HOW MISPERCEPTION AFFECTS THE STRUCTURE OF THE L2 MENTAL LEXICON: A CONCEPTUAL REPLICATION OF CUTLER (2005)

Brian Rocca, Indiana University
Frank Martino
Isabelle Darcy, Indiana University

Cutler (2005) was one of the first attempts to quantify how misperception of second language (L2) sounds might affect word recognition. In this conceptual replication, we build on Cutler's work by replicating her analyses using the EVP-Phon database—which we designed to simulate the L2 English mental lexicon—and focus on how misperception might affect the structure of the mental lexicon. Misperceiving L2 sounds may lead learners to create lexical representations that are pseudo-homophones (e.g., if a learner cannot discriminate English /ɛ/-/æ/, then *pen-pan* are homophones) or pseudo-phonological neighbors (e.g., *pen* /pɛn/ and *man* /mæn/ are phonological neighbors when they should not be). We quantify the number of pseudo-homophones and pseudo-neighbors in a learner's mental lexicon at each CEFR proficiency level for two misperception patterns: /ɛ/-/æ/ and /l/-/r/. This allows us to analyze how lexical encoding issues could grow as more words are added to the lexicon.

INTRODUCTION

When second language (L2) learners begin acquiring an L2, they start by learning words. Learning a word means a person has stored a memory of that word (i.e., a lexical representation) in their mental lexicon. Each representation has information about a word's form, meaning, and use (Hulstijn, 2001).

Words in the mental lexicon can be connected to one another based on semantics or phonology. Words that are semantically related are words like *blue* and *red* because they belong to the same category of *colors*. Words that are phonologically related are called phonological neighbors (i.e., minimal pairs). These are words that differ by adding, subtracting, or replacing one phoneme (Vitevitch & Luce, 2016). For example, the word *like* /laɪk/ has the neighbors *alike* /ə.laɪk/ (+1 phoneme), *lie* /laɪ/ (-1 phoneme), and *look* /lʊk/ (replace 1 phoneme). When a word has a relatively large number of phonological neighbors, it has high phonological neighborhood density (PND). When a word has relatively few neighbors, it has low PND. The structure of a neighborhood can be visualized by drawing a line between all neighbors. Figure 1 visualizes the neighborhoods for a high PND word *(like)* and a low PND word *(lift)*.

In this paper, we explore how the misperception of sounds could affect the structure of phonological neighborhoods, and we outline ways that lexical characteristics, such as PND and lexical frequency, could potentially affect phonological learning.

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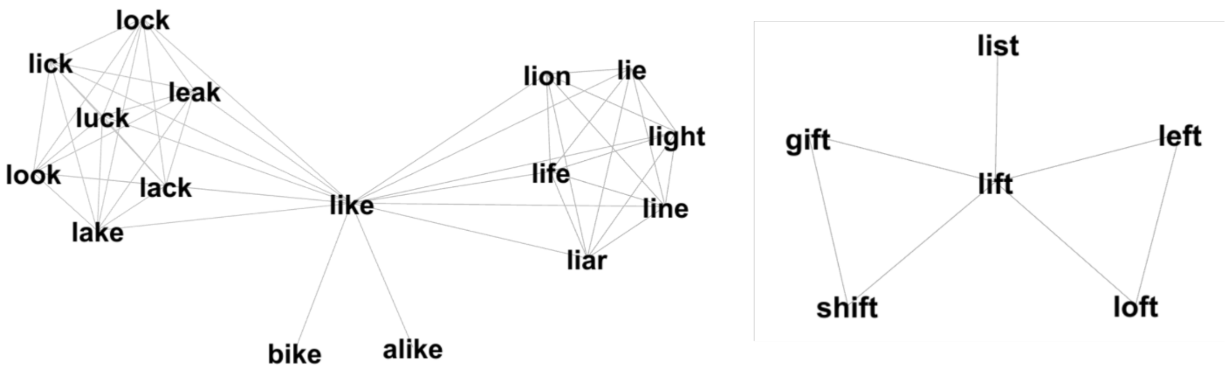

Figure 1. Phonological neighborhoods for the words “like” (high PND, n=14) and “lift” (low PND, n=5) according to the EVP-Phon (see Method section for details).

The phonological network

Learners have a phonological system they use to perceive and produce sounds and a mental lexicon where sounds are stored. These are distinct but interacting systems. How sounds are encoded (i.e., stored) in lexical representations is likely to be important for pronunciation because we assume that speakers draw on representations when producing words (Llompart & Reinisch, 2019).

Because the phonological component of the mental lexicon is structured as a network, the connections between lexical representations affect behavior, such as word recognition. As the speech stream unfolds, listeners continuously make predictions about which sound will come next, and they begin activating possible words (Luce & Pisoni, 1998). Once a word becomes activated, its neighbors also become activated and compete for recognition. To select a word among those activated, listeners must inhibit all competitors. Evidence for this has been found using a task in which participants must repeat the word they hear, as well as in an auditory lexical decision task (in which participants hear an auditory stimulus and must indicate whether they heard a real word or a nonword/fake word). This task requires participants to search their mental lexicon for a lexical representation that matches what they heard. When responding to high PND words, both L1 (Luce & Pisoni, 1998) and L2 speakers’ responses (e.g., Choi et al., 2021) are slower and less accurate because of increased competition.

PND can also affect how precisely the sounds of words are encoded (i.e., stored) in lexical representations. Precision refers to how strictly sounds are stored (see Barrios & Hayes-Harb, 2021). For example, if /ɛ/-/æ/ are perceptually confusable for an English learner, do *lecture* (with [ɛ]) and the nonword *l*[æ]*cture* sound equally acceptable? Llompart & Reinisch (2020) found that when they taught novel words (i.e., new, made-up) to German learners of English, learners began to encode the contrast more precisely if minimal pairs were presented together in the same trials (helping notice the contrasting information). Similarly, research shows that learners of English encode /ɛ/-/æ/ more precisely if those words have high PND. This has been found for L1 German (Llompart, 2021) and L1 Korean speakers (Rocca et al. 2023). One rationale for these results is that similar sounding words lead to more miscommunication which helps learners notice that there is a difference between potentially confusable sounds and that this difference affects the meaning of words (Rocca et al., 2023).

Quantifying L2 phonological neighbors

The structure of phonological neighborhoods in the L2 mental lexicon is still not well understood. Typically, PND figures are taken from databases such as CLEARPOND (27,751 words; Marian et al., 2012) or the KU Similarity Neighborhood calculator (19,340 words; Vitevitch, n.d.). However, one limitation in using these databases for L2 research is that they were built to reflect the size of the L1 mental lexicon, and typical L2 learners' vocabularies are smaller. Additionally, using this database to count phonological neighbors for L2 speakers carries the assumption that L2 lexical encoding mirrors L1 encoding. However, if a learner misperceives /l/ as /r/, then they likely perceive words like *light* and *right* as homophones: /raɪt/. If minimal pairs are perceived as homophones, they will likely be stored as homophones (e.g., Ota et al., 2009). When two words are erroneously perceived/stored as homophones, this is referred to as pseudo-homophony.

Cutler (2005) was one of the first to quantify the potential lexical ambiguities resulting from perceptual confusions. She focused on three word-recognition issues: 1) pseudo-homophony, 2) spurious activation of embedded words (e.g., "pen" is activated when a learner hears "panda" because it is encoded as p[ɛ]nda), and 3) temporary ambiguity (if a learner cannot distinguish /l/-/r/, then *register-legislate* are perceived as homophones until the sixth phoneme distinguishes them). Cutler calculated how many instances of each issue would occur for misperception of /ɛ/-/ae/ and /l/-/r/. Table 1 presents the results for pseudo-homophones according to each misperception pattern. These results indicate almost twice as many pseudo-homophones for /l/-/r/ misperception than /ɛ/-/ae/. These statistics were calculated using the CELEX British database (Baayen et. al, 1996), which contains 70,000 words. Using this database provides an upper bound on how many instances of a particular word-recognition issue *could* occur.

Table 1

Pseudo-homophone results in Cutler (2005)

Misperception pattern	Pseudo-homophones	Percent of lexicon
*/æ/ →/ɛ/	137	0.2%
/ɛ/→/æ/	135	0.19%
/l/→/r/	287	0.41%
/r/→/l/	311	0.44%

Note: *This shows the number of pseudo-homophones when /æ/ is misperceived as /ɛ/.

The current study builds on Cutler's (2005) work by examining how misperception can affect the structure of the L2 English mental lexicon. In simulating the L2 mental lexicon, a database like

CELEX (Baayen et. al, 1996) is too large – it would only work for people with extremely large vocabularies. Even using the CLEARPOND (Marian et al., 2012) or KU Similarity Neighborhood calculator (Vitevitch, n.d.) for L2 learners may not be ideal, because these databases reflect the average L1 speaker's mental lexicon. Instead, we perform Cutler's three analyses using a database we built to reflect the average L2 mental lexicon: *the English Vocabulary Profile Phonological database* (EVP-Phon; see Methods). Due to space restrictions, this paper focuses on pseudo-homophony and one novel analysis: pseudo-phonological neighbors (see supplementary materials for analyses of embedded words and temporary ambiguity). Pseudo-neighbors are words that should not be phonological neighbors but are, because of misperception. For example, if /l/ is perceived as /r/, then *rock* /rak/ and *clock* /krak/ become phonological neighbors (but should not be). Additionally, the EVP-Phon allows us to take proficiency levels into account.

METHODS

The EVP-Phon Database

Using a method similar to Luef (2022), we created the *EVP-Phon* database to quantify the PND of words for L2 English speakers at each Common European Framework of Reference for Languages (CEFR) proficiency level (see supplementary materials). The EVP-Phon is based on the English Vocabulary Profile (EVP), which is part of Cambridge University Press' *English Profile* (see Capel, 2015; Harrison, 2015). The goal of the EVP is to identify learners' productive vocabulary at each proficiency level. This was done largely by analyzing the Cambridge Learner Corpus—over 50 million words of written exam scripts produced by English language test takers (Harrison, 2015).

We used the American English version of Cambridge's EVP to create the EVP-Phon. To make it compatible with other PND databases, like CLEARPOND (Marian et al., 2012) or the KU Similarity Neighborhood Calculator (Vitevitch, n.d.), homophones and homographs were removed. When choosing which homophone/homograph to keep in the database, we kept the one used at the earliest CEFR level. If they were tagged with the same level, we kept the word with higher lexical frequency. This created a database of 6335 words at the C2 level with a total of 7,369 phonological neighbors. One notable difference between the EVP-Phon and other databases (CLEARPOND, etc.) is that irregular forms are not included (e.g., "drove" or "mice"). These forms likely have distinct representations and are not derived from morphology, but because Cambridge's EVP does not capture at which levels these forms are used, we could not add them to the database. Table 2 provides estimates for the size of the lexicon and number of phonological neighbors at each proficiency level in the EVP-Phon. These levels are cumulative (so A2 = A2 + A1 words). In the next section, we report how many pseudo-homophones and pseudo-neighbors appear in the EVP-Phon if a learner misperceives /ɛ/-/ae/ or /l/-/r/.

Table 2

Estimates of words known at each proficiency level in the EVP-Phon

Level	Total size of lexicon	Total PND
A1	562	536
A2	1403	1659
B1	2715	3330
B2	4394	5387
C1	5358	6238
C2	6335	7369

RESULTS

Analysis 1: Pseudo-homophony

We first substituted all instances of /ɛ/ for /æ/, so that a word like *bet* /bɛt/ became a homophone with *bat* /bæt/. This makes *bet* and *bat* pseudo-homophones. Similarly, a word like *ready* [rɛdi] became *r[æ]dy. Because r[æ]dy does not match another real word in the EVP-Phon, this transformation does not create a pseudo-homophone. Next, we obtained the pseudo-homophone totals. This calculation was done separately for each CEFR proficiency level. Table 3 shows the number of pseudo-homophones at each level for /ɛ/→/æ/ substitutions (i.e., /ɛ/ is misperceived as /æ/). For example, there are 22 homophone pairs at the C2 level—a total of 44 words. Third, this process was repeated with /l/→/r/ substitutions, and then again with /r/→/l/ substitutions. Following Vitevitch (n.d.), /r/ in the EVP-Phon consists of three sounds (/ɹ, ɝ, ɚ/) while /l/ consists of two sounds (/l, l̩/). This creates a difference in results when substituting /l/→/r/ and /r/→/l/. However, there was no difference between /ɛ/-/æ/ because this is substituting one sound for another. Table 3 shows that /l/-/r/ misperception results in approximately 4 times as many pseudo-homophones as /ɛ/→/æ/ misperception. There is also a relatively steady increase in pseudo-homophones from level to level, with steeper increases at the B1 and B2 levels for /l/-/r/ substitutions.

Table 3

Pseudo-homophony in the EVP-Phon

Level	Pseudo-homophones		
	*/ɛ/-/æ/	/l/→/r/	/r/→/l/
A1	3	5	5
A2	5	19	18
B1	9	45	39
B2	14	74	69
C1	18	84	78
C2	22	95	87

*The results are the same for /ɛ/→/æ/ and /æ/→/ɛ/ misperception.

Overall, our analysis returned fewer pseudo-homophones compared to Cutler (2005; Table 1). For /ɛ/-/ae/ misperception, we found 22 pseudo-homophones at the C2 level vs. ~136 in Cutler. For /l/→/r/, we found 95 pseudo-homophones and 87 for /r/→/l/ (C2 level). This is approximately 200 fewer than what Cutler found. However, because the EVP-Phon is 1/10 the size of the CELEX database (Baayen et. al, 1996), this actually means that a larger percentage of the lexicon becomes homophonous (95 pseudo-homophones = 1.5% of the lexicon) compared to what Cutler finds with the CELEX database (0.41%).

One difference between our analysis and Cutler's (2005) is that Cutler counts *excess-access* as a pseudo-homophone pair but only if /æ/ is misperceived as /ɛ/. This substitution results in excess-[ɛ]ccess, both of which match the real word *excess*. However, misperceiving /ɛ/ as /æ/ results in *[æ]cc[æ]ss-*acc[æ]ss, both of which are nonwords. In our analysis, *[æ]cc[æ]ss counts as a word because we assume that learners can create representations which others may consider a nonword (Darcy & Thomas 2019). For this study, we also assume that learners encode what they perceive—though we recognize that this may not always be the case (e.g., Darcy et al., 2012).

Analysis 2: Pseudo-neighbors

First, we substituted /ɛ/→/æ/. Second, we removed pseudo-homophones so that only one word from the homophone pair remained. This was done because we assume only one phonological representation for each word and keeping both words would erroneously inflate the number of neighbors. Third, we counted the number of phonological neighbors in the database at each proficiency level. Fourth, we compared this neighbors dataset that assumes misperception to the dataset that assumes no misperception, and we identified which words become neighbors because of misperception. Then we restarted the process with /l/→/r/ substitutions followed by /r/→/l/ substitutions.

Table 4 shows the number of pseudo-neighbors as well as the total number of phonological neighbors in the lexicon after each substitution. These figures show a similar number of pseudo-neighbors for each misperception pattern at the A1 level; however, pseudo-neighbor growth for /l/-r/ misperception continues to almost double for each proficiency level until finally slowing at

C1. At the C2 level, misperception of /l/→/r/ creates 1676 pseudo-neighbors, which represents 20% of all neighbors. The number of pseudo-neighbors found is surprising because we are assuming that perception is native-like except for one substitution. If we truly tried to simulate the average learner's perceptual system, the additional substitutions would likely make the structure of the lexicon immensely more complicated than what we find here.

Table 4

Phonological neighbors created after sound substitutions

Level	Pseudo-neighbors			Resulting total phonological neighbors		
	/ɛ/-/æ/	/l/→/r/	/r/→/l/	/ɛ/-/æ/	/l/→/r/	/r/→/l/
A1	65	75	74	588	586	589
A2	190	319	323	1824	1831	1869
B1	342	723	692	3614	3692	3734
B2	500	1213	1164	5775	5993	6025
C1	565	1380	1310	6645	6946	6946
C2	641	1676	1613	7807	8263	8280

DISCUSSION

The current study examined how misperception could affect the structure of the L2 English mental lexicon. Using a database built to simulate the size of the L2 English mental lexicon, we found larger counts of both pseudo-homophones and pseudo-phonological neighbors for /l/-/r/ misperception than /ɛ/-/ae/. Compared to Cutler (2005), we found fewer pseudo-homophones in terms of raw numbers, but a larger proportion of the L2 lexicon becomes homophonous for each misperception pattern.

It is important to keep in mind that the EVP-Phon database was created using mostly writing data from learners with different L1 backgrounds and that each phonological representation uses the dictionary form. Therefore, representations are based on native speaker representations. As far as we are aware, this is how all PND databases are currently constructed. Nevertheless, it is a useful tool when working with learners who come from different language backgrounds, and it also offers the opportunity to begin creating more tailored L1→L2 databases to more fully understand how perception affects the structure of the mental lexicon. As our analyses revealed, misperceiving just one sound for another can create up to 1600 pseudo-neighbors.

It is still unclear how exactly pseudo-homophones and pseudo-neighbors affect learners' lexical behavior, but here we outline several possibilities using /l/→/r/ misperception as an example. Figure 2-A shows the phonological neighborhood for the word *rock*. At the C2 level, *rock* has 9 neighbors, assuming no misperception. Figure 2-B shows the same neighborhood again but with *rock*'s pseudo-neighbors (only words containing /l/ or /r/ are included for simplification). First, this figure shows that *rock-lock* have merged into pseudo-homophones. Second, there are other words that have potential homophones: leak-reek, lack-rack, look-rook, lake-rake. *Reek*, *rack*, *rook*, and *rake* are not in the EVP, so they are not shown here; however, it is possible that learners know them and they therefore could become pseudo-homophones. Third, even though Figure 2-B is only showing /l/-/r/ neighbors, the size of the neighborhood is almost twice as large as the original. Overall, Figures 2A-2B show that misperceiving just one sound for another can substantially affect a neighborhood's size and structure.

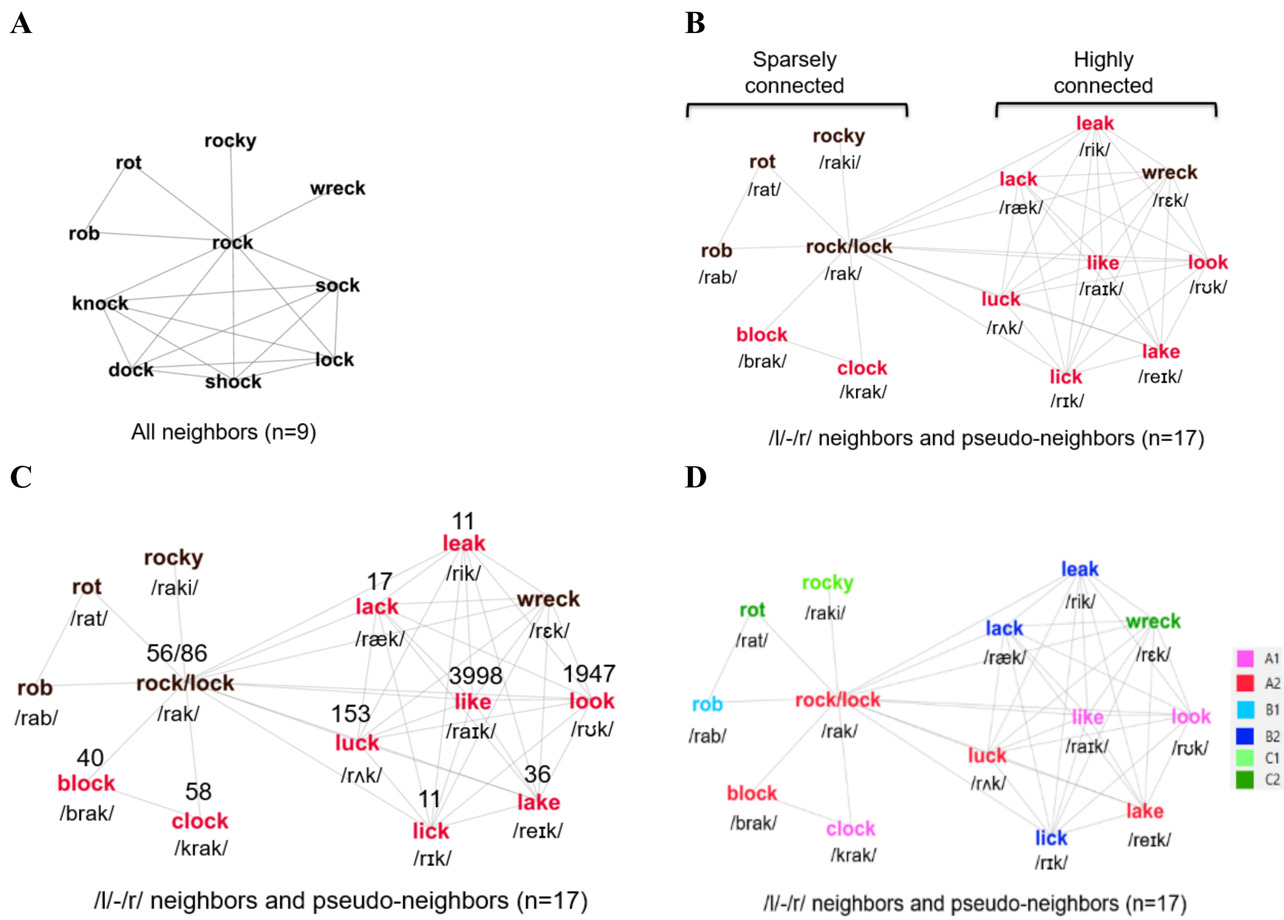

Figure 2. Visualizing the neighbors and pseudo-neighbors of the word rock

> *Note.* Panel A) Visualization of all of *rock's* neighbors without any misperceptions. Panel B) *rock's* /l/-/r/ neighbors when /l/ is misperceived as /r/. Panel C) Lexical frequency of pseudo-neighbors (SUBTLEX-US; Brysbaert & New, 2009). Panel D) CEFR-Proficiency at which a word enters the lexicon.

If a learner at the C2 level has a neighborhood similar to Figure 2-B, how can an instructor help them update that neighborhood so that it begins to resemble Figure 2-A? Hypothetically, a first step could be to help learners acquire accurate /l/-/r/ perception, for instance by training with syllables (e.g., /ra/-/la/) or words. Either way, lexical representations need to then be updated to reflect the updated perceptual system. A potential challenge here pertains to selecting words for training: Are all words equally good candidates? Or do their lexical characteristics and number of connections make some words (such as those on the left of Figure 2-B which have fewer connections) better candidates than others? Fewer connections could mean less influence from other words and therefore easier to change. This is what Luef et al. (2022) found when analyzing the pronunciation of L2 English voiceless stops. The pronunciation of low PND words was more target-like than high PND words. While an interesting finding, this may be more indicative of how representations update naturally. In a training/instructional setting, learning might generalize further throughout the neighborhood when training with high PND words. However, updating representations of highly connected words may be harder because they are more entrenched, so learning might be slower overall but could generalize further over time due to the high connectivity.

Other lexical characteristics, such as lexical frequency (Llompart, 2021) could also play a role. Words with lower lexical frequency might be less entrenched and therefore easier to change through practice (see Figure 2-C). In this case, *lick*, *lake*, *leak*, and *lack* would be good training candidates. Although, in a longitudinal analysis of low proficiency English learners' vowel productions, Munro and Derwing (2008) found a possible effect of frequency in which learners' vowel productions in high frequency words might be more intelligible than low frequency words. In this case, words like *look*, *like*, *luck* would be better candidates for training for lower proficiency learners.

Alternatively, Darcy & Holliday (2019) theorized that the timing of word learning might affect how sounds are encoded in lexical representations. They propose that words learned later in the acquisition process (i.e., more recently) should be represented more precisely because learners' phonological systems have become more attuned to the L2. Because recent representations are less entrenched, training with these words could be more effective because learning might permeate the system through them. Figure 2-D shows at which proficiency level the words in *rock*'s neighborhood are first used. In this case, *lack*, *leak*, and *lick* would be good training candidates.

We hope that readers come away with the main point that lexical characteristics might be an important aspect to consider when trying to understand how learners acquire vocabulary and how they encode sounds in words. Of course, the predictions and possibilities presented here are speculative and must be empirically tested. For example, do lexical characteristics affect word *recognition*, word *learning*, and word *production* differently (as seen in L1 English speakers; see Vitevitch & Luce, 2016)? Do the effects of lexical characteristics change depending on a learner's proficiency and vocabulary size? Do lexical characteristics similarly affect vowels versus consonants or even sonorants versus obstruents? Answers to these questions might explain differential effects of high/low PND and high/low frequency discussed earlier. Additionally, we can ask whether lexical characteristics have the same effects with different L1-L2 combinations. For example, PND (adding, subtracting, or replacing one phoneme) might work well for L1 German-L2 English and L1 Korean-L2 English but might have to be reconceptualized for different language pairings.

In conclusion, this study builds on Cutler (2005) by demonstrating that misperceiving just one segment for another could change phonological neighborhoods in substantial ways, and it opens up new avenues for research. Indeed, the reality of the structure of the L2 English mental lexicon must be vastly more complicated than what is suggested here. How this structure affects behavior (speed and accuracy), modality (pronunciation versus word recognition), and learning are open questions. In the discussion section, we outlined possibilities for how different lexical characteristics may affect the way learners encode sounds into lexical representations. We also outline a number of novel questions that need to be answered to help us move forward in understanding how lexical characteristics impact the L2 mental lexicon. The EVP-Phon is a promising tool to begin exploring these questions, and we hope others find it useful.

ABOUT THE AUTHORS

Brian Rocca is a PhD candidate at Indiana University. His main research interests are second language phonology, the bilingual mental lexicon, and language pedagogy.

Frank Martino works in the field of psychometrics and high-stakes standardized assessments. His research interests reside at the intersection of statistics, data science, and linguistics/NLP.

Isabelle Darcy is a professor in the Department of Second Language Studies at Indiana University (USA) and publishes on pronunciation pedagogy, second language phonology, and the bilingual mental lexicon.

Contact information:

Indiana University
Department of Second Language Studies
Ballantine Hall 718
1020 E Kirkwood Ave.
Bloomington, IN 47405 USA
+1 812 855 0033
idarcy@indiana.edu

REFERENCES

Baayen, R. H., Piepenbrock, R., & Gulikers, L. (1996). The CELEX lexical database [CD-ROM]. Linguistic Data Consortium. https://doi.org/10.35111/gs6s-gm48

Barrios, S., & Hayes-Harb, R. (2021). L2 processing of words containing English /æ/-/ɛ/ and /l/-/ɹ/ contrasts, and the uses and limits of the auditory lexical decision task for understanding the locus of difficulty. *Frontiers in Communication*, 6, Article 689470. https://doi.org/10.3389/fcomm.2021.689470

Brysbaert, M. & New, B. (2009). Moving beyond Kucera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior Research Methods*, *41*(4), 977–990. https://doi-org.proxyiub.uits.iu.edu/10.3758/BRM.41.4.977

Capel, A. (2015). The English vocabulary profile. *English Profile in Practice*, *5*, 9–27.
Choi, M. K., Holliday, J. J., & Munson, B. (2021). The influence of lexical characteristics and talker accent on the recognition of English words by native speakers of Korean. *The Journal of the Acoustical Society of America*, *150*(2), 769–782. https://doi-org.proxyiub.uits.iu.edu/10.1121/10.0005735
Cutler, A. (2005). The lexical statistics of word recognition problems caused by L2 phonetic confusion. In *Interspeech 2005 – 9th European Conference on Speech Communication and Technology* (pp. 413–416). 9th European Conference on Speech Communication and Technology, Lisbon, Portugal, September 4-8, 2005. Retrieved from ISCA Archive: http://www.mpi.nl/publications/escidoc-57393
Darcy, I., Dekydtspotter, L., Sprouse, R. A., Glover, J., Kaden, C., McGuire, M., & Scott, J. H. (2012). Direct mapping of acoustics to phonology: On the lexical encoding of front rounded vowels in L1 English–L2 French acquisition. *Second Language Research*, *28*(1), 5–40. https://doi-org.proxyiub.uits.iu.edu/10.1177/0267658311423455
Darcy, I., & Holliday, J. J. (2019). Teaching an old word new tricks: Phonological updates in the L2 mental lexicon. In J. Levis, C. Nagle, & E. Todey (Eds.), *Proceedings of the 10th Pronunciation in Second Language Learning and Teaching.* Conference, ISSN 2380-9566, Ames, IA, September 2018 (pp. 10–26). Ames, IA: Iowa State University.
Darcy, I., & Thomas, T. (2019). When blue is a disyllabic word: Perceptual epenthesis in the mental lexicon of second language learners. *Bilingualism: Language and Cognition*, 22(5), 1141–1159. https://doi.org/10.1017/S1366728918001050
Harrison, J. (2015). What is English Profile? In J. Harrison & F. Barker (Eds.), *English Profile Studies 5: English Profile in Practice* (pp. 1–8). Cambridge University Press.
Hulstijn, J. (2001). Intentional and incidental second-language vocabulary learning. In P. Robinson (Ed.), *Cognition and Second Language Instruction* (pp. 258–286). Cambridge University Press. https://doi.org/10.1017/CBO9781139524780
Llompart, M. (2021). Phonetic categorization ability and vocabulary size contribute to the encoding of difficult second-language phonological contrasts into the lexicon. *Bilingualism: Language and Cognition, 24*(3), 481–496. https://doi.org/10.1017/S1366728920000656
Llompart, M., & Reinisch, E. (2019). Imitation in a second language relies on phonological categories but does not reflect the productive usage of difficult sound contrasts. *Language and Speech*, *62*(3), 594–622. https://doi.org/10.1177/0023830918803978
Llompart, M., & Reinisch, E. (2020). The phonological form of lexical items modulates the encoding of challenging second-language sound contrasts. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *46*(8), 1590-1610. https://doi.org/10.1037/xlm0000832
Luce, P. A., & Pisoni, D. B. (1998). Recognizing spoken words: The neighborhood activation model. *Ear and Hearing*, *19*(1), 1–36. https://doi.org/10.1097/00003446-199802000-00001
Luef, E. M. (2022). Growth algorithms in the phonological networks of second language learners: A replication of Siew and Vitevitch (2020a). *Journal of Experimental Psychology: General*, *151*(12), e26–e44. http://dx.doi.org/10.1037/xge0001248

Luef, E. M., Resnik, P., & Gráf, T. (2022). Diffusion of Phonetic Updates within Phonological Neighborhoods. *ELOPE: English Language Overseas Perspectives and Enquiries*, *19*(2), 149–168. https://doi.org/10.4312/elope.19.2.149-168

Marian, V., Bartolotti, J., Chabal, S., Shook, A. (2012). CLEARPOND: Cross-Linguistic Easy-Access Resource for Phonological and Orthographic Neighborhood Densities. *PLoS ONE 7*(8): e43230. https://doi.org/10.1371/journal.pone.0043230

Munro, M. J., & Derwing, T. M. (2008). Segmental acquisition in adult ESL learners: A longitudinal study of vowel production. *Language Learning*, *58*(3), 479-502. https://doi.org/10.1111/j.1467-9922.2008.00448.x

Ota, M., Hartsuiker, R. J., & Haywood, S. L. (2009). The KEY to the ROCK: Near homophony in nonnative visual word recognition. *Cognition, 111*(2), 263-269. https://doi-org.proxyiub.uits.iu.edu/10.1016/j.cognition.2008.12.007

Rocca, B., Llompart, M., & Darcy, I. (2023). The effects of phonological neighborhood density, perception, and vocabulary size on English learners' phonolexical encoding of confusable segmental contrasts [Manuscript submitted for publication]. Department of Second Language Studies, Indiana University.

Vitevitch, M.S. (n.d.). *KU similarity neighborhoods*. https://calculator.ku.edu/density/about.

Vitevitch, M. S., & Luce, P. A. (2016). Phonological neighborhood effects in spoken word perception and production. *Annual Review of Linguistics*, *2*, 75–94. https://doi-org.proxyiub.uits.iu.edu/10.1146/annurev-linguistics-030514-124832