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Effects of list composition and task demands on interlingual homograph processing in unbalanced trilinguals

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Research Article

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Abstract

We investigated how list composition (pure vs. mixed) and task demands (lexical decision vs. go/no-go) affect interlingual homograph (IH) processing in Dutch–English–French unbalanced trilinguals. Across six experiments with English (L2) as the target language, participants responded to identical Dutch-English homographs presented in three types of stimulus lists: a pure English (L2) list, a mixed Dutch–English (L1–L2) list, or a mixed English–French L2–L3 list. Linear mixed-effects analyses on response times and error rates revealed inhibition effects for IH, stronger in mixed lists and even stronger in go/no-go tasks. The results support the predictions of the BIA+ and Multilink+ models, highlighting the roles of list composition, language dominance, and task schema in modulating cross-language lexical activation effects. We argue that response mappings play a crucial role in shaping inhibition during multilingual lexical access.

Highlights

- Task and list context modulate homograph processing in trilinguals
- Go/no-go displays less cross-language interference than lexical decision
- Mixed lists amplify interlingual homograph inhibition effects
- Response accuracy reveals task-specific control dynamics in trilinguals
- Findings support BIA+/Multilink+ with task schema and response binding

1. Introduction

A German beer company used the slogan *Die Nacht wird Hell* ("The night will be bright"), in which the polysemous word *Hell* carried overtones of two meanings (light and blond) and was also the brand name of the pale beer in question. This slogan confused bilingual speakers of English and German, who linked the word *Hell* to its meaning in their native language English: They could not understand why an advertisement for beer would say that drinking results in an infernal night. Thus, it was confusing to the bilinguals that a word like *Hell* is orthographically identical but semantically different across languages. Such a word is called an interlingual homograph (IH) or a "false friend."

From a scientific perspective, at least two aspects of this anecdote are of general importance for word recognition research in multilinguals, that is, speakers of two or more languages. These aspects concern (1) the parallel activation of words from relevant languages (here L1 German and L2 English) and (2) the decision about what the intended word is. In the present article, these two issues are the focus of experimental investigation. In particular, we will be examining the performance of trilinguals in different language conditions (pure or mixed) and different tasks (lexical decision or go/no-go). Trilinguals are defined here as multilingual language users who have mastered three languages to such an extent that they can hold a simple conversation in all of them (cf. Grosjean, 1982).

A closer look at the anecdote suggests that, during word recognition process of the English–German bilinguals, the word form "Hell" resulted in the simultaneous activation of words in both German and English. This phenomenon has been called "*language non-selective lexical activation.*" Since the 1990s, a host of studies has supported this view that an input letter string can coactivate word candidates of multiple languages under many experimental circumstances (e.g., Finkbeiner, Almeida, et al., 2006; Finkbeiner, Gollan, et al., 2006; Ivanova & Costa, 2008, in the domain of speaking; e.g., Brysbaert & Duyck, 2010; Dijkstra, De Bruijn, et al., 2000; Dijkstra & van Heuven, 2002; Duyck et al., 2007; Kroll & Stewart, 1994; Libben & Titone, 2009; Poort & Rodd 2019; Van Wijnendaele & Brysbaert, 2002, in the domain of reading).

Furthermore, according to the anecdote, the bilinguals had difficulty in deciding which of the two activated representations was intended to be selected. Indeed, it has been experimentally

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established that factors like the language composition of the stimulus list, as well as the demands of the task at hand, affect the reaction times (RTs) of the bilinguals to IHs (e.g., De Groot et al., 2000; Dijkstra et al., 1998; Dijkstra, De Bruijn, et al., 2000; Dijkstra, Timmermans, et al., 2000; Hsieh et al., 2021; Lemhöfer & Dijkstra, 2004; Smits et al., 2006, 2009).

The anecdote thus exemplifies one of the most prominent issues in research on monolingual and bilingual word recognition: How are words activated, and how is their activation modulated in context-sensitive decision making and recognition?

1.1. Lexical activation in the native and non-native languages of multilinguals

The theoretical notion of "activation" is possibly the most important metaphor in current psycholinguistic research. Activation allows mental representations to become available in a continuous, time-dependent manner. Activation rates can be made dependent on stimulus properties (e.g., word frequency), processing context (e.g., stimulus list), and the demands of the task at hand (e.g., lexical decision or word naming). As activation is quantifiable, it has become an indispensable aspect of computational models, allowing the simulation of reaction times to items of different types under various circumstances. For instance, quantified activation is part and parcel of models of lexical processing in the monolingual domain, such as the IA model for word recognition by McClelland and Rumelhart, 1981, Rumelhart & McClelland, 1982 and in the bilingual domain, for instance, the related BIA+ model (Dijkstra & van Heuven, 2002) and Multilink+ (Dijkstra et al., 2019, 2023).

The Multilink+ model for word retrieval explicitly assumes not only that multilingual is language nonselective in nature, but also that it is *graded*, with lexical activation strength modulated by such factors as language dominance, relative language proficiency, age of acquisition, frequency of usage, task demands, and stimulus list composition.

With respect to language dominance, the model assumes that in trilinguals the native language (L1) is generally represented more strongly than the non-native languages L2 and L3, usually with L2 being stronger than L3. In the model, the strength of a language corresponds to the average baseline activation (resting-level activation) of its words. Said differently, each word in a language is characterized by an activation strength reflecting its subjective frequency of usage: L1 words have been used more often than L2 words, and those have been used more often than L3 words. The activation metaphor further assumes that a lower baseline activation for a word also results in a slower activation increase and later recognition.

Available empirical evidence is in support of these assumptions, although it is surprisingly scarce. In addition, studies have mainly incorporated *cognates* as stimulus materials, that is, translation equivalents with form identity. In a German (L3) lexical decision study with Dutch–English–German trilinguals, Lemhöfer et al. (2004) found that cognates in three languages (ECHO: German, Dutch, English) showed larger facilitation effects than cognates in two languages (KUNST: German, Dutch) relative to one-language control words (ZELT: German). This is evidence in favor of language nonselective and interactive effects between languages.

Van Hell and Dijkstra (2002) conducted a lexical decision study with Dutch–English and Dutch–English–French participants. In their study, the native language (Dutch) was the target language. Even when Dutch items were presented in an exclusively Dutch context, facilitation effects arose not only for Dutch–English cognates, but even for Dutch–French cognates if the participants were proficient enough in their L3. This is further evidence supporting language nonselectivity and graded effects. Bidirectional cognate effects have also been observed for trilingual children in a picture naming task (Poarch & Van Hell, 2012), showing a result pattern that also depended on language proficiency and dominance.

In the present article, we will test Multilink+'s account of nonselective graded activation effects by examining IH processing in Dutch–English–French trilinguals. In addition to being the weakest language of our participants, French (L3; a Romance language) could be considered linguistically more distant from Dutch (L1; a Germanic language) than English (L2; a Germanic language with considerable Romance influence). As such, relative language dominance and language distance might conspire to produce larger cross-language effects for English than for French in our Dutch–English–French trilinguals.

1.2. Relating lexical activation to stimulus list composition and task demands

According to the opening anecdote, the English–German bilinguals had difficulty in determining the intended reading of the word *Hell* even in a German context. This suggests that their L1 (English) was strong enough to overcome L2 (German) activation even under these adverse circumstances. This raises an important issue for empirical research: To what extent does language co-activation (language non-selectivity) in bilinguals depend on processing context – specifically, the composition of the stimulus list (pure vs. mixed language content) and the nature of the task?

Previous research on IHs (e.g., De Groot et al., 2000; Dijkstra et al., 1998, 2000; Lemhöfer & Dijkstra, 2004; Smits et al., 2006, 2009) has demonstrated that both stimulus list composition and task demands shape bilingual lexical access. These factors are discussed below, each followed by how they were operationalized in the present study.

1.2.1. Stimulus list composition: Pure versus mixed lists

Dijkstra et al. (1998) tested Dutch–English bilinguals using both pure (monolingual) and mixed (bilingual) stimulus lists in lexical decision tasks. In their first experiment, participants performed an English (L2) lexical decision task on items in a purely English list that included IHs and matched English controls. There was no evidence for a homograph effect: Response times were influenced only by English frequency, suggesting apparent selective access to the English lexicon. However, cognates (e.g., *tomaat–tomato*) were recognized faster than controls, indicating some level of nonselective activation.

In the second English lexical decision experiment, the mixed stimulus list contained both English (L2) and Dutch (L1) words. In this experiment, half of the nonwords (derived from English words) were replaced by such Dutch words, which also required a "no" response. Here, responses to IHs were slower and less accurate than controls, especially when the homograph had a high frequency in Dutch. This mixed-list inhibition effect provided strong evidence for language nonselectivity.

Largely comparable results and compatible conclusions were reached by De Groot et al. (2000) in a similar series of experiments that extended the study by Dijkstra et al. (1998). In their second experiment, Dutch–English participants had to make language-specific lexical decisions to a set of IHs and their controls, either in their L1 (Dutch) in one condition or in their L2 (English) in another condition. No homograph interference appeared in the L2

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lexical decision times or error rates, not even when the L1 reading had a higher frequency than the target reading. However, when L1 was the target language, and the L1 reading had low frequency, significant inhibition effects emerged. In their third experiment, L1 words were introduced into an L2 list by replacing one-third of the English-like nonwords with Dutch words. Now strong inhibition effects arose for the IHs, replicating Dijkstra et al.'s findings. The same outcome was obtained when pure L2 items were added as "no"-response trials in an L1 lexical decision task. Crucially, inhibition occurred when a "yes" response was required for a low-frequency homograph reading, reinforcing the notion of frequency-sensitive competition between languages.

We note that both studies reported null effects for homographs in a pure (one-language) list. Some earlier studies (e.g., Gerard & Scarborough, 1989; Soares & Grosjean, 1984) also reported null effects under those conditions. However, some other studies suggest the presence of covert activation of the non-target reading of the IH (Broekhuis et al., 2024; De Moor, 1998). In particular, in a lexical decision experiment with Dutch–English–French trilinguals, Broekhuis et al. (2024) failed to observe significant IH effects for Dutch–English and English–French homographs in a pure English language list, but further analysis revealed the hidden presence of an inhibitory effect for Dutch–English homographs that reflected a unique contribution of L1 frequency. Furthermore, De Moor (1998) observed that the L1 reading of an L1–L2 homograph could still produce semantic priming in subsequent trials, indicating the presence of covert activation in the absence of overt interference. In line with these findings, a review of the relevant literature Bailey et al. (2024) conclude that the degree and direction of cross-language effects in bilinguals are task and context-sensitive, and may manifest as ubiquitous facilitation and/or context-dependent interference effects. Therefore, when IHs are processed in pure lists, interference effects might mask any underlying facilitation by co-activation.

Furthermore, Dijkstra, De Bruijn et al. (2000) demonstrated that inhibition only emerged when participants had experience linking a particular language to a "no" response. Mere expectation was insufficient: Participants only showed homograph effects once they had encountered L1 words in the (second half of the) lexical decision task, regardless of whether they had been forewarned.

Maximal inhibition for IHs was obtained when L1–L2 homographs were presented in an L1–L2 mixed list, where pure L1 and pure L2 words were intermixed, and when L2 was the target language. We interpret this as a consequence of this mixed stimulus list causing a strong response conflict in the decision process of homographs, resulting in a sizeable inhibition effect. Importantly, this inhibition arises because participants learned to link the "no" response to the L1 words during the experiment, not because they acted on expectations.

Together, these studies show that inhibition effects for IHs primarily (but not exclusively) occur in mixed-language lists and when the target reading is low in frequency.

1.2.2. Stimulus list composition and the present study

The influence of IHs thus depends on the list context in which they are presented – whether pure or mixed. Interestingly, a language known by a multilingual speaker might exert effects even when it is not actually present in the experiment at hand. Earlier studies only explored inhibition effects in pure lists or mixed lists with languages matching the homograph. We extended this by examining mismatched conditions, such as presenting a Dutch–English homograph like *kind* (meaning "child" in Dutch) in an English–French lexical decision and go/no-go task. This helps clarify how list composition impacts decision criteria.

Three list types were used: (a) in the pure L2 list, "yes" (or "go") trials were monolingual English words and "no" (or "no-go") trials were English-based nonwords; (b) in the L1–L2 list, "yes" trials were English words and "no" trials were Dutch words; (c) in the L2–L3 list, "yes" trials were English words and "no" trials were French words. We note that, while in condition (a) a lexical decision is made, strictly speaking, conditions (b) and (c) ask for a language decision (due to the absence of nonwords in the list). Relative to the nonword condition in (a), conditions (b) and (c) therefore allow us to assess the pure effect of, respectively, adding L1 or L3 words in the L2 stimulus list. In the L2–L3 list condition, Dutch–English (L1–L2) homographs are tested in an English–French context. Since French is not one of the homograph's source languages, any effect would stem from decision processes, not lexical activation. Importantly, with L2 as the target language, the inclusion of L1–L2 homographs allowed us to examine their processing in pure L2, mixed L1–L2, and mixed L2–L3 lists; in other words, in lists without contextual competition from other languages, lists with a relatively strong and direct competition (from L1), and lists with a relatively weak and indirect competition (from L3). We did not include L2–L3 homographs in the various lists, because they would have required the addition of a considerable number of control words and nonwords (making the experiments unacceptably long). As a consequence, the effect of L3 on the processing of individual items is only assessed indirectly through changes in list composition rather than directly through manipulation of L2–L3 lexical competition.

Three possible outcomes were predicted for the L2–L3 list. First, participants might treat all non-target languages alike. The "no" response would not only be linked to the French language but to all non-target languages (here: Dutch L1). This might induce generalized inhibition due to response conflict – similar to the L1–L2 condition. Second, if participants link the "no" response only to French, Dutch readings might not interfere. This would resemble the pure L2 condition with no inhibition. Third, participants might face difficulty assigning a clear decision rule to the homograph, producing smaller inhibition than in L1–L2 but more than in the pure L2 list. Comparing the L2–L3 results to both the pure L2 and L1–L2 lists allows us to determine whether inhibition there will resemble that in pure L2 lists and whether it is as strong as in L1–L2 lists or smaller.

1.3. Task demands: Lexical decision versus go/no-go task

Task demands are known to modulate homograph effects. In a generalized lexical decision task, mixing Dutch (L1) words, English (L2) words, and nonwords, Dijkstra et al. (1998) required bilingual Dutch–English participants to respond "yes" to both L1 and L2 words and "no" to nonwords. This setup produced facilitation for IHs, suggesting access to the fastest available reading (regardless of language), and revealing frequency effects in both languages.

In contrast, Dijkstra et al. (2000) used a go/no-go task, where participants responded only to target-language words. This task emphasized selective attention and inhibition. If participants could fully suppress irrelevant languages, no interference should occur. However, frequency-sensitive inhibition effects persisted, showing that even under optimal conditions for language selectivity, non-target language activation could not be suppressed.

In both lexical decision and go/no-go tasks, the higher-frequency reading was activated first. If it was in the non-target language, it

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delayed access to the target reading – especially when the latter was low-frequency. Inhibition effects were largest (>200 ms) when target readings had low frequency and non-target readings were frequent.

Thus, although lexical decision and go/no-go tasks both yielded evidence in favor of language nonselectivity, their result patterns were quite different, and the go/no-go task elicited stronger inhibition due to increased cognitive demands.

1.3.1. Task demands in the present study

To test task effects, we directly compared the standard lexical decision task and the more cognitively demanding go/no-go task. The go/no-go task requires both conflict monitoring and response inhibition (Barac et al., 2016; Donkers & van Boxtel, 2004; Nieuwenhuis et al., 2003), making it ideal for isolating decision-level effects.

Both tasks were crossed with the three list types in an orthogonal design – an innovation in this line of research. Based on prior findings (Dijkstra, Timmermans, et al., 2000), we expected stronger inhibition effects in the go/no-go task when homographs had high frequency in L1. We predicted longer RTs and greater inhibition in the go/no-go task, particularly in the L1–L2 list, and possibly in the L2–L3 list as well.

2. The present study

We conducted six experiments using English (L2) as the target language. Different groups of trilingual participants completed either a lexical decision or a go/no-go task, with three types of list composition: pure L2, L1–L2, and L2–L3. The L2–L3 condition, never previously tested, allows us to isolate decision-based interference. This fully crossed design enables us to disentangle lexical activation from decision-level effects and provides insight into how multilinguals manage language co-activation under varying contextual demands.

Any observed interaction between task and list type will reveal how deeply task demands influence lexical access and response decision processes in trilinguals. If lexical access is nonselective, all three languages should be activated in both tasks, regardless of differing proficiency (Dutch = L1, English = L2, French = L3). More proficient languages should activate more quickly, creating a gradient from L1 to L3.

3. Method

3.1. Design

In all experiments, L2 was explicitly presented as the target language. In lexical decision Experiment 1, no-responses were given to nonwords, and in Experiments 2 and 3, no-responses were given to L1 and L3 words (replacing the nonwords), respectively. In the go/no-go task, participants did not give a "no" response as a negative answer, but waited for the next item to appear ("no-go").

3.2. Participants

A different group of participants took part in each experiment. All were students in Linguistics at the University of Antwerp and had normal or corrected-to-normal vision. They were all unbalanced Dutch–English–French trilinguals: native speakers of Dutch who were proficient in English and had a good knowledge of French. Dutch was the dominant language of daily communication, used at home, at university, and in social interactions. English was learned as a foreign language at secondary school for at least 6 years and was used regularly, particularly in academic contexts. French had also been studied as a foreign language during secondary education, but in comparison with English, it was typically used only occasionally in informal situations outside the university context.

After the experiment, language background information was collected using a short language background questionnaire, in which participants reported their age of acquisition, self-rated proficiency, and frequency of use for each language; see Supplementary Material for their global characteristics (unfortunately, following a relocation of offices, the paper questionnaires completed by individual participants are no longer available). A small number of participants whose native language was not (only) Dutch were excluded from analyses.

The general characteristics of participants in all six experiments are given in Table 1. Participant characteristics are very similar to those in earlier studies by the research group (e.g., Smits et al., 2006; Smits et al., 2009). We decided to test somewhat larger participant samples in the go/no-go task than in lexical decision, because information on the sensitivity of the go/no-go task with respect to homograph processing was lacking (cf. Dijkstra, Timmermans, et al., 2000). Thus, the experiments were designed primarily to evaluate within-task rather than between-task effects.

3.3. Stimulus materials

The critical items in all experiments consisted of 20 Dutch–English (L1–L2) IHs, selected from the CELEX lexical database (Baayen et al., 1995). Word frequencies were verified using the SUBTLEX-UK and SUBTLEX-NL databases (Keuleers et al., 2010; van Heuven et al., 2014), and Zipf values were calculated using the formula $log_{10}(frequency\ per\ million \times 1000)$ (van Heuven et al., 2014). The Dutch meanings of the homographs had higher frequencies than their English counterparts.

To assess semantic and phonological overlap as well as familiarity, 10 students from the same population as the experimental participants rated the homographs on three scales (1 = "none" to 5 = "very strong"). Twenty homographs were selected based on having clearly distinct meanings, different pronunciations across languages, and adequate familiarity to university students (see the Appendix).

All homographs had a higher frequency in Dutch (M = 4.77, SD = 0.53, range: 3.79–5.76) than in English (M = 4.03, SD = 0.54, range: 3.33–5.60). It is thus likely that the Dutch reading of each homograph would reach its activation threshold first. For each homograph, a matched English control word was selected with the same number of letters (M = 3.90) and a comparable frequency (M = 4.10, SD = 0.62, range: 3.02–5.29). A t-test confirmed that homographs and controls did not differ significantly in frequency (t = 0.19, p > .1). In addition, 10 English dummy words were included, matched in frequency and length with the other English items. These dummy items were included at the beginning of each experimental block to familiarize participants with the task and stabilize response behavior prior to the presentation of the critical experimental items. Fifty English-like nonwords were generated using the Wuggy pseudoword generator (Keuleers & Brysbaert, 2010), derived from real English words and matched in length with the homographs and controls.

In total, each experiment contained 100 items: 20 Dutch–English homographs, 20 English control words, 10 English dummy words, and 50 non-target items (nonwords, or words from Dutch or French, depending on list composition). Stimulus materials were kept the same for both tasks. For all lists, correct responses were "yes" or "go" in half of the cases and "no" or "no-go" in the other half. Nonwords, present in pure L2 lists, required a "no" decision in Lexical Decision, and a "no-go" decision in Go/no-go.

The experimental list consisted of one practice block followed by four experimental blocks of 20 trials each.

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Table 1. Overview of participant characteristics per experiment, task, and language context

	Task	Participants	Number females	Mean age (range in years)	Number right-handed	Experience (in years)
Exp. 1	LDT in L2	24	22	22.3 (19–24)	23	9.7
Exp. 2	LDT in L1 + L2	24	18	20.3 (19–23)	22	8.8
Exp. 3	LDT in L2 + L3	24	17	20.2 (19–23)	22	8.7
Exp. 4	GNGT in L2	24	20	21.6 (19–31)	22	9.7
Exp. 5	GNGT in L1 + L2	31	27	21.4 (19–28)	26	9.7
Exp. 6	GNGT in L2 + L3	30	25	22.4 (19–31)	26	10.5

Note: LDT = lexical decision task; GNGT = go/no-go task. Exps. 2, 3, 5 and 6 involve language decisions. Experience = Mean experience with English in years; mean experience with French is 1 year less for each participant.

To construct an English–Dutch list, the 50 nonwords were replaced by 50 monolingual Dutch words. These were matched item-by-item with the IHs and English controls, both in letter length (M = 3.90) and word frequency. Frequency matching was statistically confirmed with both the homographs (t = 0.22, p = .83) and the English controls (t = 1.26, p = .23). The mean frequency of the Dutch words was 43 per million (log frequency M = 1.23).

In the English–French list, the 50 nonwords were replaced by 50 monolingual French words. These were also matched in length (M = 3.90) and word frequency with the IHs and English controls. None of the French words contained letters not present in English (e.g., accented vowels or French-specific consonants such as "ç"). Frequencies were matched using the Lexique2 database (New et al., 2007), and a t-test confirmed no significant frequency difference between French words and their matched English items (t = 1.41, p = .17).

3.4. Procedure

The experiment was conducted on Dell Optiplex 380 computers with 15″ monitors in a dimly lit room. Stimuli appeared centrally on the screen, and response times were recorded with millisecond accuracy using the DMDX software (Forster & Forster, 2003). Participants responded using Logitech "Wingman Precision" game controllers: the front buttons for responses and the "start" button to initiate each block.

Instructions were given in English to avoid activating non-target languages. These standardized instructions were used across all six experiments and informed participants to make "yes" or "go" responses to English (L2) words, and "no" or "no-go" responses to all other items. Crucially, the instructions did not specify the nature of the items requiring a negative or no-go response – i.e., nonwords (Experiments 1 and 4), Dutch L1 words (Experiments 2 and 5), or French L3 words (Experiments 3 and 6).

Participants were instructed to respond as quickly and accurately as possible using their dominant hand for "yes" or "go" responses. Each session began with 12 practice trials, none of which appeared in the experimental blocks. Homographs and control words were evenly distributed across blocks. Short breaks were provided after each block.

Each trial began with a fixation cross (+) displayed for 500 ms, followed by a word or nonword that remained on-screen until the participant responded or until 2,500 ms elapsed. The next trial started 500 ms after a response or timeout.

4. Results

All experiments were analyzed following the same procedure. First, the data were cleaned for all six experiments. Data of participants whose error rates exceeded 15% for the whole stimulus list were excluded from analysis (n = 8). Two IHs (*slang*, Dutch "snake," and *hoop*, Dutch "hope") and their English controls (*birch* and *fowl*) were removed from the data in all experiments because more than 50% errors were made on the control words in all six experiments. RTs shorter than 300 ms and longer than 1,500 ms (outliers) were excluded (n = 140).

The remaining data points (n = 5,364) for the IHs and their controls (the 18 remaining pairs) were used for the RT and error analyses. There were 4,846 (90.34%) correct responses for the RT analysis and 518 error responses (9.66%) for the error analysis. Table 2 reports the mean RTs and error rates for IHs and controls across all six experimental conditions, defined by Task (Lexical Decision Task [LDT] vs. Go/no-go Task [GNGT]) and List Composition (Pure L2, Mixed L1–L2, and Mixed L2–L3). Overall, RTs for IHs were consistently longer than those for control words, indicating robust inhibitory effects of IHs across conditions.

A comparison of the logarithmic and inverse transformations showed that the latter was more successful in reducing non-normality. All RTs were transformed with the formula −1000/RT.

4.1. Reaction times

Reaction times and error rates were analyzed by means of linear mixed models with fixed and random factors (see, e.g., Baayen et al., 2008). All analyses were conducted in R (R Core Team, 2014) using the LMM in the lmerTest package (Kuznetsova et al., 2016), which includes fixed- and random-effects parameters.[1]

During model-building, we started with a model that included only the two random-effect predictors, that is, participants and items, and added one fixed-effect factor at a time (Baayen et al., 2008). One by one, we added the factors Word Type, List Composition, and Task. To compare two models that differed only in the presence or absence of a fixed-effect factor, we used likelihood ratio tests with α = 0.05 as the level of significance. If the model with an extra fixed factor was significantly better than the simpler model, we proceeded with the more complex model and followed the same procedure for the next fixed effect. If no significant difference was found, the simpler model was adopted. The final model is provided in Table 3.

In the pure L2 list, we observed a significant homograph inhibition effect (β = 0.0550, SE = 0.02142, t = 2.57, p < .05). Participants

[1]To investigate the relationship between the size of the homograph effect and response speed, additional analyses are possible, such as ex-Gaussian analyses (Balota et al., 2008) and Quantile analyses of RT (Balota et al., 2008, Balota & Yap, 2011; Rouder et al., 2005). Furthermore, delta plots may provide further insights into the data (e.g., Roelofs & Piai, 2017; Roelofs et al., 2011). For an application of such analyses, see Biloushchenko (2017).

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Table 2. Mean reaction time (milliseconds) and mean error rate (percentage) for interlingual homographs (IHs) and control words as a function of list composition and task

Task	Condition	Reaction time		Error rate	
		IH	Control	IH	Control
Lexical decision	Pure L2	678 (192)	647 (153)	7.0 (25.6)	4.1 (19.9)
	L1–L2	702 (203)	594 (149)	33.1 (47.1)	3.5 (18.3)
	L2–L3	673 (205)	648 (186)	14.8 (35.6)	6.7 (25.1)
Go/no-go	Pure L2	740 (230)	670 (177)	19.1 (39.3)	10.1 (30.2)
	L1–L2	781 (249)	607 (158)	24.1 (42.8)	1.7 (13.0)
	L2–L3	666 (231)	595 (160)	12.3 (32.9)	2.4 (15.3)

Note: Standard deviations are reported in parentheses.

responded more slowly to IHs (M = 678 ms, SD = 192) than to control words (M = 647 ms, SD = 153), yielding an inhibition effect of 31 ms.

The inhibition effect was significantly stronger in the L1–L2 list (i.e., English–Dutch), as shown by a strong interaction between Word Type and List Composition (β = 0.2099, SE = 0.02937, t = 7.15, p < .001). In this condition, IHs were responded to with an average RT of 702 ms (SD = 203), compared to 594 ms (SD = 149) for controls, resulting in an effect of 108 ms.

In contrast, no significant difference in IH interference was observed between the L2–L3 list (i.e., English–French) and the pure L2 list (β = 0.0034, SE = 0.02805, t = 0.12, p > .1). IHs were responded to at 673 ms (SD = 205), and controls at 648 ms (SD = 186), yielding a comparable inhibition effect of 25 ms.

For all three List Compositions, IHs also elicited higher error rates than control words. Figure 1 shows the RT and error differences across the conditions. This was particularly evident in the L1–L2 condition (e.g., 33.1% vs. 3.5% in the LDT), reflecting increased lexical conflict due to language overlap. The inclusion of PreviousRT as a covariate significantly improved model fit (β = 0.0002, t = 8.63, p < .001), confirming the presence of trial-to-trial dependencies (cf. Baayen & Milin, 2010).

Importantly, while a significant interaction was found between Word Type and Task (β = 0.0907, SE = 0.02465, t = 3.68, p < .001), there was no significant three-way interaction between Word Type, List Composition, and Task. This indicates that the pattern of IH interference was comparable across tasks, although numerically stronger in the go/no-go task.

As shown in Table 2, IH inhibition effects were consistently larger in the go/no-go task than in the LDT. For example, in the L1–L2 list, RTs averaged 781 ms (SD = 249) for IHs and 607 ms (SD = 158) for controls (effect = 174 ms). In the pure L2 list, the inhibition effect was 70 ms (740 vs. 670 ms), and in the L2–L3 list, it was 71 ms (666 vs. 595 ms). These differences mirrored the LDT pattern but were amplified in magnitude.

To assess whether the inhibition effect in the English–Dutch list was significantly larger than in the English–French list, the model was re-run with the English–Dutch list as reference. The interaction between Word Type and List Composition remained highly significant (β = −0.2065, t = −7.51, p < .001), confirming that the English–Dutch list elicited stronger IH interference than the English–French list, independent of task.

Finally, homograph inhibition effects were statistically significant in each of the six individual experiments, as assessed by re-leveling the reference levels. For the LDT, homograph effects were significant in all three list conditions: pure L2 (t = 2.57, p = .01), L1–L2 (t = 11.82, p < .001), and L2–L3 (t = 2.83, p = .005). The same pattern held for the go/no-go task: pure L2 (t = 5.14, p < .001), L1–L2 (t = 13.96, p < .001), and L2–L3 (t = 6.17, p < .001).

4.2. Errors

The generalized linear mixed-effects analysis is reported in Table 4. As the fixed-effects estimates indicate, the homograph effect in the pure L2 list was not significant (β = 0.3763, SE = 0.2497, z = 1.51, p = .13), with error rates of 4.1% (SD = 19.9) for controls and 7.0% (SD = 25.6) for IHs in the LDT.

In contrast, the homograph effect was significantly larger in the L1–L2 list (i.e., English–Dutch), with a strong interaction between Word Type and List Composition (β = 2.5420, SE = 0.3248, z = 7.83, p < .001). IHs elicited 33.1% errors (SD = 47.1), compared to only

Table 3. Model estimates for the fixed-effect predictors in the RT analysis of the Dutch–English homographs across tasks and list composition

Model: RT ~ Task × List Composition × Word Type + PreviousRT + (1 | Subject) + (1 | Item)					
	Estimate β	$SE\ \beta$	df	t	p
Intercept	−1.7700	0.05036	201.8	−35.15	<.001***
Homograph	0.0550	0.02142	287.4	2.57	<.05*
English–Dutch	−0.1466	0.06273	145.0	−2.34	<.05*
English–French	−0.0082	0.06259	143.8	−0.13	>.10
Go/no-go task	0.0185	0.06512	161.4	0.28	>.10
Previous RT	0.0002	0.00002	2987	8.63	<.001***
Homograph × English–Dutch	0.2099	0.02937	2885	7.15	<.001***
Homograph × English–French	0.0034	0.02805	2880	0.12	>.10
Homograph × go/no-go	0.0907	0.02465	2891	3.68	<.001***
English–Dutch × go/no-go	0.0422	0.08839	148.3	0.48	>.10
English–French × go/no-go	−0.1803	0.08740	146.6	−2.06	<.05 *

Note: Significances: *p < .05; **p < .01; ***p < .001.

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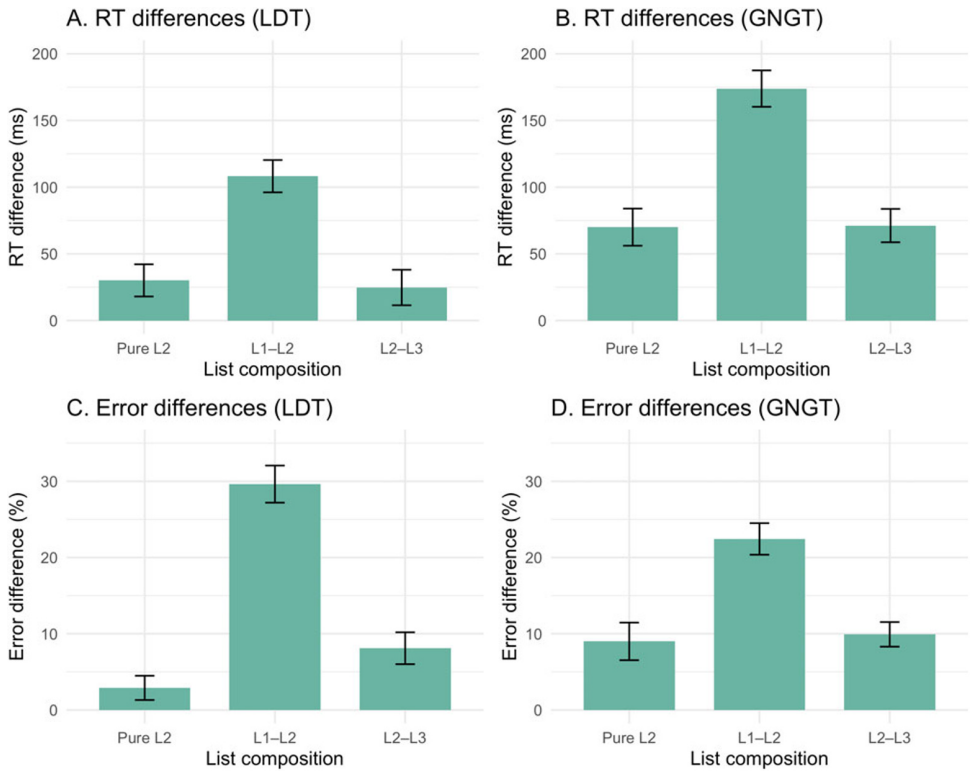


Figure 1. Differences in mean reaction times and error rates for interlingual homographs (IHs) relative to control words in the lexical decision (LDT) and go/no-go (GNGT) tasks. Standard errors are indicated.

Table 4. Model estimates for the fixed-effect predictors in the error analysis of the Dutch–English homographs across tasks and list composition

Model: Error ~ Task × List Composition × Word Type + PreviousRT + (1 | Subject) + (1 | Item)				
	Estimate β	*SE* β	*z*	*p*
Intercept	−3.6327	0.3515	−10.33	<.001***
Homograph	0.3763	0.2497	1.51	.132
English–Dutch	−0.2115	0.3791	−0.56	.577
English–French	0.3124	0.3546	0.88	.378
Go/no-go task	0.5269	0.3439	1.53	.126
Homograph × English–Dutch	2.5420	0.3248	7.83	<.001***
Homograph × English–French	0.8579	0.2920	2.94	.003**
Homograph × go/no-go	0.3567	0.2601	1.37	.171
English–Dutch × go/no-go	−2.0161	0.4242	−4.75	<.001***
English–French × go/no-go	−1.8561	0.4301	−4.32	<.001***

Note: The intercept refers to control words in the pure English condition in the lexical decision task. Significances: *p < .05; **p < .01; ***p < .001.

3.5% (*SD* = 18.3) for controls in the LDT. A similar pattern was found in the L2–L3 list (i.e., English–French), where IHs produced significantly more errors than controls (β = 0.8579, *SE* = 0.2920, z = 2.94, p = .003), with means of 14.8% (*SD* = 35.6) and 6.7% (*SD* = 25.1), respectively.

The model selection process yielded the same best-fitting structure as in the RT analysis: three second-order interactions (Word Type × List Composition, Word Type × Task, and List Composition × Task) were retained.

To assess whether the error increase in the L1–L2 list was significantly larger than in the L2–L3 list, the model was re-run with the L1–L2 list as reference. This comparison yielded a highly significant difference (β = −1.68, z = −5.27, p < .001), confirming that participants made more errors in response to IHs in the English–Dutch list than in the English–French list.

No significant differences in overall error rates were found between the two tasks. There was neither a main effect of Task on control items (z = 1.53, p = .13) nor a significant interaction between Task and Word Type (z = 1.37, p = .17), suggesting that the homograph effect in error rates was consistent across both LDT and go/no-go situations.

Finally, we examined whether the homograph effect reached significance within each of the six experimental conditions. In the Lexical Decision task, homograph effects were significant in the L1–L2 (z = 11.47, p < .001) and L2–L3 (z = 5.53, p < .001) lists, but not in the pure L2 condition (z = 1.51, p = .13). In the go/no-go task, homograph effects were significant in all three lists: pure L2 (z = 3.35, p = .0008), L1–L2 (z = 10.48, p < .001), and L2–L3 (z = 5.86, p < .001).

5. General discussion

This study investigated the interactive effects of stimulus list composition and task demands in trilinguals. After summarizing our main findings for these two factors separately, we will interpret

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their joint effects within a theoretical activation framework for trilinguals, thus extending the Multilink+ and BIA+ models for bilingual word recognition (Figure 2).

5.1. Stimulus list composition

With respect to the effects of stimulus list composition, we will first discuss how pure L2 versus mixed-list composition modulates inhibition effects for L1–L2 homographs in L2 lexical/language decision and go/no-go tasks. Next, as a more specific question, we investigate whether performance in a mixed L1–L2 list resembles that in a pure L2 list, a mixed L2–L3 list, or falls in between. We will consider not only general activation effects due to language nonselective access, but also the effect of stimulus–response bindings of words of different languages.

5.1.1. Comparing effects of pure L2 and mixed lists on L1–L2 homograph processing

As a consequence of language nonselective lexical activation, we predicted lexical selection problems for L1–L2 IHs that would result in an inhibition effect relative to L2 control words in an L2 task. This effect should arise not only in pure L2 lists, but also when the items are embedded in lists that mix one-language words from L2 or L3. In all situations, the strong L1 reading of the IH should be coactivated with the weaker L2 target reading, leading to L1-on-L2 interference. This reasoning should hold for both lexical decision and go/no-go tasks.

Consistent with this account, all six experiments revealed significant inhibition effects for L1–L2 homographs compared to controls – in both RTs (LDT: 108 ms, go/no-go: 174 ms) and error rates (LDT: 29.60%, go/no-go: 22.40%) – except in the pure L2 list's error rates for the English lexical decision task. These findings replicate earlier work on L1–L2 lists (e.g., Dijkstra et al., 1998, 2000) and show that inhibition is greater in L1–L2 lists compared to pure L2 lists.

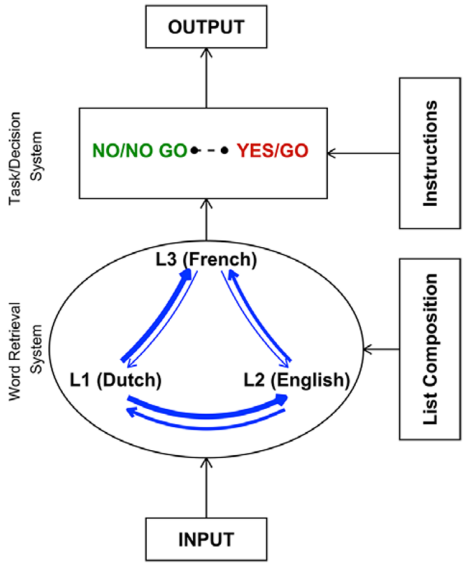


Figure 2. Extended theoretical framework of the Multilink+ and BIA+ models for multilingual word recognition, based on the present study. The figure shows lexical representations of different languages in the word retrieval system and potential task-dependent response conflict for lexical decision (LDT) and go/no-go (GNGT) tasks in the task/decision system. Leverage points of list composition (a form of linguistic context) and instructions are indicated.

We conclude that homographs were consistently responded to more slowly than control words across tasks and list types due to the coactivation of the dominant L1 reading. For our unbalanced trilinguals, the L1 readings were objectively and subjectively more frequent than L2 readings (and L3 readings). Notably, inhibition effects were observed even in pure L2 lists, without any L1 words present.

5.1.2. Comparing effects of pure L2 lists, mixed L1–L2 lists, and mixed L2–L3 lists

In our study, we were able to examine how the processing of L1–L2 interlingual homographs varies across language contexts involving languages that differ in relative strength in both lexical decision and go/no-go tasks. We therefore examined whether performance in a mixed L1–L2 list resembles that in a pure L2 list, a mixed L2–L3 list, or falls in between. Since L1 is stronger than L2, and L3 is weaker, we expected a larger homograph inhibition effect on RTs in L1–L2 lists than in either pure L2 or L2–L3 lists, with little difference between the latter two. We did indeed observe this pattern across both tasks. In errors, inhibition was greater in L1–L2 and L2–L3 lists than in pure L2, but the effect was still strongest in the L1–L2 list.

Why did we observe this effect in both tasks? The lexical decision and go/no-go tasks have in common that participants learned to associate "yes" or "go" responses with L2 items and "no" or "no-go" responses with non-L2 items. Although the Dutch (L1) IH readings were not response-relevant when L2 was the target, these dominant readings would still be quickly activated, possibly triggering initial misclassification and response conflict. Early on, these homographs might be classified as non-members of L2, calling for a negative response ("no, this is not an L2 word"); but as soon as the L2 reading of the homograph became sufficiently active, the positive response ("yes, this is an L2 word") would prevail. It would require time to resolve this response conflict.

In L1–L2 lists, the conflict was further amplified: The presence of many L1 items in these lists reinforced the link between L1 and the "no" response. Thus, homographs in these lists created greater conflict than in L2–L3 or pure L2 lists, resulting in larger homograph inhibition effects.

In contrast, we found that inhibition effects in L2–L3 lists resembled those in pure L2 lists, but were significantly smaller than in L1–L2 lists. We propose that this finding can be explained by a combination of two factors: (1) On a particular trial, the weaker L3 words (or L3 readings of IHs) are likely to have been activated more slowly than both L2 and L1 words (or their readings in homographs), and (2) the weaker L3 words may have led to a weaker response binding over the experiment as a whole. In addition to activation differences between L2 and either L1 or L3, this weaker response binding relative to that of the L1 may underlie the absence of a difference between L2–L3 and L2 lists. This hypothesis should be tested in future research (e.g., by including L2–L3 homographs), also taking into account the number of participants in the two tasks in the present study was not directly comparable.

5.2. Task demands

To assess the effect of different task demands, we also directly compared homograph effects across the lexical decision and go/no-go tasks. The latter task likely involves more complex decision-making and attentional control, potentially amplifying inhibition effects. At the same time, the influence of list composition might remain consistent across tasks.

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Prior studies (Dijkstra, Timmermans, et al., 2000; Donkers & van Boxtel, 2004; Nieuwenhuis et al., 2003) have linked go/no-go tasks to conflict monitoring. In our data, RTs did not differ significantly between tasks in the pure L2 or L1–L2 lists, and were slightly faster in the L2–L3 list for go/no-go ($t = -2.06$, $p = .04$). However, stronger task differences emerged in error rates (see Table 4): Significantly fewer errors occurred in the go/no-go task in the L1–L2 and L2–L3 lists (both $p < .0001$).

These results support the idea that go/no-go tasks promote more cautious processing and increased conflict monitoring by the participants, likely heightening the duration of response conflict resolution and thereby increasing homograph inhibition in RTs. Indeed, the homograph effect was larger in the go/no-go task, though only in RTs (see Table 3).

We note that the larger homograph effects in the go/no-go task did not change the pattern in the homograph effects among the three lists in the lexical decision task, as there was no third-order interaction between Word Type, Experimental Task, and List Composition.

We conclude that, compared to lexical decision, go/no-go tasks induced stronger inhibition effects due to more complex decision and response requirements. However, the relative pattern across list types was unchanged from the lexical decision task.

5.3. An activation-based account of list and task effects in word retrieval

Our findings for IHs in pure and mixed list conditions in trilinguals are in line with an extension of a theoretical account that emphasizes interactions between lexical activation, stimulus list composition, and task-specific decision mechanisms. Such an account has been formulated in several papers over the years by Dijkstra and colleagues (Dijkstra et al., 2005; Peeters, et al., 2019; Smits et al., 2006; Vanlangendonck et al., 2020). This account is compatible with the BIA+ model for bilingual word recognition (Dijkstra & Van Heuven, 2002) and has even been partially simulated with the Multilink+ model (Dijkstra et al., 2019, 2023).

In the account, list and task effects are ascribed to the workings of a task/decision system that relates lexical activation to the responses required in the task at hand (the "task demands"). Stimulus–response bindings are established when lexical representations are consistently linked to "yes" or "no" responses.

Underlying this account is the assumption of language nonselective lexical access in both the lexical decision and the go/no-go task. Even in a pure L2 list, the Dutch (L1) counterparts of English (L2) IHs are activated, which, in the study at hand, resulted in significantly slower responses and more errors to IHs than to control words. The competition between the two readings of an IH is stronger in a mixed list, due to the presence of words from both languages. In the present study, this led to an increased interference effect for both RTs and errors in the L1–L2 condition. Whether the associated increase in the IH interference effect should be ascribed exclusively to decision-level effects or also to increased bottom-up lexical activation in the non-target language (L1 Dutch) was not directly investigated in our research, which focused on the task-specific links between activated lexical items and possible responses.

More specifically, in the pure L2 list condition of the language-specific lexical decision task, items of the target language are explicitly bound to a "yes" response; non-target language items are infrequent and not relevant for responding. In contrast, in a mixed stimulus list, the frequently occurring items of the non-target language (e.g., L1 in L1–L2 lists) are systematically tied to the "no" response (as proposed by Dijkstra, 2005). A strengthening of these bindings leads to increasing conflict when a homograph activates a non-target reading. Analogous types of this account have been proposed for lexical decision and word naming (Smits et al., 2006, 2009).

6. Conclusion

Our trilingual experiments support the view that word retrieval involves dynamic interactions among language-dependent lexical activation, list composition, and task demands. Words from all three languages can be coactivated, with stronger activation for L1 than for L2 or L3. The strength of inhibition effects in L1–L2 IHs depends on (a) the relative dominance and associated activation of the non-target reading, which is co-dependent on the relative the *language strength of a language* and their associated *subjective frequencies of usage* (L1, L2, or L3), (b) how *list composition* influences response bindings, and (c) the complexity of the *task schema* required to produce the appropriate response (cf. Green, 1998).

In all, we showed in detail that homograph inhibition reflects lexical competition and decision-level processes, and that its magnitude varies with language strength and task constraints. Our findings extend the theoretical account based on the BIA+ and Multilink+ models (Dijkstra & Van Heuven, 2002; Dijkstra et al., 2019, 2023) by clarifying how stimulus- and task-related factors jointly modulate multilingual word recognition. For instance, they suggest that associations between language membership and response choice may be fine-tuned over trials depending on language context, and that task demands may involve the setting of an inhibition parameter that reflects conflict monitoring and response suppression in the task at hand. It is both reassuring and revealing that mechanisms proposed for bilingual processing extend to trilinguals performing different tasks.

Supplementary material. For all data and other supplementary material accompanying this article, please visit: https://osf.io/phqc6/?view_only=a984a84392c347f78eb3800d72790f41.

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Competing interests. The authors declare none.

Ethics statement. All procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

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A. Appendix

Table A1. Interlingual homographs (IHs) and control words with their mean Zipf frequencies and the Dutch meaning of each homograph

Dutch-English homographs					English controls		
Word	Meaning	Length	English Zipf	Dutch Zipf	Word	Length	English Zipf
Boot	Boat	4	4.43	4.98	Toad	4	3.69
Brand	Fire	5	4.68	4.65	Spoon	5	4.29
Breed	Wide	5	4.26	3.79	Towel	5	3.87
Brief	Letter	5	4.26	4.87	Broad	5	4.22
Hoop	Hope	4	3.59	5.57	Fowl	4	3.43
Kin	Chin	3	3.54	3.89	Row	3	4.75
Kind	Child	4	5.6	5.52	Mute	4	3.16
Leek	Layman	4	3.56	4.98	Nail	4	4.18
Lid	Member	3	4.16	4.52	Jar	3	3.96
Loop	Course	4	3.82	5.07	Girl	4	5.29
Rug	Back	3	3.57	4.91	Ray	3	4.56
Rust	Peace	4	3.33	4.88	Duck	4	4.53
Slang	Snake	5	3.56	4.33	Birch	5	3.43
Slap	Limp	4	4	3.85	Rash	4	3.61
Slim	Smart	4	3.8	5.05	Rude	4	4.27
Slot	Lock	4	3.78	4.72	Snag	4	3.02
Toe	Closed	3	4.08	5.76	Fur	3	4.03
Trap	Stairway	4	4.22	4.72	Dear	4	5.08
Wet	Law	3	4.76	4.91	Hat	3	4.76
Wit	White	3	3.67	4.52	Jaw	3	3.88
Mean		3.90	4.03	4.77		3.90	4.10
SD		0.72	0.54	0.53		0.72	0.62
Range		3–5	3.33–5.60	3.79–5.76		3–5	3.02–5.29

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