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Refining key concepts of the Ontogenesis Model of the L2 lexical representation

Denisa Bordag[1,2], Kira Gor[3] and Andreas Opitz[1]

[1]Leipzig University, Leipzig, Germany; [2]University of Haifa, Haifa, Israel and [3]University of Maryland, College Park, USA

Author's Response

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Address for correspondence:
Denisa Bordag, Universität Leipzig, Beethovenstr. 15, 04107 Leipzig, Germany.
Email: denisav@uni-leipzig.de

1 Introduction

In our keynote article Ontogenesis Model of the L2 Lexical Representation (OM), we introduced a blueprint of a model that focuses on the multidimensionality of the L2 lexical representations (LRs), their properties, and development. Although its emphasis is on L2 LRs, it is also applicable to the development of L1 representations. We attempted to synthesise current research by drawing on a wide range of studies and bringing various research lines together. Such an approach makes it possible to outline a comprehensive model that connects seemingly disparate strands of research on L2 representations and their development (Escudero & Hayes-Harb, 2021) and to accommodate studies that are rarely considered together and have so far led a rather isolated life in the literature (Lemhöfer, 2021).

At the same time, zooming out to gain a broader overview of the area necessarily entails a less detailed account of individual subareas, as noted in several commentaries, especially when operating under space limitations. These subareas are often addressed by less extensive models than the OM that handle particular aspects in more detail than is possible for a holistic model with comprehensive ambitions. We understand theory building and modelling as a continuum, with studies exploring individual phenomena and formulating narrow-scope, high-resolution hypotheses about them at one end and comprehensive models and theories with complex architectures that try to cover larger areas and are of a more general character at the other. While the OM is closer to the latter, we acknowledge the usefulness and necessity of the existence of models with varying scope as they build upon and complement each other, and can serve various purposes to different degrees.

For example, one ambition of the OM is to be accessible and useful for second language instruction. As pointed out by Baxter, Leoné and Dijkstra (2021a), the OM can serve as a "valuable theoretical underpinning for educational research". For this particular purpose, it is less essential to present considerations of how different aspects of the OM can be computationally implemented; it is more important to synthesise current knowledge for further research that specifies which tasks and teaching methods contribute to the development of which components of lexical representations or to the reduction of fuzziness and moving towards the optimum in each specific dimension or domain. Baxter, Droop, van den Hurk, Bekkering, Dijkstra and Leoné (2021b) demonstrated such an approach that can induce more research-informed and effective language instruction and thus L2 learning.

We were pleased that most commentators valued the approach that we decided to take when formulating the OM and agreed that it is a welcome, thought-provoking step, which can foster further productive research on L2 LRs. We identified three main topics in the commentaries, each addressed by several commentators. The first topic concerns the interaction of L2 representations with the L1 lexicon, the second topic – the concept of fuzziness and the optimum, and the third topic – OM's potential for computational implementation. In the following, we address the three topics in separate sections and devote the concluding section to several other issues raised by individual commentators.

2 L2 - L1 interaction

The OM focuses on the L2 lexicon, its units and their development. However, it neither denies the cross-linguistic interaction, nor claims that the L2 "dances on its own" (cf. Kroll, Vargas Fuentes & Torres, 2021). Throughout the keynote, we refer to L1 effects on the acquisition of L2 lexical representations, focussing on the ontogenesis of individual components of L2 units rather than the global mechanisms of the L1-L2 interaction. This focus of the OM highlights particular aspects of the L2 lexicon to achieve their greater visibility rather than diminishing the relevance of other aspects that are addressed more often, e.g., in bilingual models such as BIA+ (Dijkstra & van Heuven, 2002) or RHM (Kroll & Stewart, 1994). As fittingly put forward by van Hell (2021), the "in-depth and comprehensive description of the developmental dynamics of L2 representations positions the Ontogenesis Model in the current literature of models describing the bilingual mental lexicon".

In particular, although we acknowledged the significance of the InterNetwork, which has a prominent function in the L1-L2 interaction, we refrained from addressing it in detail. However, we give credit to the opinions expressed in some commentaries (e.g., Ecke & Hall, 2021; van Hell, 2021; Mishra, 2021) that an overall model of a multilingual mind needs to cover also this area, in addition to other aspects that are not foregrounded or addressed by the OM, such as the processing mechanisms (the OM's focus is on representation), the L2-L1 interaction, and the interaction between L1-L2-L3-Ln, etc. We agree with Ecke and Hall (2021) that based on the similarity of architectures between the two models, the Parasitic Model (Hall & Ecke, 2003) is a possible extension of the OM that focuses on the L1-Ln interaction, which the OM eschewed.

In the presented version, the OM models the situation when L1 is a dominant language. This is indeed not always the case, as evidenced by heritage speakers whose L1 loses its dominance later in life (cf. Kroll et al., 2021). The OM offers the means to capture the individual variance not only for different speakers, but also for individual LRs and even their single components. It can therefore also model scenarios in which L2 lexical representations reach their optima (in one or more dimensions or domains), while the corresponding L1 equivalents are at their optima as well, and also scenarios in which L1 LRs distance away from the reached optima due to attrition leading to increased fuzziness. Indeed, it remains a debatable question in the SLA field whether to label a language as L1 or L2 based on language dominance versus age of acquisition. Crucially, the OM does not claim that L2 representations would fundamentally differ from L1 representations or be subserved by different cognitive mechanisms or brain structures (on the contrary!), and it considers variation also in L1, regardless of the terminology used (e.g., compared to the L2/non-dominant language, a larger proportion of the L1/dominant language units reach their optima). The OM's ability to grasp various acquisition scenarios is especially suited to addressing the restructuring dynamics of the developing and attriting lexicons and LRs.

3 Fuzzy lexical representations and the optimum

Fuzziness and the optimum are two crucial concepts explored in the OM that have been addressed in the previous literature only to a limited degree. Several commentators (Gyllstad 2021; Gass, 2021; Darcy, 2021; Baxter et al., 2021a; Ecke & Hall, 2021; Li & Zhao, 2021; Escudero & Hayes-Harb, 2021; Lemhöfer, 2021; Mishra, 2021; Nicol, 2021; Wolter, 2021; Calabria, 2021) have rightly noted that these concepts need to be elaborated upon, which was not possible in the limited space provided by the keynote. Aware of this, we opted for writing a companion article devoted uniquely to fuzzy lexical representations (FLR) (Gor, Cook, Bordag, Chrabaszcz & Opitz, in press) as part of the research topic *Fuzzy Lexical Representations in the Nonnative Mental Lexicon* (https://www.frontiersin.org/research-topics/15827/fuzzy- lexical-representations-in-the-nonnative-mental-lexicon). Even though it was submitted before we received the commentaries, it addresses many of the questions raised in them. Below, we discuss the most important issues raised by commentators and refer to the mentioned article for further details.

According to the OM and the FLR hypothesis (Gor et al., in press), the general property of most L2 LRs is their fuzziness, defined as imprecise, ambiguous or low-resolution encoding at one or more of the OM's dimensions. Fuzziness, as a proxy for poor encoding, will have different manifestations depending on its locus, as well as different effects on the LR and its functioning in different networks; accordingly, multiple scenarios need to be entertained (see Baxter et al., 2021a; Ecke & Hall, 2021; Escudero & Hayes-Harb, 2021; Lemhöfer, 2021).

The unique properties of each LR, including its degree of fuzziness, are influenced by major factors, such as L1 TRANSFER (problems with phonological encoding of L2 sounds, initial borrowing of the meanings encoded during L1 acquisition, and for same-script L2s – orthographic L1 transfer), AGE OF ACQUISITION (lower entrenchment for words acquired later in life, as is the case for adult L2 learners), THE TYPE OF INPUT leading to the acquisition of the LR (naming objects present in the environment versus relying on translation equivalents or inferring the meaning from multiple contexts in extensive reading), and THE AMOUNT OF INPUT (the number of encounters with the LR). Consequently, the individual profile of each LR, which is shaped by the settings for each of the factors that impact the dimensions and components of the LR, defines its ontogenetic trajectory.

The FLR hypothesis argues that inexact encoding characterises both L1 and L2 LRs and postulates a certain continuity between L1 and L2, with a major difference that many more words in L2 involve fuzzy encoding compared to L1 (see *3.3 The optimum* below). Fuzzy encoding has implications for lexical competition and leads to problems with identifying the unique lexical candidate in word recognition. Both L1 and L2 word recognition rely on the same core lexical processing mechanisms – lexical activation, competition, and selection – deployed differently when FLRs are involved. However, there is one notable difference between the sources of fuzziness in L1 and L2 – during the main phase of monolingual L1 acquisition, there is no other language to borrow from (Darcy, 2021). When L2 starts to be acquired, it can to some degree induce fuzziness in the L1 lexicon as well (Kroll et al., 2021).

3.1 Approaches to modelling fuzziness

The main claim of the FLR hypothesis is that fuzzy encoding of either word form (phonological or orthographic), meaning, or both is pervasive in L2, and may have different sources and lead to processing consequences. While similar approaches to lexical encoding, such as the lexical entrenchment hypothesis (Diependaele, Lemhöfer & Brysbaert 2013; Brysbaert, Lagrou & Stevens, 2017) and the computational models of bilingual visual word recognition, such as BIA+ and Multilink (Dijkstra, Wahl, Buytenhuijs, van Halem, Al-Jibouri, De Korte & Rekké, 2019) rely on input frequency as the main factor influencing the quality of lexical encoding, the FLR hypothesis considers other factors beyond input frequency. These factors – arising from a particular L1-L2 combination, age-related cognitive issues, or the type of input (see above) – interact with input frequency to produce different acquisitional trajectories for individual LRs.

The existing bilingual computational models typically use accurate form encoding at the input level and model the learning process based on native-like encoding of the word form (cf. the bilingual implementation of DEVLEX II, ZHAO & LI, 2010). This assumption fundamentally diverges from the real process of shaping L2 LRs. One possible solution to test in a computational model would be to introduce the INTAKE level for the L2 word form (cf. Corder, 1967; Gass, 1997) that would reflect the encoding difficulties experienced by L2 learners. At the intake level, phonological encoding would have ambiguous or missing

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segments, and with such low-resolution encoding, the phonological network would reflect these initial intake-level properties of L2 LRs. Different developmental trajectories can be envisaged when more input is received for a particular LR. If the initial encoding is summative because L2 learners have a generally inefficient phonological categorisation system well attuned to the phonetic properties of L1, but poorly attuned to L2 (cf. Escudero, Benders & Lipski, 2009), the initially confusable similar-sounding words, such as the English words *garnet* and *garment* or *caddy*, *candy*, and *candle* will gradually receive accurate encoding. In a computational model, initial fuzzy intake for such LRs will have to become nativelike with additional input (similar to backpropagation). Conversely, if the words are differentiated by an L2 phonological contrast difficult for a speaker of a particular L1, such as the English /l/-/r/ contrast for L1 speakers of Japanese or Korean, more input may not lead to improved phonological encoding of the words *lock* and *rock*. For *lock* and *rock*, additional input will also be limited in its impact on the strength of unique form-meaning connections, with lexical confusions occurring even in high-proficiency L2 speakers. Persistent fuzzy phonological encoding will have implications for the semantic network as well – while in L1, *lock* and *key* will be associated, in L2, *rock* and *key* will be associated as well. These semantic 'anomalies' could be modelled by building fuzziness into the initial phonological intake level to ensure that simulated L2 lexical networks will develop in realistic ways.

Another observation regarding fuzzy form-meaning links in L2 is based on the evidence that L2 learners confuse words with a larger Levenstein distance than L1 speakers (Cook, Pandža, Lancaster & Gor, 2016). An adequate computational simulation of the Russian L2 lexicon (as opposed to the L1 lexicon) should therefore produce the connections between words such as */malatok/* ("hammer") and */malako/* ("milk") with a Levenshtein distance of two that will be similar in strength to minimal pairs of words with a Levenshtein distance of one. These form-based connections will also cascade from the form to the meaning representation, as demonstrated in human participants.

3.2 Fuzziness at the representational or processing level

A potential alternative to the representational account locates fuzziness at the processing level (Lemhöfer, 2021; Nicol, 2021). While the FLR hypothesis clearly identifies the difficulties at the processing level, often associated with phonological or semantic mismatches between L1 and L2, as the source of FLRs, it also supports fuzziness at the representational level. Admittedly, it is difficult to tease apart the online phonological processing problems triggered by perceptual difficulties involving a particular L2 contrast, such as the /l/-/r/ contrast in English for L1 speakers of Japanese and Korean, and the representational deficits. This is especially true when auditory input is used in experiments.

The FLR hypothesis relies on empirical evidence to substantiate the representational account of fuzziness – in addition to the widely accepted online processing-level account. First, it is challenging to explain lexical confusions of phonologically similar L2 words that are not phonological neighbours (have a Levenshtein distance of 2 or higher), when they do not involve particularly difficult L2 contrasts (e.g., */malatok/* "hammer" and */malako/* "milk" in Cook et al., 2016), within the online processing account. Indeed, such words do not present perceptual difficulties that would make them perceptually confusable for L2 speakers. Furthermore, the two similar-sounding words are not presented auditorily together in either of the experiments in Cook and colleagues (2016); rather, the result of online perceptual processing of one word is compared to its mental representation to access its meaning in a pseudo-semantic priming task. According to the FLR hypothesis, it is because the L2 LRs are poorly encoded, and the form-meaning mappings are weak, that transient or permanent lexical confusions arise.

Second, a pattern of semantic confusions was observed in L2 participants in semantic judgment experiments that did not involve any spoken input, but only an orthographic one (Ota, Hartsuiker & Haywood, 2009, 2010). The findings that Japanese speakers considered *hard* and *lock* semantically related supports the idea of a lexical confusion of *lock* and *rock*, with fuzzy phonological encoding as its source. Poorly encoded phonological form must have led to poorly encoded orthographic form, because there is nothing inherently more difficult in contrasting two letters, "l" and "r" than many other English letters. Accordingly, fuzzy form-meaning mappings for such word pairs did not arise because of perceptual problems experienced in online processing of the written input during the experiments.

Third, the question arises of whether inhibition in pseudo-semantic cross-modal priming (cow-HAMMER) observed in L2 signals fuzziness in L2 LRs, rather than reflects a universal pattern of semantic activation of phonological neighbours also reported in L1 (Pecher, de Rooij & Zeelenberg, 2009; see Lemhöfer, 2021). The prevailing L1 evidence supports the cascaded model of visual word recognition (McClelland & Rumelhart, 1981), according to which semantic information is activated before orthographic processing is finished. Transient semantic activation of phonological onset competitors was reported for visual-world eye-tracking as well as a semantic property task in L1 (Pecher et al., 2009; Yee & Sedivy, 2006); importantly, in L1 this activation disappeared when the interval between the target noun and its property was increased (Pecher et al., 2009). In contrast, L2 participants were more taxed by handling semantic activation of phonological neighbours (Cook et al., 2016 and Ota et al., 2009, 2010). They showed processing delays and/or increased error rates even when they had sufficient processing time, but were dealing with a problematic L2 phonological contrast (Ota et al., 2009), and when the L1 control group showed no processing delays (Cook et al., 2016).

3.3 The optimum

The constructs of the optimum and fuzziness in the OM are related in that when an LR is at its optimum, fuzziness is reduced to a minimum and is functionally not a significant factor in the processing of the LR. As with fuzziness, the optimum can be reached in one or more of the domains, and accordingly there are multiple scenarios describing the developmental trajectories and unique profiles of individual LRs.

In this sense, Gyllstad's (2021) comparison of the optimum to the concept of 'ultimate attainment' could be somewhat misleading. While ultimate attainment characterises the achieved level of acquisition of an individual speaker, the term optimum refers to the utmost acquisition stage for individual components of a lexical representation. The terms dissociate if one considers that the lexicon of a learner who has reached the ultimate attainment level can contain a large amount of fuzzy lexical representations below their optima, with some of them fuzzy due to fossilisation.

The optimum can be viewed as an ideal state of an LR, when all components are perfectly encoded and the degree of fuzziness is zero. Clearly, although such an idealized state can be imagined, it would be hard to operationalise for multiple reasons, one being that language itself is in a constant state of development. Therefore, we suggest that a proxy of an optimum is defined for empirical purposes based on practical considerations and observations of both L1 and highly proficient L2 speakers; for example, an optimally encoded LR or its component is best adjusted for the processing of the particular language. Then, an optimum proxy would refer to the properties that the components of a given representation have in educated L1 speakers, for whom the given LR belongs to their core vocabulary, which can be experimentally established. Since there will be certain individual variation even in such a case, the optimum is modelled as a range in the OM (see Figure 1 in Bordag, Gor & Opitz, 2021, for a visual representation).

With respect to the proportion of fuzzy representations in L1 and L2 (i.e., those below their optima), it may be useful to refer to the depth of word knowledge model of the mental lexicon (Wolter, 2001) that reflects a wide range of lexical knowledge not only in L2 but also in L1 speakers, starting with the core of 'well-known words' and moving to the periphery of 'slightly known words'.

The core, as we define it, comprises LRs that are functionally at their optima. As the core is smaller for L2 speakers, they experience more pervasive fuzziness effects in communicative situations where this is not an issue in L1. This can be demonstrated in the following imaginary simplified example: take the 10 000 most frequent words. Of these, let 60% be at their optima in an L1 speaker. An L2 learner may however know only 60% of these words, i.e., 6000. From these, 50% (somewhat less than in L1 due to specific L2 encoding problems) belong to the core of their L2 vocabulary, i.e., to the LRs that are at their optima, which is 3000. If the native speaker and the L2 speaker are engaged in a conversion for which they need the 5000 most frequent words (between B2 and C1 in CEFR), the L2 speaker already experiences heavy consequences of (representational) fuzziness, while the L1 speaker experiences none.

4 Computational implementations

The OM relies primarily on behavioural research, and its blueprint presented in Bordag et al. (2021) does not aim to be a computational model. This fact has been addressed in several commentaries, which of course then missed precise specifications for computational implementation (Meara, 2021; Li & Zhao, 2021; Jamieson, Johns, Taler & Jones, 2021; Ellis, 2021).

Computational modelling is certainly an important method that provides insights into which processes or representations are more plausible in light of experimental results on L1 and L2 acquisition and processing and, as such, it is a desirable complement to any language acquisition model or theory. At the same time, as mentioned in the introduction, models can be positioned differently on the continuum with respect to the smaller scope/high resolution vs. larger scope/lower resolution dimension – with holistic models like the OM approaching the latter end of the continuum. Although there have been significant advances in computational modelling in recent years, with the developed algorithms and the domains they cover growing in size and complexity, the models still offer solutions to relatively narrow areas that often focus on single domains such as semantics (e.g., co-occurrences-based semantic space models such as HAL by Lund & Burgess, 1996 or BEAGLE by Jones & Mewhort, 2007), the phonetics/phonology interface (e.g., the L2LP model and its computational implementation of learning Spanish front vowels, van Leussen & Escudero, 2015), or form-meaning mappings (DevLex-II, Li, Zhao & MacWhinney, 2007; Zhao & Li, 2010). Even complex models that consider additional aspects of human language processing – e.g., the effects of age (Montag, Jones & Smith, 2015), reading history (Aujla, in press), and multilingual language exposure (Johns, Sheppard, Jones & Taler, 2016) – are typically able to implement only one aspect at a time, while disregarding most other factors that affect language acquisition.

As demonstrated by Meara (2021), in order to formulate a computational model, many low-level specifications (such as definitions for connections or activations) are necessary that may or may not be crucial for the main claims or purposes of a given model or theory (Poibeau, Villavicencio, Korhonen & Alishahi, 2013). In many cases, neither experimental nor computational evidence can agree on which of several possible mechanisms is the one deployed by the human mind (cf. e.g., the debate on sequentiality vs. interactivity of phonemic perception and lexical recognition and possible implementations in van Leussen & Escudero, 2015). We believe that for comprehensive models such as the OM, it may be advantageous not to commit itself to certain implementation mechanisms, and thus leave the options open – to inspire their implementation in various existing or not-yet-existing computational frameworks.

In addition, not all computational simulations are likely to reflect the way language is acquired and processed by humans. For instance, Jamieson et al. (2021) mention Word2Vec (Mikolov, Sutskever, Chen, Corrado & Dean, 2013) and GloVe (Pennington, Socher & Manning, 2014) as examples of fully specified models that derive lexical representations. Essentially, these models deal with semantic similarity based on distributional similarity (going back to Firth, 1957; Harris, 1954). These models use contextual co-occurrences to construct word vector spaces, in which words are represented as multidimensional vectors, such that the similarity between vectors correlates with the semantic similarity between those words. Each word is mapped to a vector, and the vector values are learned in a manner similar to a neural network. In particular, GloVe assumes that the relationship between the meanings of two words can be approximated by a ratio of the global co-occurrence probabilities of each of these words with its context words (Kirschenbaum, 2021). Such accounts simplify the emergence of semantic relations by reducing it to approximations of contextual co-occurrences. For L2 lexical acquisition, the role of L1-L2 semantic mappings or of the nonlinguistic context of exposure to the LR also matter. Moreover, these models work on very large corpora containing millions of sentences, which are necessary for the calculation of distributional similarity, but are unavailable to individual speakers. Capturing the meaning component of a human lexical representation is unlikely to work on the same basis.

In general, we believe that thinking about second language acquisition should not be limited to topics that can be computationally implemented at present, as this would limit the possibility of envisaging new concepts or solutions. However, we agree that the central concepts of any model should be formulated as clearly as possible to be a solid basis for later implementations, albeit these implementations might encompass only particular aspects or areas of a given comprehensive model.

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In section 3.1 we showed how the implementation of selected aspects of fuzziness as a central concept of the OM could contribute to more psycholinguistically adequate performance of computational models. We believe that although the OM does not currently offer "its own" computational implementation, it can serve as a theoretical roadmap or a blueprint highlighting areas of research on (second) language acquisition that await elaboration by both experimental research and computational modelling.

5 Conclusions

Given the limited space, we tried to address in more detail the particular topics that were especially raised in several commentaries. Some issues remain to be specified or resolved empirically. For example, Gyllstad (2021) points out that our term "lexical unit" can subsume various approaches to the representation of multiple word expressions (MWE). Currently, the OM is compatible with both Gyllstad's examples in Figure 1, and more empirical research is needed to determine whether these examples indeed correspond to two different accounts or rather to different stages in the development of MWE representations, or whether transparency versus opacity in MWEs (for example) results in different representations. In a similar vein, figurative/metaphoric senses of lexical units currently pose a challenge to the modelling of meaning both in the OM and other models (cf. Wolter, 2021).

Further empirical research is also necessary to establish how the concept of fuzziness is materialised in production as compared to word recognition that the OM primarily explores (cf. Mishra, 2021; Nicol, 2021). Emotional distance in L2 (cf. Kroll et al., 2021) is another topic that should be included in the model, and we have already envisaged its integration within the FLR hypothesis in our companion article (Gor et al., in press). In future publications, the OM should also be more directly related to neurolinguistic evidence and studies on aphasia (cf. Calabria, 2021), as well as to evidence from various populations that differ e.g., in their degree of literacy (Gass, 2021). We hope that the OM will be inspiring for scientists from many areas of both L1 and L2 research and that its further specification and development will turn into a joint collaborative effort.

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References

Aujla H (in press) Language experience predicts semantic priming of lexical decision. *Canadian Journal of Experimental Psychology.*

Baxter P, Leoné F and Dijkstra T (2021a) Helping busy Suzy fight fuzzy in foreign language learning. *Bilingualism: Language and Cognition.*

Baxter P, Droop M, van den Hurk M, Bekkering H, Dijkstra T and Leoné F (2021b) Contrasting Similar Words Facilitates Second Language Vocabulary Learning in Children by Sharpening Lexical Representations. *Frontiers in Psychology* **12**:688160.

Bordag D, Gor K and Opitz A (2021) Ontogenesis Model of the L2 lexical representation. *Bilingualism: Language & Cognition*, 1–17. https://doi.org/10.1017/S1366728921000250. Published online by Cambridge University Press on June 17, 2021.

Brysbaert M, Lagrou E and Stevens M (2017) Visual word recognition in a second language: A test of the lexical entrenchment hypothesis with lexical decision times. *Bilingualism: Language and Cognition* **20**(3), 530–548.

Calabria M (2021) On the semantic optimum and contexts. *Bilingualism: Language and Cognition.*

Cook SV, Pandža NB, Lancaster AK and Gor K (2016) Fuzzy nonnative phonolexical representations lead to fuzzy form-to-meaning mappings. *Frontiers in Psychology* **7**, 1345.

Corder SP (1967) The Significance of Learners' Errors. *International Review of Applied Linguistics in Language Teaching* **5**, 161–170

Darcy I (2021) From fuzzy to fine-grained representations in the developing lexicon: Commentary on Bordag, Gor, and Opitz. *Bilingualism: Language and Cognition.*

Diependaele K, Lemhöfer K and Brysbaert M (2013) The word frequency effect in first-and second-language word recognition: A lexical entrenchment account. *Quarterly Journal of Experimental Psychology* **66**(5), 843–863.

Dijkstra T and van Heuven WJB (2002) The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition* **5**(3), 175–197.

Dijkstra T, Wahl A, Buytenhuijs F, van Halem N, Al-Jibouri Z, De Korte M and Rekké S (2019) Multilink: a computational model for bilingual word recognition and word translation. *Bilingualism: Language and Cognition* **22**(4), 657–679.

Ecke P and Hall CJ (2021) Bilingual Aspects of the Ontogenesis Model: Parasitic Connections at all Levels of Representation? *Bilingualism: Language and Cognition.*

Ellis N (2021) Fuzzy Representations. *Bilingualism: Language and Cognition.*

Escudero P, Benders T and Lipski SC (2009) Native, non-native and L2 perceptual cue weighting for Dutch vowels: The case of Dutch, German, and Spanish listeners. *Journal of Phonetics* **37**(4), 452–465.

Escudero P and Hayes-Harb R (2021) The Ontogenesis Model may provide a useful guiding framework, but lacks explanatory power for the nature and development of L2 lexical representation. *Bilingualism: Language and Cognition.*

Firth JR (1957) Modes of meaning. In FR Palmer (ed.), *Papers in Linguistics* (pp. 190–215). London: Oxford University Press.

Gass S (1997) *Input, Interaction, and the Second Language Learner*. Mahwah, NJ: L. Erlbaum.

Gass S (2021) Use it or lose it? Spell it? Sign it?: Reaching the optimum. *Bilingualism: Language and Cognition.*

Gor K, Cook S, Bordag D, Chrabaszcz A and Opitz A (in press) Fuzzy lexical representations in late second language learners. *Frontiers in Psychology.* https://www.frontiersin.org/articles/10.3389/fpsyg.2021.732030/abstract

Gyllstad H (2021) The Ontogenesis Model: How do multiword units fit in, and are most lexical representations in the L1 really at their optima? *Bilingualism: Language and Cognition.*

Hall CJ and Ecke P (2003) Parasitism as a default mechanism in L3 vocabulary acquisition. In J Cenoz, B Hufeisen and U Jessner (eds.), *The multilingual lexicon* (pp. 71–85). Dordrecht: Kluwer Academic Publishers.

Harris ZS (1954) Distributional structure. *Word* **10**(2–3), 146–162.

Jamieson RK, Johns BT, Taler V and Jones MN (2021) The importance of formal modelling for the development of cognitive theory. *Bilingualism: Language and Cognition.*

Johns BT, Sheppard C, Jones MN and Taler V (2016) The role of semantic diversity in lexical organization across aging and bilingualism. *Frontiers in Psychology* **7**, 703.

Jones MN and Mewhort DJK (2007) Representing word meaning and order information in a composite holographic lexicon. *Psychological Review* **114**, 1–37.

Kirschenbaum A (2021) *Unsupervised Approaches for Morphological Analysis.* Unpublished dissertation.

Kroll JF and Stewart E (1994) Category interference in translation and picture naming: evidence for asymmetric connections between bilinguals memory representations. *Journal of Memory and Language* **33**, 149–174.

Kroll JF, Vargas Fuentes N and Torres J (2021) Representing words in a second language: Can the L2 dance on its own? *Bilingualism: Language and Cognition.*

Lemhöfer K (2021) What is fuzziness, and what does it explain? *Bilingualism: Language and Cognition.*

https://doi.org/10.1017/S1366728921000894 Published online by Cambridge University Press

Li P, Zhao X and MacWhinney B (2007) Dynamic self-organization and early lexical development in children. *Cognitive Science: A Multidisciplinary Journal* **31**, 581–612.

Li P and Zhao X (2021) Computational Mechanisms of Development? Connectionism and Bilingual Lexical Representation. *Bilingualism: Language and Cognition*.

Lund K and Burgess C (1996) Producing high-dimensional semantic spaces from lexical co-occurrence. *Behavior Research Methods, Instruments & Computers* **28**, 203–208.

McClelland JL and Rumelhart DE (1981) An interactive activation model of context effects in letter perception: I. An account of basic findings. *Psychological Review* **88**, 375–407.

Meara P (2021) Modelling L2 vocabulary acquisition: The devil is in the detail. *Bilingualism: Language and Cognition*.

Mikolov T, Sutskever I, Chen K, Corrado GS and Dean J (2013) Distributed representations of words and phrases and their compositionality. *Advances in Neural Information Processing Systems*, 3111–3119.

Mishra RK (2021) The limits to 'fuzziness' in the L2 learner. *Bilingualism: Language and Cognition*.

Montag JL, Jones MN and Smith LB (2015) The Words Children Hear: Picture Books and the Statistics for Language Learning. *Psychological science* **26**, 1489–1496.

Nicol J (2021) How fuzzy are L2 phonological representations? *Bilingualism: Language and Cognition*.

Ota M, Hartsuiker RJ and Haywood SL (2009) The KEY to the ROCK: Near-homophony in nonnative visual word recognition. *Cognition* **111**, 263–269.

Ota M, Hartsuiker RJ and Haywood SL (2010) Is a FAN always FUN? Phonological and orthographic effects in bilingual visual word recognition. *Language and Speech* **53**, 383–403.

Pecher D, de Rooij J and Zeelenberg R (2009) Does a pear growl? Interference from semantic properties of orthographic neighbors. *Memory & Cognition* **37**(5), 541–546.

Pennington J, Socher R and Manning CD (2014) GloVe: Global vectors for word representation. *Proceedings of the 2014 Conference on Empirical Methods in Natural Language Processing*, 1532–1543.

Poibeau T, Villavicencio A, Korhonen A and Alishahi A (2013) Computational modeling as a methodology for studying human language learning. In A Villavicencio, T Poibeau, A Korhonen and A Alishahi (eds.) *Cognitive aspects of computational language acquisition* (pp. 1–25). Springer, Berlin, Heidelberg.

van Hell J (2021) Ontogenesis model of L2 lexical representation: Cross-language links to account for bilingual lexical processing. *Bilingualism: Language and Cognition*.

van Leussen JW and Escudero P (2015) Learning to perceive and recognize a second language: the L2LP model revised. *Frontiers in Psychology* **6**, 1000.

Wolter B (2001) Comparing the L1 and L2 mental lexicon: A depth of individual word knowledge model. *Studies in Second Language Acquisition* **23** (1), 41–69.

Wolter B (2021) Refining optimum levels of acquisition and L1 semantic influences in the Ontogenesis Model. *Bilingualism: Language and Cognition*.

Yee E and Sedivy JC (2006) Eye movements to pictures reveal transient semantic activation during spoken word recognition. *Journal of Experimental Psychology: Learning, Memory and Cognition* **32**(1), 1–14.

Zhao X and Li P (2010) Bilingual lexical interactions in an unsupervised neural network model. *International Journal of Bilingual Education and Bilingualism* **13**(5), 505–524.