The Origin of the Linguistic Gender Effect in Spoken-Word Recognition: Evidence from Non-Native Listening

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Abstract

Two eye-tracking experiments examined linguistic gender effects in non-native spoken-word recognition. French participants, who knew German well, followed spoken instructions in German to click on pictures on a computer screen (e.g., *Wo befindet sich die Perle*, "where is the pearl") while their eye movements were monitored. The name of the target picture was preceded by a gender-marked article in the instructions. When a target and a competitor picture (with phonologically similar names) were of the same gender in both German and French, French participants fixated competitor pictures more than unrelated pictures. However, when target and competitor were of the same gender in German but of different gender in French, early fixations to the competitor picture were reduced. Competitor activation in the non-native language was seemingly constrained by native gender information. German listeners showed no such viewing time difference. The results speak against a form-based account of the linguistic gender effect. They rather support the notion that the effect originates from the grammatical level of language processing.

Introduction

Gender is a grammatical category that varies largely across the languages of the world. The range goes from elaborate gender systems in some languages to the absence of gender in others. Both German and French are languages with grammatical gender. The form of definite articles, for example, marks gender in both languages. German definite articles are $der_{(masc.)}$, $die_{(fem.)}$, and $das_{(neut.)}$; French definite articles are $le_{(masc.)}$ and $la_{(fem.)}$ respectively. Grammatical gender usually becomes most noticeable when we learn a second language with gender. Is it *der Berg* ("mountain") or *die Berg* in German? Do the French say *le citron* ("lemon") or *la citron*? The present study investigated how gender marking influences the recognition of spoken-words in a non-native language. Results help clarify the origin of the linguistic gender effect.

It is generally accepted in the psycholinguistic community that during the recognition of spoken words, multiple word candidates get simultaneously activated and compete against each other (e.g., Marslen-Wilson & Welsh, 1978; McQueen, Norris, & Cutler, 1994). When a native speaker hears, for example, the German word *Perle* ("pearl"), lexical representations of words with similar onsets, such as *Perücke* ("wig"), will initially be activated along with *Perle*. Activated word candidates compete for recognition until they no longer match incoming segmental information. Thus, *Perücke* will drop out of the competitor set as the /l/ in *Perle* is being heard. It has also been shown that non-native listeners consider candidate words in both the non-native and their native language simultaneously (e.g., Marian & Spivey, 2003; Weber & Cutler, 2004). Thus, for French listeners the beginning of German *Perle* may additionally activate French words like *perruque* and *persil*.

Eye-tracking is a methodology that has been found to be eminently suited for the investigation of competitor activation (e.g., Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). It makes use of the fact that participants make saccadic eye movements to pictures of objects on a computer screen as the names of the objects are mentioned in spoken sentences. Locations and latencies of eye movements on pictures are recorded using a camera mounted on a headband and can be used to examine lexical competition in spoken-word recognition. While participants hear the name of a target picture, they look more often to pictures with names that are similar in onset with the target name than to pictures with phonologically unrelated names. It has been shown that such competition effects, defined as fixation proportions to pictures, closely map to activation levels of word candidates as simulated in computational models of spoken-word recognition such as TRACE (Allopenna, Magnuson, & Tanenhaus, 1998; Dahan, Magnuson, & Tanenhaus, 2001).

By now, numerous eye-tracking studies have successfully confirmed phonological competitor activation in spoken-word recognition. Dahan, Swingley, Tanenhaus, and Magnuson (2000) took the subject one step further by testing whether morphosyntactic context can affect competitor activation. In particular, they tested whether gender marking on definite articles influences the recognition of subsequent nouns. A number of studies had already looked at lexical gender effects in word recognition using experimental paradigms other than eye-tracking (e.g., Bates, Devescovi, Hernandez, & Pizzamiglio, 1996; Colé & Segui, 1994; Grosjean, Dommergues, Cornu, Guillelmon, & Besson, 1994). These studies found that the presence of gender-congruent articles or adjectives enhances the recognition of target nouns whereas gender-incongruent forms slow recognition down. Dahan et al. (2000), investigated the role of gender information on spoken-word recognition more directly: They tested the activation of competitors that matched the initial sounds of a target noun

but mismatched the gender marking on the article. They found that the presence of a gender-marked definite article could prevent early activation of competitors inconsistent with that gender: Upon hearing *cliquez sur le bouton* ("click on the$_{(masc.)}$ button"), French listeners did not fixate the picture of a *bouteille* ("bottle$_{(fem.)}$") more often than pictures with unrelated names.[1]

The study by Dahan et al. (2000), however, could not assess the origin of the lexical gender effect. Are listeners really sensitive to grammatical gender information in the preceding context or is it simply listeners' sensitivity to the co-occurrence of the form of the article with the form of the noun that restricts lexical access? In order to reduce the high co-occurrence of definite articles and nouns, Dahan and colleagues interposed a gender-marked adjective in a follow-up study. In their preliminary results, activation of gender-mismatching competitors was no longer reduced when low frequency gender-marked adjectives preceded target nouns. This was seen as evidence for a form-based origin of the gender effect. In a Russian eye-tracking study, however, Sekerina (2003) found that gender-marked color adjectives do restrict referential sets to gender-matching nouns. She interpreted the results as evidence for a grammar-based effect of gender in spoken-word recognition.

Spoken-word recognition in a non-native language offers the possibility to distinguish between a form-based and a grammar-based account of the linguistic gender effect. The gender of a noun can differ across languages: *Canon* is, for instance, feminine in German but masculine in French. The present study tested whether French listeners, who are highly proficient in German, use native French gender information during the recognition of spoken words in German. Since the form of the article differs in German and French, presentation of the German article should not give rise to co-occurrence information for the French form of the article and a given noun. Thus, if the gender of words in French exerts an effect on the recognition of spoken words in German (even though French is not presented), this would strongly suggest that the locus of the gender effect is not form-based.[2]

Recent eye-tracking studies have shown that listeners cannot deactivate the lexicon of the native language even in a monolingual non-native situation where the native vocabulary is irrelevant (Marian & Spivey, 2003; Spivey & Marian, 1999; Weber & Cutler, 2004). Native language competitors that were phonologically related to the non-native target were activated more than phonologically unrelated words: Upon hearing the English target *desk*, Dutch listeners, who knew English well, fixated the picture of a lid more than unrelated pictures because the Dutch name for lid (*deksel*) was phonologically related to *desk* (Weber & Cutler, 2004). Similarly, grammatical information from the native language might interfere with non-native listening. Imagine native French speakers listening to German in an eye-tracking study. Spoken instructions in German tell them to click on target pictures on a screen. The name of the target picture is preceded by the definite article in the instructions, and target and competitor names overlap in onset in both languages. In the non-native presentation language German, target and competitor names share gender, so the gender marking on the article cannot exclude the competitor as a lexical candidate. In the native language French, however, target and competitor differ in gender. If we find no competitor activation for French listeners, this would suggest that they use native French gender information to disambiguate between target and competitor.

Experiment 1

Method

Participants Eighteen native speakers of French, mostly students (mean age of 22), took part in the experiment for monetary compensation. They had normal or corrected-to-normal vision and normal hearing. On average, they had studied German as a foreign language for 10 years in secondary education, starting at a mean age of 12 (ranging from 10 to 16). To confirm their high proficiency in the non-native language, they underwent a vocabulary test in German after completing the eye-tracking experiment. For each target and competitor noun in the experiment plus a number of filler nouns with neuter gender, they had to name the correct gender. The average score was 78% correct.

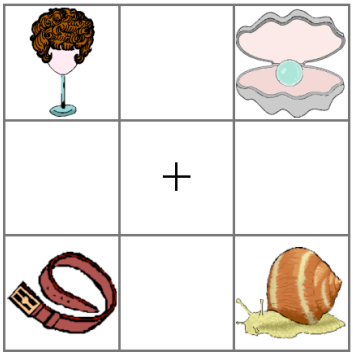

Figure 1: Example of visual display presented to participants.

[1] Dahan et al. (2000) also showed that when no phonological overlap between picture names was given, gender-marked articles were not sufficient to restrict participants' attention to pictures with gender matching names.

[2] Only very few studies have looked at gender marking effects in non-native spoken-word recognition. Guillelmon and Grosjean (2001), for example, found in an auditory naming study no effects of congruency for late English-French bilinguals. It is not established yet whether gender marking influences competitor activation in a second language.

Table 1: Examples of German (G) target-competitor pairs and their French (F) translations.

		target	competitor
same-gender pair	G	Perle$_{(fem.)}$	Perücke$_{(fem.)}$
	F	perle$_{(fem.)}$	perruque$_{(fem.)}$
		"pearl"	"wig"
different-gender pair	G	Kassette$_{(fem.)}$	Kanone$_{(fem.)}$
	F	cassette$_{(fem.)}$	canon$_{(masc.)}$
		"tape"	"canon"

Materials Thirty German nouns referring to picturable objects were chosen as targets.[3] Each target was paired with a competitor. The onset of the competitor overlapped phonemically with the onset of the target in both German and French (e.g., German target *Perle* /pɛrlə/ was *perle* /pɛrl/ in French; German competitor *Perücke* /pɛrykə/ was *perruque* /pɛryk/ in French). The target was always of the same gender in German and French, but the gender of the competitor divided the pairs into two groups (see Table 1). In 15 "same-gender" pairs, target and competitor shared gender in both languages. The target *Perle* ("pearl"), feminine in both German and French, was for example paired with the competitor *Perücke* ("wig"), also feminine in both languages. In these pairs, neither German nor French gender information could constrain initial competitor activation. In 15 "different-gender" pairs, target and competitor still shared gender in German, but were of different genders in French. The target *Kassette* ("tape"), feminine in both languages, was for instance paired with the competitor *Kanone* ("canon"), which is feminine in German but masculine in French. Whereas German gender information could not exclude the competitor as a potential lexical candidate in these pairs, French gender information could.

Two phonologically unrelated distractors, with random gender, were added for each target (e.g., *snail* and *belt*). Neither the German nor the French names of the unrelated distractors overlapped with the German target nouns. The target was heard in the experiment, whereas competitor and unrelated distractors were not heard. The overall lexical frequency of targets and competitors did not differ significantly in either of our target-competitor pairs.

Thirty filler trials were added. Great care was taken in the fillers to dispel expectations that pictures with phonologically similar names or matching gender were likely targets. Three more representative trials were constructed as practice trials.

All pictures were colored line drawings, taken from the IMSI MasterClips Image Collection (1990). In pre-tests, we asked participants to name and rate target and competitor pictures. The agreement between participants' responses and intended names was 88% correct, and the goodness of the pictures was rated with a mean of 5 on a scale from 0 to 6.

German target nouns, preceded by their definite article with nominative case marking, were embedded in a carrier sentence (e.g., *Wo befindet sich die Perle*, "Where is the pearl"). Spoken instructions were recorded. The duration of putative overlap between target and competitor (e.g., the duration of /pɛr/ in *Perle*) was on average 200 ms for same-gender pairs and 174 ms for different-gender pairs.

Procedure Participants were tested individually. At the beginning of a session, they received instructions in German, telling them to click on the object on the screen that was mentioned in a sentence. Sentences were presented auditorily over headphones and started 550 ms after the appearance of the pictures on the screen. The set of pictures was not shown to the participants before the experiment.

While they were listening, participants' eye movements were monitored using an SMI EyeLink head-mounted eye-tracker. A camera on the participants' dominant eye provided the input to the tracker. Onset and offset times and the spatial coordinates of the participants' fixations were recorded (250 Hz sampling rate). All pictures were presented in color on a 3 x 3 gray grid (see Figure 1). Each cell measured 7.5 x 7.5 cm, corresponding to a visual angle of approximately 7°, which is well within the resolution of the eye-tracker (better than 1°). The pictures of a target item, its competitor, and two unrelated distractors were displayed together in one trial. Positions of target and competitor objects were randomized across trials. Each experimental trial was preceded by at least one filler trial. Along with the eye movements, the position of the mouse click was recorded.

For the analysis, graphical software was used to display the locations of the participants' fixations as dots superimposed on the four pictures for each trial and each participant. Fixations were coded as pertaining to the cell of the target object, the competitor object, or one of the two unrelated distractors. Fixations that lay clearly outside the cell of an object were not used for the computation of the fixation probabilities. Saccade times were not added to fixation times.

Results and Discussion

Seventeen trials were removed from the analysis because participants clicked on an object other than the target or no fixation on the target object was found (3.2% of all trials). The low percentage of errors suggests that French participants had no difficulties performing the task in German. Fixation proportions, at successive 10 ms time frames, were averaged over participants and items for separate analyses.

[3] Since the French gender system is limited to feminine and masculine, selected German target nouns were either of feminine or masculine gender, but never neuter.

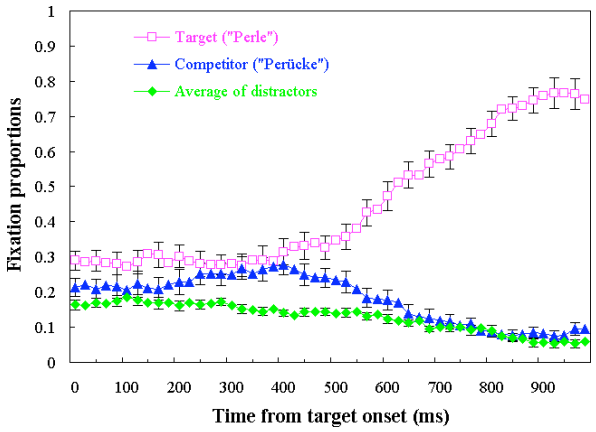

Figure 2: Same-gender pairs. Fixation proportions of French listeners over time for German targets, competitors, and averaged distractors.

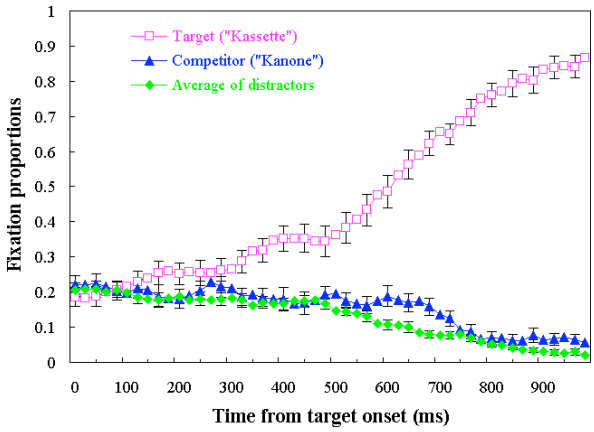

Figure 3: Different-gender pairs. Fixation proportions of French listeners over time for German targets, competitors, and averaged distractors.

Figure 2 presents the averaged proportions of fixations after target noun onset for trials with same-gender pairs. Fixation proportions for the two unrelated distractors were averaged. It takes typically about 150 to 200 ms before a programmed eye movement is launched (e.g., Matin, Shao, & Buff, 1993). Thus, fixations on the target object that are triggered by acoustic information are observable starting around 200 ms after target noun onset.

In same-gender pairs, French listeners fixated competitor objects more than distractor objects. Between 200 and 600 ms, the proportion of fixations was on average 23.9% for the competitor and 14.9% for the unrelated distractors. A one-factor ANOVA on the mean proportion of fixations between 200 and 600 ms, with picture (with the two levels 'competitor' and 'unrelated distractors') as the within-participants factor, showed that the competitor was fixated significantly more than the average of the unrelated distractors ($F_1[1, 17] = 11.41$, $p < .005$; $F_2[1, 14] = 13.92$, $p < .005$). Neither gender information from the non-native presentation language, nor gender information from their native language could narrow the lexical candidates down to the target. In consequence, the competitor was activated during the presentation of the target due to their phonological similarity.

Prior to the point that fixations could be driven by acoustic information from the target noun, no variation between fixation proportions was found. Analyses in the 0-200 ms time window showed no reliable difference in initial fixations between competitor and unrelated distractors ($F_1[1, 17] = 2.15$, $p > .1$; $F_2 < 1$). Thus, the difference between fixations to the competitor and the unrelated distractors in the 200-600 ms time window cannot be attributed to a general bias toward the picture of the competitor.

The pattern of results changed for different-gender pairs. French participants no longer fixated competitor objects more than distractor objects (see Figure 3). Over the 200-600 ms time window, 17.9% of the fixations were on average to the competitor and 15.6% to the distractors. A one-factor ANOVA confirmed the lack of a difference in viewing times (F_1 & $F_2 < 1$). As before, no reliable differences were found for different-gender pairs in initial fixation proportions between 0 and 200 ms after target noun onset (F_1 & $F_2 < 1$).

In different-gender pairs, gender information carried by the article in German could not constrain competitor activation, but French gender could. Despite its phonological similarity with the target noun, the competitor was not activated when the article of the target noun did not match in gender with the competitor in French. Evidently, French listeners used native French gender information to constrain competitor activation in German.[4] The experiment was conducted in German, and the linguistic form of the article did not exclude the competitor as a potential lexical candidate. In other words, the probability of the target noun being *Perle* or *Perücke* was equally high after hearing the phoneme sequence /diːpɐr/, *die Per*. Nevertheless, competitor activation was eliminated for French listeners. This suggests that the high form-based co-occurrence of article and target did not constrain lexical access in our experiments, but rather grammatical gender carried by the article did.

Experiment 2

As a control, we presented the same stimuli to listeners whose native language was German. If native gender information of the pictures had restricted eye movements in Experiment 1, both same-gender pairs and different-gender pairs should now offer competition for German listeners in Experiment 2, since in German target and competitor share gender in both pairs.

[4] The same analyses were run again after removing trials for which the French native speakers made a mistake in the vocabulary test. The results were comparable.

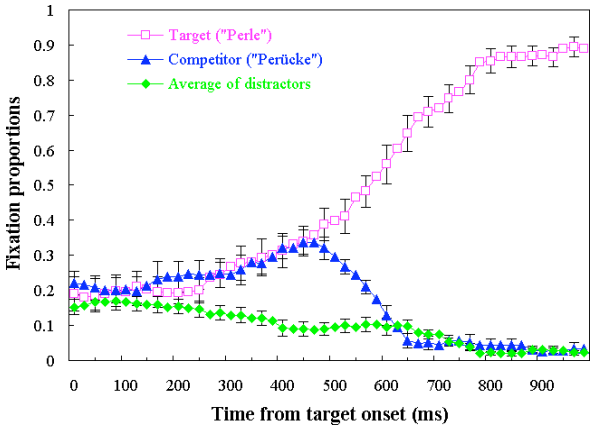

Figure 4: Same-gender pairs. Fixation proportions of German listeners over time for German targets, competitors, and averaged distractors.

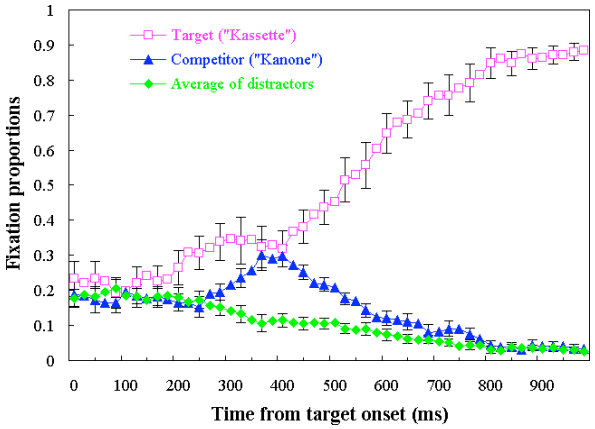

Figure 5: Different-gender pairs. Fixation proportions of German listeners over time for German targets, competitors, and averaged distractors.

Method

Participants Twelve native speakers of German participated, in return for a small payment. They were all students (mean age of 21), and had normal or corrected-to-normal vision and normal hearing. They had all learned French as a second language in school, but were not required to exercise their proficiency here.

Materials The materials were as in Experiment 1.

Procedure The procedure was as in Experiment 1. Participants were not made aware of potential cross-language competition in the experiment.

Results and Discussion

Participants never clicked on an object other than the target. Figure 4 shows the averaged proportions of fixations after target noun onset for trials with same-gender pairs. As is immediately apparent, higher fixation probabilities were observed for the competitor than for the unrelated distractors. Over the 200-600 ms time window, the proportion of fixations was on average 26.74% for the competitor and 11.16% for the unrelated distractors. This difference was significant in a one-way ANOVA ($F_1[1, 11] = 22.97$, $p < .002$; $F_2[1, 14] = 19.47$, $p < .01$). Just as the French listeners in Experiment 1, German listeners activated competitors when gender-marked articles could not exclude them as potential lexical candidates. No reliable difference in viewing times was observed in the first 200 ms after target noun onset ($F_1[1, 11] = 1.30$, $p > .2$; $F_2[1, 14] = 1.97$, $p > .1$).

In contrast to the French listeners, however, German listeners also looked more often at the competitor than at the unrelated distractors in different-gender pairs. Between 200-600 ms after target noun onset the proportion of fixations was on average 20.98% for the competitor and 11.84% for the unrelated distractors. An ANOVA showed a significant effect of type of picture ($F_1[1, 11] = 10.68$, $p < .01$; $F_2[1, 14] = 8.34$, $p < .02$). Again, viewing times for competitor and unrelated distractors did not differ in the first 200 ms after target noun onset (F_1 & $F_2 < 1$).

The results of Experiment 2 showed that during the presentation of the target noun, German listeners activated the competitor in both same-gender and different-gender pairs.

Summary

A recent eye-tracking study by Dahan et al. (2000) has shown that grammatical context can constrain lexical access. In their study, French participants followed spoken instructions in French to click on pictures on a screen while their eye movements were monitored. Eye movements to pictures were interpreted as evidence for the activation of the words corresponding to those pictures. We know from previous eye-tracking studies that competitor pictures with names that overlap in onset with the name of a target picture are fixated more than pictures with unrelated names (see e.g., Tanenhaus et al., 1995). In the spoken instructions in Dahan et al's study, the names of the target pictures were immediately preceded by articles. In the absence of gender marking on the article (i.e., French plural article *les*), competitor activation was found for phonologically related nouns. However, when competitors matched in initial sounds with a target noun but mismatched in gender marking on the preceding article, early competitor activation was eliminated.

The present eye-tracking studies investigated the role of linguistic gender for the process of listening to a non-native language. An interesting aspect of non-native listening is that the gender of words can vary between the native and the non-native language. Thus, gender information as conveyed

by the presentation language, i.e. the non-native language, can be opposed to gender information from the listeners' native language. In Experiment 1, French participants followed spoken instructions in German to click on pictures on a computer screen (e.g., *Wo befindet sich die Perle*, "Where is the pearl"). When target and competitor noun shared gender in both German and French, French participants fixated competitor pictures more than unrelated pictures. However, when target and competitor were of the same gender in German but of different gender in French, early fixations to the competitor picture were eliminated. This result was interpreted as evidence that competitor activation in the non-native language was constrained by native gender information. In Experiment 2, German listeners were presented with the same materials and showed no such difference in viewing time.

In general, our results support Dahan et al's (2000) findings that gender information influences lexical access, but also crucially offer new insights with respect to the origin of the gender effect. On one account, listeners compute distributional regularities between the co-occurrence of the form of the article and the form of the noun and use these form-based regularities to restrict lexical access. On another account, distributional regularities would be computed using grammatical categories. On the form-based account, probabilities would express the likelihood of the target being *Perle* upon hearing the segmental sequence /diːpɛr/; on the grammar-based account, probabilities would express the likelihood of the target being *Perle* upon hearing /pɛr/ plus having feminine gender information from the context. Within one language, these two accounts are difficult to tease apart. However, non-native listening offered the possibility to separate them, because linguistic gender effects of the non-presentation language are unlikely to be caused by form-based regularities of that language.

The fact that, for French listeners in Experiment 1, competitor activation in German was eliminated when French gender information mismatched the gender of the target speaks against an form-based account of the linguistic gender effect. Our results rather support the notion that the linguistic gender effect originates from the higher, grammatical level of language processing.

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