Mental representations
of Dutch regular morphologically complex neologisms

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ISBN: 978-90-76203-89-8
Cover: Jochen Boons
Printed and bound by Ipskamp Printing, Enschede

Mental representations of Dutch regular morphologically complex neologisms

Proefschrift

ter verkrijging van de graad van doctor
aan de Radboud Universiteit Nijmegen
op gezag van de rector magnificus prof. dr. J.H.J.M. van Krieken,
volgens besluit van het college van decanen
in het openbaar te verdedigen op woensdag 15 november 2017
om 12.30 uur precies

door

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geboren op 11 augustus 1980
te Uden

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Introduction

Chapter 1

Neologisms built up out of real morphemes are created by language users to describe new events, objects, etc. Children form these neologisms at an early stage of language acquisition to describe things for which they do not yet have words in their mental lexicons, the brain's dictionary (e.g., Clark, 1993; Bloom, 2000). Older language users also create new words in cases when they cannot remember the correct word. They may, for example, create the Dutch morphologically complex word *dementheid* 'dementedness' instead of the common *dementie* 'dementia'. Listeners and readers typically do not have trouble understanding these neologisms, because their meanings can be derived from the meanings of their real morphemes (*dement+heid* 'demented'+'ness'). The central question in this dissertation is whether neologisms like *dementheid* also form mental representations, and if so, do they form abstract representations or exemplars?

Storage versus decomposition

Little to no research has been conducted on the storage of regular morphologically complex neologisms. The research that has been done on neologisms has focused on novel monomorphemic pseudowords that strongly resemble real words. This research shows that storage of these words takes place (e.g., Dumay, Gaskell, & Feng, 2004; Gaskell & Dumay, 2003; Bakker, Takashima, Van Hell, Janzen, & McQueen, 2014; Takashima, Bakker, Van Hell, Janzen, & McQueen, 2017). Research using regular morphologically complex neologisms can provide insights into whether storage of the entire neologisms takes place or whether neologisms are mainly decomposed into their real morphemes to derive their meanings. In other words, research into neologisms can add to our knowledge on the storage and decomposition of regular morphologically complex words.

Current psycholinguistic theories on the comprehension of real words provide us with three logical options for the way regular morphologically complex words can be processed. First, a number of theories assume full storage of all complex words, which can thus be processed as whole units regardless of their internal structure (e.g., Butterworth, 1983). Second, some theories assume that all regular complex words are fully parsed into their stems and affixes (e.g., Taft, 1994; Pinker, 1991). Third, mixed models have been proposed in which words may be processed as whole units and stored in the mental lexicon, but they may also be decomposed into stems and affixes during processing (e.g., Caramazza, Laudanna, & Romani, 1988; Laudanna & Burani, 1995; Baayen, Dijkstra, & Schreuder, 1997). The model by Caramazza et al. (1988), which they have named the Augmented Addressed Morphology Model, is based on the crucial assumption that a letter string activates both a whole-word orthographic representation and the combined morphemes that comprise the word. The model is a cascaded dual-route model, which means that the second route (combining morphemes comprising the word) comes into play only after completion of the first route (activation of the whole-word orthographic representation). In contrast, Baayen et al. (1997) argued for a parallel dual-route race model, in which decomposition into stem and affix and full form access work in parallel. High-frequency complex words are processed faster than low-frequency words; the assumption being that high-frequency complex words are more likely to be processed as whole units, while low-frequency complex words are more likely to be decomposed into stems and affixes. Alegre & Gordon (1999) proposed a frequency threshold of six occurrences per million, above which complex words (regularly inflected forms) would have their own lexical representations. Regular complex words with frequencies below this threshold would only be accessed through their stems and affixes.

One of our research goals is to verify the validity of the models mentioned above. If we find evidence for storage of neologisms, the models proposed by Taft (1994) and Pinker (1991) cannot be accurate.

Abstract representation versus exemplar

If regular morphologically complex words are stored, the question arises in what form. Words can either be stored as abstract representations or as (clouds of) exemplars/ episodes. Abstract representations only provide information that is necessary to distinguish the words from other words in the language. Abstract representations do not provide detailed information about the properties of the tokens; they do not specify, for instance, whether the neologism was attested in written or spoken language, the situational context (e.g., who uttered the word or what did the room where it was uttered look like) or the linguistic context (e.g., what were the preceding and following words).

Exemplars, in contrast, contain more specific information. Each exemplar provides detailed information about one token of the word. Exemplars may be modality specific and contain information about the context in which the tokens occured, including the situational and linguistic context. Words can be represented as clouds of exemplars.

An exemplar of a neologism acts as a starting point for a new cloud. A second encounter with the neologism, which is now technically no longer a neologism, can be added to the first exemplar expanding the cloud. Both abstract representations and exemplars are assumed to be stored in lexical memory. We define exemplar models as those models that assume that the mental lexicon only consists of clouds containing representations of different tokens of the same word, and where the mental lexicon does not contain any abstract lexical representations of the words' pronunciations. It is also possible that tokens are stored in episodic memory. In this case, they are known as episodes (e.g., Goldinger, 1998) and they are specified with as much detail as exemplars. We do not distinguish between exemplars and episodes and will refer to them as exemplars.

Evidence that memory may contain detailed representations for word tokens comes predominantly from auditory priming experiments (e.g., Bradlow, Nygaard, & Pisoni, 1999; Craik & Kirsner, 1974; Goh, 2005; Goldinger, 1996; Janse, 2008; Mattys & Liss, 2008; McLennan, Luce, & Charles-Luce, 2003; McLennan & Luce, 2005; Palmari, Goldinger, & Pisoni, 1993). In these experiments, words are repeated and the second token of the word is either identical to the first token or it differs in, for instance, speech rate, time-compression, the articulation of a certain segment, or speaker's voice. Most of these experiments show that participants react faster and more accurately to the second token if it is identical to the first one. These results strongly suggest that participants store the acoustic details of the first token of each word and that the recognition of the second token involves this detailed representation.

We focus on the question whether memory representations for neologisms contain token-specific information, including modality and context, or whether they are abstract. This distinction shows the relevance of a memory representation of a neologism for language processing. Does it only affect the processing of the second token of this neologism if it occurs in circumstances that are similar to those in which the neologism was first encountered or also when circumstances are different?

The role of sleep

Dumay et al. (2004) and Gaskell & Dumay (2003) examined the acquisition of novel monomorphemic words that closely resemble real words, for instance, *cathedruke*, which is very similar to the real word *cathedral*. They studied the development of lexical representations for novel monomorphemic words indirectly by measuring the response latencies on the real words that sound similarly. They observed that listeners recognize a word such as *cathedral* faster if they had heard at least 12 tokens of a phonologically similar pseudoword (e.g., *cathedruke* for *cathedral*. However, five days after the familiarization, listeners recognized the real words more slowly. Gaskell and colleagues argued that this inhibitory effect is due to the pseudowords becoming lexical competitors for real words. They thus concluded that the formation of a lexical representation takes some time. Tamminen & Gaskell (2008) demonstrated that new words remain lexical competitors up to eight months after exposure, so the formed representations seem robust.

Gaskell & Dumay (2007) investigated whether sleep affects the formation of lexical representations. They observed that if participants learned words at 8 p.m., they did not show (inhibitory) competition effects immediately for similar sounding real words but only after a 12 hour interval including a night's sleep. Participants who learned the words at 8 a.m. showed no competition effects neither immediately nor after 12 hours of wakefulness, but showed competition effects after 24 hours, that is again after a night's sleep. Thus, sleep appears to be a necessary condition for competition effects to arise. Further support for the role of sleep on establishing traces in lexical memory comes from the study by Davis, Di Betta, Macdonald, & Gaskell (2008). They observed that participants show lexical competition and faster recognition times only for the novel words they learned on the previous day, in contrast to words they learned on the same day.

Bakker et al. (2014) replicated the studies of Gaskell and colleagues: both auditorily and visually acquired neologisms showed competition effects after 24 hours when tested in the same modality. Bakker and colleagues also showed priming of morphologically simple neologisms across different modalities (primed visually and tested auditorily and vice versa). Auditorily acquired neologisms contributed to the lexical competition in the written modality after 24 hours. On the other hand, visually acquired neologisms required extra training and a consolidation period of a week before they contributed to the lexical competition during auditory word comprehension. This study thus shows that words acquired in one modality can affect the processing of that word in another modality. Bakker and colleagues focused on the processing of morphologically simple neologisms, which do not have meanings without context. On the contrary, we focused on the processing of regular morphologically complex neologisms, whose meanings can be derived. Research by Takashima et al. (2017) on novel words has shown that meaning influences the way novel words are processed. Their novel words were morphologically simple. Half of their novel words had no meanings, the other half, however, received meanings through either pictures or verbal descriptions. The words that were learned with meanings were remembered better than those that were learned without meanings.

The meanings of our neologisms can be derived from the meanings of their real morphemes and the Dutch morphological rules. People can understand the meanings of our novel words without any context. One of our research question is whether sleep affects the formation of this type of neologisms?

Methodology

For our studies, we chose to test native Dutch speaking participants for the simple reason that Dutch speaking participants are readily available in Nijmegen, where this research was conducted. Another reason to choose the Dutch language is that the spelling of Dutch words is, amongst other principles, based on the phonological principle and thus shows shallow phoneme-to-grapheme mapping. That is, a word is spelled according to the sounds audible in the standardized pronunciation of the word. Participants can therefore easily produce a written representation of an auditorily acquired word. Borgwaldt, Hellwig, & De Groot (2005) observed that of the seven languages they examined, only Italian and Hungarian have less ambiguous orthographies than Dutch.

Our neologisms consist of real stems and real affixes and are combined according to the Dutch morphological rules. Yet, the combinations of these stems and affixes tested in the experiments form non-existing words. The derived neologisms are morphologically well-formed and semantically transparent, for example, *kortafheid* 'abruptness' consists of the real stem *kortaf* 'abrupt' and the real suffix *-heid* '-ness'. We used neologisms with the suffixes *-baar*, *-heid*, and *-ing* since they are the most regular and productive derivational suffixes of Dutch. When participants encounter neologisms built up out of real parts, they can use their knowledge of the meanings of the parts combined with their knowledge of the Dutch morphological rules to derive the meanings of these neologisms. The suffixes change the characteristics of the stems: verbs into adjectives (*-baar*), adjectives into nouns (*-heid*), and verbs into nouns (*-ing*).

We added real words and pseudowords as fillers to the experimental materials. The real filler words were derived words ending in different suffixes and were registered in CELEX (Baayen, Piepenbrock, & Gulikers, 1995). We formed the pseudowords by changing up to a maximum of three letters/sounds in our neologisms and real words. We ensured that the resulting pseudowords do not violate the phonotactic and orthographic conventions of Dutch. The changes were always in the stems and never in the suffix.

We used a priming paradigm in all of our experiments. Priming means that if a word is perceived once, it is easier to process when encountered afterwards than a word that was not perceived before (e.g., Cutler, 2012, p.15). Priming also works cross-modally (e.g., Tanenhaus, Flanigan, & Seidenberg, 1980). This means that a word perceived in one modality (e.g., it is read) is more easily processed in another modality (e.g., it is heard) than a word that was not perceived before.

We used a design with stems of neologisms (e.g., *tembaar* 'tamable') as well as neologisms (e.g., *tembaarheid* 'tamability') functioning as primes and the corresponding neologisms functioning as targets. The design allowed us to compare lexical processing of a neologism that has not been encountered before with lexical processing of a neologism that has been encountered once. The stem priming condition functioned as a baseline which allowed us to investigate whether priming in the identity priming condition resulted from the full neologism or just its stem. If it was the stem of the neologism that induced priming, the stem and the neologism should produce similar priming effects. If, in contrast, participants stored the full neologisms, the neologisms should result in more priming than their stems alone. The time interval between prime and target was either 39 items (approximately 1.5 minutes), 30 minutes, 12 hours or a week. In case of priming effects, we know for sure participants used their long term memory and not only their working memory, since working memory can only contain five to nine items (Miller, 1956).

In order to measure priming, we asked participants to make a decision whether the perceived words are real words or pseudowords (i.e., lexical decision). A real word should receive a 'YES' response and a pseudoword a 'NO' response (Zwitserlood, 1996; Cutler, 2012, p.15 & 44). Aside from lexical decision tasks, we also conducted self-paced reading tasks and listening comprehension tasks. These tasks allow us to investigate the priming of neologisms in a more natural way.

In our lexical decision experiments, participants were asked to give a 'YES' response to the words they were able to derive the meaning of (real words and neologisms). If they were not able to do so, they had to give a 'NO' response (pseudowords). This is a natural categorization that most participants were able to carry out without requiring any specific instruction about how to respond to neologisms. Previous studies have shown that if participants are forced to classify potential words as pseudowords, excessively long response latencies occur: Native speakers find it difficult to reject words that are easily interpretable (Coolen, Van Jaarsveld, & Schreuder, 1991).

In our self-paced reading experiments, the neologisms and/or their stems were implemented in sentences and whole stories. Participants were asked to read carefully and at a comfortable reading speed. They initiated the text by a button press and the full text was displayed in dashes which marked letter positions. By pushing the button again, they saw the first word of the text. On pressing the button again, the second word appeared and the first word was replaced by dashes. This procedure was repeated until the participants had read the whole text. We registered the time between two button presses reflecting the time participants needed to read a word.

In our listening comprehension experiments, participants had to listen to stories in which the stems of the neologisms or the neologisms themselves were presented. Afterwards, participants answered questions about the stories they had heard.

Outline

In this dissertation, I present three studies in which we investiged how Dutch regular morphologically complex neologisms are processed. In Chapter 2, we investigated whether neologisms leave detectable traces in memory after just one exposure. We tested this by conducting two relatively simple priming experiments in which the primes (stems of the neologisms or the neologisms themselves) as well as the targets (neologisms) were processed. One was a visual lexical decision experiment and the other was a self-paced reading experiment. In both experiments, we only used regular morphologically complex neologisms ending in the suffix *-heid*. The time interval between primes and targets was 39 items, which is equal to approximately 1.5 minutes. This implies that if participants form a representation in memory, they have to use their long term memory because of the time interval of 39 items (Miller, 1956).

Chapter 3 addresses the question whether neologisms remain in memory for a longer period of time. In addition, we investigated whether sleep influences the process of storage of a neologism. We used the materials from Chapter 2, but we also added regular morphologically complex neologisms ending in the suffixes *-baar* and *-ing*, to be able to generalize our conclusions. We conducted two visual lexical decision experiments in which the prime was presented in one part of the experiment, the familiarization phase, and the target was presented in a second part, the test phase. In one experiment, participants conducted the second part of the experiment 12 hours after they had conducted the first part. In the other experiment, participants conducted the second part of the experiment a week after they had conducted the first part. The time interval of 12 hours gave us the opportunity to test whether sleep had any influence on storage: half of the participants had a night's sleep while the other half did not.

In Chapter 4, we studied the question of what types of traces are formed by neologisms. Here again, we used the priming paradigm with the regular morphologically complex neologisms ending in the suffixes *-baar*, *-heid*, and *-ing*. Again, the experiments consisted of a familiarization phase and a test phase. We presented the primes and targets in different modalities: the primes were presented in the visual modality and the targets were presented in the auditory modality or vice versa. Furthermore, participants completed a different task in the familiarization phase of the experiment than in the test phase of the experiment. The familiarization phase was either a self-paced reading task (Experiment 1) or a listening comprehension task (Experiments 2 and 3). The test phases were either an auditory lexical decision task (Experiment 1), a visual lexical decision task (Experiment 2), or a self-paced reading task (Experiment 3). Participants were led to believe they were participating in two different experiments, although they actually participated in two parts of one and the same experiment. By doing so, we can draw conclusions about the types of traces neologisms form in memory.

In Chapter 5, I summarize and discuss the results of these three studies. I will make a well-founded assumption on whether or not storage of Dutch regular morphologically complex neologisms takes place, and on the type of representation these neologisms form. Moreover, I discuss the implications for psycholinguistic models of morphological processing.

In the Appendix, I present tables that describe the data collected in this dissertation.

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Storage of neologisms in the mental lexicon

Chapter 2

This chapter is a reformatted version of:
Laura de Vaan, Robert Schreuder, and R. Harald Baayen (2007). Regular morphologically complex neologisms leave detectable traces in the mental lexicon. *The Mental Lexicon*, *2(1)*, 1-24.

Abstract

This chapter investigates whether regular morphological complex neologisms leave detectable traces in the mental lexicon. Experiment 1 (subjective frequency estimation) was a validation study for our materials. It revealed that semantic ambiguity led to a greater reduction of the ratings for neologisms compared to existing words. Experiment 2 (visual lexical decision) and Experiment 3 (self-paced reading in connected discourse) made use of long-distance priming. In both experiments, the prime (base or neologism) was followed after 39 intervening trials by the neologism. As revealed by mixed-effect analyses of covariance, the target neologisms elicited shorter processing latencies in the identity priming condition compared to the condition in which the base word had been read previously, indicating an incipient facilitatory frequency effect for the neologism.

Introduction

Studies in first language acquisition have reported that one trial often suffices for children to form quick and rough hypotheses about the meaning of a word, a phenomenon referred to by Bloom (2000) as fast mapping. The learning of new words is not restricted to childhood. Words for new concepts, persons, place names, brand names continue to be encountered throughout one's life. Among these new words, one category is especially interesting from a morphological point of view, namely, derivational neologisms. Baayen & Renouf (1996) presented a corpus-based survey showing that such complex neologisms are not uncommon in written text. The present chapter addresses the question of how such neologisms are processed, and whether a single exposure to such a neologism already leaves a trace in lexical memory.

In models of the mental lexicon in which words are assumed to have their own representations in lexical memory (Butterworth, 1983), the question arises how frequently a word has to be encountered for such a representation to be acquired. In distributed approaches (Rumelhart & McClelland, 1986; Seidenberg & Gonnerman, 2000), the corresponding question is how many exposures are required for the connection weights to become sufficiently well-tuned to allow a processing advantage for the whole with respect to its parts to emerge. The phenomenon of fast mapping suggests that initial representations may already be set up after a single exposure, or, alternatively, that the tuning of connection weights proceeds extremely rapidly. However, it is not clear whether fast mapping also applies to morphologically complex words that are to a very large extent predictable from their constituents.

Two approaches can be distinguished in previous work addressing the development and existence of lexical representations. One line of research is represented by the studies of Dumay et al. (2004) and Gaskell & Dumay (2003). They studied the development of representations for pseudowords in lexical memory by tracing the effects of these new representations during lexical competition in the auditory processing of existing words. Their materials consisted of novel nonsense sequences that overlapped strongly with existed words, such as *cathedruke* versus *cathedral*. They presented their materials repeatedly to their participants, and observed a facilitating effect of having heard *cathedruke* for recognizing *cathedral*. However, after five days, they observed that the recognition of *cathedral* was slowed by prior familiarization with *cathedruke*. They attribute this inhibitory effect to *cathedruke* having become a lexical competitor of *cathedral*. Dumay et al. (2004) observed similar inhibitory effects already 24 hours after the initial familiarization with the pseudowords. Thus, one night's sleep seems sufficient for a lexical representation to develop. This result is certainly consistent with the fast mapping reported in the acquisition literature.

Several scholars working on visual comprehension, by contrast, have argued that regular complex words would not leave any traces in lexical memory (Pinker, 1991), or only traces after a great many exposures (Alegre & Gordon, 1999; Pinker & Ullman, 2002a, b). Pinker and Ullman argue that memory traces for regular complex words are in fact superfluous given that regular words can be processed adequately by rules. They argue that such memory traces would be functional only in tasks that require sensitivity to the word's physical form. The study by Alegre and Gordon is especially interesting in that it proposes a threshold frequency of six per million below which rules would be effective for English inflection, and above which memory traces would be active. However, the work by Alegre and Gordon has been interpreted in very different ways. Pinker & Ullman (2002a) refer to this study as indicating that only some higher-frequency words are stored, but that the majority of English inflections are processed by rule. Eddington (2002), on the other hand, argues that this study shows that the majority of English inflections are processed through memory. The problem here is that a threshold of six per million has very different consequences depending on whether calculations are worked out on the basis of type counts or on the basis of token counts. Inspection of the frequencies available for English in the CELEX lexical database shows that 91.6% of the types would be processed by rule, but that no less than 72.2% of the tokens would be processed by rote.

A threshold of six per million is questionable, however, for several reasons. A threshold below which representations do not exist meets with the logical problem that in order to install a representation once it is sufficiently frequent, the system must have kept track of how often the word has been encountered before. But this implies the existence of some kind of memory trace, the existence of which is denied by the threshold theory. Consequently, the threshold proposed by Alegre & Gordon (1999) is probably best understood as indicating how frequent a word must be for its developing representation to emerge from the measurement error in visual lexical decision. Furthermore, studies in Dutch have reported frequency effects far below this threshold (Baayen et al., 1997; Baayen, Schreuder, De Jong, & Krott, 2002), and a study of English word formation shows frequency effects below the threshold for English as well (Baayen, Wurm, & Aycock, 2007).

The present chapter aims to provide further insight into the development of traces for complex words in lexical memory during reading by investigating how neologisms are processed when encountered for the first and second time in experimental lists as well as in coherent discourse. The neologisms that we investigated all contained the suffix *-heid* (cf. '-ness' in English). The suffix *-heid* is the most regular and productive derivational suffix of Dutch. In addition, it is a suffix that we have studied extensively in previous work (Baayen, Schreuder, Bertram, & Tweedie, 1999; Bertram, Schreuder, & Baayen, 2000).

With Experiment 1, we validated that our target words were indeed neologisms, using subjective familiarity rating. Experiments 2 and 3 addressed the processing of these neologisms. Experiment 2 made use of the visual lexical decision task, and Experiment 3 of self-paced reading. In both experiments, we implemented long-distance priming with 39 intervening words and two conditions. In one condition, henceforth the stem priming condition, the stem primed the neologism (*gammel* -

gammelheid ’wobbly’ - ’wobbliness’). In the other condition, henceforth the identity priming condition, the neologism primed itself (*gammelheid* - *gammelheid*). This design offers the possibility of comparing lexical processing of a neologism that has not been encountered before (the stem priming condition) with lexical processing of a neologism that has been encountered exactly once (the identity priming condition). If Alegre & Gordon (1999) and Pinker (1991) are right, we should not observe a difference between these two conditions, as the brain would not retain memory traces for regular complex words that have been encountered only once. However, if we observe that the processing of a neologism is facilitated by prior exposure to that neologism, we have evidence that prior experience leaves traces in at the very least working memory.

Experiment 1: Familiarity Rating

Experiment 1 was designed as a validation study for the materials of Experiments 2 and 3.

Method

Participants

Twenty two students of the University of Nijmegen took part in this experiment. All students were enrolled in the Dutch Language and Culture program and were native speakers of Dutch.

Materials

The materials consisted of 42 neologisms with the suffix *-heid* (’-ness’) and 63 existing words ending in *-heid* attested in the CELEX lexical database (Baayen et al., 1995), and five practice items. We selected adjectival stems for the neologisms for which suffixation with *-heid* resulted in semantically interpretable strings. We excluded intensifiers (*piepklein* ’teeny’), color adjectives (*blauw* ’blue’) and adjectives ending in *-en* (*houten* ’wooden’), as such adjectives do not lend themselves well to suffixation with *-heid* (Bertram, Baayen, & Schreuder, 2000) as well as adjectives from informal registers with negative connotations (*teut* ’tipsy’). Furthermore, we avoided neologisms that would have a high-frequency coderivative ending in *-iteit*, as such words might exert a blocking force (Booij, 2002; Rainer, 1988). We also avoided neologisms ending in *-igheid* whenever the resulting noun denoted an act, for example, *stom* ’stupid’; *stommig* ’somewhat stupid’; *stommigheid* ’stupid act’ (Booij, 2002), as the combination *-igheid* is arguably a separate independent suffix with its own semantics.

None of the neologisms were attested in the CELEX database and none had a frequency greater than ten in the Dutch section of the world wide web (as of January 2003). The existing words had a CELEX lemma frequency in the range of [0–9623], a mean of 365.60, and a median of 17 (counts based on a corpus of 42 million words). All adjectival base words had a minimum length of three characters and a maximum length of eight characters.

We randomized the materials in six different orders, resulting in six lists. Each list was preceded by five practice trials and a short instruction with three examples. The experimental materials are listed in the Appendix.

Procedure

Participants were tested as a group during a class. We asked the participants to rate on a seven point scale how often they thought they had encountered these words.

Results and Discussion

One rating value was missing and was assigned the neutral score of 3.5. The mean ratings for the neologisms and existing words were respectively 2.54 and 4.88. In addition to the factor Status (neologism versus existing word), we included five covariates to the data set: Surface Frequency (the string frequency of the form presented), Base Frequency (the lemma frequency of the adjectival base), Length in letters, morphological Family Size (the number of different words in the morphological family (Schreuder & Baayen, 1997)), and a measure of the number of meanings of the word's base: its Number of Synonym sets in WordNet (henceforth Synsets) (Miller, 1990; Vossen, Bloksma, & Boersma, 1999), following Baayen, Feldman, & Schreuder (2006). This measure gauges the ambiguity in the semantic interpretation of the complex word.

Because of the skewness of the distribution for Surface Frequency, Base Frequency and Number of Synsets, we applied a logarithmic transformation to these variables. Since the Surface Frequency measure is zero for all neologisms, we analyzed the existing words and the neologisms separately. A mixed-effect model of covariance with participant and word as crossed random effects (Bates & Sarkar, 2005; Faraway, 2006) and the rating scores for the existing words as dependent variable revealed main effects of Surface Frequency, Family Size, Length, and Number of Synsets. Ratings increased with increasing Surface Frequency ($\hat{\beta} = 0.431, t(1535) = 8.243, p < .0001$), Family Size ($\hat{\beta} = 0.190, t(1535) = 2.354, p = .0187$) and Length ($\hat{\beta} = 0.202, t(1535) = 3.338, p = .0009$), but decreased for increasing Numbers of Synsets ($\hat{\beta} = -0.466, t(1535) = -2.169, p = .0303$). For the neologisms, a stepwise mixed-effect regression analysis resulted in a model with significant main effects of Length and Number of Synsets. As for the existing words, ratings increased with increasing Length ($\hat{\beta} = 0.238, t(877) = 2.805, p = .0051$) and decreased for increasing Numbers of Synsets ($\hat{\beta} = -0.560, t(877) = -3.359, p = .0008$).

Recall that random effects are random variables with zero mean and unknown standard deviation. In mixed-effects models, these unknown standard deviations are estimated from the data. For the present models, the standard deviations are for Word: 0.7971 (existing words) and 0.4737 (neologisms), for Subject: 0.8031 (existing words) and 0.7107 (neologisms), and for the residual error: 1.4805 (existing words) and 1.4081 (neologisms). These standard deviations provide direct insight into the amount of variance (squared standard deviations) that can be traced to the participants, the words, and the residual error. It is common to find that the standard deviation for Word is less than that for Subject, especially in chronometric experiments, indicating that we tend to have much less experimental control over our participants than over our experimental materials.

A greater number of meanings for the base words of the formations ending in *-heid* led to lower subjective frequency estimates, both for existing words and for neologisms. The coefficient for the neologisms, -0.560, was more negative than the coefficient for the existing words, -0.466. The negative sign of these coefficients suggests that a greater semantic ambiguity of the base word of a formation ending in *-heid* may render the semantic interpretation of that formation more uncertain, which would lead to lower ratings. The greater magnitude of the effect for neologisms suggests that this problem of semantic interpretation is enhanced in the case of neologisms. In order to ascertain whether the coefficient for the neologisms is significantly more negative, we fitted a model to the combined data, without including Surface Frequency as a predictor. The significance ($F(1, 2415) = 4.07, p = .0438$) of the interaction of Number of Synsets by Type of Word (existing versus neologism) revealed that the effect of semantic ambiguity was indeed more detrimental for the ratings of neologisms. The greater effect of the Number of Synsets for neologisms, and the absence of a significant effect of the morphological family size for neologisms jointly support our intuitions that the words that we labelled as neologisms are indeed unknown to our participants.

Experiment 2 proceeds to investigate how neologisms are processed under time pressure, using visual lexical decision.

Experiment 2: Visual Lexical Decision

The key question addressed with Experiment 2 is whether neologisms leave traces in lexical memory in isolated word reading. Since our neologisms are fully regular, decompositional theories denying storage to regular complex words, such as the theory of Pinker (1991), predict that no such traces should exist. To test this prediction, we made use of a design in which one group of participants first saw the stem and a fixed number of trials later in the experiment also had to respond to the neologism containing that stem. A complementary group of participants first saw the neologism (instead of its stem) and the same number of trials later in the experiment had to respond to the same neologism. If a neologism leaves a memory trace, participants who had previously responded to the neologism should be faster in their responces to the second presentation of the neologism compared to the participants who had previously encountered only its stem. In order to make sure that each participant had to parse neologisms the same number of times, each participant was presented an equal number of times with the order stem-neologism and the order neologism-neologism. In this way we ensured that across participants the amount of prior experience with stem and affix was controlled for the critical comparison between the presence versus absence of prior experience with the neologism.

The task that we used for Experiment 2 was visual lexical decision, which required participants to classify neologisms such as *lobbigheid* as words and not as nonwords. This is a natural categorization, that most participants carried out without requiring any specific instruction about how to respond to neologisms. The neologisms that we used are possible words of Dutch that do not violate any phonological or morphological constraint. They were well-interpretable, as attested by their occasional attestation on the internet. Furthermore, previous studies have shown if participants are forced to classify possible words as nonwords, excessively long response latencies ensue: Native speakers find it difficult to reject words that are well-interpretable (Coolen et al., 1991).

Method

Participants

Twenty-six undergraduate students at the University of Nijmegen were paid to take part in this experiment. All were native speakers of Dutch, none had participated in Experiment 1.

Materials

We used the same neologisms as in Experiment 1, with the exception of *saploosheid* 'juicelessness' and *blitsheid* 'trendyness'. We excluded *saploosheid* because of its high degree of semantic similarity to another neologism, *saprijkheid* 'juicerichness'. We discarded *blitsheid* because we suspected that *blits* 'trendy, neat', a former vogue word, is currently not well known to our participant population. In this way, we obtained a list with 40 neologisms. We created two master lists with these 40 neologisms. In each master list, we replaced 20 of the neologisms by their stem so that if one master list contained the stem, the other master list held the neologism for that stem. We then added the complete list of 40 neologisms to both master lists.

To distract attention from the neologisms, we added 40 existing words ending in *-ing* and 40 ending in *-baar* as filler words. The filler words ending in *-ing* had a CELEX lemma frequency in the range of [2–46], a mean of 7.9 and a median of 5; the filler words ending in *-baar* had a CELEX lemma frequency in the range of [0–83], a mean of 13.63 and a median of 6.5.

We matched each word with a pseudoword by changing one or two letters, making sure that the resulting word did not violate the phonotactic or orthographic conventions of Dutch. The changes were always in the stems and never in the suffix. Each master list contained 20 monomorphemic pseudowords (matching 20 stems of neologisms ending in *-heid*), 20 pseudowords ending in *-heid*, 40 ending in *-ing*, and 40 ending in *-baar*. We reused 20 pseudowords ending in *-ing* and 20 pseudowords ending in *-baar* in parallel to the stems and their neologisms ending in *-heid* that appeared twice. The total number of pseudowords ending in *-baar* and *-ing* was 60 for each suffix. As a result, a master list contained in all 20 stems, 20 neologisms, 40 neologisms (corresponding with the stems and neologisms mentioned before), 40 existing filler words ending in *-ing* and 40 existing filler words ending in *-baar*, together 160 word trials, matched with 160 pseudoword trials. We pseudo-randomized both master lists in three different orders. We made sure that the number of trials between a stem and its corresponding neologism, between a neologism and its repetition, and also between a pseudoword and its repetition was held constant at 39 intervening trials. Each of the resulting six lists was preceded by 24 practice trials. The experimental materials are listed in the Appendix.

Procedure

Participants were tested individually in a noise-attenuated experimental room. They were asked to decide as quickly and accurately as possible whether the letter string appearing on the computer screen was a possible Dutch word. After the practice session, a few participants were unclear about how to respond to the neologisms. We made it clear to them that both existing and possible words required a yes response, and that only impossible words (phonotactically legal, but meaningless) required a no response. The experiment was run without any further breaks. An experimental trial began with a fixation mark, positioned in the center of the screen for 500 ms. 50 ms later, the stimulus appeared centered at the same position. Stimuli were presented on a Nec Multisync color monitor in white lowercase, 36 point letters on a dark background and they remained on the screen for 1750 ms.

Results and Discussion

We coded no-reponses to neologisms as errors and removed these data points from the analyses of the response latencies. The by-item error scores ranged from 4% to 46%. As we are dealing with neologisms in lexical decision, these high error rates are unsurprising. We applied a logarithmic transformation to the response latencies for the prime and those for the target to reduce the non-normality of their distribution in order to avoid distortion of the statistical model by outliers with undue leverage.

The group means response latencies (RTs) across all participants and words, 737 ms for the condition in which the base preceded the target, and 769 ms for the condition in which the neologism preceded the target, suggested a significant inhibitory priming effect, instead of the expected facilitatory priming effect. A linear mixed-effects model with participant and word as crossed random effects supported this unexpected priming effect as significant ($\hat{\beta} = 0.0301, t(830) = 2.08, p = .0376$).

However, a closer inspection of the data using appropriate controls shows that this initial analysis is highly misleading.

In our full analysis we added Base Frequency, Family Size, Length (in letters), Number of Synonym sets in Wordnet and the mean number of items in a synset as covariates. As in Experiment 1, we logarithmically transformed Base Frequency, Family Size and Number of Synsets, in order to reduce the skewness in their distributions. Crucially, we also added several non-lexical, experimental control variables.

Since we expected the processing load of the prime to affect the latencies for the target, we also included the response latency of a given participant to the prime as covariate for that participant's response to the target 40 trials later in the experiment (henceforth Prime RT), a possibility afforded by mixed-effect models. Similarly, we included the lexical decision by a given participant for a given prime (word or nonword, henceforth Prime Decision) as a factor. We also registered the response latencies of a given participant to the four preceding words as potential covariates for that participant's response to the target. As these four response latencies were all mutually correlated, we used principal components analysis to orthogonalize these covariates, to which we first applied a logarithmic transformation. Of the resulting principal components, only the first turned out to be predictive for the response latencies to our targets. In what follows, we refer to this principal component as PC Preceding RTs.

We fitted a mixed-effect model of covariance to the RTs to the target, using a stepwise variable selection procedure, with participant and word as crossed random effects. We observed main effects of Base Frequency, Condition, Prime RT, Prime Decision and PC-Preceding RTs as well as an interaction of Prime RT by Prime Decision (see Figure 2.1). No other predictors and interactions reached significance. Inspection of the residuals revealed marked non-normality, indicating serious lack of goodness-of-fit for this model. We therefore removed outliers with standardized residuals outside the interval $[-2.5, 2.5]$ (2.16%), and refitted the model (see, e.g., Crawley, 2002). The residuals of this trimmed model were approximately normally distributed, indicating that removal of overly influential outliers resulted in a model with superior goodness of fit.

Response latencies decreased with increasing Base Frequency, as expected for neologisms ($\hat{\beta} = -0.0104, t(807) = -2.66, p = .0080$). Response latencies were now shorter in the identity priming condition (in which participants responded to the neologism for the second time)($\hat{\beta} = -0.0466, t(807) = -3.29, p = .0011$) than in the stem priming condition (in which the neologism was entirely new). There was no significant interaction of Base Frequency by Condition.

Furthermore, response latencies were longer for participants who had previously rejected the prime as a word ($\hat{\beta} = 1.3837, t(807) = 3.90, p = .0001$). Response latencies also increased with increasing Prime RTs ($\hat{\beta} = 0.2353, t(807) = 7.39,$ $p < .0001$). Prime Decision interacted with Prime RT ($\hat{\beta} = -0.1888, t(807) = -3.56,$

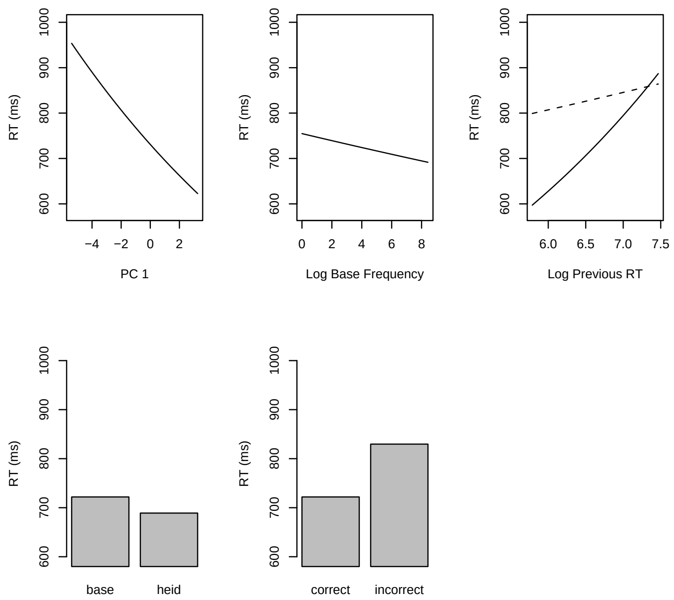

Figure 2.1: Partial effects for response latencies in visual lexical decision. In the upper left panel, the dashed line represents prime-target pairs for which the prime was incorrectly classified as a pseudoword, and the solid line the prime-target pairs for which the prime was accepted as a word.

$p = .0004$): For those trials for which a participant had previously rejected the prime as a word, the reaction time to the prime was not predictive for the reaction time to the target. RTs decreased with increasing PC Preceding RTs ($\hat{\beta} = -0.0492$, $t(807) = -7.22, p < .0001$). As the PC Preceding RTs were themselves negatively correlated with the preceding RTs, we conclude that longer preceding RTs implied longer RTs to our target words. This finding is in agreement with the results reported by Taylor & Lupker (2001) for word naming. Unlike in their study, however, which reported small effects of around 10 milliseconds, the longitudinal effect of the processing complexity of the preceding trials emerges as a much more substantial effect in our mixed-effect analysis: The difference in the RTs, calibrated for the medians of the other predictors, between the smallest and largest values of PC Preceding RTs was of the order of magnitude of 300 ms. Hence, it is a control variable that is worth taking into account.

We complete the specification of the mixed-effect model with reporting the standard deviations. The standard deviation for the random effect of Word was estimated at 0.0297. In this model, there were three random effects involving Subject. The standard deviation for the by-subject adjustments to the intercept was 0.1164. In addition, participants turned out to be differentially sensitive to the Family Size count (log-likelihood ratio $= 12.36, p = 0.0021$). The standard deviation for the by-subject adjustments to coefficient of Family Size was 0.0505, and the estimated coefficient for the correlation of the by-subject adjustments to intercept and Family Size was -0.156. The residual standard deviation was 0.1777.

The reversal of the priming effect, from inhibitory in a model without controls, to facilitatory in the model with appropriate controls, is brought about not by the inclusion of the lexical covariate (Base Frequency), but by the experimental control variables. Subanalyses show that each of the control variables contributes independently to this reversal. For instance, if a participant rejected a neologism as a word when the neologism was presented as the prime, and later reversed this decision for the target, this revision led to a longer response latency for the target, contributing to the greater raw group mean for the priming condition in which the neologism was repeated. In other words, the facilitatory priming effect emerges more clearly for prime-target trials where participants accepted the neologisms at both occasions. The full model therefore provides much better insight into how in our experiment task requirements, the details of the transfer of prior processing onto later processing, and between-trial correlational structure may not only mask but completely reverse a priming effect as visible in raw group means.

We also fitted a mixed-effect model of covariance to the Prime RTs, using a stepwise variable selection procedure, with participant and word as crossed random effects. We observed main effects of PC-Preceding RTs, Base Frequency and Condition as well as an interaction of Condition by Family Size.

Response latencies to the prime decreased with increasing Base Frequency, as expected for neologisms ($\hat{\beta} = -0.0196, t(1034) = -4.19, p < .0001$). (We note that the coefficient for Base Frequency for the prime is almost twice that observed for the target ($\hat{\beta} = -0.0104$). This reduction in the Base Frequency effect may be due either to attenuation at the second exposure, to the absence of bare stems among the targets, or to both.) There was a significant main effect of Condition: Response latencies to the prime were longer in the identity priming condition (in which participants responded to a neologism) than in the stem priming condition (in which participants responded to an adjectival base) ($\hat{\beta} = 0.1500, t(1034) = 4.27, p < .0001$). There was no significant interaction of Base Frequency by Condition. Response latencies to the prime increased with increasing PC Preceding RTs ($\hat{\beta} = 0.0423, t(1034) = 5.88, p < .0001$). Inspection of the correlational structure of this control variable shows that its interpretation remains identical to that for the target words.

The effect of Condition was modulated by Family Size ($F(1, 1034) = 6.93, p = 0.0086$): For participants who had to respond to an adjectival base, response latencies to the prime decreased with increasing Family Size ($\hat{\beta} = -0.0300, t(1034) = -2.98, p = 0.0030$), while Family Size was not significant in the identity priming condition

($\hat{\beta} = 0.0071, t(1034) = 0.70, p = 0.4853$). Recall that in Experiment 1, a larger number of meanings (synsets) led to significantly lower ratings for neologisms than for existing words. This finding is mirrored in part by the present effect of Family Size, the count of words that are not only semantically but also formally related. For words that are not neologisms, a higher synset or a higher family count leads to higher ratings and shorter latencies, respectively. For neologisms, we find either lower ratings or no facilitation (non-significant inhibition).

We complete the specification of the mixed-effect model with reporting the standard deviations. The standard deviation for the Word random effect was 0.0575, and that for the Subject random effect was 0.0946. In addition, there was a significant random effect of Subject by Family Size (log-likelihood ratio $= 14.83, p = 0.0006$), indicating that the Family Size count was predictive, but correlated negatively with the RTs for some participants, and positively with the RTs for others. The standard deviation for the by-subject adjustments to coefficient of Family Size was 0.0775, and the estimated coefficient for the correlation of the by-subject adjustments to intercept and Family Size was 0.353. The standard deviation of the residual error was 0.2285.

The analysis of the response latencies to the prime showed no effect of Family Size for the neologisms. The analysis of the response latencies to the target showed that participants differ in their sensitivity to Family Size. For some participants the response latencies decreased with increasing Family Size, for others the response latencies increased with increasing Family Size. From the study of Bertram, Baayen, & Schreuder (2000), we know that for well-established formations ending in *-heid* response latencies in visual lexical decision decrease with increasing Family Size. Considered jointly, these results suggest that the family size effect in lexical decision is absent for neologisms, begins to emerge already after only 1 exposure (either facilitatory or inhibitory), and ultimately becomes facilitatory.

The presence of a family size effect in the latencies for the prime that was a base word and its absence for the neologism allow us to infer that the priming effect is not driven simply by greater attentional resources being drawn to the base in the identity priming condition. If such were the case, then we would have expected a family size effect primarily for the condition in which the neologism is the prime, contrary to fact.

In summary, Experiment 2 shows that the processing of a neologism is affected by the kind of prime encountered previously. Participants recognized a neologism at the second exposure, allowing them to respond more quickly. The lexical decision made 40 trials previously (roughly 1.5 minutes) was also reflected in the latencies to the targets, with earlier rejection of the neologism as a word leading to prolonged RTs. In both priming conditions, the response latencies to the prime were predictive for the processing of the target. We conclude that the primes left traces in working memory, independently of the type of prime (stem versus neologism).

Experiment 2 made use of long-distance priming for isolated words presented in a list. The assessment in Pinker (1999) of frequency effects in lexical decision is that it is the lexical decision task that leads participants to make use of frequency information that they would not use in reading or listening to words in normal discourse. We put this claim to the test by embedding the target words of Experiment 2 in natural discourse, and by switching from lexical decision to self-paced reading, a task with a higher degree of ecological validity. We continued to make use of long-distance priming, as both priming conditions occur in natural speech. For instance, the sequence of an adjectival stem followed by the corresponding noun further on in the discourse is not uncommon, as witnessed by example (1) (Kastovsky (1986), see also Baayen & Neijt (1997)).

> (1) "... and whether our own conversation doesn't sound a little *potty*. It's the *pottiness*, you know, that's so awful."

Similarly, the sequence of a noun ending in *-ness*, followed later in the discourse by the same noun occurs, is a common phenomenon, as witnessed by example (2).

> (2) "But prime ministerial *pottiness* is ever with us. Who, doe-eyed and dripping sincerity, invited our trust - and made himself the ultimate repository of that virtue? Tony Blair. So who now lives or dies on the red line he created? Pause, though, for *pottiness* is a three-syllable word of some complexity."
> (Preston, 2004, June 21)

Experiment 3 therefore addressed the question of whether similar differential effects of priming arise when participants read the same stimuli, but now presented in cohesive discourse without having to make lexical decisions, using the self-paced reading paradigm.

Experiment 3: Self-Paced Reading

Method

Participants

Thirty-two undergraduate students at the University of Nijmegen were paid to take part in this experiment. All were native speakers of Dutch. None had taken part in the preceding experiments.

Materials

We used the same neologisms as in Experiment 2. We created 40 short texts with a median length of 65 words in which we used these neologisms. For each text, we created two variants that differed with respect to whether the prime was the base adjective or the neologism itself. Exactly 40 words later in the text, the prime was followed by the target neologism. Each text was followed by a question about its content, in order to ensure that participants would read the texts carefully for content.

The Appendix presents an example of the parallel texts for the neologism *tembaarheid* 'tamability', respectively the condition with stem priming and the condition with identity priming, primes and targets are shown in bold, the neologisms are also underlined. Special care was required for the construction of the parallel texts. First, since prime and target belonged to different word categories (adjective versus noun), it was impossible to simply replace the adjectival prime by the target without effecting minimal changes in the syntax. Second, adjectives in Dutch may be inflected for person and number, in which case they are suffixed with a schwa. The texts were constructed in such a way that the number of inflected adjectival primes was kept as small as possible (6 out of 40 adjectival primes were inflected). Third, the texts were presented over several lines, such that primes and targets did not appear on the first or last position of a line.

We created two master lists. Each master list contained 20 texts with the stem as prime and 20 texts with the neologism as prime, such that a given participant read a given prime-target pair only once. The order in which the texts were presented was randomized four times. For each random order, we used two lists that differed only in whether the base or the neologism was presented as prime. Each one of the resulting eight lists was preceded by three practice trials; a fourth practice trial followed a short pause after the first 20 critical trials.

Procedure

Participants were tested individually in a noise-attenuated experimental room in front of a monitor and a panel with three buttons. They received standard self-paced reading instructions and were asked to read carefully and at a comfortable reading speed. The course of a trial was as follows. The participants saw a fixation point, indicating where the text would begin. By pushing the middle button they initiated the trial and the full text with dashes marking letter positions was displayed. By pushing the middle button again they saw the first word of the text. When the participants pressed the middle button again, the second word appeared and the first word was replaced by dashes. This procedure was repeated until the participants had read the whole story, at which point the word VRAAG 'question' was presented in the center of the screen, followed by a yes/no question about the text. We asked the participants to indicate their response by means of a button press (the right button for yes, the left button for no).

Results and Discussion

Inspection of the group means for the two priming conditions, averaging over participants and words, revealed a small inhibitory effect that, unlike for Experiment 2, failed to reach significance (stem priming condition: 431 ms, identity priming condition: 437 ms; $p > 0.8$).

As for Experiment 2, we added covariates to our model in order to obtain improved insight into the structure of our data. We included Base Frequency, Family Size, Length (in letters), Number of Synonym sets in Wordnet and the mean number of items in a synset as lexical covariates. Because Experiment 2 revealed an effect of the prime on the latencies of the target, we included as a first experimental control Prime RT, the reading time of a given participant for the prime, as a covariate for the participant's response to the target 40 trials later in the experiment. We also included the (orthogonalized) reading times of a given participant to the four preceding words as covariates for that participant's response to the target (henceforth, Preceding RTs) to control for between-text differences in the preceding words and syntax, and to control for reading speed.

As in Experiment 2, we logarithmically transformed the Base Frequency, Family Size, Number of Synset measures, the reading times for the prime and to the RTs for the target, as well as to the Preceding RTs to reduce the non-normality of their distribution and to avoid distortion of the statistical model by outliers with undue leverage.

We fitted a mixed-effect model of covariance to the reading times for the targets, using a stepwise variable selection procedure, with participant and word as crossed random effects. We observed main effects of Prime RT, PC-Preceding RTs and Length as well as an interaction of Condition by PC-Preceding RTs (see Figure 2.2). Inspection of the residuals revealed marked non-normality, indicating a lack of goodness of fit. We therefore removed outliers with standardized residuals outside the interval $[-2.5, 2.5]$ (2.21%), and refitted the model. The residuals of this model were more normally distributed, indicating improved goodness of fit for the trimmed model.

Reading times increased with increasing Prime RT, as expected given the results of Experiment 2 ($\hat{\beta} = 0.1014, t(1233) = 5.10, p < .0001$): If the prime required longer reading time, than it is not surprising that the target, which partially or completely repeats the prime, also required longer reading time. Reading times also increased with increasing PC-Preceding RTs (the first principal component of the orthogonalized four preceding reading times, $\hat{\beta} = 0.1504, t(1233) = 16.29, p < .0001$). Inspection of this control variable shows that the PC-Preceding RTs were positively correlated with the preceding RTs. Longer preceding RTs implied longer RTs to our target words, indicating that greater lexical and syntactic complexity of the immediately preceding context rendered the reading of the neologism more difficult. Longer words elicited longer reading times as well, as expected ($\hat{\beta} = 0.0375, t(1233) = 3.44, p = .0006$).

The effect of prime type manifested itself in the form of an interaction with PC-Preceding RTs ($\hat{\beta} = -0.0251, t(1233) = -2.24, p = .0251$): Reading times were shorter in the identity priming condition (in which participants responded to the neologism for the second time) than in the stem priming condition (in which the neologism was entirely new), proportional to the processing costs for the four preceding words as measured by means of PC-Preceding RTs. Previous experience with the neologism

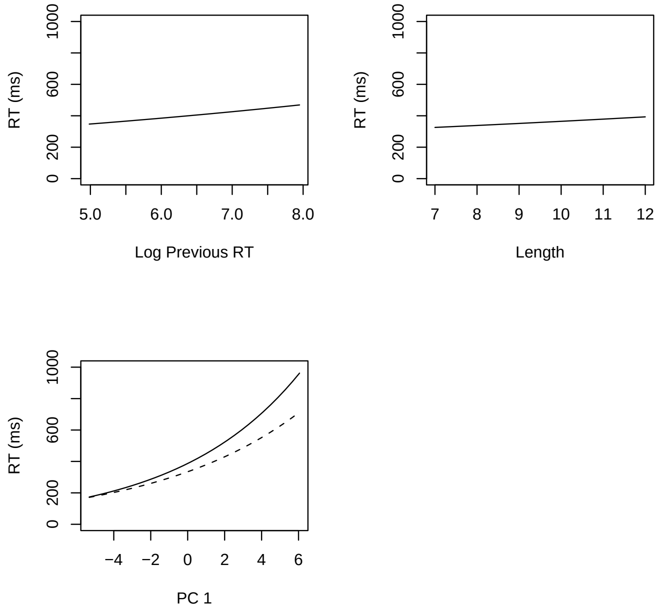

Figure 2.2: Partial effects for self-paced reading latencies. The dashed line in the lower left panel represents the identity priming condition, the solid line the stem priming condition. (The effect of PC1 was linear in log RT, but is nonlinear for RT in ms.)

facilitated subsequent processing, exactly as expected for a budding frequency effect. Other predictors such as Base Frequency and Family Size were not significant. The estimates of the standard deviations of the random effects in this model were, for Word: 0.0580, for Participant: 0.1029, and for the residual error: 0.2882.

We also fitted a mixed-effect model of covariance to the Prime RTs, using a stepwise variable selection procedure, with participant and word as crossed random effects. In this case, we incorporated all four principal components. Only the first (57% of the variance) and second (16% of the variance) principal component (respectively PC1-Preceding RT and PC2-Preceding RT) reached significance in the analysis. We also observed main effects for Condition and Family Size as well as an interaction of Participant by Condition.

Response latencies to the prime were longer in the identity priming condition (in which participants responded to a neologism) than in the stem priming condition (in which participants responded to an adjectival base) ($\hat{\beta} = 0.1538, t(1241) = 3.14$, $p = 0.0017$). Response latencies to the prime were longer for words with larger morphological families ($\hat{\beta} = 0.0355, t(1241) = 2.78, p = 0.0055$). Response latencies also increased with increasing PC1-Preceding RTs ($\hat{\beta} = 0.1602, t(1241) = 20.67$, $p < .0001$), and with increasing PC2-Preceding RTs ($\hat{\beta} = 0.0372, t(1241) = 2.83$, $p = 0.0047$). Inspection of the correlational structure of these control variables shows that their interpretation remains identical to that for the target words: greater RTs to preceding trials correlated positively with the RTs for the prime.

We complete the specification of the mixed-effect model with reporting the standard deviations. The standard deviation for the random effect of Word was estimated at 0.1590. In this model, there were three random effects involving Participant. The standard deviation for the by-subject adjustments to the intercept was 0.0709. In addition, participants turned out to be differentially sensitive to Condition (log-likelihood ratio $= 34.43, p < .0001$). The standard deviation for the by-subject adjustments to coefficient of Condition was 0.1609, and the estimated coefficient for the correlation of the by-subject adjustments to intercept and Condition was 0.913. The residual standard deviation was 0.3177.

A comparison of the reading times for the primes and those for the targets reveals an interesting difference concerning the predictivity of the Family Size measure. For the primes, the Family Size count was inhibitory for both base words and neologisms, for the targets, the Family Size count was not significant. Recall that in visual lexical decision, Family Size is facilitatory with existing words, possibly because a lexical decision can be based on a global evaluation of the amount of lexical activation, for example Grainger & Jacobs (1996) and Schreuder & Baayen (1997). In self-paced reading, new information has to be integrated in the current discourse representation. Apparently, this integration process is slowed down when a word has a large morphological family. Such words are more ambiguous, they require more processing resources in order to select their appropriate meaning given the preceding discourse. Interestingly, the absence of a Family Size effect for the targets suggests that this process of disambiguation and discourse integration takes place once only. When an integrated word (or its derivative ending in *-heid*) is encountered a second time, its interpretation given the discourse is retrieved (as witnessed by the predictivity of the reading time for the prime for the reading time of the target), and its family members are no longer considered.

Compared to Experiment 2, Experiment 3 added not only a semantic context, but also a syntactic context. The syntactic context of the prime (adjective) differs slightly from that of the target (noun). In other words, the stem priming condition and the identity priming condition differed not only with respect to the presence of *-heid*, but also with respect to the local syntax. This difference in syntactic context may have attenuated the effect of Condition, but given the positive results of Experiment 2, where no difference in syntactic issue was at issue, it is clear that the effect of syntactic context cannot account for the effect of Condition all by itself.

General Discussion

The question addressed in this paper is whether neologisms leave detectable traces in lexical memory. According to Alegre & Gordon (1999) and Pinker (1991), regular morphological complex words do not have their own lexical representation. Experiment 1, a subjective familiarity rating, showed that neologisms ending in *-heid* ('-ness') were processed qualitatively differently from existing words with respect to the effect of their number of meanings, as gauged by the count of their synonym sets in WordNet. For both existing words and neologisms, a larger number of synonyms led to lower subjective frequency estimates. But for neologisms, this detrimental effect on the ratings of semantic ambiguity was stronger. This suggests that the interpretation of a neologism becomes more difficult when the base word is more ambiguous.

Experiment 2 (visual lexical decision) and Experiment 3 (self-paced reading) showed that a neologism is processed in a qualitatively different way after even a single exposure. Both experiments made use of long-distance priming. The prime, which preceded the target neologism by 40 trials, was either the neologism's base, or the neologism itself. In visual lexical decision, neologisms elicited shorter response latencies in the identity priming condition compared to the stem priming condition. We conclude that participants recognized a neologism at the second exposure, allowing them to respond more quickly.

In self-paced reading, the difference between the two priming conditions emerged in interaction with the processing complexity of the preceding words in the discourse. We gauged the complexity of the preceding discourse by means of a measure (obtained through principal components orthogonalization) that captured a large proportion of the variance in the reading times of the four words preceding the target. The coefficient of this measure (the first principal component) was significantly more facilitatory for neologisms that had been read before, than for neologisms of which only the base had been seen previously. Given that there were 39 intervening trials in our experiments, and that the span of short-term memory for words is much shorter than this, limited to five to nine words, these results allow us to conclude that neologisms leave traces in lexical memory.

The question that arises at this point is what the nature is of these memory traces. Do neologisms receive a lexical entry in the mental lexicon after just a single exposure? Is this entry a whole-word representation similar to the entries of monomorphemic words? Or is this entry a combinatiorial trace that, given base and suffix, provides a direct link to their joint interpretation as computed when the neologism was first encountered? Is the initial memory trace qualitatively different for inflected words, derived words, and contiguous words in the syntax? At this stage of our research, we must leave questions such as these unanswered. We think that the present memory effect is not restricted to derived words, but extends both to inflected words and to (novel) collocations. And it may well be that the memory traces in our data are inherently combinatorial, as argued by Baayen et al. (2007) for low-frequency complex words in general.

Our present results also remain silent about further consolidation in memory. Recall that Dumay et al. (2004) and Gaskell & Dumay (2003) observed that pseudowords that overlapped strongly with existed words became lexical competitors of the existing words already 24 hours after the initial familiarization (12 exposures) with the pseudowords. Gaskell & Dumay (2007) show that the integration of a pseudoword in lexical memory crucially requires at least one night's sleep, and not just by the passing of twelve hours between training and testing.

Our experiments differ in several respects from those of Dumay et al. (2004) and Gaskell & Dumay (2003, 2007). We used long-distance priming within one and the same experiment. This suggests that the consolidation in long-term memory for which a night's sleep is required did not take place. A second difference is that we observed effects of lexical learning after only one exposure, whereas Gaskell & Dumay (2003) presented their materials repeatedly to their participants. A third difference is that we studied lexical learning directly by investigating novel, but morphologically well-formed and semantically transparent derived words. Gaskell and colleagues, by contrast, studied lexical learning indirectly, by tracing the consequences of acquired nonwords on the processing of other well-established, existing words.

Given the importance of sleep for lexical consolidation, it is unlikely that full-fledged lexical entries for morphologically complex neologisms are established in long-term memory immediately after a single exposure. Chapter 3 addresses the question whether sleep is important for the consolidation of neologisms in lexical memory. What our experiments do allow us to conclude is that neologisms do leave traces beyond immediate working memory, and that these traces facilitate subsequent processing. Hence we expect to find that even such ephemeral traces are in fact consolidated after a night's sleep.

A crucial result that supports the importance of lexical traces for language processing is that the long-distance priming effect was present not only in visual lexical decision, but also in natural discourse. Although Alegre & Gordon (1999) and Pinker (1991, 1999) have argued that especially low-frequency words would not have their own lexical representations, our results suggest that memory traces for even the lowest-frequency complex words play a functional role in discourse processing. Hence, it is unlikely that Pinker's dismissal of experimental evidence for frequency effects in visual lexical processing for regular complex words as task artifacts is justified. Our data bear witness to the relevance of previous experience with complex words also in connected discourse. In fact, we predict that the discourse context in which a neologism is first encountered leaves a trace in episodic memory, and that lexical processing of the neologism after one night's sleep will be facilitated notably when it appears in a similar context.

This chapter also offers some methodological innovations, enabled by mixed-effect modeling with participant and word as crossed random effects (Faraway, 2006). First, we were able to bring at least part of the correlational structure of the latencies for our target words and the latencies for the items preceding our target words in the experiment into our statistical models, by means of orthogonalized measures for the latencies to the preceding trials. This provided us with the necessary power to observe an effect of priming in self-paced reading, and protected us against the erroneous and theoretically unexpected conclusion suggested by the raw group means that prior experience would lead to inhibition rather than to facilitation.

Second, mixed-effect modeling also allowed us to observe that the latency to the prime, and the lexical decision to the prime, were predictive for how the target was processed 40 trials later in the experimental list. To our knowledge, priming studies have thus far only considered the effect of priming at the factor level. Mixed-effect analysis of covariance with participant and word as crossed random effects allowed us to zoom in on the effect of priming at the level of the responses of specific participants to specific words.

Appendix

Experimental materials of Experiments 1 and 2:

kortafheid; lobbigheid; labielheid; pitloosheid; saprijkheid; saploosheid*; summierheid; tactvolheid; tembaarheid; tilbaarheid; visrijkheid; pipsheid; blitsheid*; enormheid; jofelheid; koketheid; onwelheid; ovaalheid; riantheid; antiekheid; banaalheid; basaalheid; dementheid; erkendheid; gammelheid; ludiekheid; ondiepheid; royaalheid; aftandsheid; beschutheid; bezweetheid; contentheid; coulantheid; bebrildheid; markantheid; beuheid; blusbaarheid; geurloosheid; kalkrijkheid; onattentheid; onbelastheid; ontroerdheid

Example of experimental materials of Experiment 3:

Stem - Neologism:
Als je vraagt naar een dier dat **tembaar** is, dan denkt bijna iedereen direct aan het paard. Paarden worden al sinds mensenheugenis ingezet als lastdieren en als werkdieren. Voordat ze ingezet kunnen worden, moeten de dieren zadelmak gemaakt worden. Hiervoor heb je veel geduld nodig. Ook de **tembaarheid** van een dier speelt mee. Bij vurige dieren duurt het nu eenmaal langer voor je ze zadelmak hebt, en je ze dus in kunt zetten als lastdier of als werkdier, dan bij rustigere dieren.

If you ask for a **tamable** animal, everyone will immediately think of a horse. Horses have been used as pack animal and as working animal since time immemorial. Before they can used, the horses have to be trained. You need to be patient for this job. The **tamability** of an animal plays also a role. It will take more time to train high-spirited horses than to train calm animals. Hence, it will take more time before you can use a high-spirited horse as pack animal or as working animal.

Neologism - neologism:
Als je vraagt naar de **tembaarheid** van dieren, dan denkt bijna iedereen direct aan paarden. Paarden worden al sinds mensenheugenis ingezet als lastdieren en als werkdieren. Voordat ze ingezet kunnen worden, moeten de dieren zadelmak gemaakt worden. Hiervoor heb je veel geduld nodig. Ook de **tembaarheid** van een dier speelt mee. Bij vurige dieren duurt het nu eenmaal langer voor je ze zadelmak hebt, en je ze dus in kunt zetten als lastdier of als werkdier, dan bij rustigere dieren.

If you ask for the **tamability** of animals, everyone will immediately think of horses. Horses have been used as pack animal and as working animal since time immemorial. Before they can be used, the horses have to be trained. You need to be patient for this job. The **tamability** of an animal plays also a role. It will take more time to train high-spirited horses than to train calm animals. Hence, it will take more time before you can use a high-spirited horse as pack animal or as working animal.

* Excluded in Experiments 2 and 3

Lifespan of lexical traces

Chapter 3

This chapter is a reformatted version of:
Laura de Vaan, Mirjam Ernestus, and Robert Schreuder (2011). The lifespan of lexical traces for novel morphologically complex words. *The Mental Lexicon*, *6(3)*, 374-392.

Abstract

This chapter investigates the lifespans of lexical traces for novel morphologically complex words. In two visual lexical decision experiments, a neologism was either primed by itself or its stem. The target occurred 40 trials after the prime (Experiments 1 and 2), after a 12 hour delay (Experiment 1), or after a one week delay (Experiment 2). Participants recognized neologisms more quickly if they had seen them before in the experiment. These results show that memory traces for novel morphologically complex words already come into existence after a very first exposure and that they last for at least a week. We did not find evidence for a role of sleep in the formation of memory traces. Interestingly, Base Frequency appeared to play a role in the processing of the neologisms also when they were presented a second time and had their own memory traces.

Introduction

In daily life, we are quite often confronted with a novel regular morphologically complex word (see, e.g., Baayen & Renouf, 1996). Usually, the meaning of such a neologism is transparent. That is, its meaning is derivable from the meanings of its existing morphemes (e.g., *kortaf+heid* 'abrupt'+'ness'). The question arises whether such a novel word is stored in the mental lexicon after just one encounter. Pinker (1991) argued that this is not the case. Nevertheless, Chapter 2 provided experimental evidence that a novel Dutch transparent derivation may leave traces in lexical memory after its very first occurrence. The present chapter addresses the lifespan of these lexical traces.

In Chapter 2, we investigated the lexical traces of completely regular derivational neologisms using a priming paradigm. Neologisms were presented visually as isolated words (visual lexical decision) or in short stories (self-paced reading). Half of the neologisms were primed by their stems (stem priming), the other half were primed by themselves (identity priming). The prime and target words were separated by a fixed number of trials. In both experimental paradigms, response latencies were shorter in the identity priming condition (in which participants responded to the neologism for the second time) than in the stem priming condition (in which the neologism was entirely new). In Chapter 2, we interpreted the repetition effect as evidence for the formation of a trace in lexical memory for the neologism. Since the target word was presented very close to the prime (after 39 intervening trials, equal to approximately 1.5 minutes), the question arises whether the observed traces were long lasting or only present for approximately 1.5 minutes. Does such a trace still exist after a couple of hours or even a week? One would expect that the lexical trace loses its strength with time and that its effect is thus less strong after, for instance, 12 hours, than after several minutes.

Dumay et al. (2004) and Gaskell & Dumay (2003) investigated the lifespan of lexical traces for novel pseudowords that are morphologically simple. These researchers studied the development of lexical representations by tracing the effects of these new representations on the auditory processing of phonologically similar existing words. They observed that listeners recognize a word such as *cathedral* more quickly if they have just heard 12 tokens of a phonologically similar pseudoword (e.g., *cathedruke* for *cathedral*). However, five days after the familiarization, listeners recognized the already existing words more slowly. Gaskell and colleagues attributed this inhibitory effect to the pseudowords having become lexical competitors for the existing words. They thus concluded that the formation of a lexical representation takes some time.

Tamminen & Gaskell (2008) studied the effect of new words on the recognition of phonologically similar words over a longer period of time. Like Gaskell & Dumay (2003), they found that lexical competition effects emerge only after a delay. In addition, Tamminen and Gaskell demonstrated that new words remain lexical competitors up to eight months after exposure.

Gaskell & Dumay (2007) investigated whether sleep affects the formation of lexical representations. They observed that if participants learned words at 8 p.m., they did not show (inhibitory) competition effects immediately, but only after a 12 hour interval including a night's sleep. Participants who learned the words at 8 a.m. showed competition effects neither immediately nor after 12 hours of wakefulness, but did so after 24 hours, that is, again after a night's sleep. Thus, sleep is a necessary condition for competition effects to show up. Further support for the role of sleep in establishing traces in lexical memory comes from the study by Davis et al. (2008). They observed that participants show lexical competition and faster recognition times only for novel words they learned the previous day, in contrast to words they learned the same day. The two groups of novel words also showed differences in an fMRI study: cortical activation was of equivalent magnitude for novel words the participants had not seen before and novel words learned on the day of scanning, while the cortical activation was significantly reduced for novel words learned on the previous day. Hence, fMRI results also suggest effects of sleep in the formation of lexical memory traces. The role of sleep in consolidating memory in general has been extensively documented, see for instance, Stickgold & Walker (2005) and Walker (2005).

The present study investigates the lifespan of regular morphologically complex neologisms (instead of the morphologically simplex pseudowords studied by Dumay et al., 2004; Gaskell & Dumay, 2003, 2007; Tamminen & Gaskell, 2008), including the role of sleep. In addition, we investigated whether the results of Chapter 2 based on neologisms created by the combination of existing words with one single suffix (*-heid* '-ness') generalize to neologisms ending in two other Dutch suffixes.

Bertram, Schreuder, & Baayen (2000) argued that the balance between parsing and storage depends on several characteristics of the affix. Words with an unproductive affix tend to be stored in the mental lexicon, whereas words with a productive affix tend to be parsed. In addition, words with an affix that has a productive rival affix tend to be stored, whereas words without such a rival affix tend to be parsed. Finally, words with affixes that do not cause a change in the meaning of the base tend to be parsed, others are either parsed or stored. The three suffixes we investigated are productive, do not have a rival affix, and do not change the meaning of the base. This decreases the likelihood that neologisms with these suffixes are stored in the mental lexicon.

We tested Dutch novel, morphologically well-formed and semantically transparent derived words ending in the suffixes *-heid* 'ness', *-baar* 'able' and *-ing* (e.g., *saprijk* + *heid* 'juice-rich' + 'ness', *ontkleur* + *baar* 'decolour' + 'able', *onthars* + *ing* 'deresinate' + 'ing'). The suffix *-heid*, which was also tested in Chapter 2, is the most regular and productive derivational suffix of Dutch. It attaches to adjectival stems and turns them into nouns. The deverbal suffix *-baar* only attaches to transitive verbs, at least in its productive use, which we investigated here. This restriction is directly related to its meaning contribution 'being able to be *Verb*-ed' (Booij, 2002). The suffix turns verbal bases into adjectives. The suffix *-ing* makes action nouns from verbs, and is particularly productive for morphologically complex verbs (Booij, 2002; Van Haeringen, 1971). In the present study, it is always attached to morphologically complex stems, as for instance in *ont+hars+ing* 'de+resinate+ing'. Suffixation of a stem with *-baar* or *-heid* does not lead to changes in the pronunciation of the stem. Suffixation with *-ing*, in contrast, leads to resyllabification of the stem-final obstruents to the following syllable formed by the suffix.

We carried out two experiments using a design in which participants were tested in two sessions. Participants were tested for half of the target words in the same session as the presentation of the primes (short priming distance) and for the other half in a different session, which took place 12 hours after the first session (Experiment 1) or one week later (Experiment 2; both long priming distance). The prime was either the stem (stem priming) or the neologism itself (identity priming). The target was always the neologism. To test whether sleep played a role in the formation of lexical traces, we tested half of the participants in Experiment 1 over the course of one day, and the other half with an intervening night's sleep.

Our experimental design provides the possibility to investigate another interesting issue. The words in the Short Priming Distance condition occur either three times in the full experiment (twice in the first part and once in the second part) or twice (once in the first part, primed by their stems, and once in the second part). This implies that we can test whether neologisms are recognized faster (and therefore have stronger lexical representations) if the reader has read them twice instead of only once. We tested this hypothesis in Experiments 1 and 2.

Finally, since this study focuses on neologisms consisting of existing morphemes, the frequencies of these morphemes may affect processing times. This would be in line with most models of morphological processing since they assume that the processing of a morphologically complex word involves the activation of its morphemes, even if the word is processed via its whole word trace in the mental lexicon (e.g., Balling & Baayen, 2008; Burani & Caramazza, 1987; Giraudo & Grainger, 2001; Plaut & Gonnerman, 2000; Schreuder & Baayen, 1995). We included this prediction in our analyses of the data.

Experiment 1: a 12 hours interval

As mentioned above, Experiment 1 was a visual lexical decision task run in Dutch. We used a design in which we crossed Prime Type (stem priming versus identity priming) with Priming Distance (short priming distance versus long priming distance), as illustrated in Table 3.1. In the case of stem priming, participants first performed lexical decision for the stem. Then they had to respond to the neologism, which was presented either 40 trials later in the same session of the experiment and 12 hours later in the second session of the experiment or only in the second session (stem priming in the short priming distance condition versus stem priming in the long priming distance condition). In the case of identity priming, participants responded only to

Table 3.1: Design of Experiment 1. Words in italics form the second exposure, words in bold form the third exposure (further explanation in text).

Session 1:				Session 2:	
		Short Priming Distance		Long Priming Distance	
Prime	intervening trials	Target	intervening time	Target	Prime Type
Stem ('wobbly')	39 trials	*Neologism* ('wobbliness')	12 hours	**Neologism** ('wobbliness')	Stem Priming
Neologism ('wobbliness')	39 trials	*Neologism* ('wobbliness')	12 hours	**Neologism** ('wobbliness')	Identity Priming
Stem ('wobbly')			12 hours	*Neologism* ('wobbliness')	Stem Priming
Neologism ('wobbliness')			12 hours	*Neologism* ('wobbliness')	Identity Priming

the neologism, never to its base. The second token appeared 40 trials after the first token or 12 hours later in the second session of the experiment (identity priming in the short priming distance condition versus identity priming in the long priming distance condition). If the second token occured after 40 trials, a third token was presented in the second session.

We included the stem priming condition as a baseline in order to investigate whether priming in the identity priming conditions results from the full neologism or just its stem. If it is just the stem of the neologism that induces priming, the stem and the neologism should show similar priming effects. If, in contrast, participants stored the full neologisms, the neologisms should show more priming than just their stems.

Participants were asked to classify regular morphologically complex neologisms consisting of existing morphemes as words. They performed the second session of the experiment either after 12 hours of awakeness or after 12 hours with a night's sleep.

Method

Participants

Twenty-four native speakers of Dutch were paid to take part in this experiment. Six of them were male and eighteen were female. The participants had at the time of the experiment a mean age of 21, in a range of 18 to 37. Twenty-two of them were undergraduate students at the Radboud University of Nijmegen, two were already graduated.

Materials

The target materials consisted of 120 Dutch, morphologically well-formed and semantically transparent derived neologisms: 40 neologisms with the suffix *-heid* (these neologisms were taken from the study in Chapter 2, e.g., *pitloos+heid* 'seedless' + 'ness'), 40 neologisms with the suffix *-baar* (e.g., *bewapen+baar* 'arm' + 'able'), and 40 neologisms with the suffix *-ing* (e.g., *beboter+ing* 'butter' + 'ing', see the Appendix for all neologisms). The suffix *-heid* was attached to adjectival stems and turned them into nouns, the deverbal suffix *-baar* was attached to transitive verbs and turned them into adjectives, while the suffix *-ing* was attached to morphologically complex verbs and turned them into action nouns.

All 120 neologisms had a different stem. Some stems are monomorphemic words, others are complex words, but all stems are existing words and are listed in the CELEX database (Baayen et al., 1995). In contrast, the neologisms are not listed in the CELEX database. Moreover, none of the neologisms with the suffix *-heid* appeared over ten times in the Dutch section of the world wide web (as of January 2003). For the neologisms with the suffixes *-baar* and *-ing*, 96% had a frequency below ten in this part of the world wide web (as of June 2006).

For session 1 of the experiment, we created four master lists. A given target neologism was represented in each list in a different condition and each condition was equally represented in each master list as was each suffix. So, we had 30 stems, 30 stems followed by their 30 corresponding neologisms after 39 intervening trials, 30 neologisms, and 30 neologisms repeated by themselves after 39 intervening trials. This makes 120 prime words and 60 target words for session 1.

To distract participants' attention from the neologisms (which might trigger specific strategies), we added existing filler words with different stems and suffixes than these in the target words, 40 ending in *-achtig*, 40 ending in *-eer*, and 40 ending in *-schap*. The filler words all appear in CELEX with a lemma frequency of maximally 14, and have a mean frequency of 1.88 and a median of 0. We added these filler words to the master lists in the same four conditions as the neologisms: 30 stems, 30 stems followed by their 30 corresponding complex words after 39 intervening trials, 30 complex words, and 30 complex words repeated by themselves after 39 intervening trials.

Finally, we added 360 pseudowords that follow the phonotactic and orthographic conventions of Dutch in the same conditions as the target words. Each resulting master list then also contained 60 pseudo stems, 60 pseudo stems followed by their 60 corresponding pseudo complex words after 39 intervening trials, 60 pseudo complex words, and 60 pseudo complex words repeated by themselves after 39 intervening trials. The pseudowords differed from the existing words and neologisms in the experiment by one or two letters. The differences always occurred in the words' stems. In order to exclude the possibility that the pseudowords primed our target neologisms, we checked whether three other participants could guess the words from which the pseudowords were derived. The participants were able to do so for only 6% of the pseudowords.

We randomized all master lists six times, which resulted in 24 lists. We ensured that the number of trials between the words sharing their stems was held constant at 39 intervening trials. Each of the resulting lists was preceded by 24 practice trials (six stems, six words, six pseudo stems and six pseudo complex words). All practice words differed in their stems from each other and from the other words in the experiment.

For session 2 of the experiment, we created a master list with all 120 neologisms. Half of these neologisms were primed once in session 1 of the experiment (by their stems or by themselves), the other half were primed twice in session 1 of the experiment (half of the neologisms primed twice were primed once by their stems and once by themselves, the other half were primed twice by themselves).

To distract attention from the neologisms, we added 40 existing complex words (filler words) ending in *-aar*, 40 ending in *-er*, and 40 ending in *-lijk*/*-elijk*. These filler words all appear in CELEX and have a CELEX lemma frequency in the range of [0–10], a mean of 2.44 and a median of 2.

We matched each filler word and each neologism with a pseudoword by changing one or two letters in their stems, making sure that the resulting pseudowords did not violate the phonotactic or orthographic conventions of Dutch. To exclude the possibility that the pseudowords primed our target neologisms, we checked also for these pseudowords whether the three participants could guess the words from which the pseudowords were derived. The participants were able to do so for only 7% of the pseudowords. The resulting list contained 240 word trials and 240 pseudoword trials.

We randomized this list six times. Each of the resulting lists was preceded by 24 practice trials. Half of the practice trials were words, half were pseudowords; each of the six suffixes (*-baar*, *-heid*, *-ing*, *-aar*, *-er*, *-lijk*/*-elijk*) were presented an equal number of times. The practice trials or their stems did not appear in the experimental part of the experiment.

Procedure

Participants were tested individually in a noise-attenuated experimental room. They first read the instructions on the computer screen. These instructions made clear that both existing and possible Dutch words required a "yes" response, and that only words with non-existing morphemes required a "no" response. The first session consisted of two blocks separated by a break. Target words were part of the same block as their prime words.

In both sessions of the experiment, an experimental trial began with a fixation mark, positioned in the center of a Nec Multisync color monitor for 500ms. After 50ms, the stimulus appeared centered at the same position. Stimuli were presented in black lowercase, 36 point letters, on a white background and they remained on the screen for 1750 ms.

Half of the participant were tested in the morning and in the evening of the same day, the other half were tested during the evening and the following morning. The interval between the two sessions of the experiment was fixed at 12 hours. The testing hours lay between 8am and 10am and between 8pm and 10pm. The experimental setting and the experimenter were the same in both sessions of the experiment.

Results and Discussion

We first analyzed the response latencies to the target neologisms that were primed only once (in italics in Table 3.1). We coded no-responses as errors and removed these data points from the analyses of the response latencies. The percentage of errors for a neologism ranged from 4% to 58%. As we are dealing with neologisms in lexical decision, these high error rates are unsurprising. Moreover, we removed all data points of the nine words with error rates over 50% (*annoteerbaar* 'annotatable', *bebrildheid* 'spectacledness', *begiering* 'feeding with liquid manure', *bekonkeling* 'hatching', *betralieing* 'barring', *föhnbaar* 'blow-dryable', *omkeiling* 'knock flying', *ontmugging* 'disinsected', and *verboersing* 'becoming rustic'). Finally, we left out of consideration all trials in which participants did not react or reacted only after 1750 ms. We then applied a logarithmic transformation to the remaining response latencies to reduce the skewness of the distribution.

The dependent variable in our analysis is response latency (RT) to the target neologism. We added Prime Type (stem priming versus identity priming), Priming Distance (short priming distance versus long priming distance) and Sleep (yes or no) as our main predictors. We also added Base Frequency as covariate (the lemma frequency of the stem of a neologism) as obtained from CELEX. We logarithmically transformed Base Frequency in order to reduce the skewness in the distribution. Finally, we also included as predictors for a given participant's response, that participant's response latency to the prime of that target word (henceforth Prime RT) and the lexical decision for that prime (word or nonword, henceforth Prime Decision). We added the latter predictor because participants erroneously classified the primes as non-existing words in 24% of the trials.

We fitted a mixed-effect model of covariance, using a stepwise variable selection procedure, with participant and word as crossed random variables (e.g., Baayen, Davidson, & Bates, 2008; Bates & Sarkar, 2005; Faraway, 2006). Inspection of the residuals revealed marked non-normality, indicating serious lack of goodness-of-fit for this model. We therefore removed outliers with standardized residuals outside the interval of $[-2.5, 2.5]$ (1.67%), and refitted the model (see, e.g., Crawley, 2002). The residuals of this trimmed model were approximately normally distributed, indicating that removal of overly influential outliers resulted in a model with a bettter goodness of fit. This final model is listed in Table 3.2.

Table 3.2: Results of the Stepwise Multilevel Regression Model (df=2191) fit to the Reaction Times of Experiment 1 for target words primed only once. Prime Type provides the effect of identity priming relative to stem priming. Distance provides the effect of long priming distance relative to short priming distance. Decision provides the effect of an incorrect decision to the prime relative to a correct decision to the prime. The standard deviation for the random effect of Word was estimated at 0.0489, and that for the Participant random effect was 0.1191. In addition, there was a significant random effect for Participant by Base Frequency (log-likelihood ratio = $11.72, p = 0.003$, standard deviation = 0.0116, estimated coefficient for the correlation = -0.599). The residual standard deviation was 0.1925.

	$\hat{\beta}$	t	$p <$
(Intercept)	5.3487	32.65	0.0001
Prime Type	-0.0535	-6.25	0.0001
Distance	0.5340	2.74	0.01
Sleep	-	-	*n.s.*
Decision	1.6067	6.50	0.0001
Prime RT	0.2058	8.69	0.0001
Base Frequency	-0.0165	-4.19	0.0001
Decision by Prime RT	-0.2200	-6.10	0.0001
Distance by Prime RT	-0.0711	-2.46	0.01
Sleep by Decision	-0.1087	-4.58	0.0001

Long priming distance generally resulted in longer reaction times to target neologisms than short priming distance and participants reacted less quickly if they had made an error on the prime. Furthermore, response latencies increased with increasing Prime RTs, but only if the participant had accepted the prime as a word. This positive effect of Prime RT was smaller after long than after short priming distance.

More importantly for our research questions, we observed an effect of Prime Type: Response latencies to the target wourd were shorter in the identity priming condition than in the stem priming condition. Prime Type did not interact with Prime Distance suggesting that the priming effect is as strong after long priming distance as after short priming distance. In other words, the lexical trace for a neologism stays in the mental lexion for at least 12 hours.

These results are very similar to the results in Chapter 2. Also in that experiment, participants responded more quickly to a neologism if primed by itself than primed by its stem. In Chapter 2 were only neologisms tested in the short priming condition which ended in the suffix *-heid*. Since we tested three suffixes, we can conclude that the effect reported in Chapter 2 is not restricted to the suffix *-heid*: Lexical traces are also formed after the single presentation of morphologically complex words ending in other suffixes, and all these traces are long lasting, surviving at least several hours.

Interestingly, our results did not show a significant main effect for sleep, but only show a significant interaction of Sleep by Prime Decision. Participants generally reacted more slowly to a target neologism if they had rejected the prime as a word, but this effect was smaller after a night's sleep. Participants were thus less influenced by their initial decision after sleep.

Since sleep did not interact with Prime Type, sleep appears not to affect the formation of lexical traces. In contrast with previous research by Gaskell & Dumay (2007), who have shown that sleep is crucial for the formation of lexical traces for novel morphologically simple pseudowords, our results and the results in Chapter 2 indicate that if a novel form is morphologically complex, sleep is not crucial. We will return to this issue in the general discussion of this chapter.

The effect of Prime Type strongly suggests that the neologisms, at their second presentation, were processed via their full form representations. Nevertheless, we also observed that the response latencies from most participants decreased with increasing Base Frequency (we observed a fixed effect of Base Frequency and a random effect by participant for Base Frequency). Since there was no significant interaction of Base Frequency by Prime Type, we can conclude that these participants processed the neologisms through their stems, at both the first and second presentation. Apparently, most participants activated the morphemes forming the neologisms as well as the lexical trace formed by the neologisms.[1]

We now address the question whether participants recognized a neologism more quickly if they had seen the neologism twice before instead of only once the neologism and once its stem. We fitted a mixed-effect model of covariance to the RTs of neologisms in the second session of the experiment with two primes (in bold in Table 3.1). We again made use of a stepwise variable selection procedure, and entered the same independent variables as in the first analysis. In the present analysis, however, we did not only add the Prime RT, but the RT to the second exposure as well (Prime RT 2) as covariates and we also included as predictor the Decision to this second exposure (Prime Decision 2). Because of collinearity of Base Frequency with Prime RT 2, we orthogonalized these covariates by using the residuals of a model predicting Base Frequency as a function of Prime RT 2 instead

[1] A logistic mixed-effect model of covariance on the errors (a binomial variable) with participant and word as crossed random variables showed significant $\hat{\beta}$s for Prime RT ($\hat{\beta} = 1.6175, z = 3.780, p = 0.0002$), Prime Decision ($\hat{\beta} = 10.2314, z = 3.251, p = 0.0012$), Base Frequency ($\hat{\beta} = -0.1484, z = -3.275, p = 0.0011$), and for the interaction of Prime Decision with Prime RT ($\hat{\beta} = -1.2241, z = -2.685, p = 0.0073$). Participants made fewer errors if they had reacted more quickly on the primes, if they had judged these primes correctly as words (especially if this had taken some time), and if the neologism had a higher base frequency. The error analysis showed no effects for Prime Type or Priming Distance, and no interactions of Priming Distance with Prime RT, or Sleep with Prime Decision. Our data thus show no evidence for speed-accuracy trade-offs.

Table 3.3: Results of the Stepwise Multilevel Regression Model (df=1111) fit to the Reaction Times of target words primed twice in Experiment 1. Decision and Decision 2 provide the effects of an incorrect decision to the first and second primes, respectively, relative to a correct decision. The standard deviation for the random effect of Word was estimated at 0.0458 and of Participant at 0.1011. The residual standard deviation was 0.1940.

	$\hat{\beta}$	t	$p <$
(Intercept)	5.7810	36.23	0.0001
Base Frequency	-0.0174	-5.32	0.0001
Prime Decision	0.0684	4.36	0.0001
Prime Decision 2	0.0785	3.67	0.0001
Prime RT 2	0.1271	5.33	0.0001

of the raw values of Base Frequency.[2] In this analysis, we also removed outliers with standardized residuals outside the interval $[-2.5, 2.5]$ (1.93%), and refitted the model. The final model is listed in Table 3.3.

The results show no effect for Prime Type. This suggests that there was no difference in the strength of memory traces for neologisms that participants had seen only once and for neologisms that they had seen twice in the first session of the experiment. The other predictors, including Base Frequency, showed effects that could be expected given the analysis of the RT's for the tokens of the target words primed only once.

In summary, Experiment 1 shows that a lexical trace is formed after a single exposure for Dutch morphologically complex neologisms ending in *-heid*, *-baar*, and *-ing*. These traces last for at least 12 hours and are not affected by a night's sleep. The strength of a memory trace (after 12 hours) is also not affected by the repetition of the neologism within 1.5 minutes after the first exposure. Finally, participants activated the memory trace in the processing of the second (and third) presentation of the neologism in addition to activating its constituent morphemes.

Experiment 2: a week interval

We observed in Experiment 1 that a memory trace for a morphologically complex neologism is as strong after 12 hours as it is after 39 intervening trials. The key question addressed in Experiment 2 is whether a memory trace for a neologism remains in the mental lexicon for more than 12 hours. Will there still be a memory trace after one

[2] No correlation was present for the predictors in the analysis of the RTs to the second exposure, analyzed above.

week? Will this trace be as strong as it is after 39 intervening trials?

Method

Participants

Twenty-four undergraduate students at the Radboud University of Nijmegen were paid to take part in this experiment. Six of them were male and 18 were female, and at the time of the experiment, they all had a mean age of 20, in the range of 18 to 24. All were native speakers of Dutch, and none had participated in Experiment 1 or in similar experiments using similar materials.

Materials

We used the same materials and design as in Experiment 1.

Procedure

The procedure was identical to the procedure of Experiment 1, except that session 2 of the experiment was presented to the participants one week, instead of 12 hours, after the first session.

Results and Discussion

We followed the same procedure for analyzing the data as for Experiment 1. We coded no-responses to the target neologisms as errors and removed these data points from the analyses of the response latencies. We also removed all data points of the eight words with error rates over 50% (*annoteerbaar* 'annotable', *begiering* 'feeding with liquid manure', *bepoeiering* 'dusting', *betralieing* 'barring', *omkeiling* 'knock flying', *ontmugging* 'disinsected', *onttuiging* 'stripping down', *verboersing* 'becoming rustic'). Finally, we left out of consideration all trials in which participants did not react or reacted only after 1750 ms.

We again fitted first a mixed-effect model of covariance to the RTs for the targets primed only once, using a stepwise variable selection procedure. We considered participant and word as crossed random variables and Prime Type, Priming Distance, Base Frequency, Prime RT and Prime Decision (participants erroneously judged the primes as non-words in 24% of the trials) as fixed predictors. The RTs and Base Frequency were again logarithmically transformed. We removed outliers with standardized residuals outside the interval $[-2.5, 2.5]$ (1.45%), and refitted the model. The final model is listed in Table 3.4.

As in Experiment 1, we observed a main effect for Prime Type. Response latencies were shorter in the identity priming condition than in the stem priming condition. We

Table 3.4: Results of the Stepwise Multilevel Regression Model (df=2241) fit to the Reaction Times to the target words primed only once in Experiment 2 . Prime Type provides the effect of identity priming relative to stem priming. Distance provides the effect of long priming distance relative to short priming distance. Decision provides the effect of an incorrect decision to the prime relative to a correct decision to the prime. The standard deviation for the random effect of Word was 0.0575, and that for the Participant random effect was 0.1137. The residual standard deviation was 0.2070.

	$\hat{\beta}$	t	$p <$
(Intercept)	5.5376	33.64	0.0001
Prime Type	-0.0446	-4.97	0.001
Distance	0.6975	3.43	0.0001
Decision	0.1057	8.35	0.0001
Prime RT	0.1723	7.13	0.0001
Base Frequency	-0.0145	-4.12	0.0001
Distance by Prime RT	-0.0932	-3.08	0.001

observed no significant interaction of Prime Type by Priming Distance, which indicates that the magnitude of the effect of Prime Type is similar after long priming distance as after short priming distance. In other words, the lexical trace for a neologism appears to stay in the mental lexicon for at least a week, without loosing strength.

Furthermore, we observed similar main effects for Prime Decision and Base Frequency as in Experiment 1. Participants reacted more quickly if they had accepted the prime as a word and to neologisms with more frequent stems. Finally, we observed main effects and an interaction for Priming Distance and Prime RT: Similar to the results of Experiment 1, participants reacted more quickly after short than after long priming distance, and this difference was smaller the more quickly the participant reacted to the prime.[3]

We then addressed the question whether participants recognized neologisms more quickly if they had seen the neologism twice instead of only once the neologism itself and once its stem. We fitted a mixed-effect model of covariance to the RTs of the

[3] A logistic mixed-effect model of covariance on errors (a binominal variable) with participant and word as crossed random variable showed significant $\hat{\beta}$s for Prime Type ($\hat{\beta}$ = -0.49488, z =-3.699, p=0.0002), Base Frequency ($\hat{\beta}$ = -0.13809, z =-2.939, p=0.0033), Prime RT ($\hat{\beta}$ = 0.84946, z =2.715, p=0.0066), and Prime Decision ($\hat{\beta}$ = 1.85377, z =13.061, $p<$ 0.0001). A negative $\hat{\beta}$ indicates a reduction in errors. Participants made fewer errors for neologisms primed by these neologisms themselves than for neologisms primed by their stems, for neologisms with stems of a higher frequency, if they had reacted more quickly on the corresponding primes, and if they had correctly classified these primes as words. The error analysis showed no effect for Priming Distance or an interaction of Priming Distance with Prime RT. Our data thus show no evidence for speed-accuracy trade-offs.

neologisms in the second session of the experiment with two primes. We again made use of a stepwise variable selection procedure, and entered the same independent variables as in the analysis of Experiment 1, namely Prime Type, Prime RT, Prime RT 2, Prime Decision, Prime Decision 2, and Base Frequency. Also in this analysis, we removed outliers with standardized residuals outside the interval $[-2.5, 2.5]$ (1.41%) and refitted the model. The final model is listed in Table 3.5.

As in Experiment 1, the results show no effect for Prime Type. This supports the suggestion from Experiment 1 that there is no difference in strength of memory traces for neologisms that participants had seen only once and for neologisms that they had seen twice in the first session of the experiment. The other predictors, including Base Frequency, showed effects that we also saw in the analyses presented above.

In conclusion, lexical memory traces for regular morphologically complex neologisms last for at least one week in the mental lexicon, and appear as strong after a week as after 39 intervening trials. Furthermore, as in Experiment 1, participants showed evidence both for lexical traces and for activation of the constituent morphemes, even when they read the neologisms for the second or third time.

Table 3.5: Results of the Stepwise Multilevel Regression Model (df=1177) fit to the Reaction Times of target words primed twice in Experiment 2. Decision provides the effect of an incorrect decision to the prime relative to a correct decision to the prime. The standard deviation for the random effect of Word was estimated at 0.0585, and that for the Participant random effect at 0.1230. In addition, there was a significant random effect for Participant by Base Frequency (log-likelihood ration = 22.96, $p < .0001$, standard deviation = 0.0121, estimated coefficient for the correlation = -0.780). The residual standard deviation was 0.1983.

	$\hat{\beta}$	t	$p <$
(Intercept)	5.2624	22.45	0.0001
Decision	0.9507	3.02	0.01
Prime RT	0.1497	5.31	0.0001
Prime RT 2	0.0669	2.80	0.01
Base Frequency	-0.0119	-2.47	0.05
Distance by Prime RT	-0.1326	-2.88	0.01

General Discussion

The questions addressed in this paper are: (1) Do regular morphologically complex neologisms ending in a variety of suffixes and presented just once leave detectable traces in lexical memory? (2) Does a memory trace remain in the mental lexicon for at least 12 hours or even a week? (3) Does sleep play a role in the formation of such lexical traces?

Chapter 2 of this dissertation showed that regular Dutch morphologically complex words ending in the suffix *-heid* are represented in the mental lexicon after the very first exposure. Experiments 1 and 2 in the present chapter, both priming experiments in which the prime was either the stem of the target neologism or the neologism itself, show that also regular morphologically complex words ending in the productive suffixes *-baar* and *-ing* are stored in the mental lexicon after the very first exposure. These affixes are productive, do not have a rival and do not change the meaning of the base. According to Bertram, Schreuder, & Baayen (2000), neologisms ending in these suffixes are therefore not likely to be stored. Nevertheless, we observed clear lexical traces for such neologisms.

Moreover, Experiments 1 and 2 show that these traces are still detectable after 12 hours (Experiment 1) and even after a week (Experiment 2) and that they do not appear to lose strength. This result is important because even native adult speakers often encounter novel complex words and they have encountered a huge number of existing complex words only once or twice (see for lexical statistic evidence e.g., Zipf, 1935). We conclude that the mental lexicon has many more entries than has traditionally been assumed (e.g., Alegre & Gordon, 1999). An alternative explanation of our priming results may be that participants did not so much form a lexical trace for the neologism itself but rather remembered how they morphologically analyzed the neologism when they first encountered it, which would be in line with a decomposition-first model (Rastle, Davis, & New, 2004; Taft, 2004). We think, however, that these two accounts are in fact two sides of the same coin. If readers remember how they analyzed a word, then they must remember the word itself as well, which implies that there is a memory trace for the word.

It may be that the participants just showed strategic, task-dependent effects. We would like to note that, if so, this does not affect our interpretation of the results. Participants may have decided to store the neologisms because they noticed that some of these words re-occured later in the experiment. Whether they were able to store these neologisms (for whatever reason) and whether these traces stay in memory for more than a few minutes form exactly the research topics of the present study. Further, since we found in Chapter 2 the same priming results in a self-paced reading experiment, in which the neologisms were presented in short sentences, we believe that these priming effects are not task specific and therefore are not likely to be purely strategically based.

The question arises whether the lexical trace formed by the neologism is an episodic trace, and thus contains information on indexical properties of the word token (e.g., the font of the word token, whether it appeared in a cold room, whether the participant had to sneeze after the word token), or whether the neologism was stored in the form of an abstract lexical representation, specifying the word's form only in abstract linguistic units (e.g., graphemes, phonemes, morphemes). This is a question that we are currently addressing in a new series of experiments. In these experiments, we investigate, among other things, whether the lexical trace is modality specific, for instance, whether the occurrence of a neologism in a spoken text facilitates the visual comprehension of the same word in visual lexical decision experiments carried out a week later. If so, the memory trace is likely to be an abstract lexical representation rather than a pure episodic memory trace.

Gaskell and colleagues (Dumay et al., 2004; Gaskell & Dumay, 2003, 2007; Tamminen & Gaskell, 2008) also investigated the formation of lexical traces for neologisms. They observed that participants needed at least 12 exposures to learn neologisms and moreover that the formation of a lexical representation required an incubation-like period crucially associated with sleep. Especially the consolidation stage would rely on the process of sleep (Stickgold & Walker, 2005; Walker, 2005). In contrast to these findings, our results show that one exposure may be sufficient for the formation of a lexical trace and that sleep is not a prerequisite. An explanation for this discrepancy in results may be found in two differences in the materials and designs between their and our experiments.

First, whereas Gaskell and colleagues tested morphologically simplex neologisms, such as *cathedruke*, we focused on fully regular morphologically complex neologisms consisting of morphemes that are already present in the mental lexicon. Therefore, our neologisms can be morphologically linked to other lexical representations, and may consequently be better embedded in the mental lexicon. This may leed to faster and more robust storage. It is also possible that combinations of existing morphemes have a different kind of lexical trace than monomorphemic words: Rather than forming independent representations by themselves, they may purely consist of the information that the relevant morphemes may be combined to form a word. For example, the word *bewapenbaar* ('armable') may be represented as just the possibility to combine the morphemes *be*, *wapen*, and *baar* (Balling & Baayen, 2008; Bybee, 1985).

Second, we studied the formation of lexical traces directly by comparing response latencies to neologisms when they had already been presented before and when they had only been primed by their stems (i.e. identity priming versus stem priming). Gaskell and colleagues, on the other hand, studied lexical storage more indirectly by tracing the consequences of acquired neologisms on the processing of well-established existing words. Their indirect test may be less sensitive than our priming procedure.

Base Frequency showed a facilitatory effect in Experiment 1 as well as in Experiment 2. A morphologically complex neologism is, necessarily, processed through morphological decomposition. Surprisingly, however, for most participants the effect of Base Frequency was independent of whether these participants had seen the neologism before. This suggests that morphological decomposition played a role in these participants' processing of both the first and the second token of the neologism. Thus, our results indicate that most participants relied for the processing of the second token both on the lexical trace of the neologism and on morphological decomposition. These results are in line with the conclusions presented by Balling & Baayen (2008) that the direct route and the parsing route in the dual route model (see, e.g., Bertram, Baayen, & Schreuder, 2000; Schreuder & Baayen, 1995) are not independent (De Jong, Schreuder, & Baayen, 2003). Both routes eventually activate the same semantic representation in the lexicon and this lexical activation resonates through the whole system. The effect of Base Frequency is also in line with the supralexical hypothesis (Giraudo & Grainger, 2001), which states that the activation of a word may lead to the activation of its constituents, and with the model of Plaut & Gonnerman (2000), which assumes independent routes for morphologically simple and complex words, ascribing morphological effects to orthographic, phonotactic, and semantic similarities.

In conclusion, our study has clearly shown that the first occurrence of a neologism consisting of existing morphemes leaves a long lasting trace in the mental lexicon. The recognition of the later occurrences of such a neologism proceeds via this trace while at the same time it also activates its constituents.

Appendix

Experimental materials of Experiments 1 and 2:

annoteerbaar; arceerbaar; balsembaar; bekeurbaar; bekogelbaar; bekrasbaar; bespuwbaar; bestijgbaar; bestormbaar; bestraatbaar; bestuifbaar; betoverbaar; bevuilbaar; bewapenbaar; blondeerbaar; braadbaar; fohnbaar; frankeerbaar; gedenkbaar; omspanbaar; ontkalkbaar; ontkleurbaar; ontruimbaar; ontrukbaar; onttroonbaar; ontwapenbaar; overreedbaar; paneerbaar; pocheerbaar; scandeerbaar; shockeerbaar; tutoyeerbaar; verfraaibaar; verknoeibaar; verkreukbaar; vernauwbaar; verpootbaar; verpotbaar; verspilbaar; ververspbaar

kortafheid; lobbigheid; labielheid; pitloosheid; saprijkheid; summierheid; tactvolheid; tembaarheid; tilbaarheid; visrijkheid; pipsheid; enormheid; jofelheid; koketheid; onwelheid; ovaalheid; riantheid; antiekheid; banaalheid; basaalheid; dementheid; erkendheid; gammelheid; ludiekheid; ondiepheid; royaalheid; aftandsheid; beschutheid; bezweetheid; contentheid; coulantheid; bebrildheid; markantheid; beuheid; blusbaarheid; geurloosheid; kalkrijkheid; onattentheid; onbelastheid; ontroerdheid

afkluiving; afzouting; bebotering; bedamming; bedrinking; bedrupping; begiering; behakking; bekonkeling; bekruising; bekwijling; benageling; beolieing; bepareling; bepoeiering; beriddering; bespijkering; betralieing; bewalming; bijeenlegging; omduikeling; omkeiling; ontadeling; ontharsing; ontmugging; onttuiging; ontvloeiing; ontzadeling; oppieping; toezinging; verboersing; vergokking; verkijking; verkletsing; verkuiling; vernaaiing; verrijding; versmeding; verspelding; wegstoting

Abstract traces for morphological complex neologisms

Chapter 4

This chapter is a reformatted version of:
Laura de Vaan, Kobie van Krieken, Winie van den Bosch, Robert Schreuder, and Mirjam Ernestus (in press). *The Mental Lexicon*, *12(2)*.

Abstract

Previous chapters have shown that novel morphologically complex words (henceforth neologisms) leave traces in memory after just one encounter. This chapter addressed the question whether these traces are abstract in nature or exemplars. In three experiments, neologisms were either primed by themselves or by their stems. The primes occurred in the visual modality whereas the targets were presented in the auditory modality (Experiment 1) or vice versa (Experiments 2 and 3). The primes were presented in sentences in a self-paced reading task (Experiment 1) or in stories in a listening comprehension task (Experiments 2 and 3). The targets were incorporated in lexical decision tasks, auditory or visual (Experiment 1 and Experiment 2, respectively), or in stories in a self-paced reading task (Experiment 3). The experimental part containing the targets immediately followed the familiarization phase with the primes (Experiment 1), or after a one week delay (Experiments 2 and 3). In all experiments, participants recognized neologisms faster if they had encountered them before (identity priming) than if the familiarization phase only contained the neologisms' stems (stem priming). These results show that the priming effects are robust despite substantial differences between the primes and the targets. This suggests that the traces novel morphologically complex words leave in memory after just one encounter are abstract in nature.

Introduction

Listeners and readers often encounter neologisms. Most of these neologisms are morphologically complex words (e.g., Baayen & Renouf, 1996; Clark, 1993; Bloom, 2000), whose meanings can be derived from the containing morphemes in combination with morphological rules (e.g., *fine+able*) or analogy (e.g., *protologism* from Greek protos 'first' plus Greek logos 'word' by analogy with *prototype* and *neologism*, Epstein, 2012). The question arises whether these neologisms are stored in the mental lexicon after just one encounter. Pinker (1991) argued that no regular complex words are stored in the mental lexicon. However, Chapters 2 and 3 provided experimental evidence that readers may store morphologically complex neologisms in memory, like they store more frequent regular complex words (e.g., Alegre & Gordon, 1999; Pinker & Ullman, 2002a, b). This raises questions about the nature of the memory traces left by encounters with morphologically complex neologisms.

The present study investigates the specificity of the traces for morphologically complex neologisms. These traces can be abstract representations which only provide information that is necessary to distinguish the words from the other words in the language. Abstract representations do not provide detailed information about the properties of the tokens; they do not specify, for instance, whether the neologism was attested in written or in spoken language, the situational context (e.g., who uttered the word or what did the room where it was uttered look like) or the linguistic context (e.g., which were the preceding and following words). These abstract representations are stored in the mental lexicon.

The memory traces of neologisms may also contain more specific information of the attested tokens. They may be modality specific and contain information about the context in which the neologism occurred, including the situational and linguistic context. We will refer to these representations as exemplars.

Evidence that memory may contain detailed representations for word tokens comes predominantly from auditory priming experiments (e.g., Bradlow et al., 1999; Craik & Kirsner, 1974; Goh, 2005; Goldinger, 1996; Janse, 2008; Mattys & Liss, 2008; McLennan et al., 2003; McLennan & Luce, 2005; Palmari et al., 1993). In these experiments, words are repeated and the second token of the word is either identical to the first token or it differs in, for instance, speech rate, time-compression, the realization of a certain segment, or speaker's voice. Most experiments showed that participants react faster and more accurately to the second token if it is identical to the first one. These results strongly suggest that participants store the acoustic details of the first token of each word and that the recognition process for the second token involves this detailed lexical representation.

The detailed representations are assumed to be part of the mental lexicon in two types of models. In both types, representations of different tokens of the same word (exemplars) are organized in clouds. Exemplar models assume that the mental lexicon only consists of these clouds and does not contain any abstract lexical representations of the words' pronunciations. Hybrid models, in contrast, combine abstract representations and exemplars. Support for hybrid models comes from priming experiments showing that the indexical properties (which may differ between different tokens of the same word) of the first token of a word (the prime) only affect processing of the second token (the target) when participants have adopted a certain level of processing speed (e.g., McLennan & Luce, 2005). For instance, a match in the indexical properties of the prime and target only speeds up responses to the targets if participants are forced to react after a certain time-interval (150ms after the offset of the spoken stimulus).

Detailed memory traces of word tokens need not be stored in the mental lexicon. They can be stored as episodes in episodic memory (e.g., Goldinger, 1998), which stores autobiographical events as time, place, associated emotions, and other contextual knowledge (e.g., Tulving, 1972; Yim, Dennis, & Sloutsky, 2013). In episodic models of language processing, episodic memory is combined with lexical memory, which contains abstract representations (e.g., Hanique, Aalders, & Ernestus, 2013). In the present chapter, we do not distinguish between exemplars and episodes, and call them both exemplars. We focus on the question whether memory representations for neologisms are abstract or contain token specific information, including modality and context (exemplars).

As mentioned above, most research on the role of exemplars in language processing has focused on speech comprehension. There has been little research on the role of exemplars in reading. The few studies that addressed this issue showed similar results as studies in the auditory domain: readers recognize the second token of a word faster if it appears in the same font as the first token (e.g., Goldinger, Azuma, Kleider, & Holmes, 2003).

We will investigate the nature of the memory traces for regular morphologically complex neologisms by directly building upon the work done in Chapters 2 and 3, in which we examined the formation of memory representations for Dutch regular morphologically complex neologisms. In these chapters, the question was addressed whether such neologisms leave traces in lexical memory with an experimental design in which participants first were presented with the stem of the neologism (stem priming) or the neologism itself (identity priming). Participants were then presented with the neologism (again) later on in the same experiment (Chapter 2) or in a second experiment (Chapter 3). The results showed that participants reacted faster to the second token of the neologism in the identity priming condition than in the stem priming condition. This strongly suggests that participants stored the neologisms that occurred as primes. If they would have only decomposed these neologisms and activated the stems, identity priming should have facilitated the processing of the targets as much as stem priming had done (contrary to fact).

In Chapters 2 and 3, all stimuli (primes and targets) were presented visually and in the same font. As a consequence, we do not know whether the participants in their experiments formed memory traces for the neologisms that contained token specific information, and thus whether these traces are abstract in nature. For instance, we do not know whether these traces were modality specific or modality general. If the prime and target had been presented in different modalities and the prime in the identity priming condition had still facilitated the processing of the target more than the prime in the stem priming condition, the lexical representation could have been classified as modality general. This would be evidence for abstract representations.

Further, the prime and target were always presented in the same situational and linguistic context. Participants saw the two tokens in the same type of experiment (lexical decision or self-paced reading), and if they were incorporated in different parts of an experiment, these were conducted by the same experiment leader in the same experiment room. The experiments could therefore not show whether the memory traces of the neologisms contained contextual information.

Importantly, the experiments conducted in Chapters 2 and 3 tested various time intervals between the primes and targets. Participants either took part in an experiment where the time interval between prime and target was 1.5 minutes, or they took part in an experiment where it was 12 hours or even a week. Although the advantage of identity priming over stem priming diminished over time, it was still present after a week. This shows that the memory traces are long-lasting. Generally, traces in episodic memory slowly disappear over time (Goldinger, 1996), and exemplar effects typically arise in short experiments with little variation, and disappear if the time interval between prime and target is long or if the experiment is more complex (e.g., Goldinger, 1996; Hanique et al., 2013). These results therefore suggest that the memory traces formed for regular morphologically complex neologisms are abstract representations.

In the present chapter, we investigated whether the memory traces of regular morphologically complex neologisms are abstract representations or exemplars by conducting three experiments with a design that is similar to the one used in Chapter 3. The experiments consist of two phases, namely a familiarization phase and a test phase. In the familiarization phase, participants were presented with half of the neologisms that we tested (identity priming) and with the stems of the other half of those neologisms (stem priming). In the test phase, participants were presented with all neologisms. We compared identity priming with stem priming, rather than with no priming at all, in order to rule out the possibility that priming from the neologism itself only results from facilitated decomposition as a consequence of base repetition.

We used this design to answer two subquestions. First, we investigated if the advantage of identity priming over stem priming remains if the prime and target are presented in different modalities (auditory versus visual). The neologisms were spelled with the simple (shallow) phoneme-grapheme mapping rules for Dutch, so that their orthographic representations provide unambiguous information about their pronunciations and vice versa. In Experiment 1, the primes were presented in the visual modality and the targets in the auditory modality. In Experiments 2 and 3, this was reversed (auditory primes and visual targets).

Second, we studied whether the advantage of identity priming over stem priming is also found if the prime and the target occur in different contexts. In all three experiments, the experimental task in the familiarization phase differed from the experimental task in the test phase. In Experiment 1, the primes were presented in sentences in a self-paced reading experiment while the targets appeared in isolation in an auditory lexical decision experiment. In Experiments 2 and 3, participants heard the primes embedded in stories and read the targets in isolation in a visual lexical decision experiment or in stories in a self-paced reading experiment, respectively.

We increased the difference in situational context between the prime and the target by giving participants the impression that the primes and target belonged to different experiments. We asked them to take part in two experiments: our experiment and a colleague's experiment. Moreover, the two phases of the experiment were conducted by different experiment leaders.

In summary, we present three experiments in which the primes were presented in very different conditions than the targets were presented in. If we still observe an advantage of identity priming over stem priming, we can conclude that the formed representations are more likely to be abstract than to be token specific exemplars.

Experiment 1: visual primes in context and auditory targets in isolation

Method

Participants

Thirty-six undergraduate students (nine male) of Radboud University were paid to take part in this experiment. They had a mean age of 22 years (range 18–32) and were native speakers of Dutch.

Materials

We tested 120 Dutch, morphologically well-formed and derived neologisms, which have been tested in Chapter 3 as well. The neologisms end in the suffixes *-baar* (e.g., *betover+baar* 'bewitch' + 'able'), *-heid* (e.g., *antiek+heid* 'ancient' + 'ness'), and *-ing* (e.g., *ontzadel+ing* 'desaddle' + 'ing'; see Appendix A for all neologisms). There were 40 neologisms for each suffix. The suffix *-baar* transforms transitive verbs into adjectives (Booij, 2002), the derivational suffix *-heid* transforms adjectival stems into nouns, and the suffix *-ing* transforms verbs into action nouns. The suffix *-ing* is particularly productive for morphologically complex verbs. Overall, the suffixes *-baar* and *-heid* are more productive than the suffix *-ing* (e.g., Booij, 2002; Van Haeringen, 1971).

Suffixation of a stem with *-heid* does not lead to changes in the pronunciation of the stem. Suffixation with *-ing*, in contrast, leads to resyllabification of stem-final consonants to the following syllable formed by the suffix (e.g., *be-bo-ter* 'to butter' $->$ *be-bo-te-ring* 'buttering') and also to voicing alternation of the stem-final obstruents (e.g., /bəklœyf/ *bekluif* 'to endure' $->$ /bəklœyviŋ/ *bekluiving* 'enduring') for four stems. Suffixation with *-baar* may lead to regressive voice assimilation (e.g., /vərpɔt/ *verpot* 'to repot' $->$ /vərpɔdbar/ *verpotbaar* 'repotable').

All 120 neologisms have different stems. All stems are real words and are listed in the CELEX lexical database (Baayen et al., 1995), whereas CELEX lists none of the neologisms. At the time of the experiments, each of the neologisms appeared in the Dutch section of the world wide web maximally 219 times, with a mean of 21.1 tokens and a median of 7 tokens. All neologisms are well interpretable, have a maximum of 13 characters (with the diphthong 'ij' counting as two characters), and have a maximum of 11 phonemes.

We conducted a rating study in order to investigate how natural the neologisms are to native speakers of Dutch and whether there are substantial differences among our neologisms. The rating study consisted of three experiments, one for every affix. The ratings for neologisms ending in *-baar* and *-ing* were provided by 71 participants. The rating experiment for neologisms ending in *-heid* was completed by 22 participants. This latter rating experiment was also reported in Chapter 2. Participants were asked to rate how often they encounter each word on a scale of one to seven. In addition to the neologisms, the complete rating study also consisted of 183 real words ending in *-baar*, *-heid*, and *-ing*, ranging in CELEX base frequency from 0 to 86305. Most real words had higher base frequencies than the neologisms (range: 0 - 435). The average ratings per neologism, split for Suffix, and the average ratings for the real words are presented in Figure 4.1. The figure shows that most neologisms appeared rather natural to the participants which resulted in a grand mean average of 2.9. This average differs substantially from the grand mean average for the real words (4.7). Neologisms ending in *-heid* generally received lower ratings (the average rating was 2.5) than the neologisms ending in the other suffixes (with average ratings of 3.1 for *-baar* and 3.1 for *-ing*; *-heid* versus *-baar*: $t(1987.4) = -29.0, p < 0.0001$; *-heid* versus *-ing*: $t(2071.1) = -27.2, p < 0.0001$). The neologisms ending in *-ing* and *-baar* also showed a significant but small difference ($t(2703.9) = 2.1, p < 0.05$). This small difference is no longer statistically significant when the effect of Base Frequency on the ratings is taken into account (with a linear model predicting Rating as a function of Base Frequency and Suffix). The relatively low ratings for the neologisms ending in *-heid* may be due to the fact that the base words ended in suffixes themselves (e.g., *pitloos* 'seedless'). We decided not to include the ratings as a predictor in the statistical analyses reported in this study (all three experiments), because the focus of this study is not on the differences among the neologisms.[4]

For the familiarization phase of the experiment, a self-paced reading task, we created 120 sentences containing the stems of these neologisms and 120 parallel

[4] We investigated whether including Rating as a predictor affects the conclusions that can be drawn from the results. This is not the case.

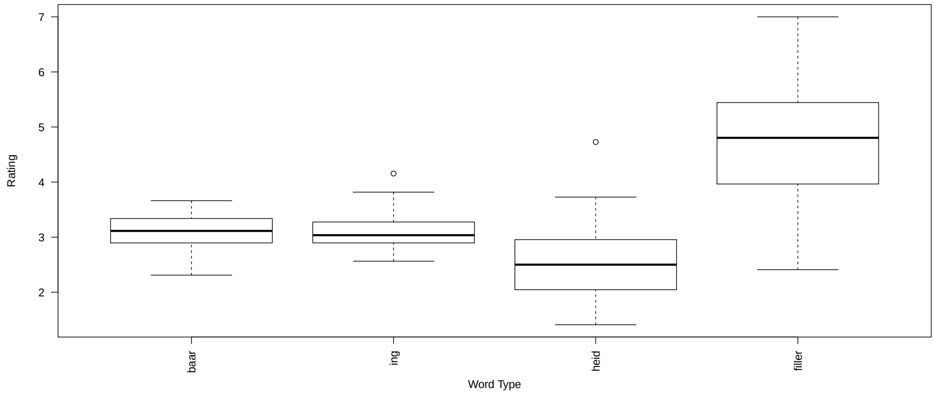

Figure 4.1: The average ratings per neologism, split for Suffix, and the average ratings for the fillers.

sentences containing the neologisms. An example of a sentence with a stem and its counterpart containing the corresponding neologism is:

(1) *Ik zou mijn zwarte haar graag willen* **ontkleuren***, maar dat blijkt niet zo makkelijk te zijn.* 'I would like to decolorize my black hair but that appears to be not that easy.'

(2) *Mijn zwarte haar blijkt niet zo makkelijk* **ontkleurbaar** *te zijn*. 'My black hair seems not to be decolorable that easily.'

The stem or the neologism was never among the last two words of the sentence. The sentences with the stems consisted of 6 to 22 words (mean: 13.2 words), while the sentences with the neologisms had a length of 5 to 23 words (mean: 12.9 words).

Special care was necessary for the construction of the parallel sentences with neologisms. It was impossible to simply replace the stem by the neologism since the two words belong to different grammatical classes. In the example given above, *ontkleuren* 'decolorize' is a verb while *ontkleurbaar* 'decolorable' is an adjective. Therefore, we had to adjust the grammatical structure of all parallel sentences.

In order to construct sentences that are as natural as possible, we inflected 85 stems that are adjectives (for gender and number; e.g., *summier* was presented as *summiere* 'minimal') or verbs (for person, number, and tense; e.g., the stem *frankeer* 'stamp' was presented as *frankeerde* 'stamped' or *frankeren* 'to stamp') by adding inflectional suffixes. For one irregular verb, we used the irregular past tense (e.g., *verkeek* 'misjudged' with the stem *verkijk* 'misjudge'). We also inflected two adjectival neologisms ending in the suffix *-baar*, as a consequence of which the neologisms ended in *-bare* (e.g., *verkreukbare* 'wrinklable' and *gedenkbare* 'memorable').

To distract participants' attention from the neologisms, we added 240 filler sentences consisting of 7 to 24 words (mean: 13.4 words). These sentences were semantically and syntactically similar to the experimental sentences. We also added 18 practice sentences to familiarize participants with the experimental task. Both, filler sentences and practice sentences only contained real words.

We created one master list with the sentences of 60 randomly selected target neologisms, the sentences with the stems of the other 60 neologisms, and the 240 filler sentences. We randomized this master list four times without any restrictions. For each of the four resulting lists, we created a counterpart. If a sentence contained a neologism, the counterpart contained the corresponding parallel sentence with the neologism's stem, and vice versa. Each master list was preceded by the practice sentences.

In order to ensure that participants read the sentences carefully for content, one out of every six sentences (target and filler sentences) was followed by a YES/NO question about its contents. For example, sentence (1) was followed by the question

(3) *Heb ik donker haar?* 'Do I have dark hair?'

Due to an error, only 59 questions were asked instead of 60.

The auditory lexical decision experiment in the test phase contained all 120 target neologisms as well as 120 real filler words and 240 filler pseudowords, all evenly divided over the three suffixes. The real filler words had an average length of 8.3 phonemes in a range of [4 – 13]. They had a CELEX lemma frequency in the range of [0–7,196], a mean of 437 and a median of 110. They appeared in the Dutch section of the world wide web with a frequency in a range of [3,580–112,000,000], with a mean of 4,298,613 and a median of 850,500.

We changed to a maximum of three phones of each target neologism and each real filler word to create the 240 filler pseudowords (e.g., *beweperbaar* from *bewapenbaar* 'armable'), ensuring that the resulting words did not violate Dutch phonotactic constraints. The changes were always in the stem and never in the suffix. In order to test whether the pseudowords primed the target neologisms, we asked three participants, not participating in any of the other experiments reported in this paper, whether they could guess the words from which the pseudowords were derived. The participants were able to do so for only 4% of the pseudowords, which were all derived from real words.

All stimuli were carefully articulated by a female speaker in a noise-attenuated booth and recorded in mono sound (sampling rate: 44.1 kHz). The target neologisms had a mean word duration of 889ms, the real filler words of 895ms, and the pseudowords of 884ms, with standard deviations of 107ms, 174ms, and 125ms, respectively.

We created one master list containing the 120 neologisms, the 120 real filler words, and the 240 filler pseudowords. This master list was randomized three times without any restrictions. Each participant was presented with one list. The lists were divided into four parts, which were presented to the participants in a random order.

Procedure

We presented the familiarization phase and test phase to our participants as two different experiments. That is, when approaching participants for our experiment, we gave them the impression that we were looking for participants who wanted to participate in our experiment and, later that day, in a colleague's experiment. Accordingly, the familiarization phase and the test phase were conducted by two different experiment leaders and participants were paid after the familiarization phase as well as after the test phase.

Participants were tested individually in a noise-attenuated experiment booth. In the familiarization phase, participants received self-paced reading instructions on the screen and were asked to read the sentences carefully and at a comfortable reading speed. The course of a trial was as follows. Participants saw a fixation point for 500ms, indicating that a sentence was about to follow. The instruction 'press the button in the middle of the button box to go to the next sentence' appeared in Dutch on the screen. When participants pressed the button in the middle with their dominant hand, the full length of the sentence was displayed in dashes, with each dash marking a letter position. By pressing the button in the middle again, they saw the letters of the first word. Words were presented in bold Courier New font 15 pt. With each button press, the following word appeared and the previous word was again replaced by dashes.

Fifty-nine sentences were followed by questions. The word *vraag* 'question' was presented in the center of the screen, followed by the yes/no question about the sentence. Participants were instructed to use their dominant hand to press the yes-button on the button box if the answer to the question was "yes" and otherwise to press the no-button with their non-dominant hand.

Participants first completed the eighteen practice sentences to get used to their task. Four of these sentences were followed by questions. After the practice sentences, participants could ask questions about the task. They then started with the actual experiment.

After this familiarization phase, participants were asked to return to the waiting room to wait for the second experiment. They had to wait approximately five minutes.

In the test phase, they were asked to decide as quickly and accurately as possible whether the item they heard through the headphones was a meaningful Dutch word. The experiment leader made clear that all meaningful words, whether they were real or not, required 'yes' responses, and that only meaningless words required 'no' responses. Participants were instructed to use their dominant hand to press the yes-button on the button box, and their non-dominant hand to press the no-button.

Each trial in the auditory lexical decision experiment began with a fixation mark positioned in the center of a monitor for 1000ms. The stimulus was played 50ms after the fixation mark disappeared. Participants had 2500ms from stimulus onset to decide whether the item was a meaningful Dutch word, before the fixation mark reappeared for the following trial.

Results and Discussion

We calculated the percentage of errors for each neologism in the auditory lexical decision experiment. It ranged from 0% to 62%. As we are dealing with neologisms in lexical decision, the high error rates are not surprising. None of the participants had error rates over 15% for the whole experiment and over 40% for the target neologisms. We kept all participants and neologisms in the dataset. The percentages of errors were 15.4% for the neologisms primed by themselves and 16.3% for the neologisms primed by their stems.

We first analyzed whether participants' responses could be predicted by whether they had only seen the neologism's stem before or the complete neologism. We conducted a general linear mixed effect model with this predictor (Prime Type: stem priming versus identity priming) in addition to the covariates the logarithmically transformed lemma frequency of the stem of the neologism as listed in CELEX (henceforth Base Frequency), Suffix (*-baar*, *-heid*, and *-ing*), and Trial Number. We included Participant and Word as crossed random variables (e.g., Jaeger, 2008). Prime Type did not show a statistically significant effect, neither as a fixed effect nor as a random slope. This result is as expected because participants were asked to accept all words that they could easily interpret (e.g., Coolen et al., 1991) and therefore their responses were mostly determined by the characteristics of the words such as the suffix, which showed a significant effect (words ending in *-ing* were more often rejected than words ending in *-baar* (22.0% versus 9.2%; $\beta = 1.4357, z = 3.49, p < 0.001$) and *-heid* ($8.5\%$; $\beta = 2.3604, z = 5.93, p < 0.0001$); words ending in *-baar* were also more often rejected than words ending in *-heid* ($\beta = 0.9248, z = 2.63, p < 0.01$)).

We then analyzed participants' response times (measured from word onset) to the neologisms in the test phase, excluding all trials in which participants did not react. If these target neologisms were directly followed by other target neologisms, these directly following target neologisms were also excluded. In addition, we excluded response times longer than the mean response time plus 2.5 times the standard deviation ($> 2088ms$). We applied a logarithmic transformation to the remaining response times (94.17%, which equals to 4068 data points), to reduce the skewness of the distribution.

We pooled the trials in which participants had responded correctly and incorrectly. We did so because if we only analyzed the correct answers, the dataset would be 13% smaller.[5] Moreover, the analysis of the responses did not show an effect of our predictor of interest, being Prime Type (as reported above). However, because the two types of responses are given by the dominant versus the non-dominant hand and may also result from different underlying processes, we included the Correctness of the answer as a predictor.

[5] Analysis of only the correct answers shows that this data loss is indeed detrimental: this analysis does not show an effect of Prime Type.

We fitted a mixed-effect model of covariance using a stepwise variable selection procedure, with Participant and Word as crossed random variables (e.g., Baayen, Davidson, & Bates, 2008; Bates & Sarkar, 2005; Faraway, 2006; p-values were generated with the library lmerTest, Kuznetsova, Brockhoff, & Christensen, 2016). The dependent variable in our analysis is Response Time (RT), that is logarithmically transformed. Our main predictor is Prime Type. To reduce variance in the data, we added as covariates word specific features that previous chapters have shown to affect RTs in lexical decision experiments: the logarithmically transformed duration of the word (henceforth Word Duration), the logarithmically transformed Base Frequency, and Suffix. We also included as covariates the correctness of the participant's response (henceforth Correctness: correct versus incorrect), whether the stems were inflected (yes or no), Trial Number, and the logarithmically transformed response time to the preceding stimulus (henceforth Previous RT).[6] For all categorical variables, we used dummy coding. Finally, we checked for random slopes for all our fixed effects.

Here, as well as in the other experiments in the chapter, we tested for simple effects of these variables as well as for significant interactions with our main predictor Prime Type. We tested for interactions because the literature indicates that the type of priming may differ as a function of processing speed (e.g., McLennan & Luce, 2005). Furthermore, we may expect that participants change their strategies (and therefore the effect of Prime Type) during the experiment as a function of the properties of the neologisms.

Inspection of the model's residuals revealed marked non-normality and we therefore removed outliers with standardized residuals outside the interval of [-2.5, 2.5], and refitted the model (e.g., Crawley, 2002). The residuals of this trimmed model were approximately normally distributed, indicating that removal of the overly influential outliers resulted in a model with a better goodness of fit. This model is summarized in Table 4.1.

We observed simple effects for the control predictors Previous RT, Suffix, and Correctness. As expected, RTs were longer if participants had also reacted slower in the previous trial. Furthermore, participants took longer to react to target neologisms ending in the suffix *-heid* than in the suffix *-baar* ($\hat{\beta} = -0.0510, t = -3.40, p < 0.001$) and longest to react to target neologisms ending in the suffix *-ing*. The effect for Correctness shows that participants took longer to reject a target neologism as a meaningful word than to accept it, which is in line with previous studies (e.g., Coolen et al., 1991), where native speakers also had difficulties rejecting items that were well-interpretable.

Most important for our study is that we observed a simple effect for Prime Type: target neologisms elicited faster responses in the identity priming condition (mean:

[6] We included stem family size in our original analyses but found that family size was never significant because it was highly correlated with Suffix. Also suffix family size is highly correlated with Suffix and therefore cannot be tested.

Table 4.1: Results of the Stepwise Multilevel Regression Model (df = 3983) fit to the Response Times to the target neologisms in the auditory lexical decision experiment of Experiment 1. Prime Type provides the effect of identity priming relative to stem priming. Suffix provides the effect of the suffix *-baar* or *-heid* relative to the suffix *-ing*. The standard deviation for the random effect of Word was estimated at 0.0611. The standard deviation for the by-subject adjustments to the intercept was 0.5034. In addition, there was a significant random effect for Participant by Previous RT (log-likelihood ratio = 6.86, $p < 0.05$; standard deviation = 0.0688, estimated coefficient for the correlation = -0.969). The residual standard deviation was 0.1594.

	$\hat{\beta}$	t	$p <$
(Intercept)	6.0735	48.83	0.0001
Prime Type	-0.0115	-2.27	0.05
Previous RT	0.1488	8.63	0.0001
Correctness	0.0173	2.01	0.05
Suffix *-baar*	-0.0420	-2.79	0.01
Suffix *-heid*	-0.0930	-6.18	0.0001

1208 ms; standard deviation: 290 ms) than in the stem priming condition (mean: 1221 ms; standard deviation: 292 ms). These results suggest that memory traces formed for the neologisms during the self-paced reading task facilitated subsequent auditory lexical decision for these same words. A trace of a neologism formed in the visual modality thus facilitated subsequent auditory processing of the word, which suggests that the memory trace is not modality specific and therefore must be abstract. Our finding that identity priming facilitated responses more than stem priming did is an extra indication that the traces are abstract, although there was a change in situational context between the prime and the target. Prime Type did not interact with Inflection, which suggests that the presence of affixes on primes did not decrease the priming effects. This is a final indication that the memory traces formed for the neologisms are abstract.

Experiment 1 strongly suggests that the visual presentations of neologisms facilitate subsequent auditory processing of these same neologisms more than the visual presentations of the neologisms' stems do. Experiment 2 investigated whether the opposite is also true, that is, whether an auditory presentation of neologisms facilitates subsequent visual processing of these words more than an auditory presentation of the stems. If the memory traces formed by neologisms are abstract, we expect that this is the case. In Experiment 2, participants were familiarized with the primes in auditorily presented stories, while in the test phase, the target neologisms were presented to the participants visually and in isolation. We extended the time interval between familiarization phase and test phase to one week, as opposed to a few minutes in Experiment 1. If we would still find that the effect of identity priming is greater than the effect of stem priming, it would be even more likely that the memory traces for the neologisms are abstract in nature.

Experiment 2: auditory primes in context and visual targets in isolation

Method

Participants

Twenty-four undergraduate students (seven male) of Radboud University were paid to take part in this experiment. They had a mean age of 21 years (range 18 – 30), were native speakers of Dutch, and none had participated in Experiment 1.

Materials

We tested the same 120 neologisms as in Experiment 1.

For the familiarization phase, a listening comprehension task, we created three sets of four stories with each set containing 60 neologisms and the stems of the remaining 60 neologisms. The neologisms and the stems were equally divided over the stories. For an example of a story, see Appendix B. Each story consisted of 686 to 861 words (with a mean of 784.25 words). For each set of stories, we created a parallel set in which the sentences with neologisms were replaced by sentences with the corresponding stems and vice versa. For example the sentence,

> (4) *Op een* ***gedenkbare*** *dag in juli besteeg Willem in alle vroegte zijn paard.* 'On a **rememberable** day in July, early in the morning, Willem mounted his horse.'

had the following counterpart in the parallel story set

> (5) *Willem* ***gedenkt*** *nog vaak de dag in juli, toen hij in alle vroegte zijn paard besteeg.* 'Willem often **remembers** the day in July, when he mounted his horse, early in the morning.'

This resulted in a total of six story sets. Each participant listened to one set.

As in the familiarization phase of Experiment 1, many of the stems were inflected: 262 of the 360 stems were followed by regular inflectional suffixes (e.g., /skɑnderə/ *scanderen* 'to chant' consisting of the stem /skɑnder/ *scandeer* 'chant' and the suffix /ə/, indicating the infinitive) and seven were conjugated irregularly (e.g., /vərkek/ *verkeek* 'misjudged', which is the past tense of /vərkɛɪk/ *verkijk* 'misjudges'). Among the 360 neologisms, 18 ending in *-baar* were inflected (e.g., /ɣədɛŋgbarə/ *gedenkbare*

’rememorable’ consisting of the neologism /ɣədɛŋgbar/ *gedenkbaar* ’rememorable’ and the suffix /ə/).

All stories presented to a given participant were read by the same speaker. Because we wished to exclude the possibility that our results would only be valid for one single speaker, we chose to have three speakers reading the stories. Each speaker read two story sets. The speakers were three female native speakers of Dutch in the age of 21, 27, and 29 years. Each story was recorded in a noise-attenuated booth in mono sound in a natural way (sampling rate: 44.1 kHz). Their durations varied between 255s and 324s, with an average of 288s. On average, the speakers produced 4.36 syllables per second.

To force participants to listen carefully to the stories, we formulated five open questions about each story, for instance:

> (6) *In welk seizoen speelt het verhaal zich af?* ’In which season does the story take place?’

The test phase of the experiment was identical to the test phase of Experiment 1, except that we presented the words auditorily instead of visually. The target neologisms had a mean word length of 10.5 characters, the real filler words of 10.1 characters, and the filler pseudowords of 9.6 characters, with standard deviations of 1.05, 2.41, and 1.42 characters, respectively. The spelling of all words, including the filler pseudowords, obeyed the Dutch regular orthographic conventions.

Procedure

The procedure of Experiment 2 was identical to the procedure of Experiment 1 in many respects. As is Experiment 1, participants were approached for two different experiments, the two phases of the experiment were conducted by two different experiment leaders, participants were tested individually in a noise-attenuated booth, and participants received instructions for a lexical decision task in the test phase.

In addition, there were four changes in procedure. Firstly, the familiarization phase of Experiment 2 was an auditory comprehension task instead of a self-paced reading task. Participants were asked to listen to a set of four stories over headphones. We used Windows Media Player to play the sets. At the end of the set, participants were asked to answer the questions on the computer screen using the keyboard. We first referred to a story. For example:

> (7) *De volgende vragen gaan over het verhaal waarin Willem zijn zoektocht naar een uniek boek voltooit.* ’The following questions are about the story in which Willem finishes his search for a unique book’

Participants then pressed the ENTER key to see the first question. The question remained on the screen while the participants typed their answers. They then pressed the ENTER key for the next question. This procedure was repeated until they had answered all five questions about the given story. They then saw a white screen for 1000ms, followed by a screen referring to the next story, after which they answered the five corresponding questions. This procedure of questioning was repeated for all four stories. After the last question, a word of thanks appeared on the screen. All text appeared in black, centered on a white screen, in bold Courier New font 18 pt.

Secondly, the procedure of Experiment 2 differed from that of Experiment 1 in that the time interval between the familiarization phase and test phase was extended from a few minutes to one week, which decreases the likelihood that the responses were only based on temporary memory traces.

Thirdly, the test phase consisted of a visual instead of an auditory lexical decision experiment. Each trial in this phase began with a fixation mark positioned at the center of the computer screen for 500ms. After 50ms of blank screen, the stimulus appeared, also centered on the screen. Stimuli were presented in black lowercase, in bold Courier New font 18 pt letters, on a white background and remained on the screen for 1750ms, which was the time interval in which the participants had to react.

Fourthly, we only offered participants financial compensation after the test phase to encourage them to participate in that phase as well. We presented that phase as a colleague's experiment for which participants were needed urgently.

Results and Discussion

Participants widely varied in their performance in the familiarization phase: whereas some participants answered 90% of the questions correctly, others only answered 20% of the questions correctly. This variation possibly reflects differences among the participants in working memory because the questions only appeared after the participants had heard all the stories. Although some participants made many errors, we decided not to exclude participants on the basis of their performance in the familiarization phase. Instead, we included participants' performance in the familiarization phase as predictor for their performance in the test phase (see below).

In the test phase, the average percentage of errors for a neologism ranged from 0% to 85%, with twelve neologisms having error rates above 50%. None of the participants had error rates of over 30% for the entire experiment (target neologisms, real filler words and pseudowords). We decided not to exclude any participants or words on the basis of these error data. The percentages of errors were 18.7% for the neologisms primed by themselves and 18.3% for the neologisms primed by their stems.

We first analyzed whether participants' responses could be predicted by whether they had only heard the neologism's stem before or the complete neologism. As for Experiment 1, we conducted a general linear mixed effect model with this predictor (Prime Type: stem priming versus identity priming) in addition to the covariates the logarithmically transformed lemma frequency of the stem of the neologism as listed in CELEX (Base Frequency), Suffix (*-baar*, *-heid*, and *-ing*), Rating, and Trial Number. We included Participant and Word as crossed random variables (e.g., Jaeger, 2008). Prime Type did not show a significant effect, neither as a fixed effect nor as a random slope. Only Trial Number, Rating, and Suffix emerged as statistically significant effects. Participants rejected more neologisms when they were further in the experiment ($\beta = 0.2064, z = 3.75, p < 0.001$) and they rejected more neologisms ending in *-ing* than neologisms ending in *-baar* (33.1% versus 15.7%; $\beta = 1.2472$, $z = 4.93, p < 0.0001$) and *-heid* (23.9%; $\beta = 1.3667, z = 4.97, p < 0.0001$). They rejected fewer neologisms when the rating scores were higher ($\beta = -0.6821$, $z = -5.48, p < 0.0001$).

For the analysis of the RTs in the test phase, we only excluded trials to which the participants did not react and the directly following neologisms. We also excluded RTs longer than 1643ms, which is the mean response latency plus 2.5 times the standard deviation. This led to a dataset of 2695 response times (93.58%). The data fitting procedure was the same as in Experiment 1. We tested as fixed predictors Prime Type, Correctness of the answer, Previous RT, Suffix, Length (word length in number of characters), Base Frequency, Trial Number, and Familiarization Performance (the

Table 4.2: Results of the Stepwise Multilevel Regression Model (df=2657) fit to the lexical decision times of Experiment 2. Suffix provides the effect of the suffix *-baar* or *-heid* relative to the suffix *-ing*. The standard deviation for the random effect of Word was estimated at 0.0688, and that for the Participant random effect at 0.1757. In addition, there was a significant random effect for Participant by Trial Number (log-likelihood ratio = 93.23, p $<$ 0.01, standard deviation = 0.0002, estimated coefficient for the correlation = -0.190). The residual standard deviation was 0.2150.

	$\hat{\beta}$	*t*	*p* $<$
(Intercept)	5.909	31.54	0.0001
Prime Type (identity priming)	-0.3064	-1.79	0.1
Trial Number	-0.00111	-2.57	0.05
Length	-0.01087	-0.83	0.1
Previous RT	0.1570	8.69	0.0001
Suffix *-baar*	-0.0632	-3.25	0.01
Suffix *-heid*	-0.0772	4.17	0.0001
Prime Type by Trial Number	0.0015	2.38	0.05
Prime Type by Length	0.0272	1.67	0.1
Trial Number by Length	0.0001	2.42	0.05
Prime Type by Trial Number by Length	-0.0001	-2.31	0.05

number of correct answers to the questions in the familiarization phase provided by the given participant). We applied a logarithmic transformation to the RTs, Previous RTs, and Base Frequency. We checked for random slopes for all our fixed effects. Finally, we removed outliers with standardized residuals outside the interval of [-2.5, 2.5], and refitted the model. The final model is shown in Table 4.2.

As in Experiment 1, we observed simple effects for our control predictors Previous RT and Suffix. Response times were longer if the Previous RTs were longer and if the neologism ended in the suffix *-ing* (953ms) instead of *-baar* (908ms) or *-heid* (893ms).

More important for our research question, we observed a three-way interaction of Prime Type, Length, and Trial Number. In order to interpret this interaction, we split the data in half, based on Trial Number (Trials in the first half of the experiment: Trial Number < 241; Trials in the second half of the experiment: Trial Number > 240). Analyses of the first half of the experiment showed a simple effect for Prime Type, regardless of the neologism's length ($\hat{\beta} = -0.0233, t = -1.96, p = 0.05$, mean RT and standard deviation for neologisms in the identity priming condition: 926ms and 274ms; for the neologisms in the stem priming condition: 943ms and 289ms). This suggests that in the first half of the experiment, participants reacted faster to a neologism if they had seen that neologism before than if they had only seen the neologism's stem.

For the second half of the experiment, we observed an interaction of Prime Type and Length ($\hat{\beta} = -0.0271, t = -2.408, p < 0.05$, mean RT and standard deviation for neologisms in the identity priming condition: 897ms and 263ms; for neologisms in the stem priming condition: 891ms and 268ms), which is shown in Figure 4.2. We split the trials based on Length (Short Words (SW): Length < 11 characters, 691 response times; Long Words (LW): Length > 10 characters, 662 response times) and investigated if Short Words and Long Words showed significant effects of Prime Type. The effect of Prime Type approached significance for the Short Words but not for the Long Words (SW: $\hat{\beta} = 0.0313, t = 1.87, p = 0.06$, mean RT and standard deviation for neologisms in the identity priming condition: 897ms and 263ms; for the neologisms in the stem priming condition: 891ms and 268ms; LW: $\hat{\beta} = -0.0224$, $t = -1.35, p > 0.1$, mean RT and standard deviation for neologisms in the identity priming condition: 909ms and 286ms; for the neologisms in the stem priming condition: 908ms and 275ms). Surprisingly, for Short Words, the effect goes in the opposite direction than for the neologisms in the first half of the experiment: participants seem to have reacted faster in the stem priming condition than in the identity priming condition.

In summary, we observed that identity priming (mean: 926ms; standard deviation: 274ms) was larger than stem priming (mean: 943ms; standard deviation: 289ms) in the first half of Experiment 2. These results strongly suggest that memory traces formed for the neologisms during the auditory comprehension task facilitated subsequent visual lexical decisions for these same words. That is, a trace of a neologism formed in the auditory modality facilitated subsequent visual processing of the

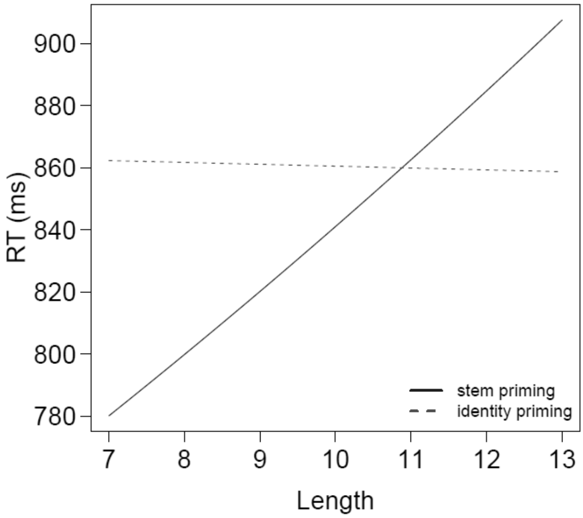

Figure 4.2: The effect of Word Length (in amount of characters) on Reaction Times (in ms) in the second half of Experiment 2, split by Prime Type.

word, which strongly suggests that the trace is not modality specific and therefore must be abstract.

To obtain additional evidence for abstract representations, we varied the situational context between the familiarization phase with the primes and the test phase with the targets. Moreover, we extended the time interval between these phases from approximately 1.5 minutes in Experiment 1 to one week in this experiment. Participants nevertheless reacted faster on the repeated neologisms than on the newly presented neologisms.

The results of the second half of Experiment 2 suggest that in the second part of the experiment participants reacted faster in the stem priming condition (mean: 891ms; standard deviation: 268ms) than in the identity priming condition (mean: 897ms; standard deviation: 263ms) for short words. These effects may reflect task specific behavior rather than natural everyday language processing. We postpone the interpretation of these results to the General Discussion.

In Experiment 3, we address the question whether a trace for a neologism formed during listening to sentences also facilitates the reading of that same neologism if it occurs in a different linguistic context. A different linguistic context may hinder priming if the formed traces for the neologisms are context specific. On the other hand, if the formed traces are abstract, we do not expect priming to be affected by the difference in sentential context.

Experiment 3: auditory primes and visual targets, both in context

Method

Participants

Twenty-four undergraduate students (seven male) studying at Radboud University were paid to take part in this experiment. They had a mean age of 21 years (range 18 – 24), were native speakers of Dutch, and none had participated in Experiment 1 or 2.

Materials

We tested the same 120 neologisms as in Experiments 1 and 2. The familiarization phase of Experiment 3 was identical to the familiarization phase of Experiment 2, with exactly the same materials.

For the test phase, a self-paced reading experiment, we created 24 short texts. Each text consisted of 8 to 16 sentences (mean: 12 sentences), 179 to 239 words (mean: 199 words), and contained five neologisms (see Appendix C for an example). The number of inflected neologisms was kept to a minimum (only six neologisms ending in *-baar* were inflected). The neologisms were always followed by at least two words in the same sentence. The reading times of these two words can show spill-over effects from the neologisms (e.g., for spill-over effects see Just, Carpenter, & Woolley, 1982; Ernestus & Mak, 2005). In addition, we created two practice texts. These texts did not contain any neologisms, and further followed the same structure as the 24 texts constructed for the test phase. Each text was followed by a question about its content, which stimulated participants to read the texts carefully.

Importantly, the semantic and syntactic context of a word was not the same in the familiarization phase as in the test phase. We illustrate this for the neologism *verrijding*, which occurred in context (8) in the familiarization phase and in context (9) in the test phase. As a consequence, the neologism could elicit slightly different interpretations in the two phases.

> (8) *De beuheid overviel hem daarnaast over de lengte van de routes die hij en zijn piano telkens moesten afleggen. Een* **verrijding** *maakte hij niet zo vaak mee, daarentegen was er wel vaak sprake van verkuiling van de oprijlaan.* ’In addition, tiredness overcame him to the length of the routes that he and his piano had to travel. A **deviation** did not often happen, however there often were many holes in the driveway.’

(9) *Hij voelde zich tijdens het rijden niet goed worden. Die onwelheid zorgde voor een* **verrijding** *op het hobbelige wegdek, waarna de man de macht over het stuur verloor.* 'He felt unwell while driving. This unwellness resulted in **making movements** on the bumpy road after which the man lost control of the vehicle.'

We created one master list containing all 24 texts. This master list was randomized three times. Each participant was presented with one list. The lists were divided into four parts, which were presented to the participants in a random order.

Procedure

The procedure of Experiment 3 was identical to the procedure of Experiment 2 in many respects. As in Experiment 2, participants were approached for two different experiments, the two phases of the experiment were conducted by two different experiment leaders, participants were tested individually in a noise-attenuated booth, the time interval between the familiarization phase and the test phase was one week, and we only offered participants financial compensation after the test phase to encourage them to participate in that phase as well. We presented that phase as a colleague's experiment for which urgently participants were needed.

In addition, there was one change in procedure. The test phase of Experiment 3 was a self-paced reading task. Participants received self-paced reading instructions, which were identical to the ones for the familiarization phase of Experiment 1.

Each text in the test phase was presented in three, more or less equally long parts (caused by the limitations posed by the E-prime software), with every part ending at the end of a sentence. To start a trial, participants pressed the button in the middle of a button box. The first part of the text, aligned to the left side of the screen, was displayed with dashes marking letter positions. By pushing the button in the middle again, participants could see the first word of the sentence in bold Courier New font 15pt. When they pressed the button in the middle again, the second word appeared and the first word was again replaced by dashes. This procedure was repeated until the participants had read the first part of the text. This first part of the text was then followed by the second and the third part, each preceded by a blank screen. Participants read these second and third parts in the way they had read the first part. When they had finished reading the third part, a yes/no question about the entire text appeared centered on the screen. Participants indicated their response by means of a button press (the 'yes'-button with their dominant hand, the 'no'-button with their other hand). To get used to the task, participants first completed two practice texts. They then started with the 24 texts of the test phase.

Results and Discussion

Since there are often spill-over effects to the following words (e.g., Just et al., 1982; Ernestus & Mak, 2005) in self-paced reading experiments, we analyzed the reading times of the neologisms themselves and of the two following words.

We excluded one target neologism from analysis, namely *arceerbaar* 'shadable', because we accidentally made a new neologism out of the neologism we meant to incorporate (*arceerbaarheid* 'shadableness'). We excluded one participant because her standard deviation of the reading times was larger than her mean reading time. We also excluded two participants with error rates over 30% for the questions, which means eight or more errors in 26 questions (mean error rate was 15%; four errors in 26 questions). These participants have probably not seriously read the stories. We further excluded data points with reading times shorter than 200ms, as well as data points that were preceded by reading times shorter than 200ms, since these extremely short reading times may indicate that participants did not read these words carefully (Jegerski, 2014). Finally, we excluded data points with reading times exceeding 1105ms and data points that were preceded by reading times exceeding 1105ms, which is the mean response latency plus 2.5 times the standard deviation. The remaining dataset consisted of 6756 data points (which forms 78.2% of the complete original data set). The resulting RTs do not point to a processing difference between neologisms that are primed by themselves or by their stems (407ms versus 404ms). We nevertheless decided to analyze the data because the effect may be obscured by the effects of other variables (as was the case in Chapter 2).

The data fitting procedure was the same as in Experiments 1 and 2. We included three random intercepts in the mixed effect models of covariance: Participant, Word, and Neologism. The random variable Word refers to the word that is analyzed, which is the identity of the neologism, the identity of the first following word, or of the second following word. The dependent variable in our analysis is Response Time (RT), which was logarithmically transformed. Our main predictors were Prime Type (stem priming versus identity priming) and Position (with the levels: "the neologism", "the first following word" and "the second following word"). Our control predictors were again Length in characters, Suffix, the logarithmically transformed Base Frequency, and the logarithmically transformed Previous RT. We checked for random slopes for all our fixed effects. Finally, we removed outliers with standardized residuals outside the interval of [-2.5, 2.5], and refitted the model.

We observed a four-way interaction between Prime Type, Position, Previous RT, and Length ($F(2, 6402.7) = 6.69, p < 0.01$). To simplify the interpretation of this interaction, we split the data into three sets representing the levels of Position, and analyzed these subdatasets separately. The datasets for neologisms, first following words, and second following words contained 2301, 2226, and 2229 datapoints, respectively (the mean RTs for stem priming were: for the reading of the neologism itself 362ms, for the reading of the first following word 440ms, and for the reading of the second following word 411ms; the mean RTs for identity priming were: for

Table 4.3: Results of the Stepwise Multilevel Regression Model (df=2220) fit to the Reaction Times for the neologisms in the self-paced reading part of Experiment 3. Prime Type provides the effect of identity priming relative to stem priming. Suffix provides the effect of the suffix *-heid* or *-ing* relative to the suffix *-baar*. The standard deviation for the random effect of Word was estimated at 0.0485 and that for the Participant random effect at 0.8405. In addition, there was a significant random effect for Participant by Previous RT (log-likelihood ratio = 22.22, p $<$ 0.01, standard deviation = 0.1431, estimated coefficient for the correlation = -0.99). The residual standard deviation was 0.1765.

	$\hat{\beta}$	t	$p <$
(Intercept)	3.3779	15.42	0.0001
Prime Type			
(identity priming)	0.3590	2.41	0.05
Previous RT	0.4205	11.28	0.0001
Suffix *-heid*	-	-	*n.s.*
Suffix *-ing*	-0.0338	-2.36	0.05
Prime Type by Previous RT	-0.0596	-2.35	0.05

the reading of the neologism itself 367ms, for the reading of the first following word 443ms, and for the reading of the second following word 411ms). Except for Position, we incorporated the predictors and the interactions that were significant in the overall analysis and applied the same fitting procedure as for the overall dataset. For the analysis of the reading times of the neologisms, the random variables Word and Neologism are completely identical (i.e., the *Word* that the participant read was the *Neologism*). We left out the random variable Neologism. The final models for the three subdatasets are summarized in Tables 4.3, 4.4, and 4.5, respectively.

For the neologisms, we observed a simple effect for the control variable Suffix. In contrast to what we found in Experiments 1 and 2, reading times were slightly longer for neologisms ending in *-baar* than for neologisms ending in *-heid* (marginally) and *-ing* (mean RTs were 361ms, 360ms, and 358ms, respectively).

We also found an interaction between Prime Type and Previous RT, as illustrated in Figure 4.3, which is important for our main question. To interpret this interaction, we split the data in half, based on Previous RT ($\leq 340ms$ and $> 340ms$) and analyzed these datasets separately. These analyses showed that RTs were shorter in the identity priming condition than in the stem priming condition, but only when participants had read the preceding word relatively slowly ($\hat{\beta} = -0.1312, t = -2.77$, $p < 0.01$). When participants had read the preceding word relatively fast, the identity priming condition and the stem priming condition did not show a statistically significant difference.

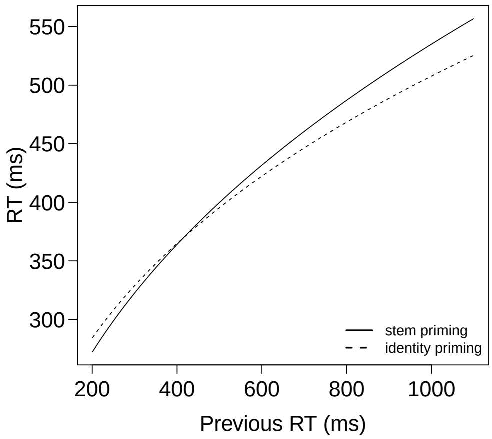

Figure 4.3: The effect of the RTs for the previous trial (in ms) on the RTs for the neologisms (in ms) in the self-paced reading task of Experiment 3, split by Prime Type.

Table 4.4: Results of the Stepwise Multilevel Regression Model (df=2163) fit to the Reaction Times for the first following words in the self-paced reading part of Experiment 3. Prime Type provides the effect of identity priming relative to stem priming. The standard deviation for the random effect of Neologism was estimated at 0.0656 and that for the Participant random effect at 1.7317. In addition, there was a significant random effect for Participant by Previous RT (log-likelihood ratio = 71.49, p $<$0.01, standard deviation = 0.2767, estimated coeffecient for the correlation = -0.99. The residual standard deviation was 0.2543.

	$\hat{\beta}$	t	$p <$
(Intercept)	3.9081	7.38	0.0001
Prime Type (identity priming)	-1.3422	-2.77	0.01
Length	-0.1818	-2.13	0.05
Previous RT	0.3569	4.07	0.001
Prime Type by Previous RT	0.2350	2.83	0.01
Prime Type by Length	0.2795	2.55	0.05
Previous RT by Length	0.0316	2.15	0.05
Prime Type by Previous RT by Length	-0.0489	-2.59	0.01

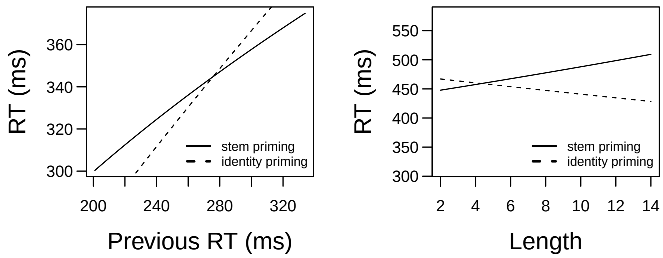

Figure 4.4: The effect of Prime Type in the self-paced reading task of Experiment 3. Left panel: The effect of half of the RTs on the neologisms (in ms), the shorter half, on the words following the neologisms, split by Prime Type. Right panel: The effect of the number of characters on the RTs (in ms) for the words following the neologisms that were read relatively slow, split by Prime Type.

Table 4.5: Results of the Stepwise Multilevel Regression Model (df=2169) fit to the Reaction Times for the second following words in the self-paced reading part of Experiment 3. Prime Type provides the effect of identity priming relative to stem priming. The standard deviation for the random effect of Neologism was estimated at 0.0597, that for the Word random effect at 0.0228 and that for the Participant random effect at 1.1983. In addition, there was a significant random effect for Participant by Previous RT (log-likelihood ratio = 54.25, $p < 0.01$, standard deviation = 0.1893, estimated coeffecient for the correlation = -1.00). The residual standard deviation was 0.2301.

	$\hat{\beta}$	t	$p <$
(Intercept)	5.076	18.07	0.0001
Prime Type			
(identity priming)	0.0717	3.51	0.001
Previous RT	0.1481	3.33	0.01
Length	0.0127	2.92	0.01
Suffix *-heid*	-0.0495	-2.50	0.05
Suffix *-ing*	-0.0724	-3.63	0.01
Prime Type by Length	-0.0181	-4.08	0.0001

The analysis of the RTs to the word immediately following the neologism showed an interaction between Prime Type, Previous RT, and Length (see Table 4.4). We split the dataset in two equal parts based on Previous RT ($\leq 334ms$ and $> 334ms$) in order to interpret this interaction. For RTs preceded by short RTs on the neologisms, we observed a simple effect for Prime Type ($\hat{\beta} = -1.6936, t = -2.57, p < 0.05$) and an interaction between Prime Type and Previous RT ($\hat{\beta} = 0.3012, t = 2.58,$ $p < 0.05$): Reading times increase relatively more in the identity priming condition than in the stem priming condition with increasing previous RTs, as shown in Figure 4.4, left panel. As a consequence, identity priming was only larger than stem priming after short previous RTs. For the other half of the data, the RTs preceded by long RTs on the neologisms, we observed an interaction between Prime Type and Length ($\hat{\beta} = -0.0180, t = -2.26, p < 0.05$): as Length increases, the benefit of identity priming compared to stem priming increases as well, as shown in Figure 4.4, right panel.

The analysis of the second following word (see Table 4.5) showed simple effects for the control variables Suffix and Previous RT. Reading times for the second following words after neologisms ending in *-baar* were longer than for the ones after neologisms ending in *-heid* and *-ing* (428ms, 409ms, and 395ms, respectively). Reading times increased along with increasing Previous RTs.

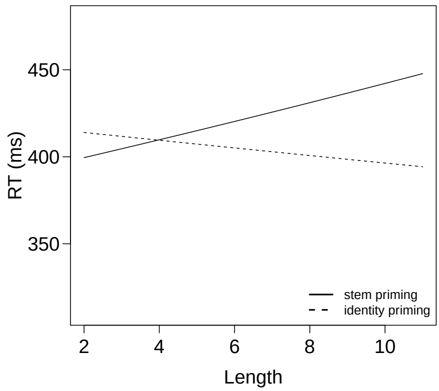

Figure 4.5: The effect of Word Length (in amount of characters) of the second following word on its reading times (in ms), split by Prime Type, in the self-paced reading task of Experiment 3.

Importantly, we also observed an interaction between Prime Type and Length, which is illustrated in Figure 4.5. To investigate how to interpret this interaction, we split the data in half, based on Length (≤ 3 characters and > 3 characters) and analyzed these datasets separately. The analysis of the RTs for the relatively long words showed a simple effect for Prime Type ($\hat{\beta} = 0.1010, t = 2.15, p < 0.05$) and an interaction between Prime Type and Length ($\hat{\beta} = -0.0216, t = -2.95, p < 0.01$): RTs for the long second following words were shorter in the identity priming condition than in the stem priming condition, but only when these words were relatively long. The analysis of the RTs for short words showed no effect of Prime Type.

In summary, Experiment 3 was constructed to find out whether a neologism also leaves a detectable trace in the mental lexicon when the prime and target are presented in different modalities as well as in different situational and linguistic contexts. The reading times for the neologism itself, the first following word, and the second following word showed effects of Prime Type. For the neologisms and the first following words, the effect of Prime Type was modulated by the reading time for the previous word. Identity priming facilitated the reading of the neologism but only if the preceding word was read relatively slow. The word following the neologism showed this facilitatory effect of identity priming only if the preceding word was read fast. For the following two words, the effect of Prime Type was (also) modulated by Word Length. Participants read the two words following neologisms faster in the identity priming condition than in the stem priming condition but only if these following words were long (and for the directly following word, this only holds for relatively slow readers).

General Discussion

This chapter addressed the question whether regular morphologically complex neologisms form abstract representations or exemplars in memory. We investigated this question by examining the processing of Dutch neologisms consisting of real stems and real productive suffixes. We first presented participants with either the stem of a neologism (stem priming) or with the complete neologism (identity priming) and then presented the target neologism. We included the stem priming condition as a baseline in order to investigate whether priming in the identity priming condition resulted from the full neologism or just its stem. If it was just the stem of the neologism that induced priming, the stem and the neologism should show similar priming effects. If, in contrast, participants stored the full neologisms, the neologisms should show more priming than just their stems.

We addressed two subquestions. First, does identity priming facilitate the processing of neologisms more than stem priming does, also if the prime and the target are presented in different modalities (visual versus auditory and vice versa)? Second, is identity priming also more beneficial than stem priming if the prime is presented in one experimental task and the target in another? If change in modality and context eliminate the benefit of identity priming over stem priming, the memory traces for neologisms are probably token specific (exemplars). If not, these traces are more likely to be abstract.

We conducted three experiments. All primes (stems and neologisms) were presented in a familiarization phase and the targets in a later phase, namely the test phase. Furthermore, participants were made to believe that these phases were independent experiments. The task in the test phase was different from the one in the familiarization phase.

In Experiment 1, the primes were presented in sentences in a self-paced reading task and the targets in isolation in an auditory lexical decision task. Target neologisms elicited faster responses in the identity priming condition than in the stem priming condition. A memory trace formed for a neologism during a self-paced reading task can thus facilitate subsequent processing of that neologism in an auditory lexical decision task. These results indicate that the formed traces are modality general and task independent, which strongly suggests that they are abstract lexical representations.

In Experiment 2, the primes were presented in sentences in an auditory story comprehension task and the targets in isolation in a visual lexical decision task. The time interval between both parts of the experiment was one week as opposed to a few minutes in Experiment 1. In the first half of the lexical decision experiment, participants reacted faster to a neologism if they had heard that neologism before than if the neologism was entirely new. These results indicate that memory traces formed for neologisms during a listening task can facilitate subsequent visual lexical decisions, even after one week. Priming effects after a week, induced by neologisms, are thus not restricted to experiments in which the primes and targets are presented in the same modality. This outcome enforces the results of Experiment 1, showing that memory traces for neologisms are modality general and task independent, which strongly suggests that they are abstract lexical representations.

Noteworthy, the second half of Experiment 2 showed a reversed pattern of results. Participants reacted faster in the stem priming condition than in the identity priming condition but only if the neologisms were short. A possible explanation for this result is that participants caught on to the morphological structures of the words after a while. These all consisted of a (pseudo)stem and a real suffix. Participants may have adopted a strategy to strip the suffixes from the stimuli and then base their lexical decisions just on the stems. Suffix stripping may be easier for shorter words because they are generally read at a glance. This would explain why stem priming had an advantage over identity priming in the second half of the experiment and especially for short words. In the test phase of Experiment 1, we did not observe an similar interaction. This, being an auditory lexical decision experiment, is less conceivable among others because of resyllabification, which makes affix stripping more difficult.

In Experiment 3, the primes were presented in the same auditory story comprehension task as in Experiment 2, and the targets were presented in different stories in a self-paced reading task. The time interval between both parts of the experiment was again one week. The reading times for the neologism itself and for the two following words all showed effects of Prime Type, which by itself suggests that neologisms leave different traces than their stems do in the comprehension system. Neologisms were read faster if they were primed by themselves than by their stems, but only if the participants read the directly preceding words relatively slowly (and thus probably had a slow local reading speed). The reading times for the following word showed the same facilitatory effect of identity priming, but only if the participants had read the preceding neologism relatively fast. These two facilitatory effects of identity priming probably represent one single effect, which arises some time after the presentation of the neologism. When slow readers (i.e., participants who were slow for the given sequence of trials) are still reading the neologism, fast readers (i.e., participants who were fast for the given sequence of trials) have already turned to the following words.

In addition, we found interactions between the effect of Prime Type and the number of the word's characters for both the reading of the directly following word and the second word: identity priming facilitated the reading of that word but only if it was long. We assume that these interactions are also related to the speed in which priming affects processing, since longer words take more time to read.

In Experiment 3, the effect of identity priming does not occur immediately when readers see the neologism. This does not come as a surprise since many effects arise rather late in this experimental paradigm, for instance, effects from biases for the grammatical subjects of subclauses following implicit causality verbs (Koornneef & Van Berkum, 2006), effects from intra- and interparadigmatic effects on verb forms (Ernestus & Mak, 2005), and effects from syntactic ambiguity (Swets, Desmet, Clifton, & Ferreira, 2008).

The results of Experiment 3 confirm the results of Experiments 1 and 2. The three experiments together clearly show that a neologism encountered in one modality facilitates the processing of the second token of that word in another modality. This is even true when the two tokens occur in very different experimental tasks (Experiments 1, 2, and 3), when participants believe that the two tasks form independent experiments (Experiments 1, 2, and 3), and when the time interval between the prime and the target is one week (Experiments 2 and 3). Experiment 3 contributes to the findings from Experiments 1 and 2 by showing that the priming effect also arises when the two tokens of the word occur in very different sentences and may therefore have slightly different meanings. These data strongly suggest that a neologism leaves a memory trace that is abstract. In addition, these traces may contain token specific information. Further research has to investigate whether this is the case.

The results also show that the difference between stem priming and identity priming is small (the maximal difference observed in the study is 17ms). Furthermore, the presence and size of the difference varies with experimental task and for some tasks also with trial number. We interpret this variation as a task effect. Important is that all experiments (or at least the first parts of all experiments) showed the same pattern: neologisms are processed more quickly when primed with themselves than when only primed with their stems.

Due to the consistent phoneme-to-grapheme and grapheme-to-phoneme mappings in Dutch, there was hardly any ambiguity about the orthographic representations of the auditorily presented neologisms and about the pronunciation of the orthographically presented neologisms. Research by Bakker et al. (2014) showed priming of Dutch morphologically simple neologisms between different modalities. They used lexical competition between these neologisms and their real phonological/ orthographic neighbors to test lexical integration. Auditorily acquired neologisms contributed to the lexical competition in the written modality after 24 hours. On the other hand, visually acquired neologisms required extra training and a consolidation period of a week before they contributed to the lexical competition during auditory word comprehension. When tested in the same modality, both auditorily and visually acquired neologisms showed competition effects after 24 hours. This study thus also shows that words acquired in one modality can affect the processing of that word in another modality.

Bakker et al. (2014) found that the conversion from visual representations to auditory representations took more effort than the conversion from auditory representations to visual representations (participants needed more training tokens and a longer consolidation period). Yet, we observed cross-modal priming almost immediately and after only one training token. A possible explanation for this difference in results is that our neologisms consisted of novel combinations of real morphemes, which already have their own representations in the mental lexicon. Participants only have to create a new link between both real morphemes (stem and suffix). In contrast, Bakker et al. (2014) investigated the acquisition of completely novel morphemes.

The question arises how priming between different modalities may take place. One possibility is that the presentation of a neologism in any modality leads to a simultaneous creation of both a visual and an auditory lexical representation. When presenting a second token of a neologism, either the visual or the auditory representation would be activated in lexical memory, depending on the modality of the second token. This activation would lead to a faster recognition of the neologism. The assumption of specific representations, however, cannot account for our findings that a change in linguistic context or a slight change in meaning also do not obstruct the priming effect. We therefore prefer the interpretation that the neologisms form abstract representations, which match to the neologisms in both modalities because of the simple (shallow) phoneme-grapheme mapping rules for Dutch.

Because we created linguistic contexts for the neologisms and their stems that were as natural as possible, we had to inflect many stems and some of the neologisms. Over 70% of the stem primes were inflected in the familiarization phases of all three experiments, while no more than five percent of the neologism primes were inflected. Inflection comprised of the adding of inflectional prefixes, interfixes, and suffixes (e.g., *visrijk* versus *visrijke* 'plentiful fish', *verkreuk* 'wrinkle' versus *verkreukte*

’wrinkled’, *omduikel* ’tumble over’ versus *omgeduikeld* ’tumbled over’). Furthermore, there were some phonological differences between the stems in the stem primes and in their corresponding target neologisms, due to final devoicing (e.g., /bəklœyf/ ’endure’ as stem for /bəklœyvıŋ/ ’enduring’) and vowel substitution in irregular verbs (e.g., /vərkek/ ’misjudged’ as stem for /vərkɛikıŋ/ ’the misjudgement’).

The inflected words functioning as the stem primes can themselves be stored in the mental lexicon and processed via these lexical representations (e.g., Butterworth, 1983; Rumelhart & McClelland, 1986; Seidenberg & Gonnerman, 2000). One might therefore argue that due to our operation of the stem priming condition, this condition is not fit as a baseline in order to investigate whether priming in the identity priming condition results from the full neologism or just its stem. There is, however, evidence that even when morphologically complex words are processed via their full lexical representations, the corresponding stems are activated as well. For instance, Stemberger & MacWhinney (1986) showed that the processing speed of inflections is not only influenced by the frequencies of the inflections themselves, but also by the frequencies of their stems. Furthermore, Crepaldi, Rastle, Coltheart, & Nickels (2010) showed that irregularly inflected words prime their base words more than orthographically matched and unrelated control words. So, *fell* primes *fall* more than *fill* or *hope* do. This strongly suggests that although many stems in the stem priming condition were inflected, the stem priming condition was fit as a baseline.

We observed differences in the processing of neologisms ending in the suffixes *-baar*, *-heid*, and *-ing*. The suffixes *-baar* and *-heid* are more productive than the suffix *-ing* (e.g., Booij, 2002; Van Haeringen, 1971), and one may therefore expect that neologisms ending in the suffixes *-baar* and *-heid* are processed faster than neologisms ending in the suffix *-ing*, which we observed in Experiment 1. Also in Experiment 2, neologisms ending in the suffix *-baar* were processed faster than neologisms ending in the suffix *-ing*, but we did not find a difference in processing speed between the neologisms ending in the suffix *-ing* and those ending in the suffix *-heid*. In Experiment 3, we observed a different pattern: Neologisms ending in the suffix *-baar* were processed more slowly than the neologisms ending in the suffixes *-heid* and *-ing*. A possible explanation for this unexpected pattern is that the targets in Experiment 3 were presented in sentences, whereas in Experiments 1 and 2, they were presented in isolation. In the sentences of Experiment 3, 37 out of 40 neologisms ending in the suffix *-heid* and 32 out of 40 neologisms ending in the suffix *-ing* were preceded by determiners and possessive pronouns, whereas 31 out of 39 neologisms ending in the suffix *-baar* were preceded by other types of words, including adverbs, nouns, pronouns, adjectives, and conjunctions. The neologisms ending in the suffixes *-heid* and *-ing* were therefore possibly more predictable than the ones ending in the suffix *-baar*, which may explain the difference in reading times. Moreover, 6 out of the 40 target neologisms ending in *-baar* were inflected in Experiment 3, whereas none of the neologisms ending in the suffixes *-heid* and *-ing* were inflected (none of the neologisms were inflected in Experiments 1 and 2 since they were presented in isolation).

This may have caused an increase in reading time too.

So far, we have argued that our results can best be explained with the assumption that neologisms are lexically stored in the form of abstract representations. The model developed by Baayen, Milin, Filipovic Durdevic, Hendrix, & Marelli (2011) offers a different account. This computational model, referred to as the naive discriminative learning model, can account for all data that have so far been interpreted as evidence for the storage of morphologically complex words without actually assuming lexical form representations for these words. The model assigns a central role to the connections between the different units in its semantic and input (orthographic) layers, which have higher weights if the orthographic unit provides more important evidence for the semantic units. These weights are essential in the model's account for all types of frequency effects. The question arises whether this model can account for our observation that just one exposure of a neologism is sufficient to observe an advantage in the subsequent processing of that neologism. One single presentation of a neologism then has a substantial influence on the weights in the naive discriminative learning model. Only simulations can show whether this model can indeed account for the data on neologisms that were presented in this chapter and in the Chapters 2 and 3 of this dissertation. Before these simulations can be conducted, however, the model has to be extended such that it can automatically learn new words (outcomes).

For now, we conclude that we presented experimental support for the formation of abstract memory traces for morphologically complex neologisms. The prior processing of a neologism facilitates the processing of its second occurrence even if the two tokens are presented in different modalities, in different linguistic contexts, in different types of experiments, and if these experiments are presented as two separate experiments.

Appendix A

Target materials of Experiments 1, 2, and 3:

annoteerbaar; arceerbaar; balsembaar; bekeurbaar; bekogelbaar; bekrasbaar; bespuwbaar; bestijgbaar; bestormbaar; bestraatbaar; bestuifbaar; betoverbaar; bevuilbaar; bewapenbaar; blondeerbaar; braadbaar; fohnbaar; frankeerbaar; gedenkbaar; omspanbaar; ontkalkbaar; ontkleurbaar; ontruimbaar; ontrukbaar; onttroonbaar; ontwapenbaar; overreedbaar; paneerbaar; pocheerbaar; scandeerbaar; shockeerbaar; tutoyeerbaar; verfraaibaar; verknoeibaar; verkreukbaar; vernauwbaar; verpootbaar; verpotbaar; verspilbaar; verversbaar

kortafheid; lobbigheid; labielheid; pitloosheid; saprijkheid; summierheid; tactvolheid; tembaarheid; tilbaarheid; visrijkheid; pipsheid; enormheid; jofelheid; koketheid; onwelheid; ovaalheid; riantheid; antiekheid; banaalheid; basaalheid; dementheid; erkendheid; gammelheid; ludiekheid; ondiepheid; royaalheid; aftandsheid; beschutheid; bezweetheid; contentheid; coulantheid; bebrildheid; markantheid; beuheid; blusbaarheid; geurloosheid; kalkrijkheid; onattentheid; onbelastheid; ontroerdheid

afkluiving; afzouting; bebotering; bedamming; bedrinking; bedrupping; begiering; behakking; bekonkeling; bekruising; bekwijling; benageling; beolieing; bepareling; bepoeiering; beriddering; bespijkering; betralieing; bewalming; bijeenlegging; omduikeling; omkeiling; ontadeling; ontharsing; ontmugging; onttuiging; ontvloeiing; ontzadeling; oppieping; toezinging; verboersing; vergokking; verkijking; verkletsing; verkuiling; vernaaiing; verrijding; versmeding; verspelding; wegstoting

Appendix B

Example of a story used in the auditory comprehension task in Experiments 2 and 3. Primes (stems and neologisms) are underlined in bold.

Op een **<u>gedenkbare</u>** *dag in juli besteeg Willem in alle vroegte zijn paard. Zijn eindbestemming lag nog zeker een uur rijden bij hem vandaan. In rustige draf reed hij voort, zich bewust van de* **<u>verboersing</u>** *van het platteland. Willems gedachten richtten zich onvermijdelijk op de vondst die hij zou gaan doen, de vondst die hem beroemd zou maken. Sinds hij geruchten had gehoord over het bestaan van een onbekend werk uit de* **<u>antiekheid</u>***, had hij grondig onderzoek verricht naar de mogelijke verblijfplaats van dit werk. Vele plaatsen had hij bezocht, maar door de* **<u>summiere</u>** *informatie die hij had, zat hij telkens op een dood spoor. Maar nu wist Willem het zeker: zijn schat zou hij vinden in de kelder van een oude geneesheer. Het was een norse man, wist Willem, die bekendstond om zijn* **<u>bebrild</u>***, vierkant hoofd en haakneus. Het zou Willem moeite kosten de man te overtuigen dat hij zijn kelder moest inspecteren. Na een lange* **<u>bekonkeling</u>** *had hij besloten zich voor te doen als een ongediertebestrijder. Met zijn redeneerkunst zou hij de oude man vast kunnen overhalen, zijn welbespraaktheid was tenslotte* *een* ***erkendheid*** *in zijn geboortedorp. Verzonken in gedachten en inwendig trillend van spanning, reed Willem gestaag door. Wat zou er gebeuren als hij zijn vondst kenbaar zou maken aan de wereld? Hij stelde zich een grootse huldiging voor en zag hoe hij* ***beridderd*** *en bewierookt werd. Deze droom duurde niet lang, want Willem zag dat hij zich op nog slechts enkele meters van zijn bestemming bevond. Hij stapte van zijn paard. De* ***ontzadeling*** *kon hem niet snel genoeg gaan. Zijn bovenlip was* ***bepareld*** *met zweet, hij veegde het weg en stapte op de deur af, de deur naar eeuwige roem. Hij klopte kort driemaal achter elkaar. De deur ging open en Willem staarde naar een* ***markante*** *man. Wat volgde was een lange stilte waarin de twee mannen elkaar taxeerden. Willem stelde zich voor als dienstverlener, hij zou de man een dienst verlenen en zijn kelder vrijmaken van ongedierte. Hoe* ***basaal****, dacht hij bij zichzelf. Tot zijn grote verbazing toonde de oude man een allesomvattende* ***pitloosheid*** *en werd hij direct de woning binnen gelaten. De kamer omringde hem met kruiden,* ***versmede*** *handwerktuigen en een arsenaal aan potjes met een ondefinieerbare inhoud. De kraan was groen uitgeslagen terwijl die toch makkelijk te* ***ontkalken*** *zou moeten zijn. De muren en het plafond vertoonden duidelijke tekenen van achterstallig onderhoud. De geneesheer zette zich neer en* ***frankeerde*** *enkele enveloppen, schijnbaar zonder enige acht te slaan op zijn bezoeker. Willem twijfelde even en verontschuldigde zich toen voor zijn onaangekondigde bezoek. De man antwoordde dat hij* ***onbelast*** *was en wees met een handgebaar aan waar de toegang tot de kelder zich bevond. Willem liep naar de deur toe en opende deze. Voorzichtig liep hij de houten trap af, inwendig boos op zichzelf voor de* ***bekwijling*** *van zijn boord. Hij depte die droog en inspecteerde de ruimte. Zijn oog viel meteen op een ogenschijnlijk normale doos die dienst deed als tafelsteun. Hij sjorde even aan het tafelblad en constateerde dat dit goed* ***tilbaar*** *was. Hij pakte het blad op en legde het op de grond. Met verhoogde hartslag maakte hij de doos open. Hij verwijderde een paar vellen* ***verkreukt*** *papier totdat een groot, gerafeld boek tevoorschijn kwam. Willem haalde het boek uit de doos en een hevige* ***ontroerdheid*** *maakte zich van hem meester. Zijn zoektocht was eindelijk voorbij, zijn schat lag in zijn handen. Vanaf nu zou hij* ***onttroonbaar*** *zijn en de grootste ontdekking in de geschiedenis gedaan hebben. Hij opende het boek en las de beginzinnen. Het waren de mooiste zinnen die hij ooit zou lezen, perfect* ***scandeerbaar*** *en van een grote verhevenheid doordrenkt. Willem stelde zich voor hoe hij de zinnen zou overschrijven, ze* ***arceren*** *en ze eindeloos herhalen. Voor een boek uit het verre verleden verkeerde het in goede staat. Het was hier en daar verouderd en gehavend, maar met de nieuwste technieken zou het zeker* ***verfraaibaar*** *zijn. Hij zou het boek bij thuiskomst eerst* ***balsemen*** *zodat het niet verder zou beschadigen. Hij las verder en ontdekte een verhaal over een oude bekende familie, ten gronde gebracht door hun* ***ontadeling*** *na een familieschandaal. Een lastig verhaal dat om uitleg voor de lezer vroeg. Maar het verhaal was goed* ***annoteerbaar*** *en Willem zag voor zich hoe hij iedereen zou verbazen met zijn unieke editie van dit boek. Zo zou hij het gaan doen, hij zou het boek eerst editeren en daarna pas bekendmaken. Zelfs als de rijksten van het land zouden besluiten tot de* ***bijeenlegging*** *van al hun goudstukken, zouden zij de waarde van deze vondst nog niet behalen . Vergenoegd stopte Willem het boek onder zijn kleren, liep naar boven, mompelde wat tegen de oude man en verliet het huis. Buiten stapte hij op zijn paard, dat hij direct kon* ***bestijgen****, en reed in galop huiswaarts.*

’On a **rememberable** day in July, early in the morning, Willem mounted his horse. His final destination was at least an hour’s ride away. He rode at a calm trot, while he was aware of the countryside **becoming rustic**. Willem’s thoughts inevitably focused on the discovery that he was about to make, the discovery that would make him famous. Since he had heard rumors about the existence of an unknown work of **antiquity**, he had thoroughly investigated the possible whereabouts of this work. He visited many places, but he always hit a dead end because of the **scant** information he had. But now Willem knew for sure that he would find his treasure in the basement of an old physician’s house. Willem knew the physician was a surly man, who was known for his **bespectacled**, square head and hooked nose. Willem would find it hard to convince the man of the need to inspect his basement. After a long **intrigue**, he decided to impersonate a pest control technician. Using this disguise and rhetoric, he would persuade the old man. After all, his eloquence was a **recognized nature** in his native village. Willem rode steadily while deep in thought, and trembled inside with suspense. What would happen if he made his discovery known to the world? He imagined a great homage and saw himself being **knighted** and incensed. This dream did not last long, as Willem saw that he was only a few meters from his destination. He got off his horse. The **desaddling** could not go fast enough. His upper lip was **pearled** with sweat; he wiped it away and walked to the door, the door to eternal fame. He knocked three times in short succession. The door opened and Willem stared at a **remarkable** man. What followed was a long silence in which the two men rated each other. Willem introduced himself as a service provider, he would provide a service to the man and make the cellar vermin-free. How **basic**, he thought. To his surprise the old man showed an overall **spiritlessness** and he was admitted directly into the man’s home. He was surrounded by herbs, **welded** hand tools, including an array of pots with indefinable contents. The tap had turned green even though it should have been easy to **descale** the tap. The walls and ceiling showed clear signs of lack of maintenance. The doctor sat down and **stamped** some envelopes, seemingly without any regard for his visitor. Willem hesitated a moment and then apologized for his unannounced visit. The man replied that he was **unencumbered** and pointed with a hand gesture to where the access to the basement was. Willem went to the door and opened it. Carefully he walked down the wooden stairs, internally angry at himself for the **slobber** on his collar. He dabbed it dry and inspected the room. His eye immediately fell on a seemingly ordinary box that served as a table support. He tried to move the tabletop and noticed that it was easy to **lift**. He lifted the tabletop and put it on the ground. With increased heart rate, he opened the box. He removed a few **crumpled** sheets of paper until a large, frayed book appeared. Willem took the book out of the box and intense **emotions** overcame him. His search was finally over, his treasure was in his hands. From now on he would be **unthronable**, and he did the greatest discovery in history. He opened the book and read its first sentences. They were the most beautiful sentences he had ever read, perfectly **parsed** and a high level of cohesion. Willem imagined how he would copy the sentences, **shade** them and repeat them endlessly. For an ancient book, it was in good condition. In some places, it was old and battered, but with the newest techniques it would definitely be **trimable**. When he arrived home, first he would **preserve** the book so that it could not be damaged any further. He read further and discovered a story about an old family, now ruined and **denobled** because of a family scandal. A difficult story that had to be explained to the reader. But the story was well **annotatable**, and Willem imagined how everyone would be surprised by this unique edition of the book. This is the way he would do it: first he would edit the book and then publish it. Even if the richest people in the country decided to **put together** all their gold, they wouldnŠt come close to the value of this discovery. Willem, content put the book under his clothes, went up, muttered something to the old man and left the house. Outside he mounted his horse, which he could immediately **ascend**, and rode home at a gallop.'

Appendix C

Example of target materials of Experiment 3. Neologisms are printed underlined in bold.

Sinds de invoering van het rookverbod zijn eigenaren van cafés **bekeurbaar** *als zij hun klanten toch toestaan binnen te roken. Ondanks alle acties en protesten van de eigenaren toont de minister van Volksgezondheid zich nog altijd moeilijk* **overreedbaar** *om het verbod af te schaffen. Alleen voor kleine cafés zonder personeel geldt het verbod niet. De* **beuheid** *van de café-eigenaren over het rookverbod is inmiddels tot grote hoogte gestegen. Wat hun klanten in hun café doen, of dat nu gaat om het opsteken van een sigaret of om* **bedrinking** *met wodka, is volgens hen geen zaak voor de politiek. Bovendien verliezen ze door deze maatregel veel klanten en dus veel omzet. Zij beweren dat mensen nu liever thuis blijven om iets te drinken, omdat ze daar niet naar buiten hoeven voor een sigaret. Veel eigenaren laten hun klanten nog altijd in hun café roken, hoewel ze hiermee flinke boetes riskeren. De eigenaren blijven intussen strijden tegen het verbod en bereiden een nieuwe actie voor, die in zijn* **ludiekheid** *ongeëvenaard zal zijn. Wat de actie precies inhoudt en wanneer deze zal plaatsvinden, willen de eigenaren niet zeggen.*

Overtreden veel café-eigenaren de wet? Ja.

'Since the introduction of the smoking ban, owners of cafes are **fineable** if they still allow their customers to smoke inside. Despite all the owners' actions and protests, the Minister of Health is still not easily **persuadable** about abolishing the ban. Only for small cafes without staff does the prohibition not apply. In the meantime, the **stiredness** of the cafe owners about the smoking ban has risen to great heights. What their customers do in their cafe, whether lighting up a cigarette or **drinking too much** vodka; according to them, has nothing to do with politics. Moreover, this law has lost them many customers and the associated turnover. They claim that people prefer to stay at home to drink, because then they don't have to go outside for a cigarette. Many owners still let their customers smoke in their cafes, even though they risk high fines. The owners continue to fight the ban and prepare for new action, which will be unmatched in its **absurdity**. The owners won't say what the action is and when it will occur.'

'Do many cafe owners violate the law? Yes.'

Conclusions

Chapter 5

The aim of this dissertation was to see whether regular morphologically complex neologisms form mental representations, and if so, what are the characteristics of these representations. I described several priming experiments in which we used Dutch regular morphologically complex neologisms. In Chapter 2, we investigated if neologisms are stored in memory after one exposure. We elaborated on this question in Chapter 3. Here, we investigated the lifespan of lexical traces for these novel words and if sleep plays a role in the formation of these memory traces. In Chapter 4, we examined the type of the traces that neologisms form. We discuss the results of these studies and their cohesion below. Further, we discuss the implications of these results for theories on the processing of words.

Evidence for storage

In all chapters, we presented long-distance priming experiments. Our materials were Dutch regular morphologically complex neologisms which consisted of real morphemes. These target neologisms were primed with just the stems of the neologisms (stem priming) or with the neologisms themselves (identity priming). In the latter case, the target neologisms are technically no longer neologisms. We measured the response latencies to the target neologisms. The intervals between primes and targets were approximately 1.5 minutes (39 items), 30 minutes, 12 hours or a week. When the interval was 1.5 minutes, primes (stems or neologisms) and target neologisms were presented within one and the same experiment. When the interval was 30 minutes, 12 hours, or a week, participants were familiarized with the primes in a familiarization phase, and they were presented with the target neologisms in a test phase. Different types of tasks were used for the familiarization phase, namely visual lexical decision tasks, self-paced reading tasks, and listening comprehension tasks. For the test phase, we used visual and auditory lexical decision tasks and a self-paced reading task.

In all experiments, mixed-effect analyses of covariance showed that neologisms which were primed by themselves elicited shorter response latencies compared to neologisms which were primed by their stems (raw descriptive data can be find in the

Appendix of this dissertation). This indicates that one exposure is sufficient to form a trace in memory for these neologisms.

In our statistical models, priming effects appeared as main effects or in interactions with other variables or both. In our visual lexical decision experiments of Chapters 2 and 3 and in the auditory lexical decision experiment of Chapter 4, we observed a main effect for Prime Type. Response latencies were shorter in the identity priming condition (in which participants responded to the neologisms for the second time) than in the stem priming condition (in which the neologism was entirely new).

In the self-paced reading experiment in which prime and target were presented in the same text with 39 intervening items (Experiment 3 of Chapter 2), we observed an interaction of Prime Type with Preceding RTs: Reading times were shorter in the identity priming condition than in the stem priming condition, proportional to the processing costs for the four preceding words. Longer preceding RTs implied a larger difference between the stem priming condition and the identity priming condition. The experiment in which the prime was presented auditorily and the target visually in context (Experiment 3 of Chapter 4) showed a similar interaction of Prime Type and Previous response latencies: response latencies were shorter in the identity priming condition than in the stem priming condition, but only when participants had read the preceding word relatively slow. When participants had read the preceding word relatively fast, the identity priming condition and the stem priming condition did not show a statistically significant difference. The results of both self-paced reading experiments differs a bit. The results of Experiment 3 of Chapter 2 showed the priming effect for all readers, whereas the results of Experiment 3 of Chapter 4 only showed the priming effect for slow readers.

The results of the experiment in which the target neologisms appeared in a visual lexical decision task and were primed auditorily in a listening comprehension task (Experiment 2 of Chapter 4) showed that participants acted differently in the second half of the visual lexical decision experiment as opposed to the first half. In the first half, participants reacted faster to a neologism if they had heard that neologism before than if they had only heard the neologism's stem. In the second half, participants reacted faster to a neologism if they had only heard the neologism's stem than if they had heard that neologism before, but only if the neologisms were short. These effects may reflect task specific behavior rather than natural every day language processing.

All in all, we found evidence to conclude that storage of neologisms which consist of real morphemes takes place. This result is inconsistent with the results of e.g., Taft (1994) and Pinker (1991), who assume a full parsing model. In their model, no storage takes place of words which can be divided into real morphemes. The question remains whether we should assume a full storage model (e.g., Butterworth, 1983) or a mixed model (e.g., Caramazza et al., 1988; Rastle et al., 2004; Taft, 2004).

If Base Frequency plays a role in processing neologisms which were encountered before, the formed trace in memory may be combinatorial. Such a trace provides, given stem and affix, a direct link to their joint interpretation as computed when the neologism was first encounterd. The lexical decision experiments in Chapters 2 and 3 showed that the response latencies decreased with increasing Base Frequency. In Chapter 2, Base Frequency showed a main effect, whereas in Chapter 3, Base Frequency by Participant showed a significant random effect. Apparently, most of the participants activated the morphemes forming the neologisms as well as the traces formed by the neologisms. In the self-paced reading experiment in Chapter 2 and in all experiments in Chapter 4, no effect of Base Frequency was observed. We think that the effect of Base Frequency of the stem has its influence when neologisms were presented without context. The study of Luke & Christianson (2011) supports the idea that the effect of Base Frequency is influenced by the type of experiment. They observed a main effect of Base Frequency for real words presented in isolation and observed a main effect of Surface Frequency for words presented in context. Further research has to be done to clarify the role of Base Frequency in processing regular morphologically complex neologisms.

In a full storage model (e.g., Butterworth, 1983), an effect for Base Frequency is not expected. Since we observed an effect for Base Frequency in several experiments, a mixed model therefore seems more likely (e.g., Caramazza et al., 1988).

In the mixed model proposed by Caramazza et al. (1988), participants form a trace for the neologism itself. In the mixed model by Rastle et al. (2004), a decomposition-first model, participants remember how they morphologically analyzed the neologism at the first encounter and use this knowlegde at the second encounter of the neologism. In our view, participants have to remember the neologism in both types of mixed models. They have to remember the neologism itself, or they have to remember the way how they analyzed the neologism at the first encounter. Either way, a memory trace for the neologism is formed. With our experiments, we therefore did not try to find support for one of them over the other.

In Chapter 2, the priming effects were found for neologisms consisting of a real stem and the suffix *-heid* (e.g., *visrijkheid* 'fishfullness', which consists of the real morphemes *visrijk* 'fishfull' and *-heid* '-ness'). In Chapters 3 and 4, we observed these priming effects also for neologisms consisting of real stems and the suffixes *-baar* and *-ing*. These three suffixes belong to the most productive suffixes of the Dutch language (Booij, 2002). The question arises if the results can be generalized to other suffixes which are less productive. Do these results generalize to other types of words, including inflected words and compound words? Further research has to be conducted to answer this question.

Finally, the studies of Juhasz, Starr, Inhoff, & Placke (2003) and Van Jaarsveld & Rattink (1988) showed a difference between the processing of nonlexicalized (novel) compound words and lexicalized compound words. Faster responses were observed to novel compound words with high frequency first phonemes than to novel compound words with low frequency first morphemes. On the contrary, for real compound words, faster response latencies were observed if the last morpheme had a higher frequency.

This difference indicates different processing strategies for novel compound words and real compound words. The question arises whether participants also apply other processing strategies for novel derived words such as our neologisms than for real derived words. Further research has to be conducted to answer this question.

Evidence for abstract representations

All experimental results of Chapter 2 show that regular morphologically complex neologisms are stored. These neologisms can either be stored as abstract representations or as exemplars. Abstract representations only provide information that is necessary to distinguish the words from other words in the language. Abstract representations do not provide detailed information about the properties of the tokens; they do not specify, for instance, whether the neologism was attested in written or spoken language, the situational context (e.g., who uttered the word or what did the room where it was uttered look like) or the linguistic context (e.g., what were the preceding and following words). Exemplars, in contrast, contain more specific information of the attested tokens of the word. They may be modality specific and contain information about the context in which the tokens occurred, including the situational and linguistic context. Words can be represented as clouds of exemplars. In this dissertation, I tried to provide an answer to the question whether regular morphologically complex neologisms are stored as abstract representations or as exemplars.

In Chapter 3, we conducted two experiments in which we varied the time interval between prime and target from 1.5 minutes, to 12 hours, to a week. We found that the formed traces for Dutch morphologically complex neologisms remain in memory for at least a week. They appear as strong after a week as after the shorter time intervals of 12 hours or 1.5 minutes.

Chapter 4 focused on the influence of whether the prime and target were presented in the same modality and in the same type of experimental task. The experiments showed that the processing of the first token of a neologism facilitates the processing of the second token of that word, even if the second token occurs in another modality and in different experimental tasks. These different tasks were presented as two separate experiments instead of two parts of one and the same experiment. We observed this facilitation also if the two tokens of a neologism occur in different sentences in which the tokens have slightly different meanings.

As said before, abstract representations only provide information that is necessary to distinguish the words from other words in the language. They do not provide detailed information about the properties of the tokens. Exemplars, in contrast, contain such properties. They may be modality specific and contain information about the context in which the words occurred. We observed that our neologisms were always processed faster when participants processed them for the second time. Changes in modality, type of task, and even context appear not to obstruct the priming effect. This suggests that memory traces for regular morphologically complex neologisms are abstract in nature.

If we had just studied the effect of change in modality from the prime to the target, we could have interpreted our results differently. For instance, instead of assuming abstract representations, we could have assumed that the presentation of a neologism in any modality leads to a simultaneous creation of both a visual and an auditory lexical representation. When presenting a second token of a neologism, either the visual or the auditory representation would be activated in lexical memory, depending on the modality of the second token. This activation would lead to a faster recognition of the neologism. This interpretation, however, cannot account for our findings that a change in linguistic context or a slight change in meaning also do not obstruct the priming effect. We therefore prefer the interpretation that the neologisms form abstract representations, which match to the neologisms in both modalities because of the simple (shallow) phoneme-grapheme mapping rules for Dutch.

The results of Chapter 4 do not tell us whether the priming effect across modalities is as strong as it is within a single modality. Based on our interpretation of the data that the lexical representations are abstract in nature, we hypothesize that the priming effect is equally strong across and within modalities and that its size is not affected by changes in the linguistic context and meaning of the neologism. Further research has to test this hypothesis.

The role of sleep

We observed priming from regular morphologically complex neologisms immediately after the first exposure. This means that participants do not need a night's sleep for the formation of a trace in memory. Our results differ in this respect from results obtained by Dumay et al. (2004) and Gaskell & Dumay (2003, 2007). Dumay et al. (2004) and Gaskell & Dumay (2003) observed that listeners recognized a word such as *cathedral* faster if they had heard at least 12 tokens of a phonologically similar pseudoword (e.g., *cathedruke* for *cathedral*). However, five days after the familiarization, listeners recognized the real words more slowly. Gaskell and colleagues argued that this inhibitory effect is due to the pseudowords becoming lexical competitors for real words. The study by Gaskell & Dumay (2007) also showed that it is the night's sleep that is necessary to observe evidence for storage. If participants learned words at 8 p.m., they showed inhibitory competition effects after a 12 hour interval including a night's sleep. Participants who learned the words at 8 a.m. showed no competition effects after 12 hours of wakefulness, but showed competition effects after 24 hours, that is again after a night's sleep. In contrast to these findings, our results from Chapter 2 and from Experiments 1 of Chapters 3 and 4 show that sleep is not a prerequisite for the formation of a trace in memory.

We even observed immediate priming for regular morphologically complex neologisms across different modalities. These results differ from the results by Bakker et al. (2014), who only observed priming of morphologically simple neologisms across different modalities after 24 hours. Auditorily acquired neologisms contributed to the lexical competition in the written modality after 24 hours, while the consolidation period for visually acquired neologisms was even longer.

An explanation for the discrepancy in results between the studies presented in this dissertation and the studies by Dumay et al. (2004), Gaskell & Dumay (2003, 2007), and Bakker et al. (2014) may be found in differences in materials and methods between their experiments and ours. The most important difference is that Bakker and colleagues and Gaskell and Dumay tested morphologically simple neologisms that were very similar to real words (e.g., Dutch *aprikoot* as competitor of *abrikoos* 'apricot', English *cathedruke* as competitor of *cathedral*). In our research, in contrast, we focused on fully regular morphologically complex neologisms that consisted of real morphemes (e.g., *betover+baar* 'enchant+able'). To derive the meaning of our neologisms, participants only had to combine the meanings of both real parts, applying the Dutch morphological rules. Participants cannot adopt this strategy when encountering monomorphemic neologisms, since these words' meanings cannot be derived from real parts. These neologisms will not have meanings without context. We know from the study by Takashima et al. (2017) that the processing of novel monomorphemic words with meanings differs from the processing of novel monomorphemic words without meanings. When monomorphemic words are presented out of context, only the letterstring of a word or the sound of a word can be stored. One can imagine that several encounters with a particular monomorphemic neologism are needed to form a long lasting representation in memory when presented out of context. Furthermore, for the formation of a trace in memory for monomorphemic neologisms, participants have to remember new sound and letter combinations whereas for our neologisms, participants only have to remember the new combinations of real parts.

There are two more differences between our experiments and those obtained by Dumay et al. (2004), Gaskell & Dumay (2003, 2007), and Bakker et al. (2014). First, they presented their materials 12 times in a repeated measures design, whereas we presented our materials just once in a long-distance priming design. Second, they measured lexical learning indirectly by tracing the consequences of acquired nonwords on the processing of well-established real words, whereas we directly measured lexical learning by using an identity priming experiment. We expect that these two differences do not explain a large part of the discrepancy in results. Further research has to investigate whether this is the case.

Statistical analyses

In all our stepwise mixed-effect regression analyses, we registered the response latencies of a given participant to the four preceding words as potential covariates for that participant's response latency to the target neologism. We acted differently as to how we incorporated these values into our analyses, taking into account that these four response latencies were all mutually correlated. In Chapter 2, we used principal components analysis to orthogonalize these covariates. Of the (four) resulting principal components, only the first turned out to be predictive for the response latencies on our targets. As the principal component itself was negatively correlated with the preceding response latencies, we concluded that longer preceding response latencies implied longer response latencies to our target words.

In Chapters 3 and 4, we did not transform the four preceding response latencies into principal components. We just included the directly preceding response latency to the target neologism as predictor. We noticed that including the directly preceding response latency led to comparable results as the analyses in which we included one or two principal components on which the four preceding response latencies load on. By doing so, we do not have to look how the preceding response latencies load on the principal components. This facilitated the procedure and the interpretation of our results.

The study of Wurm & Fisicaro (2014) showed that it should be possible to include the response latencies of the four preceding words to the target neologisms as predictors without orthogonalization. They argue that correlated control variables do not influence the results of the analyses. Additional analyses have to show if comparable results will be obtained by doing so.

Conclusions

This dissertation has shown that Dutch regular morphologically complex neologisms form abstract representations in the mental lexicon. Dutch morphologically complex neologisms ending in *-baar*, *-heid*, and *-ing* form traces that can be detected after 1.5 minutes, 30 minutes, 12 hours, and after a week. The strength of the trace is solid. The traces can be detected regardless of modality in which the first and second tokens of the neologisms are presented. This result is of great importance since native adult speakers often encounter new complex words. Besides, adults encounter many real words only one or two times (see for lexical statistic evidence e.g., Zipf, 1935). Based on these findings, we conclude that there are many more entries in the mental lexicon than is often assumed.

Appendix

The following tables describe the data collected in this dissertation, split by condition (stem priming versus identity priming). The column 'all targets' contains the mean Reaction Times (RTs) on the target neologisms, their standard deviations (sd), and the percentage of incorrect answers for all target neologisms. The column 'correct targets' contains the mean RTs and standard deviations for the correct answers to the target neologisms. The column 'correct pairs primes-targets' contains the mean RTs and standard deviations only for those reactions to the target neologisms that were correct themselves and were preceded by correct answers to their primes.

Table A.1: Chapter 2, Experiment 2: Visual Lexical Decision

	Stem priming		
	all targets	correct targets	correct pairs primes-targets
Mean RT (in ms)	813	737	735
sd RT (in ms)	301	222	224
% incorrect answers	20.8		
	Identity priming		
	all targets	correct targets	correct pairs primes-targets
Mean RT (in ms)	807	769	747
sd RT (in ms)	279	254	251
% incorrect answers	19.2		

Table A.2: Chapter 2, Experiment 3: Self-Paced Reading

	Stem priming	**Identity priming**
Mean RT (in ms)	431	437
sd RT (in ms)	236	246

Table A.3: Chapter 3, Experiment 1: a 12 hours interval

		Stem priming	
	all targets	correct targets	correct pairs primes-targets
Mean RT (in ms)	838	823	804
sd RT (in ms)	241	225	219
% incorrect answers	13.2		
		Identity priming	
	all targets	correct targets	correct pairs primes-targets
Mean RT (in ms)	809	796	785
sd RT (in ms)	231	219	217
% incorrect answers	11.1		

Table A.4: Chapter 3, Experiment 2: a week interval

		Stem priming	
	all targets	correct targets	correct pairs primes-targets
Mean RT (in ms)	850	834	814
sd RT (in ms)	249	236	226
% incorrect answers	15.6		
		Identity priming	
	all targets	correct targets	correct pairs primes-targets
Mean RT (in ms)	827	813	786
sd RT (in ms)	243	235	216
% incorrect answers	12.1		

Table A.5: Chapter 4, Experiment 1: visual primes in context and auditory targets in isolation

	Stem priming	
	all targets	correct targets
Mean RT (in ms)	1221	1202
sd RT (in ms)	292	286
% incorrect answers	13.1	
	Identity priming	
	all targets	correct targets
Mean RT (in ms)	1208	1192
sd RT (in ms)	290	279
% incorrect answers	12.7	

Table A.6: Chapter 4, Experiment 2: auditory primes in context and visual targets in isolation

	Stem priming	
	all targets	correct targets
Mean RT (in ms)	921	916
sd RT (in ms)	281	273
% incorrect answers	25.0	
	Identity priming	
	all targets	correct targets
Mean RT (in ms)	914	912
sd RT (in ms)	274	261
% incorrect answers	23.5	

Table A.7: Chapter 4, Experiment 3: auditory primes visual targets, both in context

	Stem priming	**Identity priming**
Mean RT (in ms)	362	367
sd RT (in ms)	119	130

English summary

In daily life, we are regularly confronted with neologisms. These neologisms are formed for new phenomena or when people cannot recall specific words. Sometimes the neologisms are directly borrowed from other languages, yet sometimes new words are created. The neologism *dementheid* 'dementedness' can be formed as alternative for the real word *dementie* 'dementia'. Nobody will have trouble to derive the meaning of the word *dementheid* from the meanings of its parts. We know the meaning of the word *dement* 'demented' and we more or less know the meaning of the suffix *-heid* '-ness'. So, *dementheid* 'dementedness' must mean 'suffering from dementia'. This dissertation contains several studies on the storage of such regular morphologically complex neologisms in the mental lexicon. Our goal is to expand the knowledge on how such neologisms are processed.

The studies in this dissertation try to provide answers to questions as: Are neologisms stored in the mental lexicon after just one exposure (either visually or auditorily)? If so, how long is the lifespan of the representations of these neologisms in the mental lexicon? In which form are the neologisms stored? Answers to these questions can improve theories of storage of real regular morphologically complex words such as *tafelpoot* 'table leg'.

Storage of morphologically complex neologisms

In Chapter 2, we tried to find an answer to the question whether people store regular morphologically complex neologisms in their mental lexicon after just one exposure. Current psycholinguistic theories on the comprehension of real words provide us with three logical options for the way regular morphologically complex words can be processed. First, a number of theories assume full storage of all complex words, which can thus be processed as whole units regardless of their internal structure (e.g., Butterworth, 1983). Second, some theories assume that all regular complex words are fully parsed into their stems and affixes (e.g., Taft, 1994; Pinker, 1991). Third, mixed models have been proposed in which words are stored in the mental lexicon and processed as whole units as well as decomposed into stems and affixes during processing (e.g., Caramazza et al., 1988; Laudanna & Burani, 1995; Baayen et al., 1997).

To investigate the question whether regular morphologically complex neologisms leave traces in memory after just one exposure, we conducted long-distance priming experiments. Our materials were Dutch regular morphologically complex neologisms which consisted of real morphemes, e.g., *dementheid* 'dementedness'. These target neologisms were primed with just the stems of the neologisms (stem priming) or with the neologisms themselves (identity priming). We measured the response latencies to the target neologisms. The priming experiments of Chapter 2 (a visual lexical decision experiment and a self-paced reading experiment) showed that neologisms which are primed by themselves elicit shorter response latencies compared to neologisms which are primed by their stems. This indicates that one exposure is sufficient to form a trace in memory for these neologisms. These results are inconsistent with the results of e.g., Taft (1994) and Pinker (1991), who assume a full parsing model. In their model, no storage takes place of words which can be divided into real morphemes. The question remains whether we should assume a full storage model (e.g., Butterworth, 1983) or a mixed model (e.g., Caramazza et al., 1988; Rastle et al., 2004; Taft, 2004).

In Chapter 3, we investigated the lifespan of lexical traces for morphologically complex neologisms by again conducting long-distance priming experiments, namely visual lexical decision experiments. We varied the time interval between prime and target. In Chapter 2, the time interval was always approximately 1.5 minutes. In the experiments in Chapter 3, the time interval was extended to 12 hours and even a week. Participants first performed lexical decisions to the primes, and 12 hours or a week later, they performed lexical decisions to the target neologisms. We observed that the formed traces for Dutch morphologically complex neologisms remain in memory for at least a week. They appear as strong after a week as they are after the shorter time intervals.

Characteristics of stored words

In Chapter 4, we studied in which form neologisms are stored, being either abstract representations or exemplars. Abstract representations are assumed to contain only vital information for making distinctions between words of a language. They do not contain information such as whether the neologism was attested in written or in spoken language, the situational context (e.g., who uttered the word or what did the room where it was uttered look like) or the linguistic context (e.g., which were the preceding and following words). These abstract representations are stored in the mental lexicon. Exemplars, on the other hand, may also contain more specific information of the attested tokens. They may be modality specific and contain information about the context in which the word occurred, including the situational and linguistic context.

To investigate the question in which form neologisms are stored, we again conducted long-distance priming experiments. In these experiments, we presented the prime in another modality than the target neologism (which was not the case in Chapters 2 and 3). Participants read the primes (stem or neologism) and heard the target neologisms, or vice versa. Participants were presented with the primes and target neologisms in different types of experiments. Furthermore, participants thought they were taking part in two separate experiments while they were actually taking part in two parts of one and the same experiment. The results of these experiments showed that neologisms are always processed faster when participants have processed them before. These results are in line with our findings in Chapters 2 and 3. The findings of Chapter 4 suggest that neologisms are stored as abstract representations in the mental lexicon.

The role of sleep

We observed priming from regular morphologically complex neologisms immediately after the first exposure (Chapter 2 and Experiments 1 of Chapters 3 and 4). This means that participants do not need a night's sleep to form a representation for the neologism in the mental lexicon. These results differ from results obtained by Dumay et al. (2004), Gaskell & Dumay (2003, 2007), and Bakker et al. (2014). They observed that sleep appears to be a necessary condition to form representations of monomorphemic neologisms.

The differences in results may be explained by the materials used. The above mentioned research has mainly focused on novel monomorphemic pseudowords. We, however, chose to use Dutch regular morphologically complex neologisms. Our neologisms consist of real stems and real affixes (namely, *-baar*, *-heid*, and *-ing*) and are combined according to the Dutch morphological rules. Participants can use their knowledge of these real morphemes to understand the meanings of our novel words. They do not need any context. The importance of meaning is supported by a study by Takashima et al. (2017). They showed a difference in the processing of simple neologisms that were primed by neologisms presented in context and the processing of simple neologisms that were primed by neologisms presented without any context.

Conclusions

This dissertation shows that regular morphologically complex neologisms form abstract representations in lexical memory. Dutch morphologically complex neologisms ending in the suffixes *-baar*, *-heid*, and *-ing* form traces that can be detected up to at least a week after their first occurrences. The strength of the trace is solid. The traces can be detected regardless of modality in which the first and second tokens of the neologisms are presented. These results are of great importance since adult native speakers often encounter new complex words. Besides, they encounter many real words only one or two times. Based on these findings, we conclude that there are many more entries in the mental lexicon than is often assumed.

Nederlandse samenvatting

In het dagelijkse leven worden we regelmatig geconfronteerd met neologismen (nieuwe woorden). Soms wordt voor een nieuw fenomeen een woord rechtstreeks uit een andere taal overgenomen, terwijl een andere keer een nieuw Nederlands woord wordt gecreëerd. Daarnaast kunnen neologismen ontstaan als mensen even niet op het bestaande woord kunnen komen. Het neologisme *dementheid* kan gevormd worden als alternatief voor het al bestaande woord *dementie*. Niemand zal problemen hebben de betekenis van *dementheid* af te leiden uit de delen. We kennen immers het woord *dement* en - bewust of onbewust - kennen we ook de betekenis van het achtervoegsel *-heid*, namelijk 'het .... zijn'. *Dementheid* betekent dus 'het dement zijn'. Dit proefschrift bevat verschillende studies naar de opslag van dergelijke samengestelde neologismen in het geheugen.

Alle studies in dit proefschrift onderzoeken regelmatig gelede neologismen in het Nederlands zoals *dementheid* met als doel: meer te weten komen over de verwerking van dergelijke neologismen. Worden ze al bij de eerste keer zien of horen in ons geheugen opgeslagen? Als dat zo is, hoe lang blijven ze in ons geheugen opgeslagen? En in welke vorm? Antwoorden op deze vragen kunnen bijdragen aan het verbeteren van theorieën over de opslag van regelmatig gelede woorden zoals *tafelpoot*.

Opslag van woorden

Het doel van Hoofdstuk 2 was om een antwoord te vinden op de vraag of neologismen al worden opgeslagen als mensen ze slechts één keer gezien hebben. De huidige theorieën over de verwerking van bestaande woorden geven grofweg drie mogelijkheden voor de verwerking van samengestelde woorden. De eerste mogelijkheid is dat alle woorden, enkelvoudig (bijv. *bed*) of samengesteld (bijv. *tafelpoot*) in zijn geheel worden opgeslagen in het geheugen (bijv. Butterworth, 1983). Een tweede mogelijkheid is dat alle regelmatig samengestelde woorden zoals *tafelpoot* worden ontleed in hun delen *tafel* + *poot* elke keer als ze gelezen of gehoord worden (bijv. Taft, 1994; Pinker, 1991). Een derde mogelijkheid is een combinatie van beide, de zogeheten 'mixed models'. Woorden kunnen herkend worden doordat ze in hun geheel zijn opgeslagen of doordat ze ontleed worden in hun delen. In sommige van deze modellen (bijv. Caramazza et al., 1988) wordt eerst in het geheugen gekeken of het gehele woord ligt opgeslagen. Zo ja, dan wordt onder andere de betekenis van dit woord opgehaald uit het geheugen. Als het gehele woord niet wordt gevonden dan wordt het woord ontleed in zijn delen en worden de betekenissen van beide delen opgehaald uit het geheugen. Deze afzonderlijke delen worden vervolgens samengevoegd met de bijbehorende regels. In andere modellen lopen deze processen parallel (bijv. Baayen et al., 1997). Dat wil zeggen dat er zowel wordt gezocht naar het gehele woord als naar de afzonderlijke delen. Afhankelijk van hoe vaak een woord in het Nederlands voorkomt, 'wint' de ene of de andere route. In het model van Alegre en Gordon (1999) is er sprake van een drempelwaarde. Zij stellen dat woorden liggen opgeslagen in het geheugen als de woorden minimaal zes keer per miljoen woorden voorkomen. Dat wil zeggen, komt een woord zes keer of vaker per miljoen woorden voor, dan wordt het woord als geheel opgeslagen in het geheugen. Onder deze drempelwaarde ligt het woord niet in zijn geheel opgeslagen en moet de betekenis van het woord bij het zien of horen ervan herleid worden uit zijn delen.

We hebben onderzocht of neologismen zoals *dementheid*, dat opgebouwd is uit de bekende delen *dement* en *-heid*, worden opgeslagen in het geheugen. Om dit te kunnen onderzoeken hebben we proefpersonen in experimenten eerst het grondwoord *dement* aangeboden of meteen het neologisme *dementheid*. Dit grondwoord of dit neologisme noemen we een 'prime'. Later in de experimenten hebben we (nogmaals) het neologisme *dementheid* aangeboden. Dit noemen we een 'target'. De tijd die proefpersonen nodig hadden om te reageren op de target neologismen, de zogeheten reactietijden, hebben we geregistreerd. Zo konden we de reactietijden vergelijken van de proefpersonen die in eerste instantie het grondwoord aangeboden kregen met die van hen die meteen geconfronteerd werden met het neologisme. Op deze manier konden we onderzoeken of neologismen al na één keer in het geheugen worden opgeslagen. In Hoofdstuk 2 hebben we twee experimenten gedaan waarin proefpersonen eerst de primes te zien kregen en 40 items later het target neologisme. In het eerste experiment waren dit allemaal losse woorden, in het tweede experiment waren prime en target verwerkt in teksten. Uit deze experimenten blijkt dat neologismen al in het geheugen worden opgeslagen als ze slechts één keer eerder gezien zijn, ongeacht of de neologismen als losse woorden zijn aangeboden of in een context.

Deze bevindingen komen niet overeen met de theorieën van bijv. Taft (1994) en Pinker (1991), die uitgaan van een model waarin alle woorden die opgebouwd zijn uit bekende delen (*kortafheid*), worden herleid uit die delen (*kortaf+heid*). Opslag van dergelijke woorden vindt volgens hen niet plaats. Uit onze resultaten blijkt echter dat opslag van dergelijke woorden wel degelijk plaats vindt. De vraag blijft of er sprake is van een model waarin alle woorden in zijn geheel worden opgeslagen (bijv. Butterworth, 1983) of dat er sprake is van een model waarin zowel opslag van het gehele woord plaatsvindt als het herleiden van een woord uit zijn delen (bijv. Caramazza et al., 1988; Baayen et al., 1997).

In Hoofdstuk 3 is onderzocht hoe robuust een neologisme in het geheugen ligt opgeslagen. Hiertoe hebben we proefpersonen de experimenten in twee delen laten uitvoeren. Deel 1 van de experimenten bevatte de primes. Dit waren de grondwoorden van de neologismen of de neologismen zelf. Deel 2 van de experimenten bevatte alle target neologismen. In beide delen van de experimenten werden de primes en target neologismen als losse woorden aangeboden. Waar de tijd tussen primes en target neologismen in Hoofdstuk 2 slechts ongeveer anderhalve minuut bedroeg, was dit in de experimenten van Hoofdstuk 3 twaalf uur of zelfs een week. De resultaten van deze experimenten laten zien dat de neologismen na een week nog in het geheugen liggen opgeslagen.

Kenmerken van de opgeslagen woorden

In Hoofdstuk 4 is onderzocht in welke vorm neologismen worden opgeslagen. Woorden kunnen worden opgeslagen als abstracte representaties of als exemplars. Abstracte representaties bevatten alleen informatie die noodzakelijk is voor het maken van onderscheid tussen de woorden in een taal. Abstracte representaties bevatten dus geen informatie over de manier waarop een neologisme voor het eerst is waargenomen, bijvoorbeeld in geschreven of gesproken taal, op welke locatie een neologisme is waargenomen, wie het woord heeft gebruikt, etc. Exemplars daarentegen bevatten dergelijke informatie wel.

Om te onderzoeken in welke vorm neologismen worden opgeslagen hebben we in Hoofdstuk 4 onze proefpersonen de primes (grondwoorden dan wel neologismen) laten lezen terwijl ze de target neologismen te horen kregen, of andersom. Tevens kregen de proefpersonen de primes en de target neologismen in verschillende type experimenten aangeboden. Bovendien werd bij de proefpersonen de suggestie gewekt dat het om twee op zichzelf staande experimenten ging in plaats van om twee delen van één en hetzelfde experiment. De proefpersonen voerden deel twee 30 minuten of een week na deel één uit. Ook deze experimenten lieten zien dat neologismen sneller worden herkend als ze eerder zijn waargenomen. Dit suggereert dat neologismen in een abstracte vorm worden opgeslagen in het geheugen.

De rol van slaap

Ons onderzoek laat zien dat neologismen direct worden opgeslagen in het geheugen. Dit betekent dat proefpersonen geen slaap nodig hebben om een representatie van het neologisme te vormen in het geheugen. Deze resultaten zijn anders dan de resultaten van het onderzoek van Dumay en collega's (2004) en Gaskell en Dumay (2003, 2007). Hun resultaten laten zien dat luisteraars een Engels woord als *cathedral* sneller herkennen als ze kort daarvoor minimaal 12 keer een daarop gelijkend neologisme als *cathedruke*, waarvan de betekenis niet te herleiden is, hebben gehoord. Na vijf dagen echter wordt *cathedral* langzamer herkend dan daarvoor. De onderzoekers geven als verklaring dat dit komt doordat *cathedruke* nu ook in het geheugen is opgeslagen. *Cathedruke* lijkt heel erg op *cathedral* en daardoor kost het meer tijd om het woord *cathedral* te herkennen. Gaskell en Dumay (2007) laten zien dat een nacht slaap noodzakelijk is om een neologisme als *cathedruke* op te slaan in het geheugen. Onderzoek van Bakker en collega's (2014), dat gebruik maakt van Nederlandse woorden zoals *abrikoot* als tegenhanger van het bestaande *abrikoos*, laat vergelijkbare resultaten zien.

De resultaten van de experimenten in Hoofdstuk 2 en de eerste experimenten van Hoofdstuk 3 en 4 laten echter zien dat slaap niet noodzakelijk is voor het vormen van een representatie van een nieuw woord in het geheugen. Een belangrijk verschil tussen ons onderzoek en dat van Gaskell en Dumay (2007) en Bakker en collega's (2014) is dat zij gebruik hebben gemaakt van enkelvoudige neologismen die heel erg lijken op bestaande woorden (in het Nederlands *abrikoot* versus *abrikoos*; in het Engels *cathedruke* versus *cathedral*). Wij hebben daarentegen gebruik gemaakt van neologismen die zijn opgebouwd uit bekende delen, bijvoorbeeld *dementheid*. Dit neologisme bestaat uit de bekende delen *dement* en *-heid*. Proefpersonen hoeven alleen maar de betekenis van beide delen te combineren. Dit gaat niet bij de enkelvoudige neologismen die Gaskell en Dumay (2007) en Bakker en collega's (2014) hebben gebruikt. Dat het verschil in materiaal van groot belang kan zijn voor het verschil in resultaten wordt ondersteund door onderzoek van Takashima en collega's (2016). Zij laten een verschil zien in verwerking van enkelvoudige neologismen die in een context worden aangeboden ten opzichte van enkelvoudige neologismen die als losse woorden aan proefpersonen worden aangeboden. Betekenis lijkt dus een belangrijke rol te spelen bij de opslag van neologismen in het geheugen.

Algemene conclusies

Dit proefschrift beschrijft onderzoek naar Nederlandse regelmatig gelede neologismen. We hebben aangetoond dat deze neologismen abstracte representaties vormen in het geheugen. De representaties die deze neologismen vormen zijn waarneembaar na anderhalve minuut, 30 minuten, 12 uur en zelfs na een week. Ook als neologismen de eerste keer visueel zijn aangeboden en de tweede keer auditief, of omgekeerd, zien we dat ze sneller herkend worden dan wanneer alleen het grondwoord is aangeboden. Deze resultaten zijn van groot belang. Volwassenen komen in hun moedertaal veelvuldig nieuwe woorden tegen. Daarnaast komen zij veel bestaande woorden maar één of twee keer tegen. Dit betekent dat volwassenen veel meer woorden in hun mentale woordenboek hebben zitten dan veelal wordt aangenomen.

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Slotwoord

28 augustus 2017. Na jaren is eindelijk het moment daar dat ik toe ben aan het schrijven van het slotwoord. Zoals zo vaak de afgelopen jaren ben ik ook nu niet thuis. Ik ben weer weg voor mijn sport, een carrière die min of meer parallel heeft gelopen aan mijn werkzaamheden die hebben geleid tot dit proefschrift.

Al jaren loop, of eigenlijk rol, ik rond op het Max Planck Instituut. We schrijven het jaar 2002 als ik het instituut voor het eerst betreed. Eén anekdote uit die tijd wil ik hier aanhalen. Ik kwam met mijn rolstoel en aankoppelfiets naar het Max Planck Instituut. In die eerste periode parkeerde ik mijn rolstoel in de buurt van mijn werkplek waarna ik mij lopend (dit keer letterlijk) over de gangen voortbewoog. Ik realiseerde me niet dat dit voor een aantal mensen zeer verwarrend was. Zij dachten dat er twee nieuwe mensen bij gekomen waren. Pas tijdens een sinterklaasbijeenkomst werd één en ander opgehelderd. Het lopen over de gangen van het MPI was van korte duur, vanaf begin 2003 zou ik alleen nog maar door de gangen rollen.

Nadat ik in 2005 mijn onderzoek voor mijn eindscriptie had afgerond, kreeg ik de mogelijkheid zelf een onderzoeksvoorstel te schrijven. Vanaf 1 januari 2008 zou ik op het MPI, met een aanstelling aan de universiteit, aan mijn PhD-project werken. Aan dat PhD-project komt met het verdedigen van mijn proefschrift een einde.

Uiteraard heb ik de klus niet alleen geklaard. Velen hebben mij gestimuleerd en geholpen. Zonder anderen tekort te doen, wil ik graag enkele mensen met name bedanken. Ik begin met jou, Rob, ook al kun jij dit zelf niet meer lezen. Jij hebt me vanaf het begin begeleid, in eerste instantie samen met Harald, en toen hij naar het buitenland vertrok, samen met Mirjam. Jouw inbreng is heel belangrijk geweest. Op cruciale momenten hakte je knopen door en zorgde je ervoor dat ik niet te ver van de oorspronkelijk onderzoeksvraag afdwaalde. Zo stelde je eens de vraag wat het belangrijkste was: het vinden van het beste model of het vinden van een antwoord op de onderzoeksvraag?

Mirjam, jij bent één van degene die ik in verwarring heb gebracht toen ik net op het instituut was. Na het vertrek van Harald heb jij mij onder je hoede genomen. Jij was de eerste die mijn teksten las en worstelde met de vraag wat ik probeerde te zeggen. Dat zal niet altijd makkelijk zijn geweest. Het werd makkelijker toen ik met Johannes aan de slag ging. Niet langer hoefde jij te puzzelen wat ik bedoelde, maar kon jij je richten op de inhoud. En de inhoud moest goed zijn. Met half werk nam je geen genoegen. Regelmatig dacht ik bijna klaar te zijn en dacht jij daar anders over.

Makkelijk vond ik dat niet altijd, maar als een artikel of hoofdstuk af was, moest ik telkenmale weer bekennen dat het veel beter was geworden. Jij had niet alleen oog voor mij als PhD-student. Ik leerde je ook kennen als iemand die interesse had in de mens erachter. Vaak informeerde je hoe het was met mijn gezondheid. Ook leefde je mee als ik wedstrijden had. Afgelopen WK stuurde ik je veelvuldig een mailtje met een vraag over een detail in mijn proefschrift. Op een gegeven moment kreeg ik een e-mail van jou met de volgende tekst 'Zo, dat ook weer opgelost. Nu het WK.' Dank je wel voor je steun en je kritische blik.

Iris, je begon later aan je promotietraject dan ik, maar al gauw was jij verder dan ik. Jij was één van de PhD-studenten aan wie ik mijn vragen stelde, vooral over de statistiek. Jij bent ook degene geweest die mij heeft geholpen dit proefschrift te laten worden zoals het nu is. Jij maakte mij, alweer een paar jaar geleden, wegwijs in het maken van het PDF-document dat ten grondslag ligt aan deze gedrukte versie. Jij stelde mij het basisdocument beschikbaar. Ik paste de lay-out naar mijn smaak aan. Ik gebruikte jouw proefschrift als handleiding. Ging ik op reis, en had ik het voornemen aan mijn proefschrift te werken, dan reisde jouw proefschrift met mij mee. Zo is jouw proefschrift dan ook in vele landen geweest.

In de vele jaren dat ik op het Max Planck Instituut heb gewerkt, heb ik vele PhD studenten, studentassisten en postdocs zien komen en gaan. Met een aantal van jullie heb ik een kamer gedeeld. Lunchen deden we veelal gezamenlijk. Over het algemeen werd er dan niet over het werk gesproken. Als ik alle namen op zou willen schrijven, loop ik de kans er enkele te vergeten. Daarom: dank aan iedereen die mijn tijd op het MPI tot een gezellige tijd heeft gemaakt. Eén persoon wil ik wel graag noemen. Stefan, ik vind het leuk hier te vermelden dat jouw promotie één van de eerste was die ik bijwoonde. Nu woon je mijn promotie bij als lid van de manuscriptcommissie/promotiecommissie.

Esmé, wij leerden elkaar kennen op de Sophiaweg, waar we allebei woonden in onze studententijd. Jij bent onlangs gepromoveerd en bent dus dezelfde weg gegaan die ik nu afleg. Jij weet als geen ander wat er op het laatste moment allemaal nog moet gebeuren. Met vragen daarover kan ik bij jou terecht.

Saskia, wij kennen elkaar al sinds jij geboren bent. In het begin verliep ons contact via onze ouders. Later schreven we elkaar brieven. Toen we beide in Nijmegen studeerden, is ons contact geïntensiveerd. Hoewel jij eerder afstudeerde en promoveerde dan ik, is onze hechte vriendschap gebleven. Ik vind het dan ook heel fijn dat jij mijn paranimf bent.

Johannes, jij bent samen met Saskia mijn paranimf en dat ben je niet voor niets. Je hebt al bewezen dat je goed kunt organiseren. Maar dat is niet de belangrijkste reden. Ik denk dat het in 2014 was dat ik dreigde vast te lopen met het schrijven van mijn laatste artikel. Ik heb je toen gevraagd mij te helpen met het Engels. Ik heb veel van je opgestoken. Door onze samenwerking vond ik het plezier in het werk weer terug. Zonder jouw hulp zou voltooiing van mijn proefschrift langer op zich hebben laten wachten. We hebben hard gewerkt samen, maar ook veel gelachen. Ik zal onze samenwerking missen. Het zijn dierbare momenten gebleken.

Lucy, dank je wel voor het lezen van de Nederlandse samenvatting en dit slotwoord. Je controleerde de tekst op leesbaarheid en correct taalgebruik. Hopelijk kun je je vinden in deze alinea, dit is tenslotte de enige alinea die je nog niet gelezen hebt.

Papa, mama en Eveline, ik denk dat het voor jullie moeilijk voor te stellen is geweest waar ik me de afgelopen jaren mee bezig heb gehouden. Jullie hadden altijd een luisterend oor als ik vol enthousiasme vertelde over mijn onderzoek en resultaten. Met dit boekje in jullie handen zal het voor jullie tastbaarder zijn waaraan ik al die jaren heb gewerkt.

Rik, mijn laatste woorden zijn voor jou. Al jaren sta je achter me. Het was niet altijd even makkelijk, zeker niet omdat ik het schrijven van dit proefschrift combineerde met een sportieve carrière. Samen hebben we naar het moment van afronden uitgekeken. Nu is het zover. Zonder jouw onvoorwaardelijke steun was het me niet gelukt. Dank je wel.

Curriculum Vitae

Laura de Vaan was born in 1980 in Uden, the Netherlands. After obtaining her gymnasium diploma from Sg. St. Ursula in Horn in 1998, she studied Dutch Language and Culture at Radboud University Nijmegen. As part of her studies, she did an internship at the Institute for Dutch Lexicology, nowadays the Dutch Language Institute. In 2005, she obtained her master's degree (cum laude). In 2008, she started her PhD project at the Centre for Language Studies at Radboud University Nijmegen. The results of her PhD research are described in this thesis. Laura combined her PhD research with a career as a Paralympic athlete. She participated in the Paralympic Games in Beijing (2008), London (2012), and Rio de Janeiro (2016). Currently, she is still active as a Paralympic athlete.

List of Publications

De Vaan, L., Van Krieken, K., Van den Bosch, W., Schreuder, R., and Ernestus, M. (in press). The traces that novel morphologically complex words leave in memory are abstract in nature. *The Mental Lexicon*, *12(2)*.

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    Danielle van den Brink

25. Perceptual relevance of prevoicing in Dutch.
    Petra Martine van Alphen

26. Syllables in speech production : effects of syllable preparation and syllable frequency.
Joana Cholin

27. Producing complex spoken numerals for time and space.
Marjolein Henriëtte Wilhelmina Meeuwissen

28. Morphology in auditory lexical processing : sensitivity to fine phonetic detail and insensitivity to suffix reduction.
Rachèl Jenny Judith Karin Kemps

29. At te same time....: the expression of simultaneity in learner varieties.
Barbara Schmiedtová

30. A grammar of Jalonke argument structure.
Friederike Lüpke

31. Agrammatic comprehension : an electrophysiological approach.
Marijtje Elizabeth Debora Wassenaar

32. The structure and use of shape-based noun classes in Miraña (North West Amazon).
Frank Seifart

33. Prosodically-conditioned detail in the recognition of spoken words.
Anne Pier Salverda

34. Phonetic and lexical processing in a second language.
Mirjam Elisabeth Broersma

35. Retrieving semantic and syntactic word properties: ERP studies on the time course in language comprehension.
Oliver Müller

36. Lexically-guided perceptual learning in speech processing.
Frank Eisner

37. Sensitivity to detailed acoustic information in word recognition.
Keren Batya Shatzman

38. The relationship between spoken word production and comprehension.
Rebecca Özdemir

39. Disfluency: interrupting speech and gesture.
Mandana Seyfeddinipur

40. The acquisition of phonological structure: distinguishing contrastive from non-constrative variation.
    Christiane Dietrich

41. Cognitive cladistics and the relativity of spatial cognition.
    Daniel Haun

42. The acquisition of auditory categories.
    Martijn Bastiaan Goudbeek

43. Affix reduction in spoken Dutch: probabilistic effects in production and perception.
    Mark Pluymaekers

44. Continuous-speech segmentation at the beginning of language acquisition: Electrophysiological evidence.
    Valesca Madalla Kooijman

45. Space and iconicity in German sign language.
    Pamela M. Perniss

46. On the production of morphologically complex words with special attention to effects of frequency.
    Heidrun Bien

47. Crosslinguistic influence in first and second languages: convergence in speech and gesture.
    Amanda Brown

48. The acquisition of verb compounding in Mandarin Chinese.
    Jidong Chen

49. Phoneme inventories and patterns of speech sound perception.
    Anita Eva Wagner

50. Lexical processing of morphologically complex words: an information-theoretical perspective.
    Victor Kuperman

51. A grammar of Savosavo: a Papuan language of the Solomon Islands.
    Claudia Ursula Wegener

52. Prosodic structure in speech production and perception.
    Claudia Kuzla

53. The acquisition of finiteness by Turkish learners of German and Turkish learners of French: investigating knowledge of forms and functions in production and comprehension.
    Sarah Schimke

54. Studies on intonation and information structure in child and adult German.
    Laura de Ruiter

55. Processing the fine temporal structure of spoken words.
    Eva Reinisch

56. Semantics and (ir)regular inflection in morphological processing.
    Wieke Tabak

57. Processing strongly reduced forms in casual speech.
    Susanne Brouwer

58. Ambiguous pronoun resolution in L1 and L2 German and Dutch.
    Miriam Ellert

59. Lexical interactions in non-native speech comprehension: evidence from electro-encephalography, eye-tracking, and functional magnetic resonance imaging.
    Ian FitzPatrick

60. Processing casual speech in native and non-native language.
    Annelie Tuinman

61. Split intransitivity in Rotokas, a Papuan language of Bougainville.
    Stuart Payton Robinson

62. Evidentiality and intersubjectivity in Yurakaré: an interactional account.
    Sonja Gipper

63. The influence of information structure on language comprehension: a neuro-cognitive perspective.
    Lin Wang

64. The meaning and use of ideophones in Siwu.
    Mark Dingemanse

65. The role of acoustic detail and context in the comprehension of reduced pronunciation variants.
    Marco van de Ven

66. Speech reduction in spontaneous French and Spanish.
    Francisco Torreira

67. The relevance of early word recognition: insights from the infant brain.
Caroline Mary Magteld Junge

68. Adjusting to different speakers: extrinsic normalization in vowel perception.
Matthias Johannes Sjerps

69. Structuring language: contributions to the neurocognition of syntax.
Katrien Rachel Segaert

70. Infants' appreciation of others' mental states in prelinguistic communication: a second person approach to mindreading.
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71. Gaze behavior in face-to-face interaction.
Federico Rossano

72. Sign-spatiality in Kata Kolok: how a village sign language of Bali inscribes its signing place.
Connie de Vos

73. Who is talking? Behavioural and neural evidence for norm-based coding in voice identity learning.
Attila Andics

74. Lexical processing of foreign-accented speech: Rapid and flexible adaptation.
Marijt Witteman

75. The use of deictic versus representational gestures in infancy.
Daniel Puccini

76. Territories of knowledge in Japanse conversation.
Kaoru Hayano

77. Family and neighbourhood relations in the mental lexicon: A cross-language perspective.
Kimberley Mulder

78. Contributions of executive control to individual differences in word production.
Zeshu Shao

79. Hearing speech and seeing speech: Perceptual adjustments in auditory-visual processing.
Patrick van der Zande

80. High pitches and thick voices. The role of language in space-pitch associations.
Sarah Dolscheid

81. Seeing what's next: Processing and anticipating language referring to objects.
Joost Rommers

82. Mental representation and processing of reduced words in casual speech.
Iris Hanique

83. The many ways listeners adapt to reductions in casual speech.
Katja Poellmann

84. Contrasting opposite polarity in Germanic and Romance languages: Verum Focus and affirmative particles in native speakers and advanced L2 learners.
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Jana Reifegerste

86. Semantic and syntactic constraints on the production of subject-verb agreement.
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88. The evolutionary dynamics of motion event encoding.
Annemarie Verkerk

89. Rediscovering a forgotten language.
Jiyoun Choi

90. The road to native listening: Language-general perception, language-specific input.
Sho Tsuji

91. Infants'understanding of communication as participants and observers.
Gudmundur Bjarki Thorgrímsson

92. Information structure in Avatime.
Saskia van Putten

93. Switch reference in Whitesands.
Jeremy Hammond

94. Machine learning for gesture recognition from videos.
Binyam Gebrekidan Gebre

95. Acquisition of spatial language by signing and speaking children: a comparison of Turkish sign language (TID) and Turkish.
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96. An ear for pitch: on the effects of experience and aptitude in processing pitch in language and music.
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97. Incrementality and Flexibility in Sentence Production.
Maartje van de Velde

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Giovanni Rossi

100. Timing turns in conversation: A temporal preparation account.
Lilla Magyari

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David Peeters

103. Investigating the genetic basis of reading and language skills.
Alessandro Gialluisi

104. Conversation Electrified: The Electrophysiology of Spoken Speech Act Recognition.
Rósa Signý Gisladottir

105. Modelling Multimodal Language Processing.
Alastair Smith

106. Predicting language in different contexts: The nature and limits of mechanisms in anticipatory language processing.
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107. Situational variation in non-native communication.
Huib Kouwenhoven

108. Sustained attention in language production.
Suzanne Jongman

109. Acoustic reduction in spoken-word processing: Distributional, syntactic, morphosyntatic, and orthographic effects.
Malte Viebahn

110. Nativeness, dominance, and the flexibility of listening to spoken language.
Laurence Bruggeman

111. Semantic specificity of perception verbs in Maniq.
Ewelina Wnuk

112. On the identification of FOXP2 gene enhancers and their role in brain development.
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116. Comprehending Comprehension: Insights from neuronal oscillations on the neuronal basis of language.
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118. Language processing in a conversation context.
Lotte Schoot

119. Achieving mutual understanding in Argentine Sign Language.
Elizabeth Manrique

120. Talking Sense: the behavioural and neural correlates of sound symbolism.
Gwilym Lockwood

121. Getting under your skin: The role of perspective and simulation of experience in narrative comprehension.
Franziska Hartung

122. Sensorimotor experience in speech perception.
Will Schuerman

123. Explorations of beta-band neural oscillations during language comprehension: Sentence processing and beyond.
Ashley Lewis

124. Influences on the magnitude of syntactic priming.
Evelien Heyselaar

125. Lapse organization in interaction.
Elliott Hoey

126. The processing of reduced word pronunciation variants by natives and foreign language learners: Evidence from French casual speech.
Sophie Brand

127. The neighbors will tell you what to expect: Effects of aging and predictability on language processing.
Cornelia Moers

128. The role of voice and word order in incremental sentence processing.
Sebastian Sauppe

129. Learning from the (un)expected: Age and individual differences in statistical learning and perceptual learning in speech.
Thordis Neger

130. Mental representations of Dutch regular morphologically complex neologisms.
Laura de Vaan