2) sailboat (1) tin boat (1)	56	[blank] (1) bread (3) bread slice (2) buttered bread (1) slice of toast (1) spread on a piece of bread (1) toast (8) toast with jam (1)
57	brush (15) hairbrush (2) scrubber (1)	58	bone (17) dog bone (1)
59	block of soap (1) butter (15) cheese (1) soap (1)	60	desk (15) drawers (1) table (1) work desk (1)
61	bike (4) motorcycle (2) motorbike (11) motor scooter (1)	62	bread (14) bread loaf (1) loaf of bread (2) slice of bread (1)
63	bride (17) wedding dress (1)	64	dinner plate (1) plate (17)
65	lemon (18)	66	bus (17) truck (1)
67	Aladdin's carpet (1) blanket (4) carpet (2) flying carpet (1) handkerchief (2) mat (3) napkin (1) rug (2) tablecloth (1) towel (1)	68	bread (7) bread loaf (2) fruitcake (1) loaf bread (1) loaf of bread (1) multigrain loaf (1) raisin bread (3) seed loaf (1) wheat bread (1)
69	[blank] (1) ball (1) circle (15) moon (1)	70	bottle (1) champagne (13) champagne bottle (3) popping bottle (1)
71	block of chocolate (2) chocolate block (1) chocolate (11) keyboard keys (1) keypad (1) squares of chocolate (1) tile (1)	72	bike (3) bicycle (1) children's bike (1) kid bike (2) training wheel bike (1) tricycle (9) tricycle bike (1)

Picture	Response (frequency)	Picture	Response (frequency)
73	chair (11) computer chair (2) desk chair (2) office chair (2) roller chair (1)	74	computer (14) computer and monitor (1) desktop (1) desktop computer (1) tv unit (1)
75	another try-hard from brisbane (1) cowboy (16) sheriff (1)	76	[blank] (1) roller (1) rolling pin (16)
77	door (18)	78	maze (18)
79	diamond (16) gem (1)	80	dice (14) die (4)
81	[blank] (1) bagpipe (3) bagpipes (14)	82	[blank] (1) cacti (1) cactus (16)
83	another guy (1) doctor (16) teacher (1)	84	chocolate doughnut (1) doughnut (16) glazed doughnut (1)
85	[blank] (1) dolphin (17)	86	dragon (17) dragon from coat of arms (1)
87	computer disk (1) disk (2) floppy disk (15) sim card (1)	88	[blank] (1) bass violin (1) cello (4) standing violin (1) violin (11)
89	camel (18)	90	bunch of grapes (1) grapes (17)
91	duck (16) geese (1)	92	bird (6) pigeon (12)
93	scuba diver (15) diver (2) scuba diving (1)	94	cartoon devil (1) devil (15) me (1) satan (1)
95	[blank] (1) possum (1) squirrel (15)	96	bus (3) double-decker bus (13) London bus (2)
97	anteater (1) echidna (3) hedgehog (6) porcupine (8)	98	egg (12) eggcup (3) egg holder (1) egg in egg cup (2)
99	antelope (1) bull (1) deer (4) moose (9) reindeer (2) stag (1)	100	[blank] (2) acorn (8) fruit (1) lemon (1) nut (5) walnut (1)

Picture	Response (frequency)	Picture	Response (frequency)
101	island (17) tropical island (1)	102	[blank] (1) carton of eggs (1) container (1) egg carton (14) icetray (1)
103	bucket (18)	104	angel (18)
105	envelope (16) letter (2)	106	donkey (15) horse (2) pony (1)
107	[blank] (2) canister (1) cylinder (1) fire extinguisher (1) gas (1) gas bottle (4) gas burner (1) gas cylinder (1) gas tank (2) portable gas stove (1) stove burner (1) tank (1) wheel (1)	108	Cleopatra (1) dress-ups (1) Egyptian queen (1) fashionista (1) fashion model (1) girl (2) goddess (1) hippy (1) lady (2) model (4) some chick (1) stylish lady (1) well-dressed female (1)
109	[blank] (2) bell (11) bicycle bell (3) cooking pot (1) pot (1)	110	air pump (4) ball pump (1) hand pump (1) pump (11) pump machine (1)
111	bird (3) flamingo (14) waterfowl (1)	112	beer bottle (2) bottle (12) drinking bottle (1) glass bottle (3)
113	[blank] (1) flipper (14) flippers (2) swimming flippers (1)	114	flute (12) piccolo (1) recorder (4) whistle (1)
115	[blank] (1) whistle (16) whistler (1)	116	kettle (16) teakettle (1) teapot (1)
117	blowhole (2) fountain (9) fountain pond (1) sprinkle pond (1) water fountain (5)	118	chips (2) French fries (6) fries (8) hot chips (2)
119	camera (18)	120	money (18)

Picture	Response (frequency)	Picture	Response (frequency)
121	[blank] (1) fruit bowl (15) fruit salad (1) fruit (1)	122	duck (9) geese (1) goose (7) swan (1)
123	[blank] (1) gallows (2) hang (1) hanger (3) hanging (3) hangman (2) hung man (1) noose (5)	124	[blank] (1) crab net (2) fish net (1) fishing net (3) hat (1) lobster net (1) net (9)
125	[blank] (1) beater (1) eggbeater (1) hand whisk (1) mixer (1) mixing spoon (1) whisk (10) whisker (2)	126	[blank] (1) cotton (2) cotton reel (1) roll of string (1) sewing thread (1) spool of thread (1) string (1) thread (9)
127	bat (1) carrot (2) fire (2) fire stick (3) flame (2) flame stick (1) Olympic torch (1) torch (6)	128	dentures (2) false teeth (3) teeth (13)
129	[blank] (1) crusher (1) food grater (1) grinder (1) meat grinder (1) meat masher (1) meat mincer (2) mince grinder (2) mincer (4) pasta (1) pasta maker (2) sharpener (1)	130	action figure (2) armour (4) knight (5) knight armour (1) man in armour (1) medieval man (1) knight of armour (1) robot (1) suit of armour (1) tinman (1)
131	bicycle (4) bike (13) pushbike (1)	132	gun (11) rifle gun (1) rifle (5) shotgun (1)

Picture	Response (frequency)	Picture	Response (frequency)
133	[blank] (1) antlers (7) antelopes (1) coral (2) hooves (1) horns (2) roots (1) seaweed (3)	134	[blank] (1) gramophone (3) megaphone (2) music box (1) recorder (1) record player (9) vinyl player (1)
135	[blank] (1) banjo (1) guitar (15) violin (1)	136	[blank] (1) water can (1) watering can (16)
137	[blank] (1) giraffe (17)	138	family (17) nuclear family (1)
139	[blank] (1) slide (12) slippery dip (2) slippery slide (3)	140	bulb (1) light (1) light bulb (14) light globe (2)
141	[blank] (1) curtain (2) curtains (15)	142	strongman (1) weightlifting (2) weightlifter (15)
143	dead fish (1) fish bone (8) fish bones (5) fish scale (1) fish skeleton (2) skeleton (1)	144	[blank] (1) fruit (1) grapefruit (2) orange (5) pomegranate (2) slice of orange (1)
145	[blank] (1) lawnmower (16) motor mower (1)	146	bunny (1) hare (2) rabbit (15)
147	rooster (18)	148	shark (18)
149	fishing line (3) fishing (1) fishing rod (13) rod (1)	150	dumbbell (2) weightlifting (2) weight (1) weightlifts (1) weights (12)
151	chicken leg (1) ham (6) lamb (1) lamb leg (1) leg ham (2) leg of ham (4) meat (2) turkey (1)	152	aces hammer (1) axe (1) chisel (1) hammer (11) handsaw (1) mallet (1) tomahawk (1) tool (1)

Picture	Response (frequency)	Picture	Response (frequency)
153	chipmunk (1) guinea pig (1) mouse (12) possum (1) rat (2) vermin (1)	154	[blank] (1) chair (1) grenade (14) hand grenade (1) perfume bottle (1)
155	towel (17) towels (1)	156	baseball helmet (1) helmet (17)
157	a (1) rake (17)	158	goat (17) lamb (1)
159	hand (18)	160	helicopter (18)
161	heart (9) love heart (8) shape of heart (1)	162	[blank] (1) lizard (16) gecko (1)
163	reindeer (3) dear (14) stag (1)	164	eskimo (1) iceberg (1) igloo (16)
165	horse (1) rocking horse (16) wooden horse (1)	166	fedora hat (1) hat (16) man's hat (1)
167	[blank] (1) axe (1) garden aces (1) hammer (4) mining tool (1) pick (8) pickaxe (1) tool (1)	168	[blank] (1) bundle of hay (1) bush (2) hair (1) haystack (2) hay (9) hay bale (1) wool (1)
169	[blank] (1) garden fork (2) hoe (1) pitchfork (7) rake (4) shovel (3)	170	[blank] (1) French horn (1) horn (9) saxophone (1) trumpet (6)
171	watch (17) wristwatch (1)	172	horseshoe (18)
173	[blank] (1) barrow (1) carousel (1) carriage (6) carrier (1) cart (1) chariot (1) horse carriage (1) transport (1) wagon (4)	174	boiler (1) combustion heater (1) fireplace (2) fire pit (1) furnace (2) heater (4) incinerator (1) machine (1) oven (4) woodstove (1)

Picture	Response (frequency)	Picture	Response (frequency)
175	[blank] (1) berries (1) berry (1) Christmas (1) crapes (2) holly (6) mistletoe (6)	176	banksia (1) bottlebrush (1) flower (10) flowers (1) hyacinths (1) lavender (2) seed (1) waratah (1)
177	[blank] (1) crane (17)	178	bear (2) polar bear (16)
179	ice cream (13) ice cream cone (5)	180	boy (17) man (1)
181	IV drip (2) IV stand (1) IV stand with bag (1) blood (1) doctor (1) drip (5) drip machine (1) drip stand (2) hospital nutrient (1) hospital drip (1) saline (1) solution (1)	182	firing gun (1) guy from Sydney trying to shoot those brisbanites (1) hunter (6) hunting (1) man shooting (2) man with gun (1) rifleman (1) shooter (3) shooting (1) shot man (1)
183	coat (16) raincoat (1) trench coat (1)	184	[blank] (1) octopus (14) squid (3)
185	dwarf (1) elf (7) garden gnome (1) gnome (7) leprechaun (1)	186	candleholder (4) candelabra (2) candle (2) candles (8) candleholders (1) Jewish candelabra (1)
187	block of cheese (1) cheese (15) cheese roll (1) wheel of cheese (1)	188	[blank] (1) burning candle (1) candle (15) candlelight holder (1)
189	home (1) house (17)	190	gift (5) present (13)
191	bird (1) hen (1) rooster (2) turkey (14)	192	bomb (1) cannon (15) firing machine (1) missile shooter (1)

Picture	Response (frequency)	Picture	Response (frequency)
193	bonfire (1) campfire (2) fire (10) fireplace (1) fire pit (1) firewood (1) wood fire (2)	194	ace (3) ace card (2) ace of clubs (1) ace of spades (4) ace of spades card (1) card (6) playing cards (1)
195	kangaroo (18)	196	comb (17) hair comb (1)
197	clothes rack (1) clothes hanger (1) coat hanger (5) coatrack (1) coatrack stand (1) coat stand (5) hanger (1) hat stand (1) rack (2)	198	[blank] (1) barrow (2) carriage (1) cart (5) trailer (4) wagon (2) wheelbarrow (2) wheel cart (1)
199	can (1) cup (1) glass mug (1) jug (12) mug (2) vase (1)	200	karate (11) karate kick (1) karate master (1) kung-fu fighter (1) martial artist (1) martial arts man (1) sensei (1) some guy (1)
201	cash machine (1) cash register (11) cash till (1) register (4) till (1)	202	closet (1) cupboard (7) door (1) wardrobe (9)
203	castle (18)	204	cat (18)
205	[blank] (1) slingshot (17)	206	bowling pin (13) pin (4) tenpin (1)
207	[blank] (1) building (2) church (15)	208	[blank] (1) Christmas tree (16) tree (1)

Picture	Response (frequency)	Picture	Response (frequency)
209	[blank] (2) bat (3) club (2) medieval mase (1) hammer (1) hitting stick (1) hitting thing (1) mace (1) porcupine (1) spike stick (1) stick (1) vegetable (1) weapon (2)	210	[blank] (1) bat (1) baton (1) chopstick (2) cue (1) cue stick (1) drumstick (1) nail file (1) pool cue (3) pool stick (3) stick (1) wand (2)
211	beetle (11) bug (5) cockroach (1) insect (1)	212	[blank] (1) clothes hanger (2) coat hanger (14) hanger (1)
213	Aladdin's other carpet (1) blanket (2) carpet (1) mat (4) rug (8) rug or mat (1) towel (1)	214	[blank] (1) beet (1) beetroot (4) onion (4) radish (2) root (1) tulip (1) turnip (4)
215	box of coloured pencils (1) colouring pencil (1) crayons (7) crayon set (1) pencil (1) pencil case (1) pencils (6)	216	clog (9) clogs (2) clog shoes (1) Dutch shoe (1) shoe (3) wooden shoe (2)
217	freezer door (1) safe (16) vault (1)	218	bat (10) baseball bat (8)
219	tooth (18)	220	cow (18)
221	chain (16) chains (2)	222	briefcase (6) suitcase (12)
223	[blank] (1) buggy (1) car (1) carriage (7) chariot (1) coach (1) old car (3) olden-day car (1) slay (1) sulky (1)	224	coffee cup (1) coffee mug (1) coffee percolator (1) cup (5) cup and saucer (2) measuring cup (2) mug (1) saucer (1) teacup (3) teacup and saucer (1)

Picture	Response (frequency)	Picture	Response (frequency)
225	[blank] (1) blender (2) coffee (1) coffee machine (9) coffeemaker (2) coffeepot (1) coffee percolator (1)	226	[blank] (2) capsicum (1) cucumber (11) pickle (1) pickles (1) vegetable (1) zucchini (1)
227	[blank] (1) bowl (17)	228	[blank] (1) chef (17)
229	hare (2) rabbit (16)	230	king (13) queen (4)
231	[blank] (1) handheld speaker (1) louder speaker (1) loudhailer (1) loudspeaker (3) megaphone (6) microphone (4) speakerphone (1)	232	[blank] (1) balance beam (2) balancing (2) limbo (1) man (2) sport (1) tightrope (5) tightrope walker (4)
233	[blank] (1) corkscrew (11) corker (1) nail (1) screw (3) screwdriver (1)	234	[blank] (1) blouse (1) collar (14) cuffs (1) top of a shirt (1)
235	[blank] (1) bead on thread (1) light (1) necklace (15)	236	[blank] (1) newspaper (15) paper (1) passport (1)
237	crab (18)	238	spoon (18)
239	[blank] (1) arrow (1) bow (3) bow and arrow (3) crossbow (9) weapon (1)	240	ambulance cross (1) ambulatory cross (1) cross (12) first aid (2) plus sign (1) red cross (1)
241	alligator (2) croc (2) crocodile (15)	242	ladybeetle (12) ladybird (1) ladybug (5)
243	stool (16) chair (1) step chair (1)	244	cup (11) mug (2) teacup (5)
245	brush (1) paintbrush (17)	246	desk lamp (1) lamp (17)
247	tap (17) watering tap (1)	248	[blank] (1) wheelbarrow (17)

Picture	Response (frequency)	Picture	Response (frequency)
249	banana chair (1) beach chair (9) chair (6) deckchair (2)	250	steam engine (1) steam train (3) steam train engine (1) train (13)
251	[blank] (1) elephant (2) buffalo (1) mammoth (13) woolly mammoth (1)	252	glue (14) glue tube (1) hot glue without dispenser (1) superglue (1) tube (1)
253	[blank] (2) magnifying glass (16)	254	crescent moon (1) moon (17)
255	box of matches (1) matchbox (5) matches (8) matchsticks (3) packet of matches (1)	256	diapers (1) babies nappy (1) diaper (1) disposable nappy (1) nappy (13) underwear (1)
257	measure (1) ruler (17)	258	measuring tape (11) tape measure (7)
259	man (1) navy sailor (1) sailor (16)	260	slice of watermelon (1) watermelon (16) watermelon slice (1)
261	birdcage (15) cage (3)	262	butter knife (2) knife (16)
263	[blank] (1) clacker (1) clapper (1) flag (1) ice block (1) instrument (1) kazoo (1) measurement (1) musical instrument (1) noisemaker (1) pole (1) toy (4) whizzer (1) wood (2)	264	[blank] (2) bishops hat (2) bishop hat (2) cap (1) hat (1) headdress (1) mitre (1) pope hat (1) popes hat (1) priest hat (1) shield (4) shields (1)
265	[blank] (1) beaters (1) blender (2) eggbeater (2) eggbeaters (1) electric beater (6) electric beaters (1) electric mixer (1) mixer (1) whisk (1)	266	baby (3) baby feeding (1) feeding (1) mother (5) mother and baby (3) mother and child (1) mother bottle-feeding baby (1) mother feeding baby (1) nursing mother with infant (1)

Picture	Response (frequency)	Picture	Response (frequency)
267	[blank] (1) bolt (10) metal nut (1) nut (5) screw (1)	268	needle (9) needle and thread (3) pin (2) sewing needle (4)
269	windmill (18)	270	nose (18)
271	[blank] (2) accordion (1) barbecue (1) flute (1) harmonica (8) instrument (1) mouthorgan (1) music (1) recorder (1) USB (1)	272	[blank] (2) animal (1) beaver (2) bird (1) mole (4) newborn mouse (1) otter (2) platypus (3) walrus (1) weasel (1)
273	bug (1) fly (1) grasshopper (1) insect (2) mosquito (10) mozzie (1) moth (1) wasp (1)	274	[blank] (1) church piano (1) grand piano (1) old piano (1) organ (7) organs (1) piano (5) piano accordion (1)
275	[blank] (1) microscope (16) telescope (1)	276	beanie (16) cotton hat (1) hat (1)
277	[blank] (1) sewing machine (17)	278	mousetrap (17) trap (1)
279	bird nest (2) birds nest (3) eggs (2) eggs in a nest (1) nest (9) nest with eggs (1)	280	clam (9) mussel (1) nut (1) nutshell (1) oyster (5) shell (1)
281	[blank] (1) bee net (1) butterfly net (1) catcher (1) fishing net (2) fishnet (1) net (11)	282	[blank] (1) bean (2) embryo (1) foetus (1) kidney (5) liver (1) tomato (7)
283	hippo (10) hippopotamus (6) rhino (2) rhinoceros (1)	284	mouth (8) mouth with teeth (1) smile (2) teeth (7)

Picture	Response (frequency)	Picture	Response (frequency)
285	[blank] (1) bridge (13) drawbridge (2) rollercoaster (1) wharf (1)	286	[blank] (2) compass (11) geometry (1) protractor (3) surveying equipment (1)
287	elephant (18)	288	mouse (18)
289	oven (18)	290	pen (18)
291	[blank] (1) gift (1) package (1) parcel (5) present (10)	292	[blank] (1) cooking pot (1) hotpot (1) large cooking pot (1) pot (14)
293	coconut tree (2) palm tree (15) tree (1)	294	eel (8) snake (10)
295	bird (1) macaw (1) parrot (16)	296	[blank] (1) paperclip (16) safety clip (1)
297	pen case (2) crayons (1) pencil case (13) pencil tin (1) pencils in pencil case (1)	298	budgie (11) bird (4) bird on perch (1) lorikeet (1) rosella (1)
299	[blank] (1) dress holder (1) dressmakers doll (1) mannequin stand (1) mannequin (12) singlet (1) top (1)	300	[blank] (1) bird (5) crane (2) duck (1) flamingo (2) pelican (4) stalk (2) yet another bird (1)
301	peacock (16) bird (2)	302	bat (4) cricket bat (1) oar (2) paddle (10) rowing stick (1)
303	[blank] (1) pear (17)	304	[blank] (1) mushroom (17)
305	parachute (11) parachuter (3) parachuting (1) parachutist (1) paragliding (1) skydive (1)	306	[blank] (1) brush (1) fine paintbrush (1) javelin (1) paintbrush (12) pen (1) spear (1)

Picture	Response (frequency)	Picture	Response (frequency)
307	balloon (1) fruit (2) orange (2) peach (10) pear (1) plum (1) rotten fruit (1)	308	[blank] (1) bell (1) chess piece (10) chess pawn (2) chess part (1) cup and ball (1) pawn (3)
309	piano (16) upright piano (1)	310	cap (7) hat (11)
311	smoking pipe (1) pipe (14) cigar pipe (1) smoking pipe (2)	312	[blank] (1) cashew nut (1) nut (2) peanut (14)
313	[blank] (1) plucker (1) tweezers (16)	314	[blank] (1) food (1) picnic (16)
315	[blank] (1) empire penguin (1) penguin (16)	316	[blank] (2) band aid (14) patch (2)
317	bag (1) clutch (1) coin purse (1) purse (15)	318	gun (10) handgun (2) luger (1) pistol (4) shotgun (1)
319	[blank] (1) drinking straw (2) straw (15)	320	bat (1) racket (5) tennis racket (12)
321	plant (11) pot plant (7)	322	speaker's podium (1) stage (17)
323	pizza (18)	324	pumpkin (18)
325	doll (17) female doll (1)	326	pirate (17) some hard-arse guy from Brisbane (1)
327	bishop (1) christian (1) monk (1) pope (3) priest (12)	328	[blank] (1) barristers wig (2) judge hat (1) judges wig (1) wig (13)
329	rail tracks (1) railway track (4) tracks (2) train track (3) train tracks (8)	330	sticky tape (10) sticky tape in dispenser (1) sticky tape roller (1) tape (5) tape measure (1)

Picture	Response (frequency)	Picture	Response (frequency)
331	[blank] (1) jigsaw (1) jigsaw puzzle (2) puzzle (14)	332	[blank] (1) cheese grater (3) grater (12) shredder (2)
333	mouse (17) rat (1)	334	ferris wheel (16) merry-go-round (2)
335	rain (10) raincloud (5) rainclouds (1) raining (1) rainy cloud (1)	336	clam (12) nut (1) oyster (3) shell (1) oyster shell (1)
337	[blank] (1) capsule (1) medicine (1) panadol (1) pill (10) tablet (4)	338	boat (4) cruise ship (2) naval ship (1) navy ship (1) sailing boat (1) ship (9)
339	zipper (18)	340	robot (18)
341	skirt (15) dress (2) veil (1)	342	[blank] (1) scissor (1) scissors (16)
343	[blank] (1) long-stemmed rose (1) rose (16)	344	backpack (14) bag (2) hiking bag (2)
345	aw (1) fencing sword (1) sword (16)	346	girl shoe (1) sandal (8) sandals (3) shoe (6)
347	[blank] (1) bed bunk (1) bunk (1) bunk bed (6) bunk bed frame (1) bunk beds (4) bunker bed (1) double bed (1) double bunks (1) shelving (1)	348	[blank] (1) ice skate (5) ice skating boots (1) ice skating shoe (1) ice skating shoes (2) skate (2) skates (3) skating shoes (1) ski boot (1) ski shoe (1)
349	wheelchair (18)	350	shell (18)

Picture	Response (frequency)	Picture	Response (frequency)
351	corn (1) flower (4) flowers (4) grass (1) plant (2) reeds (1) weed (2) weeds (2) wheat plant (1)	352	[blank] (1) artwork (1) painting (4) painting of stag (1) picture (7) picture frame (3) wall picture (1)
353	tortoise (2) turtle (16)	354	shovel (17) spade (1)
355	lace-up shoe (1) shoe (16) shoes (1)	356	nail (5) screw (12) screw or nail (1)
357	[blank] (1) chimney (17)	358	cigar (16) cigarette (2)
359	[blank] (3) board (1) board game (1) game (3) game board (2) golf course (1) golf holes (1) ladder (1) mousetrap (1) panel (1) shelf piece (1) ticktacktoe (1) wooden game (1)	360	[blank] (4) badminton (2) ball (2) birdie (1) fan (1) flipper (1) funnel (1) handheld fan (1) pong (1) shuttlecock (2) spotoi (1) tennis putt (1)
361	cigarette (12) cigarette or smoke (1) duri (1) smoke (3) smoking (1)	362	[blank] (1) cabbage (2) flower (4) lettuce (10) rose (1)
363	[blank] (5) car piece (1) chainsaw (1) cook (1) pasta maker (1) saw (2) sewing machine (1) sled (1) sprinkler (4) stand (1)	364	[blank] (1) Egypt (2) Egyptian memorial (1) Egyptian statue (3) Egyptian sculpture (1) Egyptian statue (1) Egyptian (1) pharaoh (1) sphinx (5) temple (1) tombs (1)
365	human skeleton (1) skeleton (17)	366	[blank] (1) orange (17)

Picture	Response (frequency)	Picture	Response (frequency)
367	slug (1) snail (17)	368	face mirror (1) mirror (17)
369	key (18)	370	thong (16) thongs (2)
371	lock (9) padlock (9)	372	beak (16) birds beak (2)
373	ar (1) army officer (2) army soldier (1) soldier (14)	374	bishop (3) pope (6) priest (8) wizard (1)
375	cobweb (1) spider web (12) web (5)	376	hypodermic needle (1) needle (13) syringe (4)
377	ski board (1) slay (1) sled (10) sledge (2) toboggan (4)	378	[blank] (1) Greek statue (1) naked statue (1) sculpture (1) statue (14)
379	[blank] (1) lights (2) satellite in the space (1) satellite (9) solar panel (1) solar panels (1) solar power (1) solar system (1) windmill (1)	380	[blank] (1) horse reels (1) chairlift (1) horse saddle (1) horse saddles (1) rains (1) saddle (5) saddle foot stirrups (1) stirrups (6)
381	doorknob (1) ink stamp (1) rubberstamp (2) stamp (14)	382	[blank] (1) bow (12) bowtie (4) ribbon (1)
383	star (18)	384	bike (1) scooter (17)
385	branch (1) leaves (11) leaves branch (1) plant (2) tree branch (1) twig of a leafy plant (1) vine (1)	386	[blank] (1) camera tripod (2) sprinkler (1) stand (1) telescope (3) tripod (8) tripod stand (1)
387	[blank] (1) metal detector (1) vacuum (9) vacuum cleaner (6)	388	microwave (4) television (6) TV (8)

Picture	Response (frequency)	Picture	Response (frequency)
389	[blank] (2) doctor stethoscope (1) doctors tool (1) heart-rate listener (1) medic (1) stethoscope (12)	390	t-shirt (12) plain t-shirt (1) shirt (3) shirts (1) top (1)
391	birthday cake (1) cake (16) layered cake (1)	392	burrito (2) taco (15) tacos (1)
393	desk (5) table (13)	394	[blank] (1) bull (17)
395	[blank] (2) brush (1) cone (4) file (1) ice cream (5) microphone (1) stick (1) tooth (3)	396	[blank] (1) mercury (1) temperature (2) temperature gage (1) test tube (1) thermometer (12)
397	bag (6) handbag (5) purse (2) satchel (4) side bag (1)	398	big toe (6) finger (2) toe (7) toenail (3)
399	[blank] (1) telescope (17)	400	ironing board (17) iron table (1)
401	acropolis (1) ancient Greek palace (1) building (6) court (1) Greece (1) Greek building (2) Greek temple (1) hall (1) museum (2) parliament house (1) temple (1)	402	[blank] (1) bucket (1) barrel (1) barrow (1) basket (1) bucket (7) plant barrel (1) pot (1) water barrel (2) well (1) wooden bucket (1)
403	[blank] (2) cutters (1) pliers (14) tools (1)	404	[blank] (1) barrel (14) keg (3)
405	tent (18)	406	toilet (18)
407	toilet paper (15) toilet roll (3)	408	tiger (18)

Picture	Response (frequency)	Picture	Response (frequency)
409	decoration (1) spinner (1) spinning top (9) spin top (1) top (1) toy (3) tradle (1) wooden twirl (1)	410	[blank] (1) American Indian hat (1) chiefs hat (1) headdress (1) Indian hat (4) Indian chef hat (1) Indian headdress (3) Indian headpiece (2) Indian headwear (3) native Indian American headpiece (1)
411	garden chair (1) beach chair (1) chair (13) deckchair (1) seat (1) wooden chair (1)	412	cyclone (3) explosion (1) hurricane (2) smoke (2) tornado (9) twister (1)
413	magician (1) male wizard (1) sorcerer (1) wizard (15)	414	flower (5) rose (3) rose flower (1) tulip (9)
415	ladder (16) stepladder (1)	416	train (9) tram (9)
417	drum (12) drum kit (1) drums (4) hards (1)	418	[blank] (1) saxophone (1) trumpet (16)
419	[blank] (1) saxophone (1) trumpet (10) trombone (3) tuba (3)	420	glue (3) paste (1) toothpaste (11) tube (2) tube of glue (1)
421	[blank] (1) hose (16) rope (1)	422	castle (11) castle tower (3) tower (4)
423	funnel (18)	424	typewriter (18)
425	owl (16) bird (1) kookaburra (1)	426	feather (16) feature (1) plant (1)
427	[blank] (1) pig (17)	428	[blank] (1) vase (17)

Picture	Response (frequency)	Picture	Response (frequency)
429	[blank] (1) paint (4) paintbox (1) paintbrush (1) paint holder (1) painting (1) paint roller (2) paint roller and tray (1) paint tin (1) paint tray (4) paint tray and roller (1)	430	[blank] (2) fire hose (1) hose wheel (2) ma wheel (1) rim (3) rims (2) shower nozzle (1) wheel (4) wheel caps (1) wheel rim (1)
431	bicycle (2) bike (8) old bike (1) old-fashioned bike (1) old-style bicycle (1) penny-farthing (3) tricycle (2)	432	[blank] (1) fennel (2) heart (2) onion (9) tulip (1) turnip (1) vegetable (2)
433	desk fan (1) electric fan (1) fan (16)	434	bobby pin (2) pin (3) safety clip (1) safety pin (12)
435	plane (1) aeroplane (2) airplane (1) plane (11) prop plane (1) spitfire (1) stunt plane (1)	436	[blank] (1) cassette (2) cassette tape (2) tape (8) video (2) videocassette (1) videotape (2)
437	[blank] (1) bucket (3) cone (4) hat (3) jelly (2) pudding (1) tall hat (1) thimble (2) top (1)	438	[blank] (1) basin (1) bowl (6) bowl and spoon (4) garlic bowl (1) grinding bowl (1) mixer (1) mixing bowl (2) mortar (1)
439	finger (11) finger points (1) forefinger (1) index finger (5)	440	fingerprint (17) thumbprint (1)
441	dam (1) lake (4) pond (13)	442	guitar (1) violin (16) viola (1)
443	fish (18)	444	flag (17) flagpole (1)

Picture	Response (frequency)	Picture	Response (frequency)
445	bat (18)	446	grand piano (3) piano (15)
447	flag (1) kite (17)	448	[blank] (1) binoculars (17)
449	[blank] (1) butterfly (17)	450	foot (18)
451	ball (3) soccer (1) soccer ball (14)	452	birdhouse (15) bird nest (1) birds house (1) owl house (1)
453	fork (18)	454	tip truck (1) truck (17)
455	boat (3) boat deck (1) cargo ship (1) containership (2) ship (9) ship vessel (1) tanker (1)	456	female (1) girl (1) lady (5) woman (11)
457	garbage (2) rubbish (2) rubbish bin (4) rubbish tin (1) trash (2) trash bin (1) trashcan (5) trashcan garbage (1)	458	firecracker (2) firecrackers (1) firework (5) fireworks (2) fireworks rocket (1) rocket (5) rocket launch (1) skyrocket (1)
459	[blank] (1) fan (15) hand fan (2)	460	cane (4) hook (1) walking cane (1) walking stick (12)
461	[blank] (1) coat of arms (3) emblem (1) shield (10) sigil (1) symbol (2)	462	basin (1) bathroom (2) bathroom sink (6) bathroom vanity (1) bath sink (1) sink (6) sink and mirror (1)
463	clothes peg (1) peg (17)	464	road (17) scenic road (1)
465	alarm clock (9) clock (9)	466	tyre (1) wagon wheel (1) wheel (16)
467	wineglass (17) wine cup (1)	468	dog (1) wolf (17)
469	zebra (18)	470	saw (18)

Picture	Response (frequency)	Picture	Response (frequency)
471	[blank] (1) balloon (1) cushion (1) frankfurter (1) sausage (14)	472	[blank] (1) cloud (13) clouds (1) shell (1) shrubs (1)
473	[blank] (1) bag (6) bag of money (2) bag of potatoes (1) coin bag (1) moneybag (3) sack (3) trash (1)	474	[blank] (1) ball of string (1) ball of wool (2) cotton ball (1) string (1) wool (9) wool ball (1) yarn (2)
475	bag (9) gift (1) paper bag (1) shopping bag (8)	476	boat (6) sailboat (5) sailing boat (2) ship (1) yacht (4)
477	solarium (6) coffin (1) iron (1) sunlounge (1) sun tanning bed (1) tanning salon (1) tanning bed (4) tanning solarium (1) tanning machine (1) tan sauna (1)	478	[blank] (5) pillar (1) column (4) Corinthian pillar (1) cricket stump (1) pedestal stand (1) pole (1) stone beam (1) string (1) strings (1) support beam (1)
479	sun (18)	480	geese (2) swan (16)
481	ambulance (18) car (1)	482	ant (15) bull ant(1) insect (2) spider (1)
483	[blank] (1) antenna (6) antenna aerial (1) aerial (4) electrical line (1) power lines (1) satellite receiver (1) satellite(3) TV aerial (1)	484	[blank] (1) apple (2) apple core (12) core (1) eaten apple (3)
485	[blank] (2) apron (17)	486	aquarium (1) fish (1) fish aquarium (1) fish tank (14) tank (2)

Picture	Response (frequency)	Picture	Response (frequency)
487	arm (19)	488	arrow (19)
489	astronaut (17) space(1) spaceman (1)	490	avocado (16) half avocado (1) mouse (1) soap or dishes (1)
491	[blank] (1) awning (1) shop (1) shopwindow (1) window (12) window shade (3)	492	banjo (8) guitar (5) lute (1) mandolin (1) sitar (1) ukulele (3)
493	tennis (1) badminton (6) badminton player (2) croquet(1) female (1) shuttlecock (1) squash player (1) tennis player (4) volley (1) yoyo (1)	494	[blank] (1) hand cream (1) hand sanitiser (1) hand soap (1) hand soap dispenser (1) hand wash (1) perfume (1) sa (1) soap (5) soap bottle (1) soap dispenser (3) soap holder (1)
495	baguette (2) bread (12) bread roll (2) breadstick (2) loaf of bread (1)	496	robber (1) balaclava (4) helmet (2) mask (7) Ned Kelly (1) ninja (2) ski mask (2)
497	balcony (17) terrace (1) veranda (1)	498	ballerina (16) ballet dancer (1) dancer (2)
499	baby bottle (6) bottle (12) sucker bottle (1)	500	barbeque (18) mobile barbeque (1)
501	[blank] (1) barbed wire (8) barbwire (5) bob wire (1) rod (1) wire (3)	502	barn (9) building (1) factory (2) farm (2) gymnasium (1) hanger (1) house (2) warehouse (1)
503	basket (17) carry basket (1) wicker basket (1)	504	bat (9) cricket bat (10)

Picture	Response (frequency)	Picture	Response (frequency)
505	robe (1) bathrobe (3) coat (2) dressing gown (4) nightgown (1) robe (7) sleeping robe (1)	506	[blank] (1) antiseptic (1) battery (16) mat (1)
507	bauble (3) Christmas tree decoration (1) Christmas (1) Christmas ball (4) Christmas bulb (1) Christmas decoration (3) Christmas decoration bauble (1) Christmas ornament (1) decoration (2) decorations (1) ornament (1)	508	bean (2) chilli (8) green bean (1) pea (4) peapod (1) peas (1) pod (1) snow peas (1)
509	bed (19)	510	brain (19)
511	bird (18) sparrow (1)	512	belt (16) collar (3)
513	seat (1) bench (9) bench seat (1) park bench (7) park bench seat (1)	514	bathers (1) bikini (14) bikinis (2) bikini set (1) swimming costume (1)
515	file (1) bedside drawers (1) bedside table (4) chest of drawers (1) desk organiser (1) draw (1) drawers (9) side table (1)	516	[blank] (1) bull (2) boar (8) hog (2) ox (1) pig (4) wild pig (1)
517	biscuit (10) cracker (2) doormat (1) mat (2) naked vovo (1) rug (3)	518	board game (8) game (1) game board (4) monopoly (1) picnic (4) play (1)

Picture	Response (frequency)	Picture	Response (frequency)
519	[blank] (2) bobsled(6) luge sled (1) race car (2) racers (1) rocket (1) rollercoaster (1) slalom (1) sledding (1) sledge (1) spaceship (1) toboggan (1)	520	[blank] (2) barricade (3) boom gate (6) fence (2) gate (1) joint (1) right angle bracket (1) road barrier (1) security gate (1) stick (1)
521	empty box (1) box (14) cardboard box (3) open box (1)	522	belly dancer (10) dancer (2) gyp or belly dancer (1) gypsy (5) lebo dancer (1)
523	braces (16) braces on teeth (1) mouth (2)	524	bikini (2) bikini top (1) bra (16)
525	bridge (19)	526	broom (19)
527	awe (1) bison (2) buffalo (4) bull (6) goat (1) mammoth (1) monster (1) ox (2) yak (1)	528	[blank] (2) train (1) bobcat (1) bulldozer (4) excavator (1) grader (1) machinery (2) tractor (5) truck (2)
529	dodging car (1) bumper car (6) bumper cars (2) dodgem car (7) dodgem cars (2) ride (1)	530	suitcase (1) businessman (13) man (1) office worker (2) professional (1) suit (1)
531	train station (1) bus (1) bus bay (1) bus shelter (3) bus stop (12) seat (1)	532	lolly (16) candy (1) wrapped candy (1) wrapped lolly (1)
533	button (18) fruit (1)	534	calculator (19)

Picture	Response (frequency)	Picture	Response (frequency)
535	[blank] (3) cable car (5) carriage (1) crane (1) lift (2) ride (1) sky lift (1) skyway car (1) snow hill climber thing (1) toboggan (1) transport (1) traveller (1)	536	garden (1) cake cutter (1) cake lift (1) cake server (1) gardening (1) gardening tool (1) pie slicer (1) serving knife (1) serving spoon (1) shovel (1) spade (4) spatula (3) tool (1) trowel (1)
537	calf (4) cow (15)	538	camel (19)
539	[blank] (1) caravan vehicle (1) camper (1) campervan (2) caravan (10) mover camper (1) RV (1) trailer home (1) van (1)	540	bottle (1) canister jar (1) glass jar (1) jar (12) jug container (1) preserve jar (1) salt container (1) vacuum jar (1)
541	[blank] (1) candle (18)	542	boat (6) canoe (8) gondola (1) gondolier (1) kayak (1) rowboat (2)
543	[blank] (2) d-clip for ropes (1) karabiner (2) clamper (1) clench (1) harness (1) lock (2) pipe (1) pipes (1) safety lock (2) shackle (1) tool (2) usb bracelet (1) vice (1)	544	army water (1) bell (1) bottle (1) canteen (1) compass (1) cutting blade (1) flask (1) flask canteen (1) stopwatch (5) timer (1) water (1) water bottle (2) water flask (1) water can (1)

Picture	Response (frequency)	Picture	Response (frequency)
545	[blank] (1) butternut pumpkin (2) capsicum (4) pumpkin (10) squash (1) zucchini (1)	546	[blank] (1) cap sealant (1) caulking gun (1) glue (4) glue gun (9) hot glue gun (2) silicon gun (1)
547	caravan (17) trailer (2)	548	carrot (18) turnip (1)
549	carton milk bottle (1) carton (4) carton milk (1) milk (6) milk carton (7)	550	cassette tape (2) cassette (7) music tape (1) radio (1) recorder (1) tape (7)
551	[blank] (1) insect (1) bug (1) caterpillar (14) centipede (1) grub (1)	552	award (4) certificate (4) deed (1) diploma (1) letter (1) paper (1) script (1) scroll (6)
553	[blank] (1) cave (17) cave entrance (1)	554	ceiling fan (4) fan (15)
555	[blank] (1) ancient man (1) caveman (4) caveman walking (1) cavewomen (1) history (1) hunter (1) man (3) murder (1) Neanderthal (3) shovel (2)	556	[blank] (1) man horse (1) centaur (5) half man and horse (1) half man half horse (1) man horse (2) minotaur (1) mystical creature (1) mythical man horse (2) Narnia (1) Sagittarius (2) sphinx (1)

Picture	Response (frequency)	Picture	Response (frequency)
557	[blank] (3) cabbage (1) cauliflower (7) flower (1) island (2) lettuce (1) mashed potato (1) pillow (1) rubbish (1) vomit (1)	558	ancient (1) ancient romans (1) cart (1) chariot (3) horse (1) horse and car (1) horse and carriage (3) horse drawn cart (1) horsemen (1) knight (2) roman chariot drivers (1) royals (1) soldiers (1) tournament (1)
559	chainsaw (17) saw (2)	560	chair (19)
561	chapel (1) church (18)	562	chicken (15) hen (2) rooster (2)
563	checkerboard (9) checkers (2) chess (2) chessboard (5) picnic blanket (1)	564	baby chicken (1) bird (6) chick (9) chicken (3)
565	[blank] (2) broken (1) bracelet (1) chestnut (1) flytrap (1) fruit (1) lychee (1) rambutan (1) sea creature (1) sea urchin (2) spike (1) spikes (2) spikey ball (1) spikey nut (1) spiky (1) weapon (1)	566	[blank] (4) shovel (1) cheese grater (1) cheese slicer (1) garden tool (1) peeler (1) scoop (1) scraper (1) shovel (3) slicer (1) spade (2) spatula (2)
567	scalpel (1) art tool (1) chipper (1) chisel (8) filer (1) paint scraper (1) panel (1) scraper (3) screwdriver (1) tool (1)	568	[blank] (4) chopping implement (1) clown (1) fine herb chopping knife (1) handlebar (1) knife (5) knife cutter (1) rolling pin (2) saw (2) tool (1)

Picture	Response (frequency)	Picture	Response (frequency)
569	[blank] (1) casket (2) coffin (16)	570	[blank] (1) chopstick (1) chopsticks (11)
571	chalk (1) cigarette (3) cigarette pack (1) cigarette packet (1) cigarettes (11) durries (1) smokes (1)	572	music (2) musical note (1) music note (4) music symbol (2) note (1) treble (1) treble clef (8)
573	[blank] (2) cutlery (1) cover (1) dinner (1) dinner tray (1) dish (1) food (2) food lid (1) food tray (1) meal (1) platter (3) salver (1) serving platter (2) silver platter (1)	574	[blank] (4) bell (2) box (1) coffee grinder (2) grinder (1) music (1) musical instrument (1) music box (5) radio (1) record player (1)
575	[blank] (1) flower (7) flowers (5) plant (1) thistle (1) waratah (4)	576	leaf (1) clover (8) four-leaf clover (6) four leaved clover (2) glover (1) petal (1)
577	clown (17) clown face (2)	578	clock (17) time (2)
579	alcohol (1) alcoholic drink with decorative umbrella (1) cocktail (5) drink (1) martini (5)	580	[blank] (3) tool (1) circle (1) cog (6) gear (4) pully apparatus (1) wheel (3)
581	coin (19)	582	clock (1) compass (18)
583	colander (4) drainer (4) sieve (2) strainer (9)	584	baby cot (1) coat (1) cot (12) cradle (2) crib (3)

Picture	Response (frequency)	Picture	Response (frequency)
585	[blank] (1) backpack (1) bag (3) bubble blower (1) donation (1) dust collector (1) urn (1) iron (2) jug (2) kettle (3) moneybox (1) ticket machine (1) torch (1)	586	electricity (1) broken cord (1) cable (1) cord (5) damaged cord (1) electrical cable (1) electrical cord (4) extension cord (1) power cable (1) power cord (1) power lead (1) wires (1)
587	musician (1) composer (1) conductor (9) constructor (1) musical (1) orchestra (4) orchestrator (2)	588	[blank] (1) log (1) bolt (1) cork (2) cup (1) lamp (1) mushroom (3) ring (1) seat (2) stool (6)
589	branch (2) bow (1) slingshot (3) stick (9) twig (4)	590	jumpsuit (7) onesie (5) overalls (5) tradie (1) uniform (1)
591	beer (1) beer container (1) bottle (1) bottles (1) carton (1) crate (2) crate of bottles (1) drink carton (1) milk (1) milk bottles (1) milk crate (1) milk tray (1) rack (1) crate of milk (1) tray of bottled drinks (1) tray of drink (1) wine (2)	592	stretch (1) aerobics (1) athlete (1) dancer (4) exercise (1) exerciser (1) gymnast (5) stretching (2) stretching after exercise (1) yoga (2)
593	[blank] (2) croissant (16) pastry (1)	594	[blank] (1) crutch (8) crutches (7) walking crutch (1) walking stick (2)

Picture	Response (frequency)	Picture	Response (frequency)
595	box (2) cube (16) square (1)	596	cake (1) cupcake (17) muffin (1)
597	bicycle (1) bicyclist (1) bike (3) biker (1) bike rider (1) cycler (1) cyclist (10) pushbike rider (1)	598	[blank] (2) clashers (1) hand clappers (1) instrument (1) musical instrument (1) cymbals (12) tambourine (1)
599	baby cot (1) baby cradle (2) bassinet (4) bed (1) cot (4) cradle (5) crib (1) manger (1)	600	dandelion (3) flower (11) weed (4) wish leaf (1)
601	[blank] (2) compass (1) dartboard (13) darts (1) shield (1) wheel (1)	602	slide (1) bouncing ladder (1) diving board (11) plank (2) pool ladder (1) slippery dip (1) springboard (2)
603	[blank] (2) bin (2) can (1) deep fryer (2) drum (1) electric deep fryer (1) food blender (1) fryer (2) juice maker (1) pot (1) rice cooker (4) slow cooker (1)	604	[blank] (5) army water bottle (1) battery (1) blow drier (1) bolt (1) bottle (2) gear (1) hairdryer (1) light (1) lint roller (1) medication (1) no idea (1) perfume (1) tool (1)
605	beach chair (1) camp chair (1) chair (10) director chair (1) director's chair (4) foldup chair (1) production chair (1)	606	dishes (10) kitchen sink (1) sink (3) sink for of dishes to be washed up (1) washing (3) washing-up (1)
607	dog (18) labrador (1)	608	dress (19)

Picture	Response (frequency)	Picture	Response (frequency)
609	[blank] (2) Athens (1) henge (1) rocks (6) rock sculptures (1) Stonehenge (4) stones (3) twelve apostles (1)	610	lock (1) doorhandle (3) doorknob (7) handle (1) key (2) key and doorknob (1) keyhole (1) key and lock (1) lock (1) lock and doorknob (1)
611	[blank] (1) cheese (1) dice (1) domino (13) domino block (1) dominoes (2)	612	book (7) checklist (1) contact book (1) diary (7) notebook (1) phonebook (1) to-do list (1)
613	bug (1) dragonfly (16) insect (1) mosquito (1)	614	architect (1) artist (11) artist drawing art tale (1) draftsman (1) drawer (1) painter (4)
615	cataloguing drawers (1) chest of drawers (1) draw (1) drawer (2) drawers (7) draws (3) tallboy (1) toolbox (2) tool chest (1)	616	bolt (1) cork (1) microphone (1) pin (10) pushpin (1) screw (1) tack (1) thumbtack (3)
617	drill (13) electric drill (2) power drill (1) screwdriver (3)	618	drumkit (11) drum (1) drummer (1) drums (5) drumset (1)
619	luggage (1) ambulance pack (1) bag (9) carry bag (1) duffle bag (2) luggage (1) sports bag (3) suitcase (1)	620	firecrackers (1) bomb (4) candle (1) cracker (1) dynamite (4) explosive (1) firecracker (1) firework (5) TNT (1)

Picture	Response (frequency)	Picture	Response (frequency)
621	[blank] (1) baby dummy (1) dummy (13) dummy or pacifier (1) pacifier (3)	622	emu (1) bird (1) emu (9) ostrich (8)
623	ear (19)	624	earrings (19)
625	wineglass (1) chalice (1) cup (8) eggcup (3) egg holder (2) goblet (3) wine cup (1)	626	[blank] (2) eggplant (12) grapefruit (1) pear (1) purple (1) vegetable (2)
627	escalator (18) escalators (1)	628	bucket (1) eskimo (1) eski (17)
629	charger (1) extension lead (1) cable (1) charger (1) cord (3) electrical cord (3) electric cord (1) extension cord (1) extension lead (1) plug (1) power cord (4) power plug (1)	630	[blank] (1) sword (1) duel (1) fencer (6) fencing (6) musketeer (1) sparing man (1) sword (1) swordfighter (1)
631	eye (19)	632	fist (19)
633	fence (16) picket fence (2) wooden picket fence (1)	634	fairy (7) fairy godmother (3) magician (2) princess (1) witch (3) wizard (3)
635	barn (1) building (2) buildings (1) chicken farm (1) factories (2) factory (11) industry (1)	636	barge (1) boat (4) decking (1) dock (1) ferry (6) river crossing boat (1) ship (5)

Picture	Response (frequency)	Picture	Response (frequency)
637	butterknife (2) chisel (2) file (3) filer (2) grater (1) instrument (1) knife (1) knife sharpener (1) nailfile (1) file (1) sander (2) server (1) tool (1)	638	[blank] (1) banner (3) decoration (2) decorations (3) festival ribbons (1) flag decorations (1) flags (2) parade (1) party streamers (1) bunting (1) streamers (3)
639	[blank] (1) fire hydrant (13) hose (1) tap (1) water (2) water distributor (1)	640	fireplace (16) fire (1) fire spot (1) open fire (1)
641	crane (1) fire engine (2) fire fighter (1) fire truck (13) truck (2)	642	fishing (1) boy (1) boy fishing (1) boy fishing off dock (1) fisher (3) fisher boy (1) fisherman (2) fishing (2) rod (1)
643	insect (1) bug (1) fly (16) moth (1)	644	garage (17) house (1) shed (1)
645	[blank] (3) fountain pen (2) hole maker (1) ink pen (1) paintbrush (1) pen (5) pencil (1) pointy thing (1) quill (2) quill pen (1) scalpel (1)	646	[blank] (2) rowing boat (1) ancient boat (1) boat (6) Chinese boat (2) galleon (1) gondola (1) pirate ship (1) rowboat (2) Viking ship (1) yacht (1)
647	dingo (1) fox (12)	648	frog (19)

Picture	Response (frequency)	Picture	Response (frequency)
649	bin (2) garbage man (10) garbage (1) garbage collector (1) man emptying rubbish (1) rubbish (2) rubbish collector (1) trash collector (1)	650	[blank] (3) gonzala (1) awning (1) birdhouse (1) bungalow (1) cabana (2) entertaining area (1) gazebo (4) hut (3) roof (1) sitting area (1)
651	clove of garlic (1) garlic (5) onion (1) pumpkin (12)	652	lizard (1) gecko (6) lizard (11) skink (1)
653	ghost (19)	654	cup (7) drinking glass (2) glass (10)
655	glasses (18) reading glasses (1)	656	gloves (18) glove (1)
657	atlas (1) earth (1) globe (13) world (4)	658	goggle (2) goggles (17)
659	[blank] (2) goal (4) goal and netting (1) goalie net (1) goalmouth (1) grate (1) net (4) rectangle (1) soccer goal (1) soccer goals (1) square (1) wall (1)	660	[blank] (2) bowl (1) cup (1) gravy (1) gravy boat (8) gravy dish (1) gravy holder (1) gravy jug (1) gravy pourer (1) milk (1) sauce (1)
661	[blank] (1) golf (4) golf club (1) golfer (13)	662	insect (1) bug (1) cockroach (1) cricket (8) grasshopper (8)
663	cemetery (1) cemetery plot (1) church (3) church form (1) crucifix (1) grave (10) podium (1) tombstone (1)	664	[blank] (3) bang board (1) dong (1) drum (3) gong (6) musical instrument (1) symbol (3) wheel (1)

Picture	Response (frequency)	Picture	Response (frequency)
665	[blank] (2) beheader (1) beheadment (1) chopping block (1) death (1) executor (1) guillotine (9) head chopper (1) saw (1) stand (1)	666	[blank] (1) mansion (1) dollhouse (1) hotel (1) house (7) lodge (1) mansion (3) shops (1) Tudor house (1) Tudor style home (1) wooden house (1)
667	gymnastic (4) gymnast (14) gymnastics (1)	668	burger (14) hamburger (5)
669	[blank] (2) hammock (16) hanger (1)	670	handcuffs (17) handcuff (2)
671	bridge (1) harp (14) instrument (1) music (1) violin (2)	672	bald head (1) bald (3) head (11) head profile (1) human (1) person in profile (1) profile face (1)
673	headphones (17) earphone (1) earphones (1)	674	baby chair (3) baby seat (1) highchair (15)
675	column heater (1) electric column heater (1) electric heater (1) gate (1) heater (14) oil heater (1)	676	club (1) golf club (1) hockey (1) hockey stick (14) knitting needle (1) stick (1)
677	[blank] (1) tool (1) clamp (1) cutters (1) garden snips (1) hedge trimmer (1) hedge trimmers (1) pliers (4) scissors (1) secateurs (1) shears (1) tool (3) tree clippers (1) wire cutters (1)	678	[blank] (2) clown hat (1) hat (1) horn (2) party blower (2) party hat (4) party horn (2) party whistle (1) party blower (1) streamer (1) trumpet (1) whistle for parties (1)

Picture	Response (frequency)	Picture	Response (frequency)
679	[blank] (1) bird (12) crane (2) egret (1) heron (1) pelican (1) stork (1)	680	[blank] (3) door hinge (1) doorjamb (1) hinge (13) screw (1)
681	bush (2) bushes (1) forest (6) hedge (6) hedges (1) hedge with birds (1) tree (1) two birds (1)	682	[blank] (4) dentist (1) gardening tool (1) hoe (7) plougher (1) rake (1) scraper (1) shovel (2) stick (1)
683	[blank] (1) golf (6) golf course (6) golf green (2) golf hole (2) putting green (1) the green (1)	684	barn (1) boatshed (2) cabin (4) cottage (2) cubbyhouse (1) demountable (1) house (7) shed (1)
685	hole punch (6) hole puncher (12) stapler (1)	686	[blank] (1) hook (17) toilet paper roll (1)
687	horse (19)	688	jug (19)
689	[blank] (1) eggtimer (1) hourglass (12) sand timer (1) timer (4)	690	suit (1) flannel (1) jacket (14) jumper (1) shirt (2)
691	double stick ice cream (1) ice block (11) ice blocks (1) ice cream (4) paddle pop (1) popsicle (1)	692	[blank] (2) arrow (2) bow (1) brush (2) paintbrush (5) spear (6) wand (1)
693	[blank] (1) fish (1) jellyfish (16) octopus (1)	694	jet ski (17) jet boat (1) water ski (1)

Picture	Response (frequency)	Picture	Response (frequency)
695	oil (1) bottle (1) container (1) fuel bottle (1) gasoline can (1) gas can (1) gas container (1) jerry can (7) petrol (1) petrol bottle (1) petrol can (2) petrol container (1)	696	[blank] (4) bottle (1) genie bottle (1) genie lamp (2) genies bottle (1) jug (2) lamp (3) oil jug (1) steel (1) vase (2) wine pourer (1)
697	tropical (1) boardwalk (1) bridge (1) decking (1) dock (3) jetty (2) pier (2) walkway (1) walkway above water (1) wharf (6)	698	jet (1) aeroplane (3) aircraft (1) fighter jet (1) fighter plane (1) grounds rocket (1) jet (6) jetfighter (1) jet plane (1) plane (3)
699	jelly (1) juicer (11) juice squeezer (1) Mexican hat (1) orange juicer (2) orange squasher (1) sombrero (1) sunbinarow (1)	700	[blank] (2) arrow (1) boat (1) bow (2) canoe (6) clip (1) disc (1) kayak (4) lid (1)
701	jumper (19)	702	knife (19)
703	kennel (8) doghouse (7) dogkennel (4)	704	bassdrum (1) bongodrum (1) drum (15) snaredrum (1) timpani (1)
705	keyboard (18) audience (1)	706	key ring (1) keys (11) set of keys (1)
707	fruit (3) papaya (1) kiwi (2) kiwifruit (10) melon (1) pomegranate (1) rockmelon (1)	708	horsemen (1) fight (1) horse (1) horse fighter (1) jouster (1) knight jousting (1) knight (11) pole jolter (1) soldier (1)

Picture	Response (frequency)	Picture	Response (frequency)
709	[blank] (1) knot (14) knotted cord (1) loop (1) rope (1) slipknot (1)	710	clothing tag (1) nametag (2) price tag (1) tag (14) ticket (1)
711	koala (19)	712	ladder (19)
713	utensil (1) ladle (11) scoop (1) scooper (1) soup server (1) soupspoon (1) spoon (3)	714	[blank] (1) babydeer (1) deer (5) fawn (2) lamb (9) sheep (1)
715	garden light (1) lamp (7) lantern (1) light (9) outside light (1)	716	autumn (1) leaf (16) maple leaf (2)
717	[blank] (1) leaf (1) leek (6) plant (1) plants (1) shallot (3) spring onion (1) squid (1) vegetable (2) weed (2)	718	lemon water (1) cool drink (1) fruit juice (1) juice (2) lemonade (10) lemon juice (2) orange juice (1) tropical drink (1)
719	binder (3) folder (16)	720	cheetah (4) jaguar (2) leopard (13)
721	mail (2) envelope (2) letter (15)	722	letterbox (9) mail (1) mailbox (9)
723	[blank] (1) log (1) balance beam (1) balancer for wood (1) beam (2) level (3) leveller (2) level measuring stick (1) metal bar (2) metal beam (1) ruler (1) spirit level (1) surface measurer (1) tool (1)	724	donut (1) buoy (1) floaty (2) floaty ring (1) life donut (1) life preserver (1) life raft (1) life ring (3) lifesaver (3) lifesaver ring (1) lifesaver tube (1) lifesaving ring (2) life raft (1)

Picture	Response (frequency)	Picture	Response (frequency)
725	leg (13)	726	lighthouse (19)
727	floating vest (1) lifejacket (9) life vest (5) vest (4)	728	goat (1) alpaca (4) goat (1) llama (13)
729	lion (19)	730	lipstick (19)
731	[blank] (1) cockroach (1) beetle (2) bug (4) Christmas beetle (1) flea (1) insect (3) lice (1) nit (1) scorpion (1) tick (3)	732	heart (2) heart and lungs (4) lungs (4) lungs and heart (1) organs (6) respiratory system and heart (1) respiratory system (1)
733	electric (1) horseshoe (1) magnet (17)	734	eye cover (1) mask (17) masquerade mask (1)
735	letterbox (3) mailbox (10) mail (1) post box (2) post office box (2) printer (1)	736	[blank] (1) match (5) matchstick (12) thermometer (1)
737	sofa (1) blow-up bed (1) cushion (1) mattress (16)	738	jug (2) measure cup (1) measuring cup (8) measuring jug (8)
739	builder (1) construction worker (1) handyman (4) man (1) mechanic (1) painter (1) plumper (1) scientist (1) tradesman (2) tradesmen (1) tradesperson (1) worker (3) workman (1)	740	[blank] (1) jar (1) bottle (1) can (2) canister (1) container (1) drum (1) food (1) gas (1) gas tank (1) jug (2) milk can (1) milk urn (1) pot (1) urn (1) vat urn (1) watering container (1)

Picture	Response (frequency)	Picture	Response (frequency)
741	medal (18) gold medal (1)	742	carousel (8) Ferris wheel (1) merry-go-round (10)
743	mic (2) microphone (16) telescope (1)	744	bike (1) motorbike (16) motorcycle (2)
745	coke (1) cup (4) drink (4) drink cup (1) fast food drink (1) milkshake (6) soda cup (1) takeaway drink (1)	746	[blank] (1) glove (7) gloves (1) mitt (1) mitten (4) mittens (3) oven mitt (1) punching glove (1)
747	[blank] (2) amp (2) device (1) DVD player (2) hard drive (2) internet (1) machine (1) modem (3) player (1) remote control (1) set-top box (1) speaker (1) technology (1)	748	[blank] (2) building (1) church (2) Islamic temple (1) mosque (9) observatory (1) temple (3)
749	railroad (1) freeway (2) highway (7) motorway (1) road (5) road lane (1) road signs (1) tollway (1)	750	[blank] (1) note (1) crotchet (1) musical note (4) music note (7) music symbol (1) note (1) semiquaver (1) treble clef (2)
751	computer mouse (3) mouse (16)	752	mummy (19)
753	arm (1) arm flexing (1) bicep (4) muscle (5) muscles (8)	754	ballerina (3) box (1) jewellery box (10) music box (5)
755	dipstick (1) nail (18)	756	napkins (1) handkerchief (3) napkin (14) tissue (1)

Picture	Response (frequency)	Picture	Response (frequency)
757	necklace (10) bead (1) beaded necklace (1) bracelet (1) pearl necklace (3) pearls (3)	758	brush (1) hanging rope (1) hangman's noose (1) knot (1) loop (1) noose (9) rope (5)
759	notepad (17) pad (1) sketchpad (1)	760	[blank] (1) nutcracker (11) chestnut (1)
761	nun (19)	762	pencil (19)
763	[blank] (4) boat motor (3) can opener (1) engine (1) motor (3) motorboat (1) ninja (1) outboard motor (2) propeller (1) staple gun (1) tap (1)	764	a board (1) artist palette (1) paint (7) paint board (1) painter (1) paint holder (1) painting palette (1) paint palette (1) paint set (1) palette (4)
765	[blank] (2) crate (3) pallet (10) planks (1) wood (2) wooden frame (1)	766	bin (11) dustbin (1) garbage bin (1) rubbish (1) rubbish bin (3) trashcan (2)
767	Chinese panda bear (1) panda (16) panda bear (2)	768	jeans (1) pants (15) trousers (3)
769	beach umbrella (4) umbrella (15)	770	pelican (18) seagull (1)
771	[blank] (1) peeler (12) comb (1) grater (2) tool (1) vege peeler (1) vegetable peeler (1)	772	[blank] (1) penholder (1) pencil (2) pencil box (1) pencil holder (7) pencils (3) pencil tin (3) stationery (1)
773	garlic (1) onion (18)	774	sharpener (14) pencil sharpener (5)
775	hexagon (4) pentagon (13) shape (2)	776	pineapple (19)

Picture	Response (frequency)	Picture	Response (frequency)
777	[blank] (6) bell (2) clamp (1) grinder (2) hydrant (1) pepper grinder (2) pepper (2) pepper cracker (1) salt and pepper grinder (1) tool (1)	778	[blank] (2) submarine scope (1) binocular (1) periscope (3) snorkel (2) spy scope (1) submarine (5) submarine lookout (1) submarine sight (1) telescope (1) water (1)
779	bowser (2) fuel (1) gaspump (2) petrol (4) petrolbowser (2) petrolpump (5) petrolstation (1) petroltank (1) pump (1)	780	[blank] (2) acorn (1) cocoon (1) fruit (2) pineapple (4) pinecone (7) pine nut (1) porcupine (1)
781	piggy account (1) money bank (1) piggybank (16) piggybank moneybox (1)	782	bag (1) clam (1) flour (1) nut (1) pastry (1) pillow (14)
783	board (1) corkboard (6) noticeboard (5) pin board (5) wall (1) whiteboard (1)	784	[blank] (2) laminator (4) paper roll (1) presser (1) printer (5)
785	grand piano (1) pianist (7) piano (8) piano man (1) piano player (1) pianist (1)	786	cone (4) hat (5) magicians hat (1) white hat (1) witches hat (8)

Picture	Response (frequency)	Picture	Response (frequency)
787	[blank] (8) arrow (1) boat rudders (1) bow (1) farming implement (1) farm machinery (1) plough (1) plougher (1) shovels (1) soil plougher (1) tractor equipment (1) unsure (1)	788	[blank] (1) gym (1) acrobat horse (1) balance beam (1) beam (1) bubblers (1) gym beam (1) gymnast horse (1) gymnastic (1) gymnastic equipment (1) gymnastics (1) gymnastics horse (1) handles (2) mini boat (1) pommel horse (2) saw bench (1) vault (1)
789	pool (8) swimming pool (11)	790	popcorn (19)
791	[blank] (2) animal (1) echidna (8) hedgehog (3) porcupine (4) rat (1)	792	[blank] (1) insect (2) krill (1) lobster (3) prawn (10) shrimp (2)
793	typewriter (1) computer printer (1) photocopier (1) printer (16)	794	overhead (1) light projector (1) microscope (1) overhead projector (4) projector (12)
795	[blank] (1) marionette (1) muppet (1) puppet (15) string puppet (1)	796	[blank] (1) vegetable (1) beetroot (4) feather (1) onion (2) radish (6) turnip (3) veggie (1)
797	pyramid (19)	798	razor (13) shaver (6)
799	radio (17) portable radio (1) transistor radio (1)	800	bird (4) crow (12) magpie (3)

Picture	Response (frequency)	Picture	Response (frequency)
801	[blank] (2) bamboo mat (2) flute (2) mat (1) musical instrument (1) musical pipe (1) outdoor mat (1) pencils (1) raft (2) rug (2) sticks (1) stick shaft (1) sushi mat (1)	802	[blank] (2) boards (1) concertina screen (1) divider (3) dressing curtain (1) dressing room (1) Japanese wall (1) partisan folding screen (1) privacy screen (1) room divider (2) screen (2) shade (1) wall (2)
803	stereo (1) CD player (1) music player (1) player (1) record (1) recorder (1) record player (13)	804	coach (1) ref (3) referee (13) umpie (1) umpire (1)
805	chair (2) rocking (1) rocking chair (16)	806	ring (15) diamond ring (1) engagement ring (3)
807	[blank] (2) fettuccini (1) peels (1) ribbon (11) rope (1) string (1) tape (2)	808	cereal (1) bowl (2) bowl of rice (1) bowls of rice (1) chopsticks (1) rice (13)
809	chicken (8) cooked chicken (1) roast chicken (7) roast chook (1) roast turkey (1) turkey (1)	810	boat (7) dingy (1) paddleboard (1) rowboat (7) rowing boat (2) tinny (1)
811	rocket (19)	812	rhino (13) rhinoceros (6)
813	barn (1) attic (2) roof (15) rooftop (1)	814	ropes (1) cable (2) cord (2) rope (13) twine or cord (1)

Picture	Response (frequency)	Picture	Response (frequency)
815	cross (4) cross necklace (2) crucifix necklace (1) Marys beads (1) necklace (4) religious necklace (1) rosary (3) rosary beads (3)	816	[blank] (1) horse strap (1) riding saddle (1) saddle (15) western saddle (1)
817	blow-up boat (1) boat (3) canoe (1) inflatable boat (1) inflatable boat and oars (1) inflatable dingy (1) inflatable raft (1) lifeboat (4) paddleboat (1) raft (1) rescue boat (1) row (1) rowboat (1) white-water raft (1)	818	aerobic (1) aerobics (2) aerobics class (1) aerobics trainer (1) athletic person (1) athlete (1) exercise (3) exercising (2) fitness (1) fitness step (1) gym class (1) runner (1) sprinter (1) step up (1) work out (1)
819	captain (3) fat nautical man (1) fisherman (3) man (1) sail man (1) sailor (7) Santa (1) seaman (2)	820	peppershaker (1) salt (4) salt and pepper (2) salt and pepper shaker (1) salt or pepper shaker (1) salt pepper shaker (1) saltshaker (7) shaker (1) sugar (1)
821	pizza (1) cheese slice (1) sandwich (17)	822	crab (1) lobster (2) scorpion (16)
823	antenna (2) microphone (1) satellite (12) satellite dish (3) telescope (1)	824	clarinet (1) instrument (1) saxophone (14) trumpet (3)
825	balance (1) balancer (1) balancing scales (1) measuring device (1) scale (3) scales (10) weigher (1) weights (1)	826	scanner (1) copy machine (1) drawing board (1) photocopier (5) scanner (9) tape player (1) walkman (1)
827	seatbelt (19)	828	scarf (19)

Picture	Response (frequency)	Picture	Response (frequency)
829	[blank] (2) catholic church (1) chace (1) cross (1) king stick (1) orb (1) priests wand (1) sceptre (4) spear (1) staff (1) stick (2) sword (2) wand (1)	830	chalkboard (1) display (1) music stand (2) presentation (1) projection (1) projection screen (1) projector (3) projector screen (5) screen (3) stand (1)
831	screwdriver (18) screw (1)	832	seesaw (18) balancer (1)
833	[blank] (2) axe (1) digger (1) execution spade (1) flag (3) gold (1) grim reaper (1) hunting knife (1) picker (1) scythe (3) sickle (2) staff (1) sword (1)	834	geometry set (1) measuring tool (1) protractor (2) right-angled measuring ruler (1) right-angled triangle (1) rule (1) ruler (2) setsquare (1) set triangle (1) triangle (3) triangle for measuring (1) triangle measure (1) triangle measurer (1) triangle ruler (1) triangular ruler (1)
835	seahorse (19)	836	seal (19)
837	crow (1) scarecrow (18)	838	goat (1) lamb (1) sheep (17)
839	[blank] (1) art (1) badge (1) card (1) iron shield (1) shield (13) sign (1)	840	barn (1) box (6) crate (6) wooden box (4) wooden cargo box (1) wooden crate (1)

Picture	Response (frequency)	Picture	Response (frequency)
841	shirt (11) button-up shirt (1) dress shirt (2) folded polo-shirt (1) folded shirt (1) men's shirt (1) pressed shirt (1) shirt or blouse (1)	842	shooting (1) army troop (1) gun (4) gunman (1) gun shooter (1) gun shooting (1) hunter (1) man shooting gun (1) marksman (1) shooter (7)
843	board shorts (2) pants (5) shorts (12)	844	shower (5) showerhead (14)
845	[blank] (1) hook (13) knife (1) scythe (2) sickle (2)	846	sink (15) basin (1) kitchen sink (2) kitchen sink and tap (1)
847	singer (18) singing (1)	848	skateboard (19)
849	singlet (11) singlet top (1) t-shirt (1)	850	skewer (5) kebab stick (2) kebab (11) shish kebab (1)
851	[blank] (2) blade (1) knife (1) plane (1) pocketknife (1) ski (5) skis (2)	852	[blank] (3) chocolate (7) chocolate bar (1) food covering (1) notepad (1) sleeping bag (6)
853	[blank] (1) skipping rope (15) jump rope (2) rope (1)	854	arm (1) arm in sling (2) broken arm (3) sling (7)
855	skull head (1) human skull (1) skull (17)	856	slipper (1) slippers (18)
857	[blank] (3) bix (1) card swiper (1) don't know (1) light projector (1) machine (1) overhead (1) projector (9) tool (1)	858	cash register (3) machine (1) money (1) money counter (1) poker machine (5) pokey (1) pokie machine (1) pokies (3) slot machine (3)

Picture	Response (frequency)	Picture	Response (frequency)
859	bricks or wall (1) brick wall (15) wall (2)	860	snowman (19)
861	sock (19)	862	spider (18) insect (1)
863	[blank] (1) breathing tube (1) joint (1) pipe (3) pole (1) snorkel (11) tube (1)	864	spatula (1) eggflip (1) egg lift (1) egg lifter (1) spatula (15)
865	stereo (1) speaker (12) speaker for sound system (1) speakers (5)	866	caterpillar (2) bones (1) spinal column (2) spine (8)
867	[blank] (1) light (8) lighting (1) satellite (1) spotlight (5) stage light (2) torch (1)	868	deer (1) antelope (3) antler (1) deer (9) elk (1) gazelle (1) mountain goat (2) reindeer (1)
869	disinfectant (1) spray bottle (11) spray (5) spray can (1) windex (1)	870	ring (1) amphitheatre (1) arena (2) coliseum (1) stadium (13) theatre (1)
871	circus (1) curtains (5) show (1) stage (9) stage curtains (1) theatre curtain (1) theatre set (1)	872	note (1) postage stamp (2) postal stamp (1) post stamp (1) stamp (13) sticker (1)
873	stairs (17) steps (2)	874	stapler (18) staple (1)
875	[blank] (1) starfish (11) aniseed (1) banana peel (1) flower (3) leaves (1) star anise (1)	876	boat wheel (1) helm (1) sailing wheel (1) sea wheel (1) ships wheel (3) ship wheel (3) steering wheel (1) wheel (7) wheel for a boat (1)

Picture	Response (frequency)	Picture	Response (frequency)
877	liberty (3) empire state building (1) new york (1) statue of liberty (14)	878	[blank] (1) crutches (3) ores (1) poles (1) stilts (11) walking sticks (2)
879	stereo system (1) cassette player (1) CD player (1) DJ (1) jukebox (1) music box (1) music player (1) record player (7) sound system with record player (1) stereo (2) stereo unit (1) tape recorder (1)	880	[blank] (2) bamix (1) blender (3) electric mixer (1) electric razor (1) electric stick blender (1) food blender (1) food processor (2) grinder (1) hand beater (1) hand blender (1) handheld tool (1) masher (1) mixer (1) stirrer (1)
881	oven (9) stove (9) stove oven (1)	882	men's dress suit (1) suit (16) uniform (1) uniform or PJs (1)
883	garden light (1) lamp (5) lamppost (5) lantern (1) light (3) light post (2) road light (1) streetlight (1)	884	[blank] (1) mat (2) ambulance bed (1) bed (1) stretcher (13) tale (1)
885	pram (16) stroller (3)	886	ship (1) submarine (18)
887	[blank] (1) workmen (1) camera (2) construction (1) construction worker (1) conveying (1) explorer (1) photographer (2) photography (1) surveyor (5) telescope (2) tradesmen (1)	888	[blank] (1) knife (1) chain claws (1) key ring (1) multi-tool (2) pocketknife (3) swiss army knife (6) swiss army pocket knife (1) swiss knife (2) tools (1)

Picture	Response (frequency)	Picture	Response (frequency)
889	swimmer (17) swimming (1) yoga (1)	890	swing (18) tree swing (1)
891	bathers (1) cozzie (1) leotard (2) one-piece (2) swimmers (2) swimming costume (4) swimsuit (7)	892	sword (1) cutlass (1) machete (1) scythe (1) sword (15)
893	sawfish (1) fish (2) marlin (1) swordfish (15)	894	fish scale (1) axolotl (1) fish (2) frog (1) tadpole (14)
895	pony (1) hair (1) horsetail (6) ponytail (8) tail (3)	896	army (3) army tank (1) army tanks (1) military tank (1) tank (13)
897	sticky tape (2) tape (16) tape measure (1)	898	tape (1) measuring tape (8) tape measure (9) tape measurer (1)
899	bag (2) kite (1) tea (1) teabag (15)	900	blackboard (1) board (1) chalkboard (3) teacher (14)
901	kettle (3) teapot (16)	902	phone (5) telephone (14)
903	receptionist (1) assistant (1) making a phone call (1) phone (3) phone operator (1) receptionist (2) salesman (1) telemarketer (5) telephone (3) telephonist (1)	904	chair (1) chair crown (1) king chair (1) monarch chair (1) queen (1) queens throne (1) royal (1) royal throne (1) throne (11)
905	[blank] (1) court (1) tennis (1) tennis court (16)	906	batter (1) squash (3) squash player (1) tennis (4) tennis player (10)

Picture	Response (frequency)	Picture	Response (frequency)
907	[blank] (2) block (2) board game (1) border (1) square (2) stained-glass window (1) stamp (1) tile (7) window (2)	908	logs (1) boards (1) pales (1) planks (4) planks of wood (4) timber palings (1) wood (5) wood planks (2)
909	tie (17) necktie (2)	910	toaster (19)
911	can (15) tin (1) tin can (1) tuna (2)	912	tissue (5) tissue box (5) tissues (9)
913	baby (15) toddler (4)	914	pumpkin (2) tomato (17)
915	brush (1) toothbrush (18)	916	flashlight (2) torch (17)
917	glue (1) paint (1) toothpaste (17)	918	[blank] (1) camper trailer (1) trailer (17)
919	car (1) gardening (1) lawnmower (2) mower (2) ride-on mower (1) tractor (12)	920	[blank] (1) give-way sign (1) road sign (2) sign (10) signpost (3) street sign (2)
921	lights (2) stop sign (1) traffic (2) traffic light (4) traffic lights (10)	922	triangle (16) triangle chime (1) triangle instrument (2)
923	train (18) truck (1)	924	ceremonial cup (1) trophy (18)
925	pirate jewellery (1) box (1) chest (1) jewellery box (4) treasure (2) treasure box (1) treasure chest (9)	926	[blank] (1) log (2) stump (2) tree head (1) tree stump (12) trunk (1)

Picture	Response (frequency)	Picture	Response (frequency)
927	[blank] (3) carrier (1) crate carrier (1) holder (1) lifting trolley (1) lifts heavy objects (1) moving device (1) trolley (8) wheel carrier (1) wheeler (1)	928	carriage (1) chariot (1) chariot racing (1) disabled jockey (1) equestrian (1) horse (3) horse cart (1) horse rider (3) horseracing (1) jockey and horse (1) racehorse (1) racing (1) trotter (2) trotter racing horse (1)
929	bird (4) pelican (1) toucan (13) tookie bird (1)	930	[blank] (1) mountain tunnel (1) tunnel (17)
931	lady (1) receptionist (1) register (1) typer (3) typewriter (7) typist (6)	932	truck wheel (1) truck tyre (2) tyre (8) wheel (8)
933	[blank] (1) monocycle (1) unicycle (17)	934	suit (1) vest (18)
935	[blank] (1) alien (1) dracula (6) evil (1) evil magician (1) evil prankster (1) monster (1) vampire (5) villain (1) warlock (1)	936	driveway (1) home (1) houses (4) mansion (1) neighbourhood (2) school (1) villa (1) village (8)
937	[blank] (1) camcorder (2) camera (7) video camera (9)	938	[blank] (1) volcano (17) mountain (1)
939	butler (1) chef (1) waiter (17)	940	almond (1) chestnut (1) nut (10) seed (1) walnut (6)

Picture	Response (frequency)	Picture	Response (frequency)
941	headphones (1) cassette player (2) headphones (2) MP (1) m-player (1) mp-player (1) music player (4) portable music (1) stethoscope (1) tape player (2) tape recorder (1) walkman (2)	942	plant (1) flower (1) foliage (1) lily pad (4) lilies (1) lily pad and lotus (1) lily (5) lily pads (1) rose (1) waterlily (3)
943	seal (8) walrus (11)	944	[blank] (1) waterfall (18)
945	clothes dryer (1) dryer (3) front loader washing machine (1) washer (1) washing machine (13)	946	hose (1) tap (8) water pump (7) water tank (1) water tap (2)
947	waterhole (1) water well (2) well (14) wishing well (2)	948	fish (1) shark (1) sperm whale (1) whale (16)
949	weed (1) bluebells (1) corn (3) cornflower (1) flower (2) plant (1) plant stem (1) wattle (1) wheat (7) wheat chaff (1)	950	boat (2) sail (2) sailboarding (1) sailboat (3) sailing boat (1) sail ski (1) windsailing (1) windsurfer (1) windsurfing board (1) yacht (6)
951	bin (14) council bin (1) otto bin (1) rubbish bin (1) wheelie bin (2)	952	[blank] (1) monkey wrench or spanner (1) spanner (8) tool (3) wrench (6)
953	cupboard (6) window (13)	954	[blank] (1) witch (18)
955	wind willow (1) air turbine (1) turbine (1) wind fan (1) windmill (11) wind turbine (3) wind wheel (1)	956	worktable (1) bench (2) bench top (1) desk (1) table (1) table for building (1) tool bench (1) workbench (11)

Picture	Response (frequency)	Picture	Response (frequency)
957	snake (2) worm (17)	958	yoyo (19)
959	glockenspiel (1) instrument (1) music (2) musical instrument (1) toy (1) xylophone (13)	960	[blank] (1) elderly (1) frame (1) walker (7) walking frame (7) walking stick (2)

Appendix I

Stimulus materials from Experiment 4-1b

Table I-1. Sentences from the onset-competitor condition of Experiment 4-1b. Critical words are marked in bold.

	Sentence
1	The woman explained to her friend that a **buffer** is a type of chemical solution
2	On the other side of the street she saw a **bulldog** with a few little puppies
3	Slowly but steadily the **burden** was getting too heavy for the donkey
4	The box did not contain the **butter** that the customer had ordered
5	She was under the impression that the **capital** of Australia was Melbourne instead of Canberra
6	He hoped nobody would notice that the **caramel** he just made tasted a little bit funny
7	He finally realised it was a **chickpea** that was blocking the drain in the kitchen
8	My mother didn't really like the **cloud** that suddenly appeared on the horizon
9	They didn't have a **coffee** that satisfied all the customers' wishes
10	There was a typo in the word **collarbone** but the rest of the letter was flawless
11	He asked his brother to have a look at the **collar** of their dog and make sure it still fit
12	Initially she thought she heard him say **comfort** but afterwards she wasn't so sure anymore
13	She had asked him to draw her an **eskimo** but the result did not look very good
14	She was sure that this had been a **factor** in the decision-making process
15	The artist found it difficult to draw the **grape** and decided to take a little break
16	He had never seen a **hamster** that was as active as this one
17	My neighbour insisted that the **handle** he bought yesterday was made of plastic
18	He didn't know if the **hint** they gave him was helpful at all
19	I pointed out to her that the **lettuce** had already started to wither
20	It doesn't happen very often that you see a **lighter** with a picture of an angel on it
21	The boy had no idea how to spell the word **magnifier** but he tried anyway
22	There were several stores that sold the **microwave** that he had been looking for
23	The baby tried to grab the **nectarine** but he couldn't reach far enough
24	In a matter of minutes the **panic** that he felt subsided and he felt calm again
25	She was not sure whether the **penalty** for the other team was totally fair
26	I was really impressed with the **pirouette** that my sister performed during her dance show
27	The man told me that the **queue** to the museum starts all the way around the corner
28	The writer crossed out the word **scapegoat** and replaced it with a different word
29	It took me a while to notice that my friend has a **scar** on the left side of her forehead
30	He wondered whether the **score** would be high enough to win the game
31	Towards the back of the room he saw the **sculpture** that was allegedly created by a famous artist

	Sentence
32	As we got closer to the **seaside**, we could smell the salt in the air
33	It was barely visible that the **socket** needed some repairs and would be unsafe to use in that state
34	After a while he realised that the **spiral** had stopped moving altogether
35	Nobody had told the woman that the **stable** had already been sold
36	The girl found a drawing of a **throat** in her biology book and studied it closely
37	The winning story concerned a **villain** who turned his life around because he fell in love
38	It took her a while to find the **wallpaper** that she wanted for her nursery
39	It's hard to imagine that the **winter** is nearly over because it hasn't even been cold yet
40	He swore he couldn't see the **wrinkle** that I was sure I had spotted on my forehead

Table I-2. Sentences from the rhyme-competitor condition of Experiment 4-1b. Critical words are marked in bold.

	Sentence
41	The people next to me were talking about the **actor** from Home and Away that they couldn't stand
42	My brother misspelled the word **bladder** but passed his exams anyway
43	She was trying to find a **block** that fit on top of the castle she had built
44	He didn't like the **bumper** of his new car because its colour did not match the rest of the car
45	It was my own suggestion to move the **choir** a bit to the other side of the stage for the finale
46	The woman insisted that the **class** she taught on Tuesdays was very entertaining
47	My father read in the paper that a **crane** had collapsed at a nearby building site
48	I asked my brother if he still had a **crush** on that girl he met at a party
49	According to my grandfather the **dairy** he used to work for still exists today
50	He doesn't really like the **drama** his girlfriend tends to cause when he cancels a date
51	I kept my fingers crossed and luckily the **drizzle** that was predicted never appeared
52	My father never really liked the **felt** on the inside of his hat because it made his head itch
53	My cousin showed me where the **fennel** was, so we could start cooking dinner
54	He started to tell me a complicated story about a **fox** that he had seen at the zoo last weekend
55	He searched everywhere, even under the **fridge**, but he could not find his reading glasses
56	The teacher explained the word **funnel** to her students by drawing a picture on the blackboard
57	There must have been a **grain** of truth in his words but I didn't believe everything he said
58	I think you should have used the **grill** for this dish instead of the oven
59	They were unsure if the **groom** would arrive in time for his wedding
60	My sister asked if she should expect a **guest** to join us for dinner tonight
61	My sister was thinking the **iron** was broken but she had merely forgotten to plug it in
62	The old man picked up the **kitten** and put it back with its mother
63	I started to think that the **list** they sent me was very incomplete
64	After a while my sister got tired of carrying the **paddle** so her friend took over from her
65	My grandmother really liked the **parrot** that her neighbour got for his birthday
66	She couldn't quite reach the **pedal** of the organ as the seat of her chair was too high
67	I noticed a strange pattern on the **pocket** of my favourite pair of jeans
68	The man knew that the **rank** of his new colleague was higher than his own
69	She complained to me that her **rib** still hurt from when she fell down the stairs
70	Luckily, he seemed to have the **sense** of responsibility that was required for his new job
71	Just behind the door was a **snail** that had managed to get into the house
72	During my art course we had to draw the **sparrow** that the teacher had brought in in a cage

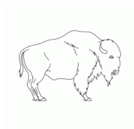
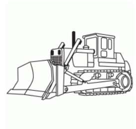
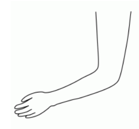
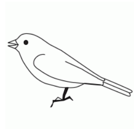
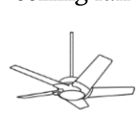
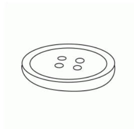
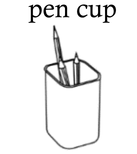
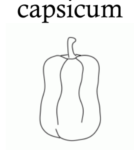
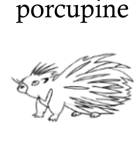
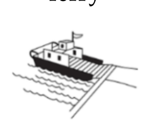
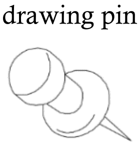
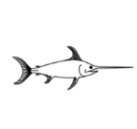
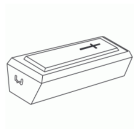
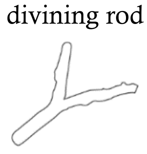
	Sentence
73	My friend mentioned that the **stress** she experiences at work is starting to affect her health
74	She simply assumed that the **switch** was broken, because nothing happened when she flicked it
75	The woman gave her daughter a small **task** to keep her busy during the school holidays
76	I just noticed that the **toast** my father has for breakfast is much darker than mine
77	It is generally quite difficult to find a **tool** of good quality in this shop
78	He took a very blurry photo of a **tower** when he was on his honeymoon
79	After he had another look at the **willow**, the gardener decided not to trim it after all
80	On the weekend I bought a **zucchini** that had the shape of a banana

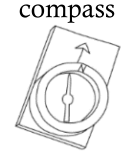
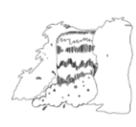
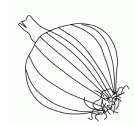
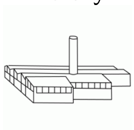
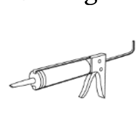
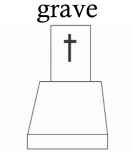
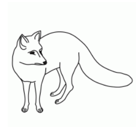
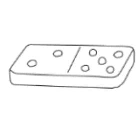
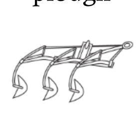
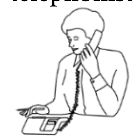
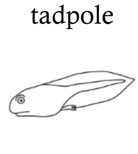
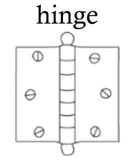
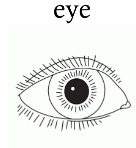
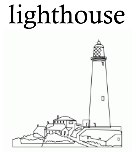
Table I-3. Filler sentences from Experiment 4-1b Target words are marked in bold.

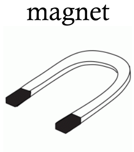
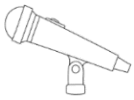
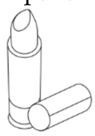
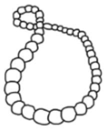
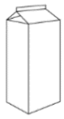
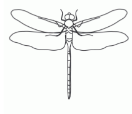
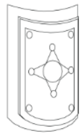
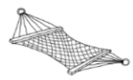
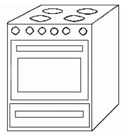
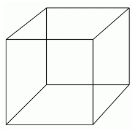
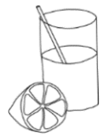
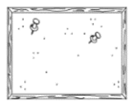
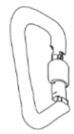
	Sentence
81	I can't figure out whether this **avocado** is ripe enough to eat today
82	The woman was quite surprised that the **baguette** came out of the oven without being burned
83	The photo that won the competition showed a **ballerina** in the middle of a very high jump
84	She didn't want to get too close to the **barbecue** because she was afraid she'd get burned
85	He didn't believe his friend, so he went over to the **bench** and saw for himself that the paint was still wet
86	The men hoped that the **boomgate** would open properly when they left the carpark
87	The boy was still talking about the **calculator** three months after he got it
88	She wondered if anyone had seen the **calf** yet that was born in the petting zoo last week.
89	After a few days, the **certificate** she had worked so hard for arrived in the mail
90	He refused to believe that the **chicken** I served had been bought from the supermarket
91	I didn't expect to find the **coin** that I'd lost when I was looking for my car keys
92	It looked like he didn't notice the **cord** until he nearly tripped over it
93	The man complained to his wife about the **cyclist** who had nearly hit him when he crossed the road
94	It took quite a bit of effort, but the **doorknob** on the back door turns very smoothly again
95	In the middle of the night the **frog** suddenly started making a lot of noise
96	I don't think it's a good idea to touch that **gecko** because you never know if it will bite
97	My father didn't manage to draw a **grasshopper**, even after trying several times
98	The man wanted the **gymnast** to practise for at least another hour
99	She asked me to get her some **headphones** that would look a bit more fashionable
100	She thought she was very lucky that her **heater** had not broken down at all last winter
101	When she returned to the room, she saw an **hourglass** that had nearly run out
102	When I closed my eyes, it was almost as if this **iceblock** tasted more like strawberry than like lemon
103	My mother asked me to take the **kayak** out of the shed and give it a good clean
104	She asked her husband to get the **keyboard** and attach it to their new computer
105	The auctioneer said the painting of a **koala** had been very difficult to sell
106	After some deliberation, he picked up the **razor** and threw it in the bin
107	They couldn't believe their eyes when the **referee** indicated there had been a foul
108	I saw my friend struggle, so I offered to take the **ribbon** and tie it around the present for her
109	Without any help my brother couldn't get the **rope** tied around the bag of rubbish properly
110	The boy asked me to show him the **scarecrow** that I had put up in our backyard
111	Initially, the woman didn't see the **seahorse** because it had hidden behind a piece of coral
112	They were curious to find out if the **seal** would show up next to their boat again

	Sentence
113	I don't think he fully understood why the **seatbelt** wasn't working but he nodded his head anyway
114	In the end I convinced my father that the **sink** in the laundry really had to be fixed
115	The man walked out of his driveway and noticed a **ski** sticking out of his neighbour's car
116	My friend is going into town tomorrow to buy a new **suit** for his job interview next week
117	It certainly looks as if that **tile** near the sink needs to be replaced soon
118	One of our neighbours happened to mention that the **toothpaste** I always buy will be on special next week
119	She chose the picture of the **treasure** and started colouring it in with her crayons
120	It is very difficult to spot the **well** in the corner of that old photograph

Table I-4. Pictures from the onset-competitor condition of Experiment 4-1b. Sentence numbers correspond to those listed in Table I-1.

Sentence	Critical word	Competitor	Distractor	Distractor	Distractor
1	buffer	buffalo 	note 	palette 	canoe 
2	bulldog	bulldozer 	cork 	singer 	arm 
3	burden	bird 	director's chair 	ceiling fan 	unicycle 
4	butter	button 	notepad 	pen cup 	kettle drum 
5	capital	capsicum 	sword 	porcupine 	ferry 
6	caramel	caravan 	crutch 	toucan 	sickle 
7	chickpea	chicken 	drawing pin 	skipping rope 	submarine 
8	cloud	clown 	rice 	swordfish 	dynamo 
9	coffee	coffin 	rocking chair 	scales 	drawer 
10	collar	colander 	walking frame 	shorts 	divining rod 

Sentence	Critical word	Competitor	Distractor	Distractor	Distractor
11	collarbone	cauliflower 	hut 	piggybank 	stretcher 
12	comfort	compass 	printer 	waterfall 	hook 
13	eskimo	escalator 	ant 	onion 	peeler 
14	factor	factory 	extension cord 	surveyor 	caulk gun 
15	grape	grave 	pianist 	fox 	domino 
16	hamster	hamburger 	speaker 	plough 	telephonist 
17	handle	handcuff 	rhinoceros 	businessman 	tadpole 
18	hint	hinge 	tail 	bumper car 	eye 
19	lettuce	letter 	caveman 	barn 	stroller 
20	lighter	lighthouse 	toddler 	cake server 	heron 

Sentence	Critical word	Competitor	Distractor	Distractor	Distractor
21	magnifier	magnet 	rowboat 	springbok 	jerry can 
22	microwave	microphone 	lipstick 	coveralls 	sleeping bag 
23	nectarine	necklace 	half-timbered house 	carton 	dragonfly 
24	panic	panda 	hole 	shield 	typist 
25	penalty	pencil 	hammock 	gloves 	stove 
26	pirouette	pyramid 	telephone 	waterlily 	lamb 
27	queue	cube 	sandwich 	mouse 	file 
28	scapegoat	skateboard 	radish 	vampire 	lemonade 
29	scar	scarf 	pin board 	canning jar 	chestnut 
30	score	scorpion 	carabiner 	dynamite 	jacket 

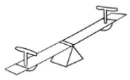
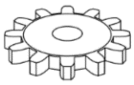
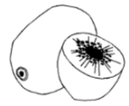
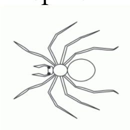
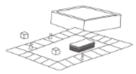
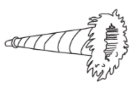
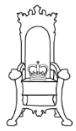
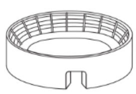
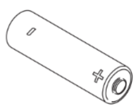
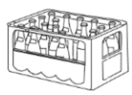
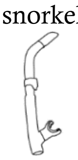
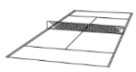
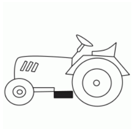
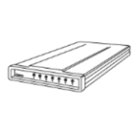
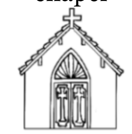
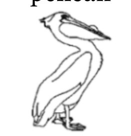
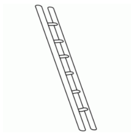
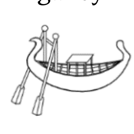
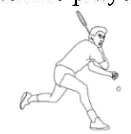
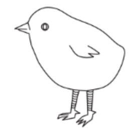
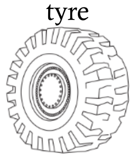
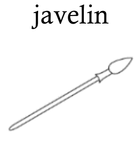
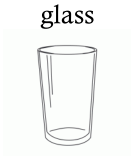
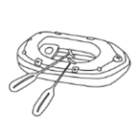
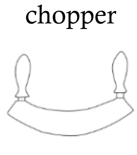
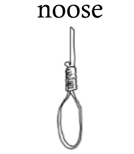
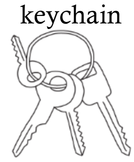
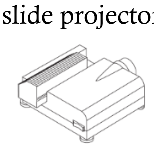
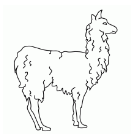
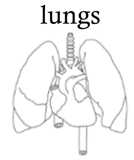
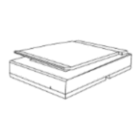
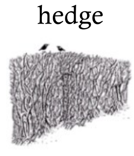
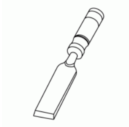
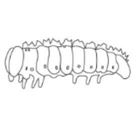
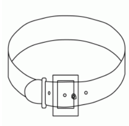
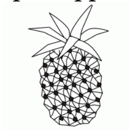
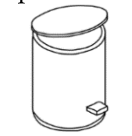
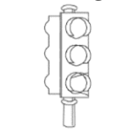
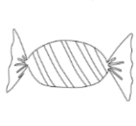
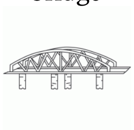
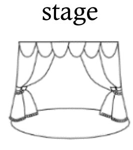
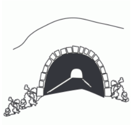
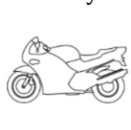
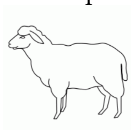
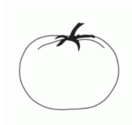
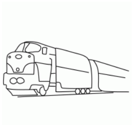
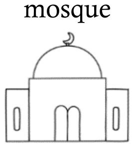
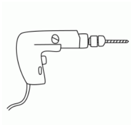
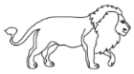
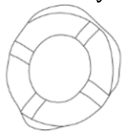
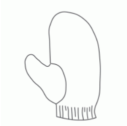
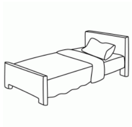
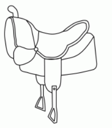
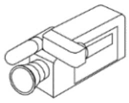
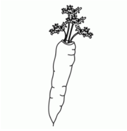
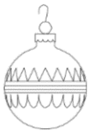
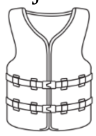
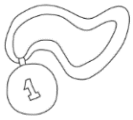
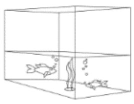
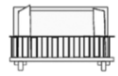
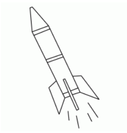
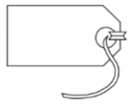
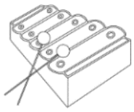
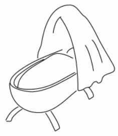
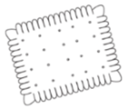
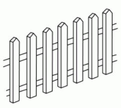
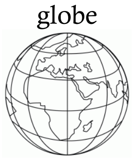
Sentence	Critical word	Competitor	Distractor	Distractor	Distractor
31	sculpture	skull 	fountainpen	leaf 	bunting 
32	seaside	seesaw 	dog 	dandelion 	cog 
33	socket	sock 	lantern 	emu 	kiwifruit 
34	spiral	spider 	waiter 	traffic sign 	board game 
35	stable	stapler 	checkerboard 	horn 	bathrobe 
36	throat	throne 	milk can 	stadium 	battery 
37	villain	village 	crate 	hoe 	toaster 
38	wallpaper	walnut 	snorkel 	triangle 	astronaut 
39	winter	window 	jug 	barbed wire 	scythe 
40	wrinkle	ring 	louse 	tennis court 	tissues 

Table I-5. Pictures from the rhyme-competitor condition of Experiment 4-1b. Sentence numbers correspond to those listed in Table I-2.

Sentence	Critical word	Competitor	Distractor	Distractor	Distractor
41	actor	tractor 	modem 	chapel 	pelican 
42	bladder	ladder 	stereo 	volcano 	galley 
43	block	clock 	whale 	saxophone 	tennis player 
44	bumper	jumper 	chick 	fencer 	deep fryer 
45	choir	tyre 	dishes 	javelin 	glasses 
46	class	glass 	fisherman 	wind turbine 	mattress 
47	crane	brain 	rubber boat 	chopper 	spatula 
48	crush	brush 	spotlight 	fireplace 	conductor 
49	dairy	fairy 	noose 	keychain 	slide projector 
50	drama	llama 	lungs 	scanner 	hedge 

Sentence	Critical word	Competitor	Distractor	Distractor	Distractor
51	drizzle	chisel 	sling 	caterpillar 	wheat 
52	felt	belt 	knife 	pineapple 	eggcup 
53	fennel	kennel 	stamp 	slot machine 	pedal bin 
54	fox	box 	traffic light 	spine 	candy 
55	fridge	bridge 	cot 	starfish 	stage 
56	funnel	tunnel 	motorcycle 	sheep 	tomato 
57	grain	train 	mosque 	fly 	tape 
58	grill	drill 	bedside table 	pinecone 	singlet 
59	groom	broom 	knot 	pommel horse 	awning 
60	guest	vest 	jellyfish 	torch 	bus stop 

Sentence	Critical word	Competitor	Distractor	Distractor	Distractor
61	iron	lion 	drawers 	lifebuoy 	balaclava 
62	kitten	mitten 	spray bottle 	salt 	goggles 
63	list	fist 	cloverleaf 	bed 	windsurf board 
64	paddle	saddle 	video camera 	worm 	nun 
65	parrot	carrot 	bauble 	lifejacket 	teapot 
66	pedal	medal 	walrus 	aquarium 	balcony 
67	pocket	rocket 	washing machine 	snowman 	label 
68	rank	tank 	umbrella 	xylophone 	hockey stick 
69	rib	crib 	satellite dish 	letterbox 	biscuit 
70	sense	fence 	apple core 	toothbrush 	globe 

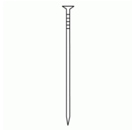
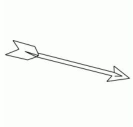
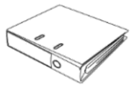
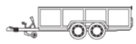
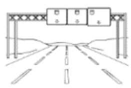
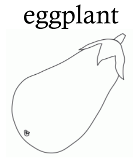
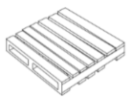
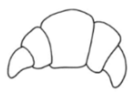
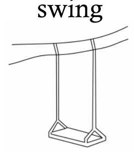
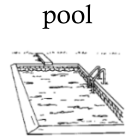
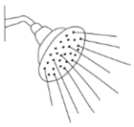
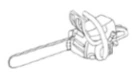
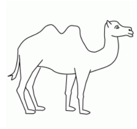
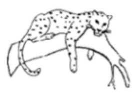
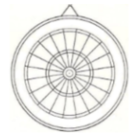
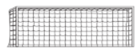
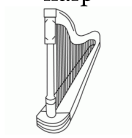
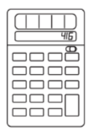
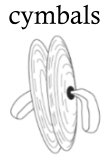
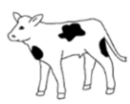
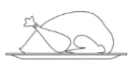
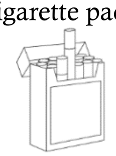
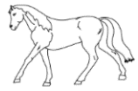
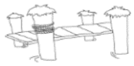
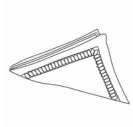
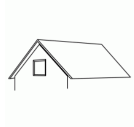
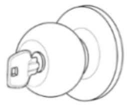
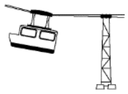
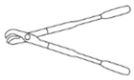
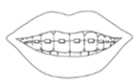
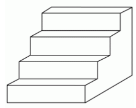
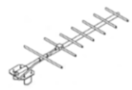
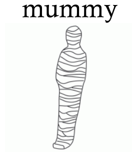
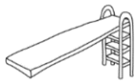
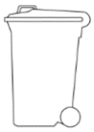
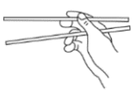
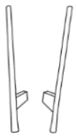
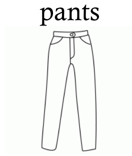
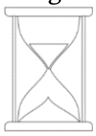
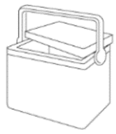
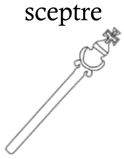
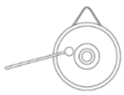
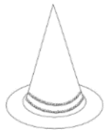
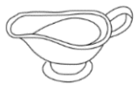
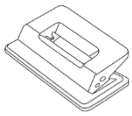
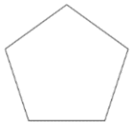
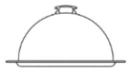
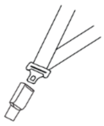
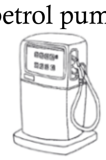
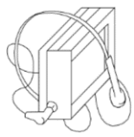
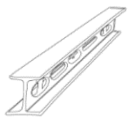
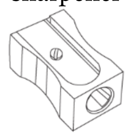
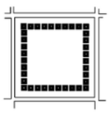
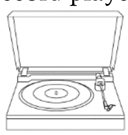
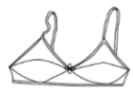
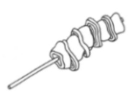
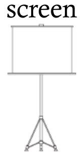
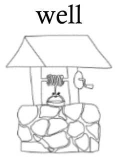
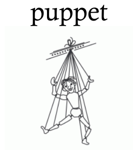
Sentence	Critical word	Competitor	Distractor	Distractor	Distractor
71	snail	nail 	juicer 	highchair 	tie 
72	sparrow	arrow 	lever arch folder 	trailer 	leg 
73	stress	dress 	ladle 	motorway 	tin 
74	switch	witch 	raft 	garbage collector 	eggplant 
75	task	mask 	pallet 	bean 	croissant 
76	toast	ghost 	mechanic 	swing 	mailbox 
77	tool	pool 	shirt 	knight 	music box 
78	tower	shower 	cave 	swiss army knife 	sailor 
79	willow	pillow 	chainsaw 	merry-go-round 	canteen 
80	zucchini	bikini 	cassette 	rosary 	ambulance 

Table I-6. Filler pictures from Experiment 4-1b. Sentence numbers correspond to those listed in Table I-3.

Sentence	Target word	Target	Distractor	Distractor	Distractor
81	avocado	avocado 	centaur 	garage 	trophy 
82	baguette	baguette 	camel 	leopard 	water pump 
83	ballerina	ballerina 	cocktail 	dartboard 	campervan 
84	barbecue	barbecue 	goal 	harp 	raven 
85	bench	bench 	statue of liberty 	fire hydrant 	earrings 
86	boom gate	boom gate 	teacher 	chair 	collecting box 
87	calculator	calculator 	swimmer 	cymbals 	trotter 
88	calf	calf 	periscope 	banjo 	golfer 
89	certificate	certificate 	guillotine 	steering wheel 	workbench 
90	chicken	chicken 	cigarette pack 	jetfighter 	runner 

Sentence	Target word	Target	Distractor	Distractor	Distractor
91	coin	coin 	horse 	slippers 	measuring cup 
92	cord	cord 	bag 	jetty 	napkin 
93	cyclist	cyclist 	gazebo 	boar 	roof 
94	doorknob	doorknob 	cable car 	hedge clippers 	braces 
95	frog	frog 	basket 	belly dancer 	stairs 
96	gecko	gecko 	jetski 	antenna 	mummy 
97	grasshopper	grasshopper 	streetlight 	setsquare 	diving board 
98	gymnast	gymnast 	wheelie bin 	timber 	stick blender 
99	headphones	headphones 	chopsticks 	stilts 	pants 
100	heater	heater 	cheese slicer 	muscle 	swimsuit 

Sentence	Target word	Target	Distractor	Distractor	Distractor
101	hourglass	hourglass 	apron 	ice skate 	eski 
102	ice block	ice block 	shooter 	drum set 	ear 
103	kayak	kayak 	projector 	dancer 	radio 
104	keyboard	keyboard 	badminton 	nutcracker 	popcorn 
105	koala	koala 	peppermill 	sceptre 	gong 
106	razor	razor 	pointed hat 	dummy 	duffel bag 
107	referee	referee 	prawn 	dolmen 	coffee grinder 
108	ribbon	ribbon 	candle 	teabag 	gravy boat 
109	rope	rope 	garlic 	shipping crate 	baby bottle 
110	scarecrow	scarecrow 	hole puncher 	bat 	pentagon 

Sentence	Target word	Target	Distractor	Distractor	Distractor
111	seahorse	seahorse 	cloche 	tape measure 	firetruck 
112	seal	seal 	plotter 	match 	room divider 
113	seatbelt	seatbelt 	cupcake 	trunk 	jug 
114	sink	sink 	chariot 	diary 	petrol pump 
115	ski	ski 	milkshake 	walkman 	yoyo 
116	suit	suit 	level 	pencil sharpener 	outboard motor 
117	tile	tile 	record player 	wrench 	bra 
118	toothpaste	toothpaste 	clover 	skewer 	screen 
119	treasure	treasure 	bobsleigh 	head 	leek 
120	well	well 	clef 	screwdriver 	puppet 

Appendix J

Additional analyses of Experiment 4-1b

Analyses reported below were conducted over a 600 ms time interval, starting at 300 ms after critical word onset. Competitor preference ratios for each type of competitor in both noise types are shown in Figure J-1.

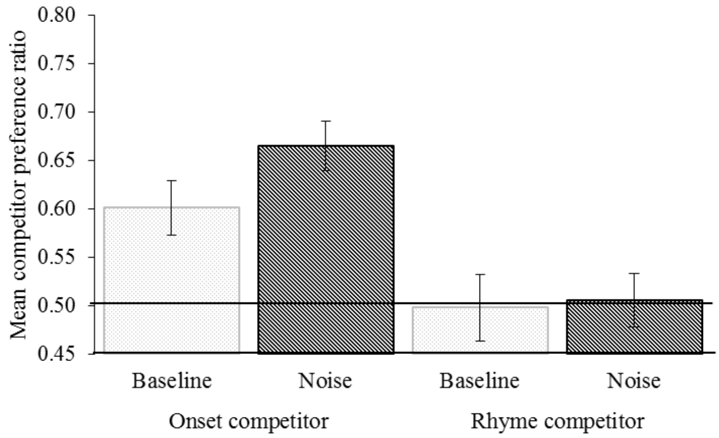


Figure J-1. Mean competitor preference ratios in Experiment 4-1b for onset and rhyme competitors, in clean speech and in noise, in the additional analysis window. Error bars represent standard errors of the means.

One-sample two-tailed *t*-tests by participants (1) and by items (2) showed that onset competitors were fixated significantly more than distractors, both in the baseline condition [$M_1 = 0.60$, $t_1(15) = 3.62$, $p = .003$; $M_2 = 0.57$, $t_2(39) = 2.49$, $p = .017$], and in the noise condition [$M_1 = 0.67$, $t_1(15) = 6.46$, $p < .001$; $M_2 = 0.62$, $t_2(39) = 3.35$, $p = .002$]. Rhyme competitors, however, did not attract more looks than distractors, neither in the baseline condition [$M_1 = 0.50$, $t_1(15) = 0.07$, $p = .948$; $M_2 = 0.47$, $t_2(39) = 0.97$, $p = .338$], nor in the noise condition [$M_1 = 0.51$, $t_1(15) = 0.20$, $p = .844$; $M_2 = 0.49$, $t_2(39) = 0.33$, $p = .745$]. This points to lexical competition from the onset competitors but not from the rhyme competitors.

The time course of competitor fixations was then analysed to determine whether listeners' looking patterns changed when noise bursts occurred in the auditory stimuli. This was done in the same way as described in section 4.1.2.2). Results of the regression analysis are shown in Table J-1.

Table J-1. Results of LMER analyses of competitor fixations in Experiment 4-1b in the additional analysis window.

Effect	By-participants			By-items		
	Est.[c]	SE	*t*-value	Est.[c]	SE	*t*-value
(Intercept)	-1.03	.08	-12.85*	-1.05	.09	-12.28*
Time	0.86[a]	.23	3.66*	0.93[b]	.21	4.48*
Noise Type	0.23	.16	1.44	0.19	.15	1.21
Competitor Type	-0.52	.16	-3.31*	-0.44	.17	-2.61*
Time * Noise Type	-0.23	.38	-0.60	-0.05	.36	-0.15
Time * Competitor Type	-0.18	.38	-0.48	-0.14	.42	-0.33
Noise Type * Competitor Type	0.09	.31	0.29	0.01	.31	0.04
Time * Noise Type * Competitor Type	-0.61	.75	-0.81	-0.86	.71	-1.21

* $p < .05$

† $p < .10$

[a]random slopes for participants and participants over aggregated items

[b]random slopes for items and items over aggregated participants

[c] Est. = estimated coefficient

The regression analysis shows a main effect of Competitor Type, which indicates that over the entire critical time window and averaged across both noise types, onset competitors attracted more looks than rhyme competitors (see the competitor preference ratios in Figure J-1). No other significant main effects or interactions were found.

Appendix K

Additional analyses of Experiment 4-2

The analyses reported below were conducted for a time interval that started at 300 ms after critical word onset and lasted 600 ms. Figure K-1 displays competitor preference ratios for each competitor type and noise type. As in Experiment 4-1, competitor preference ratios were compared to 0.5 in a one-sample two-tailed *t*-test by participants (1) and by items (2). Onset competitors were fixated significantly more than distractors, both in the baseline condition [M_1 = 0.63, $t_1(23) = 4.64$, $p < .001$; M_2 = 0.62, $t_2(39) = 4.79$, $p < .001$], and in the noise condition [M_1 = 0.65, $t_1(23) = 8.29$, $p < .001$; M_2 = 0.62, $t_2(39) = 5.08$, p < .001]. Rhyme competitors, however, did not attract more looks than distractors, neither in the baseline condition [M_1 = 0.53, $t_1(23) = 1.57$, $p = .130$; M_2 = 0.52, $t_2(39) = 0.61$, $p = .546$], nor in the noise condition [M_1 = 0.50, $t_1(23) = 0.03$, $p = .975$; M_2 = 0.50, $t_2(39) = 0.08$, $p = .938$]. Thus listeners experienced competition from onset competitors both in clean speech and in noise, but did not experience competition from rhyme competitors in either condition.

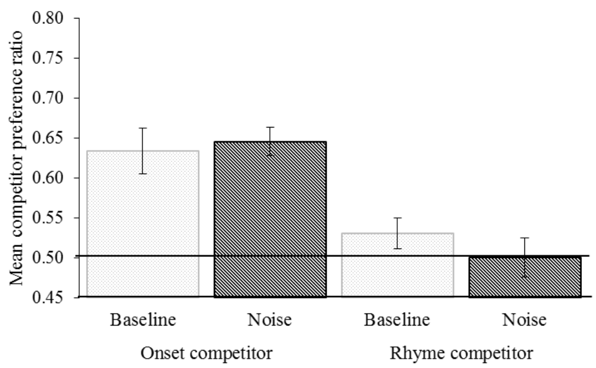


Figure K-1. Mean competitor preference ratios in Experiment 4-2 for onset and rhyme competitors, in clean speech and in noise, in the additional analysis window Error bars represent standard errors of the means.

The time course of competitor fixations was analysed following the same method with LMER models as described in section 4.2.1.2. Results of this regression analysis are shown in Table K-1.

Table K-1. Results of LMER analyses of competitor fixations in Experiment 4-2 in the additional analysis window.

Effect	By-participants			By-items		
	Est.[c]	SE	*t*-value	Est.[c]	SE	*t*-value
(Intercept)	-0.95	.07	-13.74*	-0.94	.07	-14.31*
Time	0.69[a]	.18	3.83*	0.64[b]	.16	4.07*
Noise Type	-0.06	.13	-0.48	-0.07	.12	-0.56
Competitor Type	-0.33	.13	-2.53*	-0.24	.13	-1.83†
Time * Noise Type	0.01	.36	0.03	0.08	.32	0.81
Time * Competitor Type	-0.79	.36	-2.19*	-0.92	.32	-2.90*
Noise Type * Competitor Type	0.05	.26	0.21	0.04	.24	0.18
Time * Noise Type * Competitor Type	-0.66	.72	-0.92	-0.48	.63	-0.76

* $p < .05$

† $p < .10$

[a]random slopes for participants over aggregated items

[b]random slopes for items over aggregated participants

[c] Est. = estimated coefficient

The regression analysis shows a main effect of Competitor Type in the by-participants analysis, although this effect does not quite reach significance in the by-items analysis. This effect suggests that over the entire critical time window, onset competitors attracted more looks than rhyme competitors (see competitor preference ratios displayed in Figure K-1). Finally, the analysis shows a significant interaction between Time and Competitor Type, with a β-value of -0.79, which indicates that the slope of fixations to onset competitors was steeper than the slope of fixations to rhyme competitors. No main effect of Noise Type was found, nor any interactions involving this fixed predictor.

Appendix L

Additional analyses of Experiment 4-5

The analyses reported below were carried out over a 600 ms time interval, starting at 300 ms after critical word onset for the onset-competitor condition and at 800 ms for trials in the rhyme-competitor condition. Competitor preference ratios for these time windows are shown in Figure L-1. In a one-sample two-tailed *t*-test by participants (1) and by items (2), competitor preference ratios were compared to 0.5. Onset competitors were fixated significantly more than distractors in both the baseline condition [$M_1 = 0.67$, $t_1(15) = 9.67$, $p < .001$; $M_2 = 0.65$, $t_2(24) = 5.88$, $p < .001$] and the noise condition [$M_1 = 0.65$, $t_1(15) = 7.78$, $p < .001$; $M_2 = 0.64$, $t_2(24) = 6.11$, $p < .001$]. Rhyme competitors, however, did not attract more looks than distractors, neither in the baseline condition [$M_1 = 0.52$, $t_1(15) = 0.85$, $p = .410$; $M_2 = 0.51$, $t_2(24) = 0.25$, $p = .802$], nor in the noise condition [$M_1 = 0.53$, $t_1(15) = 1.31$, $p = .209$; $M_2 = 0.53$, $t_2(24) = 1.10$, $p = .280$]. These findings suggest that listeners experienced competition in clean speech and in noise from onset competitors but not rhyme competitors.

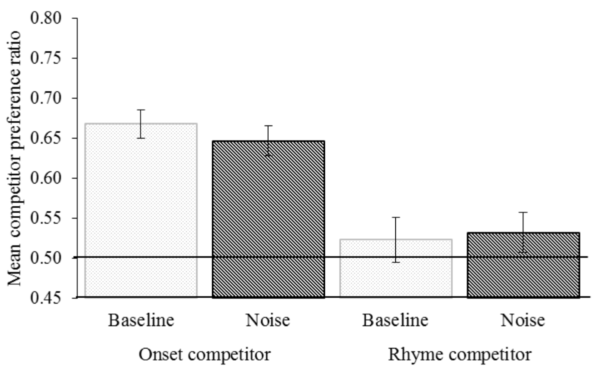


Figure L-1. Mean competitor preference ratios in Experiment 4-5 for onset and rhyme competitors, in clean speech and in noise, in the additional analysis window. Error bars represent standard errors of the means.

The time course of competitor fixations was analysed with LMER models, using the same method described in section 4.2.4.2. The results of the regression analyses are shown in Table L-1.

Table L-1. Results of LMER analyses of competitor fixations in Experiment 4-5 in the additional analysis window.

Effect	By-participants			By-items		
	Est.[c]	SE	*t*-value	Est.[c]	SE	*t*-value
(Intercept)	-0.88	.08	-11.74*	-0.89	.08	-11.72*
Time	0.65[a]	.19	3.34*	0.64[b]	.21	2.99*
Noise Type	-0.17	.15	-1.10	-0.12	.13	-0.88
Competitor Type	-0.07	.13	-0.57	-0.05	.15	-0.35
Time * Noise Type	0.48	.39	1.25	0.23	.43	0.55
Time * Competitor Type	-1.64	.39	-4.24*	-1.68	.43	-3.94*
Noise Type * Competitor Type	0.16	.26	0.55	0.33	.27	1.24
Time * Noise Type * Competitor Type	-0.15	.77	-0.19	-0.77	.85	-0.90

* $p < .05$

[a] random slopes for participants over aggregated items

[b] random slopes for items over aggregated participants

[c] Est. = estimated coefficient

There is a significant interaction between Time and Competitor Type. Since onset competitors were coded with -0.5, the β-value of -1.64 for this interaction indicates that the slope of fixations to onset competitors was steeper than the slope of fixations to rhyme competitors. No main effect of Noise Type was found, nor any interactions involving this fixed predictor, which implies that the presence of noise bursts in the signal did not influence listeners’ looking behaviour.

Appendix M

Stimulus materials from Experiment 5-2

first-syllable stress	second-syllable stress
booking	bouquet
campus	campaign
carton	cartoon
cashew	cashier
convent	convex
distance	distinct
district	distress
diver	divert
harpist	harpoon
humid	humane
impact	impress
influence	inform
liquid	liqueur
massive	masseur
motive	motel
music	museum
mystic	mistake
robot	robust
ruler	roulette
typhus	typhoon
union	unique

Appendix N

Additional analyses of lexical competition and language dominance for Experiment 4-1a

The results displayed in Table N-1, Table N-2, and Table N-3 below were obtained with LMER analyses over the 1s time interval from 400-1400 ms from critical word onset. This is the same analysis window that was used for the cross-language comparison for experiment 4-1. Analyses were conducted as described in section 6.1.2.

Table N-1. Results of LMER analyses of competitor fixations in Experiment 4-1a (L1) for self-reported language dominance, in the additional analysis window.

Effect	By-participants		
	Est.[b]	SE	*t*-value
(Intercept)	-0.85	0.10	-8.29*
Time	-0.01[a]	0.15	-0.05
Competitor Type	-0.49	0.16	-3.09*
Language Dominance	0.15	0.21	0.75
Time * Competitor Type	0.52	0.29	1.78†
Time * Language Dominance	-0.12	0.29	-0.42
Competitor Type * Language Dominance	-0.13	0.32	-0.43
Time * Competitor Type * Language Dominance	-0.81	0.59	-1.39

* $p < .05$

† $p < .10$

[a] random slopes for participants over aggregated items

[b] Est. = estimated coefficient

Table N-2. Results of LMER analyses of competitor fixations in Experiment 4-1a (L1) for proficiency-based language dominance, in the additional analysis window.

Effect	By-participants		
	Est.[b]	SE	*t*-value
(Intercept)	-0.89	0.09	-9.90*
Time	-0.02[a]	0.20	-0.12
Competitor Type	-0.42	0.18	-2.36*
Language Dominance	0.39	0.18	2.15*
Time * Competitor Type	0.53	0.31	1.69
Time * Language Dominance	0.05	0.40	0.14
Competitor Type * Language Dominance	-0.22	0.36	-0.62
Time * Competitor Type * Language Dominance	-0.50	0.62	-0.81

* $p < .05$

[a] random slopes for participants and participants over aggregated items

[b] Est. = estimated coefficient

Table N-3. Results of LMER analyses of competitor fixations in Experiment 4-1a (L1) for L1-use language dominance, in the additional analysis window.

Effect	**By-participants**		
	Est.[b]	SE	*t*-value
(Intercept)	-0.85	0.09	-9.49*
Time	0.02[a]	0.17	0.13
Competitor Type	-0.51	0.17	-2.93*
Language Dominance	0.01	0.18	0.06
Time * Competitor Type	0.54	0.28	1.94†
Time * Language Dominance	-0.37	0.34	-1.08
Competitor Type * Language Dominance	0.59	0.35	1.71
Time * Competitor Type * Language Dominance	-1.23	0.56	-2.21*

* $p < .05$
† $p < .10$
[a] random slopes for participants and participants over aggregated items
[b] Est. = estimated coefficient

The analysis in Table N-1 found no significant main effects or interactions that involved the predictor Language Dominance.

The analysis in Table N-2 shows a main effect of Language Dominance, and the β-value of 0.39 indicates that competitors attracted more fixations from L2-dominant listeners than from L1-dominant listeners.

The analysis in Table N-3 shows a main effect of Competitor Type (more looks to onset competitors) and a significant interaction between Time, Competitor Type and Dominance. To interpret this interaction, mean fixation proportions for onset and rhyme competitors in the baseline condition were plotted separately for each dominance group (see Figure N-1). This shows that, as expected, the L1-dominant listeners experience a strong competition from onset competitors and experience rhyme competition both at an earlier and at a later point in time. The competition that L2-dominant listeners experience occurs at a similar time for onset and rhyme competitors.

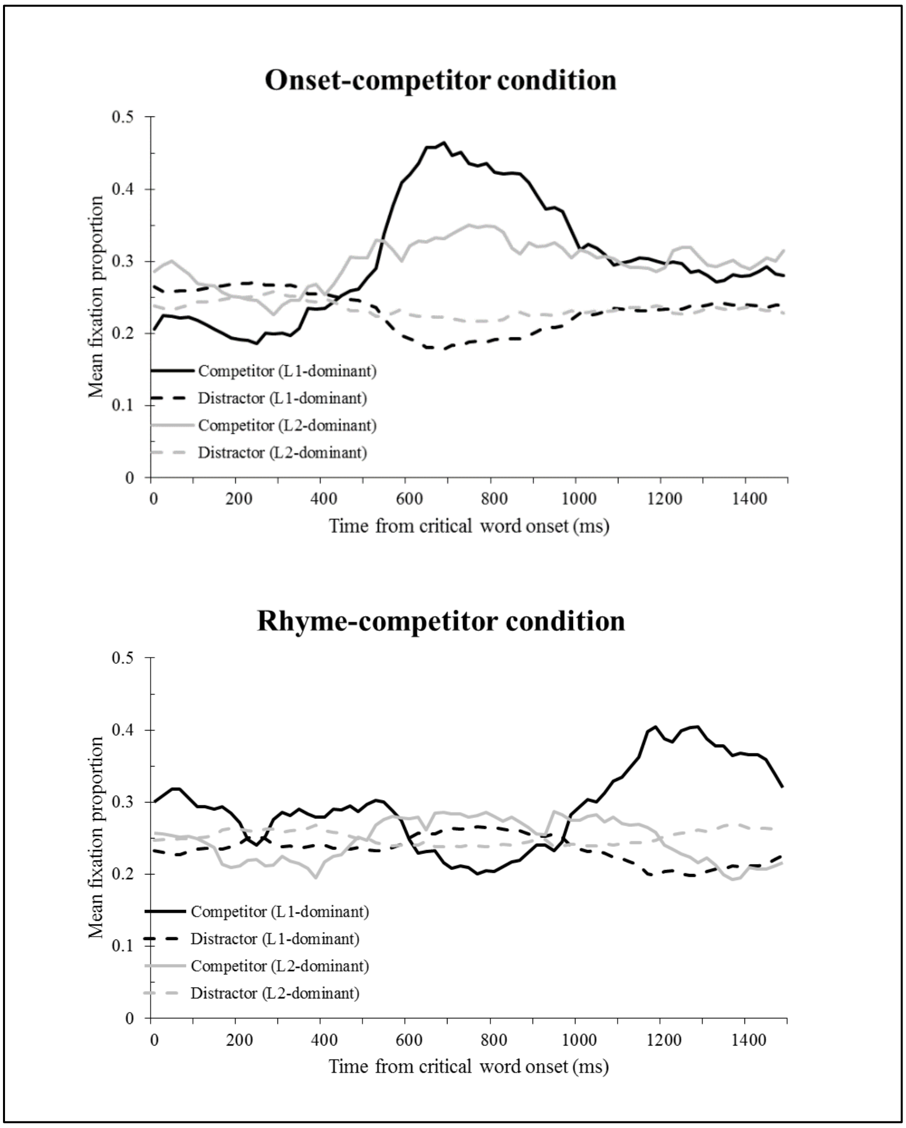


Figure N-1. Mean fixation proportions from critical word onset for the onset-competitor condition (top) and the rhyme-competitor condition (bottom) for L1- and L2-dominant listeners as per the L1-use measure.Fixations are plotted from critical word onset, for competitors and distractors.

Appendix O

Additional analyses of lexical competition and language dominance for Experiment 4-1b

The results displayed in Table O-1, Table O-2, and Table O-3 below were obtained with LMER analyses over the 1s time interval from 400-1400 ms from critical word onset. This is the same analysis window that was used for the cross-language comparison for experiment 4-1. Analyses were conducted as described in section 6.1.2 and revealed no significant main effects or interactions involving the predictor Language Dominance.

Table O-1. Results of LMER analyses of competitor fixations in Experiment 4-1b (L2) for self-reported language dominance, in the additional analysis window.

Effect	By-participants		
	Est.[b]	SE	*t*-value
(Intercept)	-0.88	0.12	-7.64*
Time	0.25[a]	0.17	1.49
Competitor Type	-0.42	0.23	-1.84†
Language Dominance	0.14	0.23	0.59
Time * Competitor Type	0.15	0.34	0.45
Time * Language Dominance	-0.34	0.34	-0.99
Competitor Type * Language Dominance	-0.33	0.46	-0.71
Time * Competitor Type * Language Dominance	0.09	0.68	0.13

* $p < .05$

† $p < .10$

[a] random slopes for participants and participants over aggregated items

[b] Est. = estimated coefficient

Table O-2. Results of LMER analyses of competitor fixations in Experiment 4-1b (L2) for proficiency-based language dominance, in the additional analysis window.

Effect	By-participants		
	Est.[b]	SE	*t*-value
(Intercept)	-0.91	0.13	-7.00*
Time	0.27[a]	0.18	1.50
Competitor Type	-0.38	0.26	-1.44
Language Dominance	0.04	0.26	0.14
Time * Competitor Type	-0.03	0.37	-0.09
Time * Language Dominance	0.24	0.37	0.65
Competitor Type * Language Dominance	-0.03	0.52	-0.06
Time * Competitor Type * Language Dominance	0.55	0.73	0.75

* $p < .05$

[a] random slopes for participants and participants over aggregated items

[b] Est. = estimated coefficient

Table O-3. Results of LMER analyses of competitor fixations in Experiment 4-1b (L2) for L1-use language dominance, in the additional analysis window.

Effect	By-participants		
	Est.[b]	SE	*t*-value
(Intercept)	-0.87	0.12	-7.19*
Time	0.21[a]	0.17	1.20
Competitor Type	-0.37	0.24	-1.53
Language Dominance	0.21	0.24	0.88
Time * Competitor Type	0.06	0.35	0.17
Time * Language Dominance	-0.34	0.35	-0.99
Competitor Type * Language Dominance	-0.32	0.48	-0.66
Time * Competitor Type * Language Dominance	-0.01	0.69	-0.01

* $p < .05$

[a] random slopes for participants and participants over aggregated items

[b] Est. = estimated coefficient

Appendix P

Conference proceedings paper ICPhS 2015

Older listeners' decreased flexibility in adjusting to changes in speech signal reliability

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ABSTRACT

Under noise or speech reductions, young adult listeners flexibly adjust the parameters of lexical activation and competition to allow for speech signal unreliability. Consequently, mismatches in the input are treated more leniently such that lexical candidates are not immediately deactivated. Using eyetracking, we assessed whether this modulation of recognition dynamics also occurs for older listeners. Dutch participants (aged 60+) heard Dutch sentences containing a critical word while viewing displays of four line drawings. The name of one picture shared either onset or rhyme with the critical word (i.e., was a phonological competitor). Sentences were either clear and noise-free, or had several phonemes replaced by bursts of noise. A larger preference for onset competitors than for rhyme competitors was observed in both clear and noise conditions; performance did not alter across condition. This suggests that dynamic adjustment of spoken-word recognition parameters in response to noise is less available to older listeners.

Keywords: Spoken-word recognition, aging, processing dynamics, hearing loss.

1. INTRODUCTION

When listeners try to understand speech, they have to segment a continuous stream of speech input into separate words. This is not a trivial task, as it is not always clear where one word ends and the next one begins and because longer words can contain embeddings of shorter words. As the speech signal unfolds, words that overlap with parts of the speech signal are activated in the listener's mind until they are no longer supported by the speech signal and can be ruled out as viable candidates. The words that 'win' this lexical competition are those words that account best for the speech input without leaving any phonemes unaccounted for [10].

In normal listening conditions, words that overlap with the start of the spoken word (onset competitors, e.g., *circus-circle*) compete more strongly for recognition than words that overlap with the end of the spoken word (rhyme competitors, e.g., *cent-tent*). Studies using the visual world paradigm, in which participants' eye movements are recorded as they hear speech while viewing visual displays, have found that onset competitors typically attract more looks than unrelated distractor pictures [1]. Rhyme competitors also attract more looks than unrelated distractors but these effects are much smaller and occur later in time [1, 12]. Under adverse listening conditions, however (e.g., casually articulated speech or noise), younger adults adjust these competition processes [4, 11]. Consequently, mismatch between a lexical candidate and the incoming speech signal no longer necessarily leads to immediate de-activation of the candidate word; onset competitors compete *less* strongly, and rhyme competitors compete *more* strongly than in ideal listening conditions. This is explained as listener adjustments for the decreased reliability of the speech signal.

Participants in [4] and [11], as indeed in most studies of speech perception, were undergraduates. This flexibility in adjustment of competitor evaluation in word recognition is potentially one of the pillars of the robustness of speech perception under difficult listening conditions. Extensive research on speech perception in aging listeners, however, has shown that in adverse listening conditions, older listeners cope less well than younger listeners and that the disparity cannot be explained fully by hearing loss [5, 6]. In particular, inhibitory capacities have been argued to decline with age, which may influence the extent to which older adults are able to suppress lexical competitors [15, 18]. Like younger adults, older listeners show a fairly strong onset-competitor effect and a rhyme-competitor effect that is smaller than the onset-competitor effect [e.g., 2, 14] but their ability to adjust competitor relationships under adverse conditions has not been investigated.

In this study, we assessed whether native Dutch listeners, aged 60 years and over, adjust lexical competition when the speech signal is occasionally interrupted by bursts of noise. The saccadic motor system appears to be largely unaffected by aging [13], so we conducted an eyetracking experiment based closely on [11]. We did not use their exact methodology, but instead adapted it in light of the characteristics of our participant population. Older participants typically exhibit more individual differences than younger participants. We therefore changed the presence of noise bursts in the speech signal from a between-subjects variable to a within-subjects variable, i.e., all participants were presented both with sentences from the baseline (noise-free) condition and with sentences from the noise condition. This approach reduces the variance due to between-subject variability.[i]

If older listeners flexibly adjust competitor evaluation in response to the decreased reliability of the speech input, we expect a weaker onset-competitor effect and a stronger rhyme-competitor effect when noise is added to the speech signal.

2. METHOD

2.1. Participants

Twenty-two participants (11 males) from the subject pool of the MPI for Psycholinguistics in Nijmegen, the Netherlands, were paid for their participation in this study. Seven additional participants' results were excluded due to calibration difficulties. All participants were native speakers of Dutch, aged 62–85 years (*M*=69.8, *SD*=6.5), with normal or corrected-to-normal vision. None of the participants wore hearing aids in their daily life. Pure-tone air conduction thresholds were determined for all participants. The mean threshold for the better ear (averaged over 0.5, 1, and 2 kHz) was 22.6 dB HL (range: 3.3-43.3, *SD* = 12.8). High-frequency thresholds for the better ear (averaged over 4, 6 and 8 kHz) ranged from 3.3-70.0 dB HL (*M* = 38.3, *SD* = 24.2). Informed consent was obtained prior to the start of the experiment.

2.2. Stimulus materials

Stimuli were based on [11] and consisted of 120 recorded Dutch sentences each containing a critical word. Sentences were constructed in such a way that the critical word was not easily predictable (e.g., *Het zag eruit als een paspoort, maar de tekst op de voorkant klopte niet.*, "It looked like a passport but the text on the front was not correct.") and were spoken by a female native speaker of Dutch. They were read out with neutral intonation and the speaker was unaware of the presence or identity of any of the critical words. Each sentence was paired with a visual display containing four black-and-white line drawings. Using a so-called 'target absent' design [7], the critical words were not represented by any of the drawings in the two experimental conditions. Instead, the visual displays contained one phonological competitor for the critical word and three distractors that were phonologically and semantically unrelated. In the onset-competitor condition, the phonological competitor drawing depicted a word that overlapped at onset with the critical word (e.g., for the critical word *paspoort*, 'passport', the onset competitor was *paspop*, 'tailor's dummy'). In the rhyme-competitor condition, the competitor drawing depicted a word that had a rhyme overlap with the critical word and only differed in its first phoneme (e.g., for the critical word *honing*, 'honey', the rhyme competitor was *koning*, 'king'). In addition to these two experimental conditions of 40 sentences each, there were 40 filler sentences, for which the visual displays contained a picture of the critical word and three unrelated distractor pictures. In all conditions, competitor and distractor pictures were counter-balanced across four fixed positions on the screen. The sentences were recorded in a sound-attenuated booth at a sampling rate of 44.1 kHz using Adobe Audition. Subsequent selection, measurement and editing of the auditory stimuli was carried out using Praat [3]. Two versions were created of each sentence. One version consisted of the original recording and this sentence was used in the baseline condition. For the noise condition, a second version was created in which between two and four separate phonemes throughout each sentence were replaced with bursts of noise. As no effect of noise position was found by [11], noise bursts replaced word-initial phonemes in half of the sentences and word-medial phonemes in the other half of the sentences. Importantly, the bursts of noise were never inserted in the critical word, nor in the two words preceding and following the critical word. The same radio noises were used as in [11]. The duration of each noise burst was adjusted individually, so that each burst replaced exactly one phoneme. The mean noise duration was 81.2 ms (range: 11-214 ms, SD = 33.8 ms), well above the gap detection thresholds reported for older listeners [8, 16, 17]. The loudness of each noise burst was adjusted so that it corresponded to 80% of the average intensity (in dB) of the sentence it was inserted in. In each condition (onset-competitor, rhyme-competitor, and filler) there were 14 sentences containing two noise substitutions and 13 each with three and four substitutions. In each sentence, bursts were evenly divided over the sentence fragment that preceded the critical word and the fragment following it.

2.3. Procedure

Participants were tested individually in a sound-attenuated booth. They were seated in front of a computer screen at a viewing distance of 95 cm, with their head held in a fixed position by means of a chin and forehead rest. Participants' eye movements were recorded at a sampling rate of 1000 Hz (monocular) using an Eyelink 1000 Tower Mount system (SR Research, Ltd.). Auditory stimuli were presented over Sennheiser HD201 headphones at a loud but comfortable level, kept constant for all participants.

Before the start of the experiment, the eyetracker was calibrated and validated using a 9-point calibration grid. After every five trials, an automatic drift correction was carried out and, if required, calibration was repeated. Following [11], participants were not given an explicit task, other than to listen to the sentences and to not take their eyes off the screen. At the start of each trial, a fixation cross was displayed in the centre of the screen. Participants were instructed to look at this cross until it disappeared. After this, visual displays were shown for 1s before the start of each sentence.

All participants were presented with all 120 sentence-display pairs in two blocks. The first block always contained sentences from the baseline (noise-free) condition, the second block consisted only of sentences from the noise condition. Items were counterbalanced across blocks and each participant was presented with a different randomisation of the stimulus list. There was no break between the baseline and the noise block and participants were not informed about the presence of noise in the second phase of the experiment.

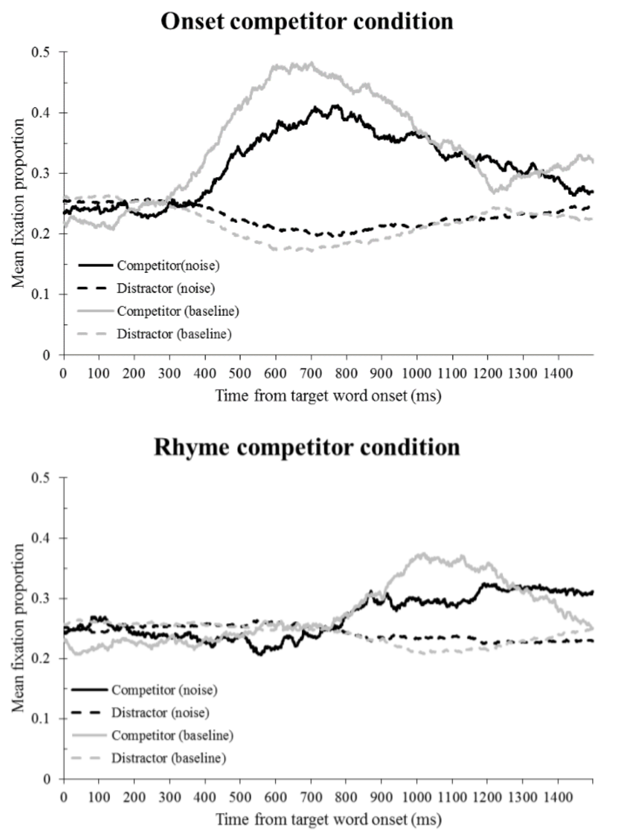
Upon completion of the eyetracking task, participants filled in a background questionnaire.

3. RESULTS

Figure 1 shows the average fixation proportions to the competitors and distractors from the onset of the target word for the onset- (top) and the rhyme-competitor condition (bottom). Distractor fixations were divided by three to account for the fact that each visual display contained three distractors and only one competitor picture.

As it is generally assumed that it takes around 200 ms to initiate an eye movement [9], the earliest time windows used for analysis in visual world studies, including [11], begin at 200 ms after target word onset. Because of our older participant population we have chosen to analyse windows that start later in time. Competitor preference ratios were therefore computed over a 600 ms time interval,

Figure 1: Mean fixation proportions from target word onset



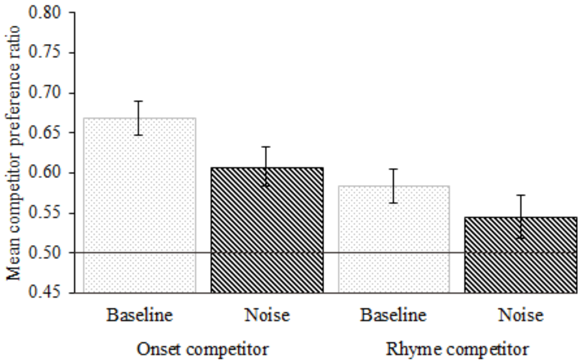
starting at 300 ms after critical word onset for the onset-competitor condition and at 800 ms for the rhyme-competitor condition (see Fig. 2). For each type of competitor, this was done by dividing the total number of fixations to the competitor by the sum of competitor fixations and distractor fixations. The number of distractor fixations was divided by three to account for the fact that for every competitor picture there were three distractors in every display.

In a one-sample two-tailed t test by participants (1) and by items (2), competitor preference ratios were compared to 0.5. In the baseline condition, both onset [$M_1 = 0.67$, $t_1(21) = 8.04$, $p < .001$; $M_2 = 0.64$, $t_2(39) = 6.21$, $p < .001$] and rhyme [$M_1 = 0.58$, $t_1(21) = 3.98$, $p = .001$; $M_2 = 0.58$, $t_2(39) = 3.25$, $p = .002$] competitors were fixated significantly more than distractors. In the noise condition, onset competitors were fixated significantly more than distractors [$M_1 = 0.61$, $t_1(21) = 4.48$, $p < .001$; $M_2 = 0.57$, $t_2(39) = 2.57$, $p = .014$], whereas rhyme competitors were not [$M_1 = 0.55$, $t_1(21) = 1.73$, $p = .099$; $M_2 = 0.54$, $t_2(39) = 1.44$, $p = .157$].

A 2x2 repeated-measures analysis of variance (ANOVA) of fixation ratios in the critical time window was conducted by participants (F_1) and items (F_2), with noise type (baseline and noise) and competitor type (onset and rhyme) as the within-subject factors. This showed a main effect of noise condition [$F_1(1,18) = 4.44$, $p = .047$; $F_2(1,78) =$

5.44, p = .022]. We also found a main effect of competitor type (onset competitors were fixated more than rhyme competitors) but while this effect is significant across participants, it misses significance over items [$F_1(1,21) = 13.21$, p = .002; $F_2(1,78) = 2.99$, p = .088]. No trace of a noise condition by competitor type interaction was found [$F_1(1,18) = 0.30$, p = .591; $F_2(1,78) = 0.24$, p = .625].

Figure 2: Mean competitor preference ratios per condition for the 600 ms analysis window



Further, as participants varied in hearing acuity from normal-hearing to mild-to-moderate hearing loss, we checked for links between participants' hearing thresholds and their preference for competitor pictures over distractors. No correlation was found between participants' competitor preference ratios (in any of the four within-subject conditions) and their pure-tone air conduction thresholds averaged over 0.5, 1 and 2 kHz and averaged over 2, 4 and 8 kHz (with r-values ranging from -.17 to .13).

4. DISCUSSION

We investigated whether older listeners adjust the parameters of lexical activation and competition when the reliability of the speech signal is decreased by occasional bursts of noise. If these listeners' performance mirrored that of the listeners in [11], we predicted a weaker onset-competitor and a stronger rhyme-competitor effect in the noise condition than in the baseline (noise-free) condition,

First, our results in the baseline condition confirmed previous findings of strong onset-competitor effects and smaller rhyme-competitor effects in young and older adults [e.g., 1, 2]. This suggests normal efficiency of speech processing in older listeners. However, in the baseline condition, mean fixation proportions to both onset and rhyme competitors reached higher peaks (0.48 and 0.37 respectively) than those found by [11] for younger adults in the baseline condition. Fixation proportions in [11] peak around 0.34 for onset competitors and around 0.24 for rhyme competitors. This may indicate that, even in noise-free listening conditions, older listeners are more cautious than younger adults in eliminating competitors as potential lexical candidates. Alternatively, it could be the result of the decrease in inhibitory capacities that is generally associated with aging: older listeners may experience more difficulties suppressing competitors than younger adults.

In the noise condition, onset competitors attracted fewer looks than in the baseline condition. This replicates the findings by [11] and could indicate that listeners adjust the parameters of lexical activation and competition. However, we also found a smaller competitor preference for rhyme competitors in noise, which speaks against such an adjustment. Listeners' increased uncertainty about the speech signal was expected to lead to a larger preference for rhyme competitors. Even though older adults were clearly affected by the noise bursts, they did not adjust their processing dynamics. This might be linked to the fact that rhyme competitors already attracted a high proportion of looks from older listeners in the baseline condition. In order to compensate for age-related deficits, older adults may employ dynamic listening strategies in noise-free situations that are similar to those used by younger adults to adjust to noisy listening conditions. When the speech signal deteriorates, older listeners could already be operating at capacity and may therefore not adjust further to the changing listening conditions.

As we did not exclude participants with poorer than normal hearing thresholds, about half of all participants suffered from mild to moderate hearing loss. Even though the difference between the results of this study and that by [11] may (partly) relate to hearing differences between age groups, there was no correlation between individual hearing thresholds and older participants' competitor preferences.

In sum, contrary to previous findings for younger adult listeners, we do not find conclusive evidence that suggests older listeners adjust the parameters of lexical activation and competition when the speech signal becomes less reliable due to the presence of noise. If it is the case that older listeners already make this type of adjustments while processing speech in normal listening conditions, this appears to leave them without resources to fall back on when listening conditions become difficult.

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[i] In a pilot study reported at the 41st Australasian Experimental Psychology Conference, Brisbane, April 2014, we replicated the exact methodology used in [11] but with older listeners. Results were entirely parallel to those discussed in this paper, so here we report only the methodologically improved, subsequent experiment.

Curriculum Vitae

Laurence Bruggeman studied Language, Speech, and Computer Science at Radboud University in Nijmegen and obtained her Bachelor's Degree in 2007. In 2010, she completed a Master's Degree in Language and Speech Technology, also from Radboud University. From 2004 to 2013, Laurence worked as a research assistant at the Max Planck Institute for Pyscholinguistics in Nijmegen, both for the Language Comprehension Department and for the Adaptive Listening Group. In 2013, she was awarded a three-year doctoral scholarship from the MARCS Institute for Brain, Behaviour and Development at Western Sydney University. As part of her PhD project, Laurence spent three months at the Max Planck Institute for Psycholinguistics, hosted by Esther Janse at the Radboud University's Centre for Language Studies. Laurence is now a postdoctoral research fellow in the Department of Linguistics at Macquarie University in Sydney.

List of Publications

Johnson, E. K., Bruggeman, L., & Cutler, A. (under revision). Abstraction and the Language Familiarity Effect in talker recognition.

Bruggeman, L. & Janse, E. (2015). Older listeners' decreased flexibility in adjusting to changes in speech signal reliability. In The Scottish Consortium for ICPhS 2015 (Ed.), *Proceedings of the 18th International Congress of Phonetic Sciences*. Glasgow, UK: the University of Glasgow. ISBN 978-0-85261-941-4. Paper number 880.

Cutler, A., & Bruggeman, L. (2013). Vocabulary structure and spoken-word recognition: Evidence from French reveals the source of embedding asymmetry. In *Proceedings of INTERSPEECH: 14th Annual Conference of the International Speech Communication Association* (pp. 2812-2816).

Cutler, A., Otake, T., & Bruggeman, L. (2012). Phonologically determined asymmetries in vocabulary structure across languages. *Journal of the Acoustical Society of America, 132*, EL155-EL160. doi:10.1121/1.4737596.

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