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Phonological Neighborhood Density Guides: Lexical Access in Native and Non-Native Language Production

Viorica Marian
Communications Sciences and Disorders
Northwestern University

Henrike K. Blumenfeld
Communications Sciences and Disorders
Northwestern University

The human linguistic capacity is subject to multiple influences both within and outside the language system. Among the factors that have been found to have a particularly robust influence on efficiency of language processing is how similar or different a word is relative to other words. Similarities and differences among words can be examined at the phonological, orthographic, lexical, and semantic levels. For example, the size of a word's semantic network influences how fast the word can be accessed, with words that have larger semantic neighborhoods processed faster than words with sparse semantic neighborhoods (e.g., Bertram, Schreuder, & Baayen, 2000; Locker, Simpson, & Yates, 2003, Nelson, Schreiber, & McEvoy, 1992). Similarly, the size of a word's phonological or orthographic neighborhood influences word access. A phonological neighbor is a word that differs from the target word by a single phoneme (Grainger, Muneaux, Farioli, & Ziegler, 2005; Yates, Locker, & Simpson, 2004). A word's neighborhood size, also referred to as its neighborhood density, has been defined as the number of items that are highly similar to it. While phonology, orthography, and semantics are all subject to neighborhood density effects, with implications for lexical activation, the objectives of the present study were to examine the role of phonological density in lexical access during language production and to explore similarities and differences in phonological neighborhood density effects on native and non-native language processing.

Neighborhood Density in Monolingual Language Comprehension

Research on the role of neighborhood density in language pro-

cessing has focused on both visual and auditory word recognition and production. In monolinguals, orthographic neighborhood density typically yields facilitative effects on visual word recognition. For instance, in lexical decision tasks, participants usually respond quicker and more accurately when presented with high-neighborhood targets than with low-neighborhood targets (Coltheart, Davelaar, Jonasson, & Besner, 1977; for review, see Andrews, 1992). In the lexical decision literature, this facilitative effect has been explained in terms of extent of activation: more neighbors trigger more overall activation, and result in easier word identification. This interactive account of lexical access is consistent with connectionist models of language processing, as well as with some localist models (e.g., the dual-route cascaded model of reading, Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; the multiple read-out model, Grainger & Jacobs, 1996). In addition to orthographic neighborhood density, visual word recognition is also subject to phonological neighborhood density effects. In visual lexical decision tasks, words with large phonological neighborhoods have triggered faster response rates and higher accuracy rates than words with small phonological neighborhoods (Yates *et al*., 2004). This suggests that phonological codes play a role even when they are not explicitly necessary to complete a task.

Moreover, just as phonological neighborhood density influences visual word recognition, so does orthographic neighborhood density influence auditory word recognition. However, while both orthographic and phonological neighborhoods facilitate visual word recognition, they have opposite effects on auditory word recognition. Namely, during auditory word recognition, words with dense *orthographic* neighborhoods are recognized *faster* than words with sparse orthographic neighborhoods (e.g., Ziegler, Muneaux, & Grainger, 2003), whereas words with dense *phonological* neighborhoods are recognized *slower* than words with sparse phonological neighborhoods (Garlock, Walley, & Metsala, 2001; Luce & Pisoni, 1998; Vitevitch & Luce, 1998; Ziegler *et al*., 2003; however, see Metsala, 1997). It has been suggested that these modality differences are due to the inherently more sequential nature of auditory input as compared to visual input (Yates *et al*., 2004). Moreover, Ziegler *et al*. (2003) suggest that facilitation from dense *orthographic* neighborhoods is localized to sub-phonemic consistency

between orthographic-phonological features, while inhibition from dense *phonological* neighborhoods during auditory word recognition is localized to lexical competition between words. It appears that during spoken language processing, lateral inhibition mechanisms at the lexical level de-activate competing neighbors and promote choice of the target (e.g, Luce & Pisoni, 1998; McClelland & Elman, 1986). While the exact mechanisms remain debated, there are no questions as to whether neighborhood density plays a role in language comprehension. To recapitulate, visual word recognition appears to be facilitated by high-density orthographic neighborhoods, as well as by high-density phonological neighborhoods. Spoken word recognition appears to be facilitated by high-density orthographic neighborhoods, but inhibited by high-density phonological neighborhoods.

Neighborhood Density in Bilingual Language Comprehension

The pervasiveness of phonological neighborhood effects across multiple tasks suggests that neighborhood density plays a robust role in word access and selection in monolinguals. It is less clear how neighborhood size affects bilingual processing. Using cross-linguistic orthographic neighbors, Van Heuven, Dijkstra, and Grainger (1998) examined neighborhood density effects during bilingual visual word recognition in native Dutch speakers who were fluent in English. Results showed that increasing the number of orthographic neighbors in English produced inhibitory effects for Dutch word recognition and facilitatory effects for English word recognition. In addition, increasing the number of orthographic neighbors in Dutch produced inhibitory effects for English word recognition. These findings are consistent with the monolingual visual word recognition literature, which typically reports facilitative effects of orthographic neighborhoods within the same language, extending it to bilingual settings.

Bilingual neighborhood density effects have also been examined for morphological neighborhoods. Analogous to phonological neighbors, morphological families consist of clusters of words that all differ by one morpheme but share another (Bertram *et al*., 2000; Dijkstra, Moscoso del Prado Martín, Schulpen, Schreuder and

Baayen, 2005). For example, the morpheme *work* is present in the words *homework*, *housework*, and *workable*. In a recent study on morphological neighborhoods in visual word recognition, Dijkstra *et al*. (2005) found that, for a visual lexical decision task in a non-native language, increased morphological family size in the non-native language lead to facilitation, while increased morphological family size in the native language lead to inhibition. This suggests that within-language facilitation effects and between-language inhibition effects are consistent across multiple levels of language processing. While cross-linguistic orthographic and morphological neighborhood effects in bilinguals provide compelling evidence for parallel activation of words in a bilingual lexicon, the fact that the cross-linguistic effect is inhibitory suggests that the non-native language is constrained by neighborhood density differently than the native language.

Neighborhood Density in Monolingual Language Production

While empirical research on neighborhood density effects during language recognition is more extensive, neighborhood density effects have also been examined during language production. Typically, in monolingual language production, activation of phonological representations surrounding the target has been found to facilitate access. For example, phonologically similar words were found to facilitate naming in studies using picture-word interference tasks (e.g., Costa & Sebastian-Galles, 1998). When phonological similarity was manipulated by varying neighborhood density in picture naming tasks, targets with dense phonological neighborhoods were processed faster than targets with sparse phonological neighborhoods (e.g., Vitevitch, 2002). In studies focusing on tip-of-the-tongue (TOT) states, Meyer and Bock (1992) showed that priming with a phonologically similar word facilitated correct retrieval (see also James & Burke, 2000). High-neighborhood targets have been found to produce fewer TOTs than low-neighborhood targets (Harley & Bown, 1998; Vitevitch & Sommers, 2003), and similar error patterns also appeared in naturally-produced speech (Vitevitch, 1997). Moreover, facilitated naming for high-neighborhood density targets was also preserved in aphasic patients, where

lexical access was disrupted (Gordon & Dell, 2001; Gordon 2002). In sum, phonological similarity is consistently found to facilitate monolingual lexical access across different language production tasks (e.g., picture naming, picture-word interference), different methods of error elicitation (e.g., TOT-elicitation, naturally-produced speech), and different populations (aphasic and non-aphasic individuals).

Neighborhood facilitation in production has been ascribed to interactive feedback between lexical and phonological levels. Gordon and Dell (2001) simulated behavioral findings of neighborhood effects within the framework of an interactive spreading activation model of production (Dell, 1986; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997). According to the model, language production follows three stages: a semantic stage where word-meaning is chosen, a lemma stage where other lexical characteristics are identified, and a phonological stage where the word form is accessed. Dell and Gordon (2001) suggest that neighborhood facilitation in production is due to feedback between the lemma level and the phonological level during word selection. The lemma activates phonological representations, which in turn activate similar-sounding lemmas (i.e., the phonological neighborhood), which in turn feed back onto the target's phonological representations and increase their activation levels, facilitating their selection.

Neighborhood Density in Bilingual Language Production

The literature on neighborhood density in *bilingual* language production is more limited. In a study looking at the role of orthographic neighborhood in native and non-native naming, De Groot, Borgwaldt, Bos, and van den Eijnde (2002) found that high-density neighborhoods facilitated naming and resulted in shorter response latencies in both languages. This neighborhood effect was facilitative *across* languages as well as *within* languages. Moreover, when delayed naming was partialled-out from immediate naming latencies, in order to detect the recognition component of naming, a difference between native and non-native languages was found. Non-native latencies were found to be more dependent on target-language orthographic neighborhood than native latencies, suggesting

that production in a non-native language is more sensitive to orthographic neighborhood effects. Although the role of *phonological* neighborhood in bilingual language processing remains unexplored, a study investigating the effect of phonological primes on tip-of-the-tongue states (TOTs) found facilitation effects both within and across languages (Askari, 1991). This finding of facilitation based on within-language or between-language similarity is consistent with De Groot *et al*. (2002), and suggests that one might expect orthographic and phonological neighborhood effects to pattern similarly in bilingual language production.

Further insight into bilingual neighborhood effects could be gained from cross-linguistic research with monolinguals. If multiple languages yielded the same patterns of outcome, then any differences observed in bilinguals could be attributed to native/non-native language status. If different languages yielded different patterns of outcome, then differences in bilinguals could also be attributed to structural differences between languages, in addition to native/non-native language status. If the latter were true, then empirical studies with bilinguals would have to be able to distinguish between the two factors. Initial evidence from cross-linguistic research suggests that neighborhood effects in production may indeed depend on structural characteristics of the tested language (Vitevitch & Rodriguez, 2005; Vitevitch & Stamer, in press). For instance, while high-density neighborhoods facilitate production in English, high-density neighborhoods were found to inhibit production in Spanish (Vitevitch & Stamer, in press). During auditory word recognition, high-density targets inhibit comprehension in English, but were found to *facilitate* recognition in Spanish (Vitevitch & Rodriguez, 2005). These differences were explained in terms of Spanish linguistic characteristics. Spanish is a language that is morphologically richer than English and in which clusters of phonological neighbors also contain morphological neighbors (e.g., niño, niña). Larger phonological neighborhoods correspond to larger morphological clusters, and these clusters facilitate recognition of targets since more (semantically consistent) activation accrues at the lexical level to support the word form. In contrast, presence of morphological clusters within phonological neighborhoods inhibits production, since one word form needs to be chosen from many semantically and phonologically consistent candidates.

Given that different linguistic structures were found to yield differences in neighborhood density effects in Spanish and English, for purposes of the present study, the confounding effects of cross-linguistic structural differences associated with the bilinguals' two languages were controlled.

Developmental Patterns in Neighborhood Density Effects

One way to understand differences between neighborhood effects in native and non-native language processing is by examining the developmental path of neighborhood density effects. Namely, developmental research on first-language learning can be used to shed light on acquisition processes associated with second language learning and the development of bilingualism. For example, it has been found that while toddlers prefer to listen to high-neighborhood words (Jusczyk, Luce, & Charles-Luce, 1994), children actually do worse at naming high-neighborhood targets compared to low-neighborhood targets (Arnold, Conture, & Ohde, 2005; Newman & German, 2002). This suggests that facilitated naming of high-neighborhood targets may in fact be the end of a developmental path that requires maturation of the language system. The presence of a developmental pathway raises questions about the role of language proficiency in sensitivity to neighborhood density. How proficient does one have to be in order to show a facilitative neighborhood effect? On the one hand, we might predict that non-native speakers may show similar patterns as native children, due to lower proficiency and a less entrenched language network. If that were the case, then bilingual speakers should be more sensitive to phonological neighborhood density in the native language compared to the non-native language. On the other hand, findings from TOT studies with adult native speakers suggest that facilitation of dense neighborhoods is more pronounced for low-frequency words than for high-frequency words (Vitevitch & Sommers, 2003; also see Andrews, 1989, for parallel findings with visual word recognition and orthographic neighborhoods). Thus, high-frequency words may be easier to access overall, and therefore may be less susceptible to neighborhood effects. In a native language, more extensive practice with and previous exposure to a language may give a word an "often

used" status and produce effects similar to those of high-frequency words. In a non-native language, the limited exposure to a word and rare instances of previous use may give a word a "rarely used" status and produce effects similar to those of low-frequency words. As a result, a non-native language may be more susceptible to neighborhood effects than a native language, a hypothesis supported by studies of orthographic neighborhood density (De Groot *et al*., 2002). If that were the case, then bilingual speakers should be more sensitive to phonological neighborhood effects in the non-native language compared to the native language.

Development of dense neighborhoods has also been linked to phonological awareness (e.g., Garlock *et al*., 2001). In children acquiring a first language, neighborhood density influenced performance on phonological awareness tasks, such as phoneme-blending (Metsala, 1999) and rime judgment (Goswami & De Cara, 2000), with better performance for familiar high-density words than for familiar low-density words. In high-density neighborhoods, the need to make fine-grained phonological distinctions may be higher than in low-density neighborhoods, leading to phoneme-by-phoneme analysis and away from a more holistic phonological processing. Similarly, research with non-native listeners suggests that auditory word recognition is more difficult in a non-native language than in a native language (e.g., Bradlow & Bent, 2002), and that this effect may be due to lack of some fine-grained distinctions in phonetic category representations. Investigating the effect of phonological neighborhood on auditory word recognition, Bradlow and Pisoni (1999) grouped words into "easy" and "hard" categories, where "easy" words had high frequencies and sparse neighborhoods and "hard" words had low frequencies and dense neighborhoods. Results showed that while both native and non-native listeners identified easy words more accurately than hard words, the difference between easy and hard items was larger for non-native listeners than for native listeners (also see Takayanagi, Dirks & Moshfegh, 2002). Since non-native listeners were less sensitive to fine-grained phonetic distinctions, their recognition abilities appeared to deteriorate in dense neighborhoods, where many similar items had to be differentiated based on such contrasts. Imai, Walley and Flege (2005) extended these findings by varying phonological neighborhood and word frequency orthogonally in an English word recognition task

with native English and native Spanish speakers. Words with both American-English accents and Spanish accents were presented. Interestingly, native Spanish speakers showed a neighborhood effect for English-accented words but not for Spanish-accented words, while native English speakers showed a neighborhood effect for Spanish-accented words but not for English-accented words. In both cases, mismatch of phonetic contrasts between input characteristics and phonological representations made word identification more difficult in dense neighborhoods than in sparse neighborhoods. Imai *et al*. (2005) reasoned that with increased second-language word learning and exposure, phonological representations become more fine-grained. In low-proficiency second language learners, phonological neighborhoods may be sparser overall, and phonological competency may lag behind. In sum, increased phonological neighborhood density may coincide with an increased ability to make fine-grained phonemic distinctions, and may therefore be linked to increased phonological competence as language abilities develop.

The present study

While the De Groot *et al*. (2002) study sheds some light on the role of orthographic neighborhood density in bilingual language production, the role of *phonological* neighborhood density remains to be specified. How exactly phonological neighborhood influences lexical access in bilingual language production is the underlying question driving the current research. Do effects of phonological neighborhood parallel those of orthographic neighborhood, and are they similar across native and non-native languages? To answer these questions, the present study examined the role of phonological neighborhood density during native and non-native picture naming. The language of testing was kept constant throughout the experiment, in order to avoid any differences in linguistic structures between languages. Instead, we manipulated whether the target language was native or non-native by testing two groups of bilinguals, one for which the target language was the native language and one for which the target language was the non-native language. In other words, two groups of bilinguals were tested in the same language,

as opposed to testing one group of bilinguals in both of their languages. As a result, any differences observed could be attributed to native/non-native language status rather than to cross-linguistic differences in language structure. German-English and English-German bilinguals were asked to produce targets with either high-density or low-density phonological neighborhoods in German. Thus, German was always the target language and English was always the non-target language. The present study followed a two-by-two design, with two independent variables, neighborhood size (high-density, low-density) and language status (native, non-native). Neighborhood size was a within-group variable and consisted of two levels, high-density phonological neighborhood words and low-density phonological neighborhood words. Language status was a between-group variable and also consisted of two levels, *native* German speakers and *non-native* German speakers.

We expected that the pattern of results in the native language would replicate that of previous studies with monolinguals and produce higher accuracy and shorter latency rates for words with dense phonological neighborhoods than for words with sparse phonological neighborhoods. In addition, we aimed to extend the paradigm to production in a non-native language. The lower proficiency levels in the non-native language were predicted to influence the pattern of results. On the one hand, if sensitivity to phonological neighborhood density emerges with language proficiency, then neighborhood effects should be more apparent in native naming than in non-native naming. On the other hand, if lower proficiency levels effectively render 'low frequency status' to all words in that language, then sensitivity to phonological neighborhood density should be more apparent in non-native naming than in native naming. In sum, participants were predicted to be faster, more accurate, and to use synonyms less frequently for large-neighborhood words than for small-neighborhood words, with the magnitude of the effect differing across native and non-native languages.

Methods

Participants. Twenty-nine bilingual speakers of German and English were tested. Of these, 14 were English-German bilinguals

(native language=English; 5 females), and 15 were German-English bilinguals (native language=German; 7 females). All bilinguals reported being dominant in their native language. English-German bilinguals started learning German at the average age of 11.8 years (*SD* = 8.6) and became fluent in it at 17.4 years (*SD* =10.0). The mean age at the time of testing was 25.6 years (*SD* = 8.9) for the English-German bilinguals and 28.7 years (*SD* = 12.9) for the German-English bilinguals, with no significant difference between the two, $t(27) = 0.8$, $p > .1$. At the time of study, German-English bilinguals had more exposure to German (in terms of self-reported percentage of time spent in a German context, *M* = 23.1%, *SD* = 16.3) than English-German bilinguals (*M* = 11.1%, *SD* = 6.8), $t(27) = 2.6$, $p < .05$. All participants were administered a German translation of the English Peabody Picture Vocabulary Test (PPVT-III, Dunn & Dunn, 1997), a widely-normed test of receptive vocabulary knowledge, where participants identify words they hear from picture sets. German-English bilinguals (*M* = 193.9, *SD* = 7.6) performed better than English-German bilinguals (*M* = 178.6, *SD* = 18.2), $t(27) = 2.9$, $p < .01$. Finally, none of the participants had language, learning or hearing disabilities; all were tested following ethical guidelines, and were paid for participation.

Materials. Fifty-seven pictures corresponding to target German words were used. Picture stimuli were black line drawings with gray shadings and were selected from the IMSI Master Clips electronic database and the Alta Vista search engine, or hand-drawn. To identify phonological neighbors of each target word, the German corpus of the CELEX lexical database (Baayen, Piepenbrock, & Van Rijn, 1995) was used, with an item coded as a phonological neighbor if it differed from the target by only one phoneme, and had the same number of phonemes in the same positions (Grainger *et al*., 2005; Yates *et al*., 2004). For example, the phonological neighborhood of the German word *Hase* (/haz´/), includes such words as *Vase*, (/vaz´/), *Hose*, (/hoz´/), and *Habe*, (/hab´/), (Note that the ideal scenario would be to also manipulate the phonological neighborhood density of English, in order to gauge the separate effect of non-target language phonological neighborhood, as well as the cumulative effect of phonological neighborhoods across both languages. However, that was not possible because differences in phonetic features between German and English precluded meaningful computa-

tions of corresponding phonological neighborhoods for English.)

Once coding was completed, stimuli were grouped into two conditions, one condition included words with large phonological neighborhoods (3 or more phonological neighbors in German) and the other condition included words with small phonological neigh-

Table 1.Stimulus Characteristics for High- and Low-Density Neighborhoods.

Stimulus characteristics	Descriptive Statistics		Inferential Statistics
	High Phonological Neighborhood Mean (*SE*)	Low Phonological Neighborhood Mean (*SE*)	
Number of German Synonyms	1.30 (0.3)	1.65 (0.3)	$t(55) = 0.88$, ns
Word Length	4.20 (0.3)	4.84 (0.2)	$t(55) = 1.71$, ns
German Frequency	0.51 (0.10)	0.48 (0.11)	$t(55) = 0.24$, ns
English Frequency	0.56 (0.10)	0.44 (0.13)	$t(55) = 0.77$, ns
German Orthographic Neighborhood	2.4 (0.68)	2.1 (0.65)	$t(55) = 0.41$, ns
English Orthographic Neighborhood	3.1 (0.45)	2.8 (0.70)	$t(55) = 0.38$, ns

borhoods (2 or fewer phonological neighbors in German). The large-neighborhood condition consisted of 31 German words, with a mean neighborhood size of 5.8 words ($SE = 0.4$). The small-neighborhood condition consisted of 26 German words, with a mean neighborhood size of 1.2 words ($SE = 0.2$). The neighborhood sizes for the two conditions were significantly different from each other $t(55) = 8.8$, $p < .001$. The rationale for choosing a significant difference between dense and sparse neighborhood conditions that was relatively small was so as to specifically address the question of sensitivity to small changes in neighborhood density across native and non-native languages. Further, an effort was made to select concrete word stimuli with relatively few available synonyms, in order

to maximize the probability that participants would name intended targets. Words in the two conditions were balanced for word length (in phonemes), spoken word frequencies of German and of English translation equivalents (CELEX lexical database, Baayen *et al*., 1995), orthographic neighborhood size in German and English, and number of synonyms available in German. There were no significant differences for these measures between the low-density neighborhood and the high-density neighborhood conditions ($p > .05$, see Table 1 for details). Appendices 1 and 2 show complete lists of stimuli in the high- and low-density phonological neighborhood conditions and include detailed information on all control dimensions.

Participants' vocabulary size was tested using a German translation of the Peabody Picture Vocabulary Test. The B-version of the English PPVT-III was translated into German by a fluent German-English bilingual, and back-translated to English by two other fluent German-English bilinguals for reliability. The German and English versions were balanced by-item on word frequency (CELEX lexical database, Baayen *et al*., 1995, $t(203) = 0.6$, $p > .5$). Finally, a Language Experience and Bilingual Status Questionnaire (LEABS-Q) was administered to assess participants' linguistic profile. The LEABS-Q consists of questions about language dominance, proficiency, language preference across settings, cultural affiliation, accent, history of acquisition (age, method, reached fluency), current and previous exposure, and general demographic background (Marian, Blumenfeld, & Kaushanskaya, 2005).

Procedure. Participants were recruited using fliers, and through the German Department at Northwestern University. The experimenter was a native speaker of German, and conversed with participants in German prior to the experimental session, in order to ensure a German language mode during testing. Prior to the experimental session, participants completed the Language Experience and Bilingual Status Questionnaire and were administered the German version of the Peabody Picture Vocabulary Test. None of the items in the experimental task were part of the PPVT. For the experimental task, participants were seated in front of a computer screen and were asked to name pictures that appeared on the screen. Responses were recorded using a Logitech microphone. The experiment was self-paced, so that the time-window allotted to make a response was not limited. Once provided, each response triggered a

500 msec inter-stimulus-interval, followed by the next picture. However, participants were asked to move from picture to picture without taking any breaks. Finally, pictures were presented in a random sequence (generated by Super Lab experimental software), in order to avoid order effects, such as trial-to-trial priming, across items and conditions.

Coding and Analyses. The following three dependent variables were measured: (1) accuracy of response, (2) latency of response, and (3) synonym use. For accuracy, the percentage of pictures named correctly using the target word was computed. For latency, the duration of time from onset of picture presentation to onset of word production was measured in milliseconds. Naming latency was derived from the experimental software's output. For synonym use, cases in which bilinguals labeled pictures using near-synonyms rather that target words were analyzed.

An answer was coded as a near-synonym if it was semantically equivalent to the target word, or highly overlapping with it, thus constituting a potentially acceptable label for the intended target. For example, labeling a *Welle* (English *wave*) a *Woge* (English *wave/billow*), or a *Tuch* (English *cloth*) a *Lappen* (English *cloth/rag*). An answer was coded as incorrect when the answer was not an acceptable label of the picture. For example, labeling a *Schrank* (English *armoire*) a *Schublade* (English *drawer*), or a *Schal* (English *scarf*) a *Scharf* (nonexistent word in German). All data were coded by a fluent German speaker. Another fluent German speaker coded 20 percent (6 participants) of the data; point-to-point reliability between the two coders was 94% (Pearson's *R*).

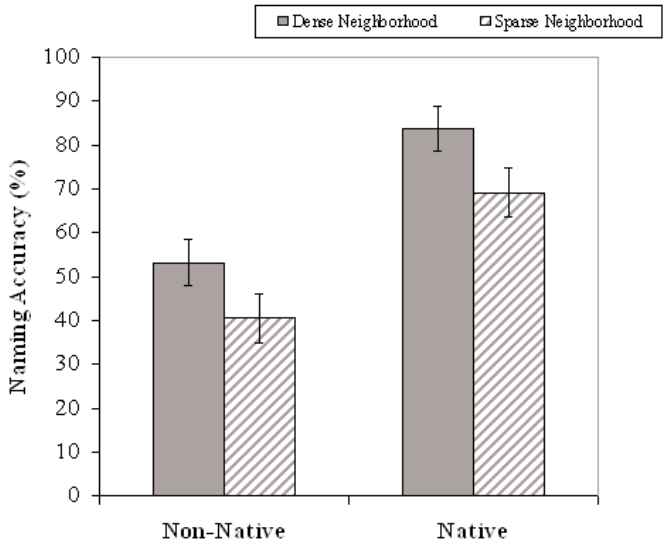
Naming accuracy, naming latency, and synonym use were analyzed for large-neighborhood and small-neighborhood conditions across the two bilingual groups, using two-way analyses of variance with neighborhood as a within-subject variable, and group as a between-subject variable. Both by-subject and by-item analyses were performed to ensure that the pattern of results was consistent for all participants and across the entire data set. In by-subject analyses, participants' number of years of education was entered as a covariate, in order to factor out the confounding influence of academic experience, which is known to correlate highly with IQ scores, speed of processing, and familiarity with de-contextualized tasks (see Brody, 1992; Ceci, 1996; Neisser *et al*., 1996 for reviews).

Results

Of the 1,653 responses produced, 62.5% (1033 cases) were coded as correct and 37.5% (620 cases) were coded as errors. Near-synonyms constituted 256 cases, or 16.0% of all data. Near-synonyms were treated as correct responses and included in overall analyses, in addition to being analyzed on their own for specific sub-patterns.

Naming Accuracy. Two-way analyses of variance, with phonological neighborhood size (large, small) as a within-subject

Figure 1. Naming accuracy for high-neighborhood and low-neighborhood words in English-German bilinguals and German-English bilinguals. By-items means and standard errors were used.



variable and group (native German speakers, non-native German speakers) as a between-subject variable in both by-subject (F_1) and by-item (F_2) analyses, and with number of years of education as a covariate in by-subject analyses were performed. Results revealed a main effect of neighborhood size, F_1 (1, 27) = 9.2, $p < .01$, F_2 (1, 55) = 5.6, $p < .05$, and a main effect of group, F_1 (1, 27) = 42.2, $p < .001$, F_2 (1, 55) = 36.4, $p < .001$ (see Figure 1). Naming accuracy was higher for target words with large phonological neighborhoods

(M = 68.5%, SE = 3.7%) than for target words with small phonological neighborhoods (M = 54.8%, SE = 3.9%) and was also higher for native speakers (M = 76.4%, SE = 3.5%) than for non-native speakers (M = 46.9%, SE = 3.5%). No interaction was found between neighborhood size and group, F_1 (1, 27) = 3.5, $p > .05$, F_2 (1,55) = 0.03, $p > .05$, suggesting that phonological neighborhood size influenced naming accuracy similarly across both groups, regardless of native vs. non-native language status. Since neighborhood size is a continuous variable, follow-up regression analyses were conducted, where neighborhood size (independent variable) was regressed on naming accuracy. A significant relationship between neighborhood size and accuracy was found across both groups (R = 0.2, $p < .05$).

Naming Latency. Two-way analyses of variance were performed, with phonological neighborhood size (large, small) and group (native German speakers, non-native German speakers) as independent variables in both by-subject and by-item analyses, and with participants' number of years of education as a covariate in the

Figure 2. Naming latencies for high-neighborhood and low-neighborhood words in English-German bilinguals and German-English bilinguals. By-items means and standard errors were used.

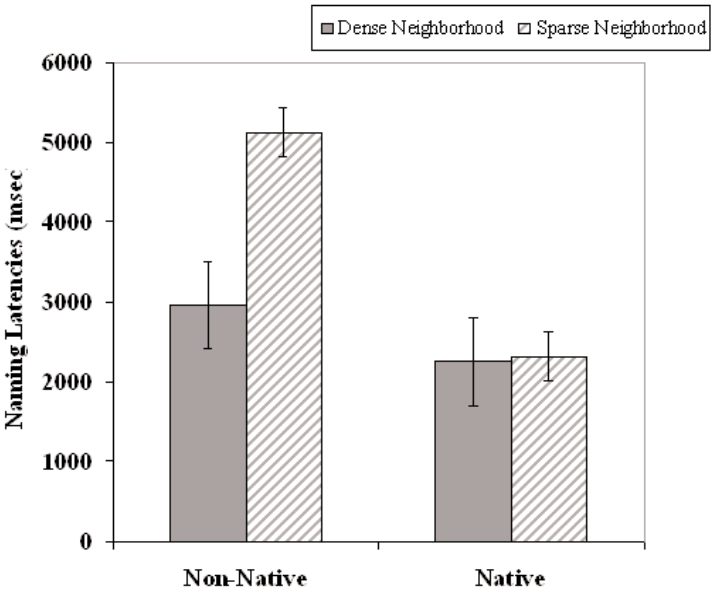


Table 2.Choice of near-synonyms for Native and Non-Native speakers. (The larger difference for non-native speakers, although in the predicted direction, was not significant when years of education were included as covariate.)

	Native speakers % (*SE*)	Non-Native speakers % (*SE*)
Low-Neighborhood	16.9 (1.5)	22.5 (1.4)
High-Neighborhood	11.8 (1.4)	12.7 (1.0)

by-subject analyses. The results were included in Figure 2 and revealed a main effect of neighborhood size, with faster naming when the phonological neighborhood was larger (M = 2,608.9 msec, SE = 214.6 msec) than when it was smaller (M = 3,719.9 msec, SE = 388.1 msec), F_1 (1, 27) = 8.4, $p < .01$, F_2 (1, 55) = 5.2, $p < .05$. Moreover, a main effect of group revealed that native speakers named pictures faster (M = 2,285.9 msec, SE = 271.3 msec) than non-native speakers (M = 4,042.9 msec, SE = 289.3 msec), F_1 (1, 27) = 9.2, $p < .01$, F_2 (1, 55) = 19.6, $p < .001$. The interaction between neighborhood size and group was significant by items, F_2 (1, 55) = 4.6, $p < .05$, but the by-subject analysis did not reach significance, $p > .05$. Follow-up t-tests revealed that non-native speakers named pictures faster with large-neighborhood targets (M = 2,964.3 msec, SE = 313.0 msec) than with small-neighborhood targets (M = 5,121.4 msec, SE = 566.1 msec), $t(55) = 3.1$, $p < .005$. For native speakers, the difference was not significant (large neighborhoods: M = 2253.4 msec, SE = 548.6; small neighborhoods: M = 2318.4 msec, SE = 303.3), $p > .05$. When neighborhood size was regressed on naming latency across items, the relationship between the two was not significant for both native speakers and non-native speakers, $p > .05$. The longer naming latencies obtained in the present data set may be due to the fact that participants were not instructed to name pictures as rapidly as possible. In general, picture-naming usually takes longer in bilinguals than in monolinguals ( ).

Choice of Near-Synonyms. Separate analyses were performed on responses in which participants used near-synonyms during naming. Two-way analyses of variance, with phonological neighbor-

hood size as a within-subject variable and bilingual group as a between-subject variable in both by-subject and by-item analyses, and with number of years of education as a covariate in by-subject analyses were performed. Results of by-subject analyses revealed a main effect of group, F_1 (1, 27) = 4.4, $p < .05$, where non-native speakers chose more near-synonyms (M = 17.9%, SE = 1.3%) than native speakers (M = 14.1%, SE = 1.2%). By-subject analyses also revealed an interaction between group and neighborhood size, F_1 (1, 27) = 6.1, $p < .05$, but no main effect of neighborhood size, F (1, 27) = 0.07, $p > .05$. The interaction was followed up with smaller analyses of covariance and revealed that native speakers chose significantly more near-synonyms for low-neighborhood targets (M = 16.9%, SE = 1.5) than for high-neighborhood targets (M = 11.8%, SE = 1.4), F (1, 13) = 7.1, $p < .05$, but non-native speakers did not show differences across the two neighborhood conditions, F(1, 12) = 4.6, $p > .05$ (see Table 2). None of the by-item analyses were significant (F_2 (1, 27) = 1.8, $p > .1$ for group, F_2 (1, 27) = 1.4, $p > .1$ for neighborhood size, F_2 (1, 27) = 0.9, $p > .9$ for the interaction), likely due to variability among items.

Phonological neighborhood size (independent variable) was regressed (by-items) against percentage of near-synonyms. No significant relationship was found between neighborhood size and percentage of near-synonyms used by native (R = 0.08, $p > .5$) or non-native (R = 0.1, $p > .1$) speakers. Moreover, the number of available synonyms in standard German vocabulary (independent variable) was similarly regressed against the percentage of times near-synonyms were used. For native speakers, there was a strong positive relationship between availability and use of near-synonyms, R = 0.5, F (1, 56) = 19.5, $p < .001$, suggesting that when more synonyms were available, native speakers were more likely to use them. For non-native speakers, that was not the case, R = 0.2, F (1, 56) = 1.6, $p > .1$, likely due to the more limited German vocabulary and number of synonyms available.

Discussion

In sum, phonological neighborhood density was found to influence lexical access in both native and non-native language produc-

tion. While naming of dense-neighborhood targets was more accurate than naming of sparse-neighborhood targets in both the native and the non-native languages, latency differences were found only in the non-native language. Further, synonym analyses suggested that native speakers, but not non-native speakers, were more likely to choose synonyms for low-neighborhood density targets than for high-neighborhood density targets.

Phonological Neighborhood Density in Native and Non-Native Language Production. The present experiment extended the study of phonological neighborhood density to production in a non-native language. Similar to accuracy patterns in native language naming, accuracy in non-native language naming was also facilitated by high-density phonological neighborhoods. However, latency results varied across native and non-native languages. While high-density neighborhoods facilitated naming latency in the non-native language, no differences between high- and low-density neighborhoods were found in the native language. This suggests that retrieval difficulties in sparse neighborhoods may be more marked for non-native individuals and supports the prediction that language proficiency influences sensitivity to neighborhood density. Differences in patterns of response times in a native and non-native language could be due to lower proficiency levels rendering overall 'low frequency status' to all words in that language, making non-native language naming more sensitive to phonological neighborhood density. These findings suggest that the neighborhood density effect appears to manifest itself differently during the course of first and second language learning, with neighborhood effects more marked while learning a non-native language and less marked while learning a native language. Recall that in children, neighborhood effects were negligible during language learning and increased as language development progressed (Arnold *et al*., 2005; Newman & German, 2002). This might suggest that neighborhood effects would be stronger in a native and highly proficient language than in a non-native and less-proficient language. However, that did not seem to be the case as the current study showed greater differences between dense- and sparse phonological neighborhoods in non-native speakers, compared to native speakers. These results are consistent with previous studies of orthographic neighborhood density in non-native vs. native language production (De Groot *et al*., 2002), as

well as of phonological neighborhood density in non-native vs. native auditory comprehension (Bradlow & Pisoni, 1999). Together, this research suggests that once a native language has been acquired, neighborhood density effects may follow different patterns with the development of subsequent languages.

Another reason for the absence of latency differences between high- and low-density neighborhoods in a native language may be the relatively small contrast between high- and low-density conditions employed in the present study. The mean number of phonological neighbors in the high-density condition was 5.8 words (*SE*=0.4), while the mean number of phonological neighbors in the low-density conditions was 1.2 words (*SE*=0.2), $t(55) = 8.8$, $p < .001$. While this difference was statistically significant, it is noticeably smaller than differences between sparse and dense neighborhoods in other similar studies (e.g., Garlock *et al*. 2001: dense: $M = 14.6$, sparse: $M = 5.8$; Vitevitch, 2002: dense: $M = 24.9, 23.9, 19.4$, sparse: $M = 14.5, 15.4, 6.8$; Yates *et al*., 2004: dense: $M = 19.1, 17.1$, sparse: $M = 3.9, 5.2$). The fact that we found a phonological neighborhood effect on naming accuracy in the current dataset speaks to the robustness of the phenomenon. The fact that we did not find a phonological neighborhood effect on naming latency in a native language suggests that speed of access is less sensitive to small variations in neighborhood density. It is possible then, that accuracy is more sensitive to even slight variations in neighborhood density, while latency differences are triggered by more dramatic changes, at least in a highly proficient language.

Choosing a Near-Synonym During Lexical Access. In the present study, the overall likelihood of using a synonym was greater when naming in a non-native language than in a native language. Moreover, when naming in a native language, participants were more likely to use a synonym for low-neighborhood targets than for high-neighborhood targets, and were more likely to use a synonym when a target word had more synonyms available than when it had fewer synonyms available. For native speakers, choosing a synonym may have been a strategy to bypass effortful retrieval of sparse-neighborhood targets. When naming in a non-native language, no discernible pattern was observed, likely due to the speakers' more limited vocabulary and number of synonyms available.

The impact of neighborhood size on synonym production dur-

ing picture naming is best explained within the context of the interactive nature of language processing, with connections both within and between phonological, lexical, and semantic representations. Peterson and Savoy (1998) conducted a picture naming study where targets did or did not have synonyms. Written words were presented for naming after the picture. Phonological priming was found for word targets phonologically similar to the picture's dominant label (e.g., *couch* primed *count*) , as well as for word targets phonologically similar to the picture's secondary (near-synonymous) label (e.g., *sofa* primed *soda*). These findings suggest that all available synonyms become active during word naming, and that their activation spreads to the phonological level. Such cascaded processing implies that for each target word, in addition to its own phonological neighborhood, the phonological neighborhoods of its synonyms also become available, with multiple phonological forms ultimately active for selection during naming. Because dense phonological neighborhoods facilitate naming (e.g., see Vitevitch, 2002), and because some of the available synonyms may have larger phonological neighborhoods than the target word, the likelihood of choosing a synonym may therefore be influenced by the ratio of the synonym's phonological neighborhood relative to the target's phonological neighborhood. This ratio is likely to favor choosing the target when it has a dense phonological neighborhood; it is likely to favor choosing a synonym when the target has a sparse phonological neighborhood. As a result, the likelihood of using a synonym should be greater for words with sparse neighborhoods, a prediction that was confirmed by naming patterns in a native language.

However, any observed differences in likelihood of using a synonym should be interpreted with caution, for at least two reasons. The first is that none of the by-item analyses were significant. Lack of significant differences in the by-item comparisons is likely due to variability among items in characteristics such as number and frequency of available synonyms. An effort was made to keep the number of available synonyms low across stimuli, and availability of synonyms was controlled across conditions. Choosing a synonym may be linked to availability of semantic neighborhoods (of which synonyms are a part), in addition to availability of phonological neighborhoods, with multiple factors contributing to word-choice. Variability in synonym knowledge is especially likely in a non-

native language, where no relationship was found between the number of available synonyms and the likelihood of using a synonym. Variability in synonym knowledge appears to be less of a factor in a native language, where a strong relationship between synonym availability and use was found. The second reason for caution is that, in the present study, synonym analyses were performed post-hoc. The rationale was that synonym analyses would follow the opposite pattern to that observed in accuracy (because the pool of cases from which synonyms were selected comes from answers coded as incorrect, and because error analyses typically follow a pattern opposite to accuracy analyses). However, synonym choice is only one of many errors types and therefore the relationship is unlikely to be linear. Error coding can be done across different parameters, such as phonology, grammar, or semantics. The small number of errors in the present study made more in-depth error analyses impossible. Future research focusing specifically on error-type analyses in bilingual error-elicitation studies is likely to provide further insight into the role of semantic, orthographic, and phonological neighborhoods in language production.

Other Contributing Factors. Differences found in the current study between native naming and non-native naming could be attributed to either language proficiency, or to age of language acquisition. In the current study, age of acquisition and language proficiency were highly correlated ($r = -.5$, $p < .01$) and the design of the study did not make it possible to separate the individual contributions of the two. In order to tease apart the influence of these two measures on naming accuracy and latencies, stepwise multiple regressions were run across participants, with age of German acquisition and with German proficiency entered as independent variables. The overall regression for accuracy was significant across both variables, $R = 0.7$, $F(1,27) = 22.8$, $p < .001$. However, German proficiency, $t(27) = 4.8$, $p < .001$, emerged as a better predictor of naming accuracy than age of acquisition, $t(27) = 1.9$, $p = .06$. The overall regression for latency was also significant, $R = 0.4$, $F(1, 27) = 5.9$, $p < .05$. German proficiency was also a better predictor of latency, $t(27) = 2.4$, $p < .05$, than age of acquisition, $t(27) = 0.8$, $p > .1$. This suggests that proficiency may play a more important role than age of acquisition in lexical access and that speakers can improve language performance by increasing proficiency, regard-

less of the age at which a language was acquired.

In addition to the role of phonological neighborhood in lexical access during picture naming, orthographic neighborhood may also play a role in spoken language production. Distributed processing models, such as the Bimodal Interactive Activation Model, posit sub-lexical links between orthographic and phonological codes (e.g., Grainger & Ferrand, 1996) and predict that orthography plays a role in naming due to feedback between these codes. Matching orthographic and phonological forms has been found to aid language processing, while mismatching orthographic and phonological forms has been found to hinder language processing (e.g., Schwartz, Kroll, & Diaz submitted). Studies of neighborhood density confirm these patterns (e.g., Grainger *et al*., 2005, Peereman & Content, 1997; Ziegler & Perry, 1998; Ziegler, *et al*., 2003).

In the present study, an analysis of stimuli revealed no correlation between phonological and orthographic neighborhood sizes ($r = 0.1$, $p > .1$). Moreover, no significant effects of orthographic neighborhood and no interactions between groups were observed for either accuracy (F_1 (1, 27) = 0.000, $p > .5$; F_2(1, 55) = 1.2, $p > .1$) or latency (F_1 (1, 27) = 0.03, $p > .5$; F_2(1, 55) = 0.5, $p > .5$) when stimuli were re-grouped into dense orthographic neighborhoods ($M = 5.5$, $SE = 0.6$) and sparse orthographic neighborhoods ($M = 0.9$, $SE = 0.2$), with the two conditions significantly different from each other, $t(55) = 8.1$, $p < .001$. The results remained insignificant when orthographic neighborhoods were computed by combining both German and English neighbors (accuracy, F_1 (1, 27) = 0.001, $p > .5$; F_2(1, 55) = 0.04, $p > .5$; latency, F_1 (1, 27) = 0.000, $p > .5$; F_2(1, 55) = 0.001, $p > .5$). The absence of neighborhood effects when orthographic neighborhoods were computed across both languages is consistent with van Heuven *et al*. (1998), who found that target-language orthographic neighborhood exerts facilitation, while non-target language orthographic neighborhood exerts inhibition in receptive visual processing, therefore creating effects that cancel each other out. The absence of differences when orthographic neighborhoods were computed in the target language only is more difficult to explain and is inconsistent with both van Heuven *et al*. (1998) and De Groot *et al*. (2002). Absence of orthographic neighborhood density effects is not due to noise from phonological neighborhood, since orthographic and phonological neighborhoods were varied

orthogonally [phonological neighborhood size did not differ between high-orthographic-neighborhood (M = 3.8, SE = 0.6) and low-orthographic-neighborhood conditions (M = 3.5, SE = 0.6), $t(55) = p > .5$]. Rather, it might be due to the relatively small difference between high-density orthographic neighborhoods and low-density orthographic neighborhoods relative to other studies. While the absence of orthographic neighborhood density influences in spoken language production could indicate little to no activation of orthographic code in this particular task, this interpretation is unlikely and the current results do not provide enough evidence to rule out orthographic influences during naming. Rather, in order to establish whether orthographic neighborhood exerts a separate and/or cumulative effect to that of phonological neighborhoods, additional research in which the contrasts between conditions are larger is necessary.

Future research

The results of the present study suggest that lexical access in German follows patterns that are similar to those observed in previous research with English speakers, but different from those observed in previous research with Spanish speakers. This is not surprising, considering that German and English are structurally similar Germanic languages. Spanish is a Romance language and is structurally different in a number of ways, including morphological clustering. The finding that phonological neighborhood density influences languages in different ways suggests that neighborhood effects vary across language structures. Future research may examine multiple different languages to establish general patterns governing neighborhood effects.

Another factor likely to influence neighborhood effects is cross-linguistic overlap between words. Specifically, cognate words, such as English *mouse* and German *Maus*, or homographs/homophones such as English *fabric* and German *Fabrik* (factory), may yield different patterns of neighborhood effects in bilinguals. Although the present study did not overtly control for cross-linguistic overlap, only a few stimuli in the set belonged to this type of words--2 items in the low-neighborhood

condition (German *Auto* and *Hose*) and 2 items in the high-neighborhood condition (German *Angel* and *Teller*). The small (and comparable across conditions) number of such items in the stimulus set renders it very unlikely that cross-language overlap was responsible for the present findings. Systematic manipulation of cross-linguistic overlap at the phonological (i.e., homophones), orthographic (i.e., homographs), and semantic (i.e. cognates) levels is a possible future direction in the study of neighborhood effects that provide another way to probe between-language facilitation and inhibition effects.

Other potentially fruitful areas of future research in non-native language naming and comprehension include manipulating not only neighborhood density, but also neighborhood frequency and synonym frequency. Moreover, it has been argued that in order to fully capture the effect of neighborhood on lexical selection, a multi-task approach is necessary (Andrews, 1997; Yates *et al*., 2004), not only in monolinguals, but also in bilinguals and second-language learners. Finally, it has been suggested that not all phonological neighbors provide identical facilitatory support (Stemberger, 2004; Vitevitch & Stamer, in press; Westbury, Buchanan, & Brown, 2002), and that the position in the word where the phoneme substitution occurs, as well as the identity of the phoneme, may modulate this effect. Since neighbors were not grouped by position in the word where phoneme alterations occurred in the present study, targets with the same neighborhood sizes might have been subject to different degrees of facilitation, a direction that can be explored in further research.

In conclusion, the present study confirmed that phonological neighborhood density influences lexical access and extended this finding to non-native language production. Cross-linguistic neighborhood effects appear to exert a different influence on language production than on language comprehension. For language production, cross-linguistic orthographic neighbors were found to facilitate lexical access (e.g., De Groot *et al*., 2002) and our results report the same pattern for phonological neighbors. For language comprehension, cross-linguistic neighbors have been found to inhibit word recognition (e.g., Van Heuven *et al*., 1998). It may be that cross-linguistic inhibition of neighborhoods during language comprehension results from increased competition from other lexical items at the lexical level, while cross-linguistic facilitation during language pro-

duction results from convergent sub-lexical information. Moreover, although phonological neighborhood density effects were apparent in both the native and the non-native languages, latency results indicated that they were more marked in the non-native language. This confirms the hypothesis that language status (native, non-native) modulates the effect of neighborhood density. The facilitative effects of phonological neighborhood density on lexical access during language production have applied implications for bilingual populations in clinical and educational settings. For instance, therapy in bilingual aphasia may make use of knowledge that high-neighborhood targets are easier to name in both languages and rely on high-density neighborhood words as a starting point in remediation. Similarly, in second language education, the knowledge that dense neighborhood words are associated with better performance might guide choice of words in vocabulary learning activities so as to provide additional support for low-neighborhood items. Research targeting special populations and focusing on intervention efficacy can further test the value of these phenomena in applied settings.

Appendix 1.List of German Stimuli in the Low-Neighborhood Density Condition.

Target Word	English Translation Equivalent	German Word Length (Phonemes)	German Word Frequency (Logarithm)	English Word Frequency (Logarithm)	German Phonological Neighborhood Size	German Orthographic Neighborhood Size	English Orthographic Neighborhood Size	Number of German Synonyms
Auto	car	3	0.00	2.40	2	0	1	1
Bein	leg	3	0.00	1.08	2	12	3	0
Blatt	leaf	4	0.48	0.00	1	0	0	4
Blume	flower	5	0.30	0.00	2	0	3	0
Decke	comforter	4	0.00	0.00	2	4	0	0
Deckel	lid	5	0.85	0.00	0	3	0	2
Eichel	acorn	4	0.00	0.00	2	1	0	3
Gitter	bars	5	0.00	1.00	2	2	6	2
Hose	pants	4	0.00	0.60	0	8	10	1
Kanne	teapot	4	0.48	0.00	0	2	0	1
Kapuze	hood	6	0.00	0.48	0	0	0	11
Kartoffel	potatoes	8	0.00	0.30	2	0	0	4
Kiste	box	5	1.98	1.52	0	5	0	3
Koffer	suitcase	5	0.95	0.30	1	1	1	4
Lockenwickler	curler	10	0.30	0.00	0	0	0	1
Mandeln	almond	7	0.00	0.00	2	5	2	0
Melone	bowler hat	6	1.08	0.00	0	0	0	3
Mops	pug dog	4	0.90	0.00	1	1	5	1
Mus	sauce	3	1.08	0.00	0	12	7	0
Pfeil	arrow	3	1.00	1.08	2	0	0	1
Pilz	mushroom	4	0.00	0.48	0	3	2	1
Platte	record	5	1.34	0.00	2	1	0	0
Pulli	sweater	4	0.00	0.30	2	1	0	6
Puppe	doll	4	0.85	0.00	0	4	1	1
Tuer	door	3	0.00	1.93	5	7	12	1
Zylinder	top hat	8	0.78	0.00	0	0	1	2
	MEAN	4.85	0.48	0.44	1.15	2.77	2.08	1.65
	SD	1.76	0.55	0.67	1.22	3.55	3.30	1.57

Appendix 2. List of German Stimuli in the high-Neighborhood Density Condition.

Target Word	English Translation Equivalent	Word Length (Phonemes)	German Word Frequency (Logarithm)	English Word Frequency (Logarithm)	German Phonological Neighborhood Size	German Orthographic Neighborhood Size	English Orthographic Neighborhood Size	Number of German Synonyms
Angel	fishing rod	4	0.30	0.00	6	3	1	2
Birne	pear	4	0.00	0.00	4	3	0	1
Brille	glasses	5	0.48	0.60	8	1	1	1
Dach	root	3	1.15	1.20	5	6	4	0
Dackel	dachshund	5	0.95	0.00	10	2	1	3
Glocke	bell	5	0.70	1.57	7	2	0	0
Hase	rabbit	4	0.00	0.00	5	10	14	0
Heft	notebook	4	0.00	0.70	4	3	6	3
Hemd	shirt	4	0.00	1.00	7	2	5	4
Igel	hedgehog	4	0.70	0.00	4	1	0	1
Kaefer	bugs	5	0.85	0.30	9	3	1	1
Kellner	waiter	6	0.00	0.78	3	0	0	4
Kirsche	cherry	4	0.00	0.30	4	0	0	0
Kissen	pillow	5	0.000	0.48	7	5	2	1
Klo	toilet	3	0.85	1.15	5	0	0	0
Korb	basket	4	0.00	0.30	3	3	0	1
Kreis	circle	4	1.36	1.60	9	3	0	0
Messer	Knife	5	1.76	0.90	3	2	1	2
Peitsche	whip	5	0.00	0.95	4	1	0	0
Pickel	zit	5	0.00	0.00	7	8	9	0
Piek	spades	3	0.00	0.48	3	2	5	6
Schal	scarf	3	0.70	0.60	5	5	0	0
Schaukel	swing	5	1.23	0.30	12	1	0	2
Schaum	foam	3	0.00	0.00	3	1	0	0
Schere	scissors	4	0.30	0.30	6	2	2	2
Schienen	tracks	5	0.30	0.70	6	4	0	2
Schrank	armoire	5	1.86	0.00	9	2	0	2
Teller	plate	5	0.00	1.04	3	4	3	0

Appendix 2, cont.

Target Word	English Translation Equivalent	German Word Length (Phonemes)	German Word Frequency (Logarithm)	English Word Frequency (Logarithm)	German Phonological Neighborhood Size	German Orthographic Neighborhood Size	English Orthographic Neighborhood Size	Number of German Synonyms
Tor	gate	3	0.00	0.00	8	7	12	0
Tuch	towel	3	1.00	0.00	3	4	6	1
Welle	wave	4	0.85	1.66	7	6	1	1
	MEAN	4.23	0.49	0.55	5.77	3.10	2.39	1.26
	SD	0.84	0.57	0.53	2.43	2.40	3.68	1.44

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