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# Interactive Processing of Morphosyntactic Features in the Bilingual Lexicon

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## Abstract

We investigated whether morphosyntactic representations in bilinguals' native language become activated by form-related representations in their second language. Specifically, we examined whether, relative to English monolinguals, German-English bilinguals would exhibit a bias to initially interpret English nouns ending in –er as referring to a male due to the association of masculine gender with this ending in German. This question was tested by recording bilinguals' and monolinguals' eye movements as they read English sentences containing a stereotypically male, female, or neutral –er noun that was an antecedent of a gender-matching or –mismatching reflexive. The bias to initially interpret the –er nouns' referent as male was assessed by the size of the "mismatch effect" or the difference between the participants' total fixation duration on feminine versus masculine reflexives. The results showed a positive mismatch effect for both the bilinguals and monolinguals in the stereotypical male condition, no mismatch effect for either group in the neutral condition, and a mismatch effect only for the monolinguals in the stereotypical female condition. The results were simulated using a connectionist interactive activation model, and the implications for future study are discussed.

## Introduction

A central question in bilingualism research concerns the extent to which the processing of lexical representations in the two languages occurs independently or interactively, and, if the latter, whether the interaction is bi-directional (i.e., processing of representations in the first language (L1) affects processing of representations in the second language (L2) and vice versa). A complementary question concerns whether the lexical representations in the two languages are stored together or separately.

The contrasting views have been tested predominately with tasks that measure the speed of bilinguals' recognition or translation of individual L2 and L1 words. For example, studies employing translation tasks have shown that, during the early stages of L2 learning, translation of L2 words into L1 words is faster than translation of L1 words into L2 words. However, as proficiency in L2 increases, translation in both directions becomes equally fast. Kroll and colleagues (e.g., DuFour & Kroll, 1995; Kroll & Stewart,

1994) proposed that the initially faster translation from L2 to L1 is due to strong associative links between lexical representations in the two lexicons, which arise from an early emphasis on retrieving the meanings of L2 words by translating them into their L1 equivalents. However, as experience with L2 increases, direct associative connections between L2 lexical representations and their concepts become stronger, resulting in independence of processing in the L2 lexicon (e.g., Altarriba & Mathis, 1997; Frenck-Mestre & Prince, 1997; Kroll & Curley, 1998).

However, results of studies employing word recognition tasks suggest that processing in the L2 lexicon never becomes completely independent. The evidence comes primarily from studies that measure the speed and accuracy of bilinguals' recognition of cognates and interlingual homographs or "false friends". Cognates are translation equivalents with identical (or nearly identical) orthography and phonology in both languages (e.g., *partner* in German and English), whereas false friends have identical orthography and phonology in both languages but different meanings (e.g. *teller* in German and English). Studies by Dijkstra and colleagues (Dijkstra, Grainger, & Van Heuven, 1999; Dijkstra, Timmermans, & Schriefers, 2000; Dijkstra, Van Jaarsveld, & Ten Brinke, 1998; Van Heuven, Dijkstra, & Grainger, 1998) have shown faster recognition of cognates relative to noncognates but slower recognition of false friends relative to noncognates. On the basis of these findings, Dijkstra et al. (1999) proposed that cognates share a single lexical representation in both the L1 and L2 lexicons whereas false friends have separate lexical representations in each lexicon. Because the false friends' separate lexical representations share connections to sublexical representations, both lexical representations become activated when either is encountered, resulting in interference. Dijkstra et al.'s proposal of interactive processing of separate lexical representations was supported by the simulation results of a bilingual interactive activation (BIA) model, which was adapted from McClelland and Rumelhart's classical interactive-activation model (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982).

Although, overall, the evidence from word-recognition

studies supports an interactive view of processing in bilingual memory, the results of individual studies vary depending on specific manipulations, such as the nature of the response, the ratios of different types of L1 and L2 words presented in the lists, and the particular instructions given to the bilingual participants. Consequently, the findings from these studies may reflect the nature of the strategic processing employed in specific experimental circumstances (e.g., Dijkstra, Grainger & Van Heuven, 1999; Dijkstra, Van Jaarsveld, & Ten Brinke, 1998; Green, 1998). A goal of the current study was to seek converging evidence for the interactive view using in a sentence comprehension task.

In particular, we examined whether morphosyntactic representations associated with L1 words interfere with processing morphologically similar L2 words. More specifically, we investigated whether fluent German-English bilinguals would exhibit a bias to interpret English animate nouns ending in –er as referring to a male due to the association of masculine gender with the -er endings of nouns in German.

## Gender and Sex in English and German

The morphological markings of gender on words reflect a grammatical or syntactic property, which, in the case of masculine or feminine gender, may not be correlated with a semantic property of male or female sex. Aside from the pronominal system in English, only a few English nouns are morphologically marked for gender (e.g., actor/actress, waiter/waitress, host/hostess). The markings on these nouns, as well as on the pronouns, are determined by the semantic sex of the referent.

In German, all nouns as well as pronouns possess one of three classes of grammatical gender: masculine, feminine, or neuter. Nouns that refer to inanimate entities may be masculine e.g., *der Stock* (the stick), feminine e.g., *die Gabel* (the fork), or neuter e.g., *das Obst* (the fruit), and therefore, their gender has no semantic correlate. However, the gender of most nouns that refer to human entities does correlate with the referent's sex; for example *Schwester* (sister) is feminine and *Bruder* (brother) is masculine. Exceptions include *Weib* (woman or wife), which is neuter, and diminutive nouns such as, *Mädchen* (girl), which are also neuter.

The grammatical gender of German nouns is based on a complex set of rules, which include a semantic rule that the gender of a noun referring to a human entity must match the sex of the referent (e.g., Zubin & Köpcke, 1986). So, for example, masculine nouns such as, *Partner* (partner) and *Student* (student), refer to males whereas the feminine nouns, *Partnerin* and *Studentin,* refer to females. Additional rules concern other semantic properties of nouns as well as their morphological or phonological properties. Across the different levels of rules there are a number of consistencies. For example, most nouns ending in -er are masculine regardless of whether they refer to an animate or inanimate entity. Exceptions include *Butter* (butter), *Leiter* (ladder),

*Mutter* (mother), which are feminine. Evidence that the –er ending of nouns is strongly associated with masculine gender comes from studies showing that German speakers will use the masculine article *der* with nonsense –er nouns and with -er nouns that are borrowed from other languages (Mills, 1986; Salmons, 1994).

## Experiment

The experiment used the association of masculine gender with the –er ending of nouns in German to test the predictions of the interactive view of bilingual memory. According to this view, when German-English bilinguals read an English noun ending in –er, which has no gender in English, the ending should nonetheless activate the masculine gender feature associated with it in German. If the –er noun refers to a human entity, then, the activated masculine gender feature should activate the corresponding semantic feature for male sex, thus biasing a male interpretation of the noun. This bias, in turn, should cause interference if the –er noun is an antecedent of a subsequent feminine pronoun, such as *herself.*

To test this prediction, we compared the eye movement patterns of German-English bilinguals and English monolinguals when they read English sentences such as the following:

(1) The butcher accidentally cut *himself/herself* with a knife.
(2) The cheerleader injured *himself/herself* during the final game.
(3) The speaker introduced *himself/herself* to the audience.

As shown by the examples, the critical sentences began with an –er noun that referred to a human entity. The –er nouns represented three stereotypical sex conditions: male (1), female (2), or neutral (3), and each was an antecedent of either the feminine reflexive, *herself,* or the masculine reflexive, *himself.* Previous studies involving only English monolinguals have shown that mismatches between a pronoun's gender and an antecedent noun's stereotypical sex results in comprehension difficulty (e.g., Kerr & Underwood, 1984; Osterhout, Bersick, McLaughlin, 1997). In studies that have recorded readers' eye-movements, the difficulty is reflected in both longer and more frequent fixations on a mismatching pronoun than on a matching pronoun (Kerr & Underwood, 1984). Thus, in the current study, we assessed the degree of bias to initially interpret the sex of the –er nouns as male by the size of a "mismatch effect", calculated by subtracting the participants' average total fixation duration on *himself* from their average total fixation duration on *herself.*

We expected that both the German-English bilinguals and English monolinguals would exhibit a positive mismatch effect for sentences containing a stereotypical male -er noun as the antecedent of *herself.* However, only the German-English bilinguals were expected to show a positive mismatch effect for sentences containing a stereotypical neutral –er noun that was the antecedent of *herself.* Finally, only the English monolinguals were predicted to show a negative mismatch effect for sentences containing a

stereotypical female –er noun that was the antecedent of *himself*. German-English bilinguals were not expected to exhibit any mismatch effect because the male bias from the masculine gender associated with –er should attenuate any interference arising from a mismatch between the nouns' stereotypical female sex and a masculine reflexive.

## Method

### Participants

Twenty native English monolinguals and 20 fluent German-English bilinguals participated in the experiment. All had normal or corrected-to-normal vision and received payment in exchange for their participation. The twenty English monolinguals (6 male and 14 female) were between the ages of 18 and 21 and were tested at the University of Notre Dame. None had any formal experience with German. The 20 German-English bilinguals (8 male and 12 female) were between the ages of 17 and 25 and were tested at the University of Vienna in Vienna, Austria. They had an average of 9 years of formal English instruction (range 5-14 years). The average age at which English instruction began was 8 (range 5-10).

### Materials

The materials consisted of 30 pairs of English sentences. Each sentence began with a definite noun phrase containing an -er noun that referred to a human entity and was the antecedent of a reflexive pronoun. Ten of the –er nouns were German-English cognates, ten were semi-cognates, (i.e., similar but not identical orthography), and ten were non-cognates, with only the –er ending common to the nouns in both languages). The sentences within a pair were identical except for the reflexive's gender. The 30 pairs represented six conditions created from crossing the two levels of the reflexive's gender (himself or herself) with three levels of the stereotypical sex of the antecedent –er noun (male, female, or neutral). The initial assignment of the nouns to a stereotypical sex condition was based on the experimenters' intuitions and subsequently verified with the results of a rating task described below.

The materials also consisted of 46 filler sentences and 30 yes/no comprehension questions. All of the filler sentences began with a definite noun phrase containing an –er noun that referred to a human entity. None of the -er nouns occurred in the critical sentences and they were never antecedents of pronouns. The 30 yes/no comprehension questions were designed to encourage the participants to read for meaning. Twenty questions referred to the meaning of a preceding filler sentence, and 10 referred to the meaning of a preceding critical sentence. For example, the critical sentence, "The hunter hurt herself after falling out of a tree." was followed by the question, "Did the hunter get hurt while climbing a tree?"

Two 106-item lists were constructed. Each list contained 30 critical sentences, one from each pair, all 46 filler sentences, and all 30 comprehension questions. Within each list, five critical sentence represented each of the six conditions, and across both lists, each critical sentence occurred once. The lists began with four filler questions, two of which were followed by a comprehension question. The order of the remaining critical and filler sentences was random except for the constraint that two critical sentences could not occur consecutively.

After the reading task, the participants completed a rating form. The form listed the 30 critical –er nouns in random order with a 9-point scale next to each one. The end points of the scale were labeled as "1 = always male" and "9 = always female". The instructions printed at the top of the rating form were as follows: "Please rate the following words for how often, in your experience, they have been used to refer to a male or a female. If, in your experience, the word is always used to refer to a male, then circle the number 1 on the rating scale next to it. If the word is always used to refer to a female, then circle 9. Feel free to use the full range of numbers on the scale." The bilinguals completed an electronic version of the rating form and indicated their rating by selecting a box beneath a number on the scale. In addition, each noun on the bilinguals' forms was preceded by a selection box that was to be selected if the noun was unfamiliar.

### Procedure

Each participant was randomly assigned to one of the two lists, with an equal number of bilingual and monolingual participants assigned to each list. The participants were seated in front of a computer monitor at a comfortable viewing distance. They were told that a list of sentences would be presented to them one at a time in the center of the monitor. They were instructed to read each sentence and then press the "b" key on the computer's keyboard to advance to the next sentence. They were told that some of the sentences would be followed by a yes/no comprehension question, which they were to answer by pressing either the "z" key, which was labeled "yes" , or the '/' key, which was labeled "no".

The sentences appeared individually on a single line in the center of a 15" computer monitor. They were displayed in 14 point black font against a white background at 640X480 screen resolution. The critical –er nouns and the reflexive pronouns each subtended approximately $1.05^{o}$ X $2.87^{o}$ of visual angle. The participants' key-press responses were recorded for each trial.

The participants' eye movements were recorded using a free-head eyetracking system (Applied Science Laboratories, Model 501). The system consists of a lightweight eye camera attached to an adjustable headband that is worn by the participant. The eye camera is positioned above the participant's left eye and captures an infrared image of the eye at a 60 Hz sampling rate. The distance between the centers of the corneal and pupil infrared reflections are used to calculate the relative eye-in-head position. The position of the participant's head with respect to the computer monitor was simultaneously measured

using a magnetic head-tracking device (Acension Laboratories). The measurements from the headtracker and eyetracker were recorded in real time as a serial data stream to a PC. An analysis program converted the data stream into the XY coordinates of the participants' fixations, sampled every 16.67 msec. A videotaped record of the participants' fixations was also made. This record consisted of the image of the sentences displayed on the computer monitor in front of the participant (the scene image) and a superimposed set of cross-hairs indicating the participant's line of gaze. The video record was recorded onto Hi8 video tape and frame-by-frame playback was used to verify the accuracy of the fixation data computed from the data stream recorded onto the PC. At the beginning of an experimental session a two-minute calibration routine was conducted to map nine eye position coordinates onto nine corresponding scene image coordinates. The accuracy of the resulting eye fixation record is approximately $0.50^0$ over a range of $\pm 20^0$.

## Results and Discussion

**Rating Task** There was a high degree of consistency between the English monolinguals' and German-English bilinguals' ratings of the –er nouns' stereotypical sex (r = .93, p < .0001). The largest difference between the two groups' ratings occurred with the nouns, *gardener* and *horseback rider*, both of which were semi-cognates. The German-English bilinguals' average ratings of these nouns were 3.30 and 3.65, respectively, indicating a "male" association, whereas the English monolinguals' average ratings were 4.85 and 5.95, respectively, indicating a "neutral" association. Both groups' ratings conflicted with the initial assignment of the two nouns to the stereotypical female condition. Because of the discrepancies between the groups' ratings of these nouns, and the nouns' initial assignment to the female condition, they were eliminated from the analyses of the reading task data, reducing the number of items representing the female condition to eight. The correlation between the German-English bilinguals' and English monolinguals' average ratings of the remaining set of 28 –er nouns was .96. Table 1 shows the groups' average ratings of the nouns in each stereotypical sex condition.

Table 1. Average ratings (standard deviations) of the critical –er nouns in each stereotypical sex condition (1 = always male; 9 = always female).

| Stereotypical Sex | English Monolinguals | German-English Bilinguals |
|---|---|---|
| Male | 2.58 (.84) | 2.38 (.61) |
| Neutral | 4.70 (.69) | 4.52 (.32) |
| Female | 7.48 (.68) | 7.27 (1.10) |

**Reading Task** A total of 14 trials were eliminated because German-English participants indicated on their rating forms that they did not know a critical –er noun. Thirty-five trials were eliminated from the German-English data and 31 trials were eliminated from the English data because of a degraded eye-tracking record.

For the remaining trials, fixations that occurred on or between the character spaces immediately preceding and following the reflexives were scored as fixations on the reflexive. For each participant and for each critical sentence, the total duration of all fixations on a reflexive were calculated. Differences between the mean fixation durations on the masculine versus feminine reflexives in each stereotypical sex condition were analyzed by paired t-tests.

In each stereotypical sex condition, the mismatch effect was calculated by subtracting the average total fixation duration on *himself* from the average total fixation duration on *herself*. Thus, a positive mismatch effect corresponds to longer fixations on *herself*, and a negative mismatch effect corresponds to longer fixations on *himself*. Figure 1 shows the average mismatch effects in the three stereotypical sex conditions for the English monolinguals and the German-English bilinguals.
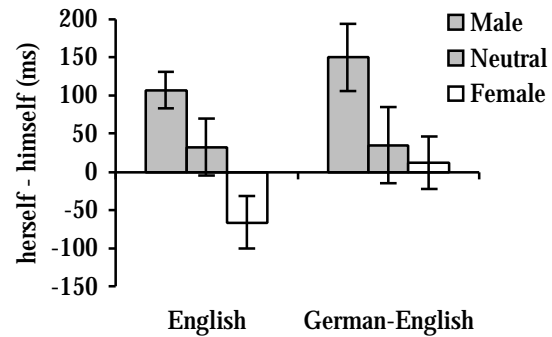


Figure 1: English monolinguals' and German-English bilinguals' average mismatch effects and standard errors in the three stereotypical sex conditions.

The English monolinguals' positive mismatch effect of 107 ms in the stereotypical male condition was reliable (t(19) = 4.40, p < .01 one-tailed by participants; t(9) = 3.00, p < .01, one-tailed by items). Likewise, the German-English bilinguals' mismatch effect of 150 ms was significant (t(19) = 3.38, p < .01 one-tailed by participants; t(9) = 1.99, p < .05, one-tailed by items). Contrary to expectations, neither group exhibited a reliable mismatch effect in the stereotypical neutral condition. However, as predicted, only the English monolinguals' showed a reliable mismatch effect (–66 ms) in the stereotypical female condition (t(19) = 1.93, p < .05 one-tailed by participants; t(9) < 1.00 by items). The absence of a mismatch effect in the female condition for the German-English bilinguals provides evidence that the male bias from the masculine gender associated with the –er nouns countered the bias from the stereotypical female sex of the nouns' referents.

Figure 2 shows both the monolinguals' and bilinguals' average mismatch effect for each of the 28 –er nouns plotted as a function of the groups' average stereotypical sex rating of the nouns. The solid regression line for the English data

shows a 0 ms mismatch effect corresponding to a rating of approximately 5.5, which is in the neutral range. In contrast, the dashed regression line for the German-English data shows a 0 ms mismatch effect corresponding to a rating of approximately 8 (female), reflecting a neutralizing effect of the masculine gender associated with the –er. Figure 2 also shows that, for the bilingual data, one neutral item (i.e., *passenger*) exhibited a large negative mismatch effect (-342 ms). When this outlier is excluded from the analysis of the overall mismatch effect in the neutral condition, the average mismatch effect increases to 74 ms, which is marginally significant ($t(8) = 1.60$, $p = .07$, one tailed).
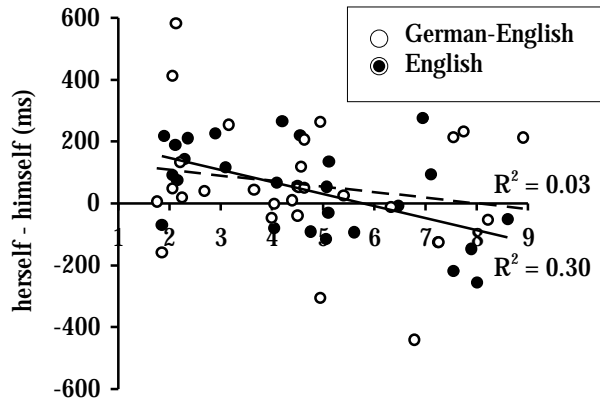


Figure 2: The 28 –er nouns' average mismatch effect plotted as a function of their average stereotypical sex rating (1 = always male; 9 = always female).

## Preliminary Model for the –ER Effect

To further examine hypotheses about the effects of the grammatical gender associated with the –er ending of nouns in German, we constructed a interactive activation connectionist (IAC) model. Figure 3 shows the relevant aspects of the model, which was fit to the data given in Table 2 below.[1] As usual, lines terminating in arrows indicate excitatory (positive) connections while lines terminating in filled circles indicate inhibitory (negative) connections. Only three basic levels of representation were included in the model: letter, lexical, and concept. The –er node at the lexical level corresponds to the masculine gender node, which becomes activated via excitatory connections with the "er" letter nodes. The "m-node" and "f-node" at the concept level represent the male and female sex properties, respectively, that are associated with the lexical-concept node. The weights of the positive connections (1 and 2) from the lexical-concept node to the m- and f-nodes reflect the associated distribution of male and female referents in the category corresponding to the lexical concept. These connections' weights are altered through experience with different exemplars (e.g., most butchers are male, and, therefore, a larger weight will be associated with the connection between the lexical concept

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[1]The complete model includes many additional concept and lexical nodes.

for *butcher* and the m-node). In the model, the weights for connections (1) and (2) ranged from 0.0 to 0.1 in increments proportional to the participants' average rating of a particular word. For *babysitter*, the weights of the connections to the m- and f-nodes were 0.017 (1/9) and 0.083 (8/9), respectively, based on the German-English bilinguals' average rating of 8 on a scale of 9 for this word.
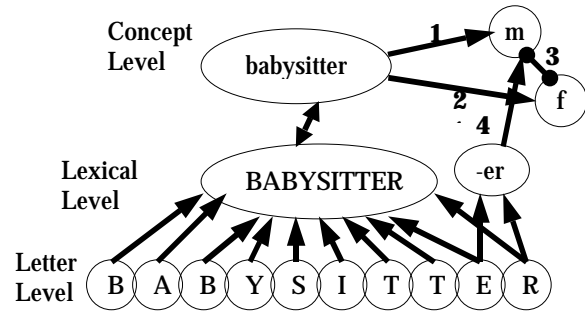


Figure 3: The IAC model of the representations of the word *babysitter* in German-English bilingual memory.

The connection (3) between the m- and f-nodes is inhibitory because the nodes are mutually exclusive. Finally, the excitatory connection (4) between the –er node and the m-node has a fixed weight of 0.035. The –er node and its connection to the m-node are absent from the IAC model of English monolingual memory.

Four versions of the IAC model were constructed, two representing bilingual memory and two representing monolingual memory. For each type of memory, one model simulated the processing of a stereotypical female –er noun and the other simulated the processing of a stereotypical male –er noun. The simulations involved presenting both the masculine and feminine reflexives for each type of noun. Specifically, external input was presented to the model for a time analogous to the average initial fixation duration on the –er nouns in the particular stereotypical sex condition (one update cycle corresponded to 100 msec). For the models of bilingual memory, the -er node also received excitatory input during this time. The input was then terminated, and the network was allowed to settle for about 7 cycles (a time corresponding to the time it took participants to read the text between noun and reflexive). Then, the activation resulting from reading the reflexive was simulated by adding external input and measuring the time (in terms of cycles) it took for the f- or m-node to reach an activation level greater than 0.8, which was stipulated as the level at which the network resolved any conflict between the reflexive's gender and the semantic sex of the antecedent –er noun.

Table 2 shows the English monolinguals' and German-English bilinguals' average fixation durations on the matching and mismatching reflexives for sentences with the four –er nouns rated most highly as stereotypically male and female, respectively. It also shows the total number of update cycles (scaled by 100) in the model before the f- or m-node's activation level exceeded the critical value of 0.8

for resolving the conflict between sex/gender agreement. The correlation between the simulation results and the data is marginally significant for the German-English data (p = 0.07) and significant for the English data (p = 0.01).

Table 2. Results of model simulations of the monolingual and bilingual total fixation durations on the reflexives.

| Stereotypical Sex/ Reflexive | English | | German-English | |
|---|---|---|---|---|
| | Data | Model | Data | Model |
| Male/herself | 542 | 600 | 1005 | 1000 |
| Male/himself | 477 | 500 | 715 | 600 |
| Female/herself | 457 | 400 | 923 | 700 |
| Female/himself | 668 | 800 | 1173 | 1200 |

## Conclusion

Our experimental results provide converging evidence for interactive processing of L1 and L2 lexical representations in bilingual memory. This evidence is consistent with results of other recent studies that also have used sentence comprehension tasks rather than individual word recognition or translation tasks (e.g., Spivey & Marian, 1999). Contrary to the results from translation tasks, we did not find evidence of independence of L2 processing in highly proficient L2 speakers. Independence may be particularly difficult to achieve when morphological endings are associated with gender in one language but not in the other. Furthermore, the difficulty may depend on whether the gender association occurs in the bilingual's first (native) or second language. Thus, a future study will examine whether native English speakers who are proficient L2 speakers of German also exhibit effects of an association of –er with masculine gender in German.

## Acknowledgments

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