Computational Mechanisms of Development?

Connectionism and Bilingual Lexical Representation

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The Ontogenesis Model (OM) of Bordag, Gor and Opitz (2021) is a good example of applying computational thinking to the study of key issues in bilingual lexical representation. With the introduction of two critical computational concepts, namely Multidimensionality and Fuzziness, this model aims at explaining bilingual lexical representation through a theoretical framework of 'ontogenesis'. A key feature of the model that distinguishes itself from other bilingual computation-minded models such as BIA and BIA+, as the authors argue, is the focus on development of lexical representation (hence ontogenesis in the name of the model). This focus is particularly important, and since the earliest days of BIA and BIA+ models, there has been an urgent need for the field to move from 'proficient bilingual model' to 'developmental bilingual model' (Li, 2002).

While the OM provides a good illustration of the complexity and the dynamic nature of bilingual lexical representation, it falls short of delivering the key promise on accounting for the *developmental* processes and underlying principles of bilingual lexical representation. In our view, there are significant gaps with the current formulation of the OM model as either a theoretical or an analytic framework. First and foremost, it largely dismisses the significant amount of work in the past two decades that has been devoted to address precisely the same questions that OM asks, the connectionist models of bilingual representation (see a few examples in Thomas, 1997; French, 1998; Li & Farkas, 2002; Lewy & Grosjean, 2008; Zhao & Li, 2010, 2013; Peñaloza, Grasemann, Dekhtyar, Miikkulainen, & Kiran, 2019; along with Shook & Marian, 2013; Kiran, Graesman, Sandberg, & Miikkulainen, 2013 and other articles in the 2013 special issue published by this journal). Bordag et al. write, "other frameworks, e.g., connectionist models, model non-optimal representations via, e.g., non-final weights and optimize them via re-weighting of connections due to new input…, fuzziness in the OM refers to imprecise lexical encoding due to a broad range of linguistic and cognitive factors and the learning conditions." This statement, on the one hand, does not do justice to the significant amount of work inspired by connectionism that has indeed incorporated 'the broad range of linguistic and cognitive factors and learning conditions', and on the other, reflects a misunderstanding of what the weight updating and optimization in connectionist networks really are. As Shirai's (2018) recent synthesis demonstrates (see especially Chapters 3 and 4), connectionist bilingual lexical representations have indeed attempted to incorporate a wide range of linguistic and cognitive factors, including the ones not even discussed in the OM model such as working memory and its impact on individual difference (see also Ellis, 2003; Wen, Biedroń, & Skehan, 2017). Further, weight updating and optimization are mechanisms used by the brain's neural circuit to accomplish the process of learning and development, and they are based on realistic biological principles that provide the necessary mechanisms for a cognitively plausible computational account, which brings us to the next point.

Second, in defending connectionism and its success in modeling developmental L2 lexical representation, we should also point out that OM lacks precisely the kind of computational mechanistic account provided by connectionist models in disentangling the complex interactions among the key linguistic and cognitive factors (see Grant, Legault, & Li, 2019; Li, 2013; Li & Zhao, 2017 for discussion). Indeed, the BIA and BIA+ models are based on connectionist-like mechanisms (e.g., the original IA models by McClelland & Rumelhart, 1981 were precursors to connectionism; see Li & Zhao, 2020). Rather than dismissing the connectionist architecture, the OM should be able to benefit from integrating computational mechanisms of connectionist models. The OM aims at modeling three key dimensions of linguistic domains, mappings, and networks (including IntraNetwork and InterNetwork), but it is unclear, unlike in connectionist models, how these dimensions can be actually modeled and implemented computationally, and what plausible mechanisms are to be deployed in the modeling enterprise so that the authors and others can verify and test. As an example, Figure 3 of Bordag et al. nicely illustrates the progressively enlarged network connections, but the OM provides no quantitative methods to actually model such progression or developmental changes. In our view, these dimensions match well with the computational architecture of the connectionism-based DevLex-II (Li, Zhao & MacWhinney, 2007; Zhao & Li, 2010), a multi-layer neural network model with three connected self-organizing maps representing basic linguistic contents (phonology, semantic, and the articulatory sequence) of the bilingual lexicon. The DevLex model was originally designed as a *developmental* model for L1 (Li & Farkas, 2004; Li et al., 2007) and DevLex-II is focused on the development of bilingual lexicon, having the same goal as the OM. Through computational mechanisms such as self-organization (SOM; Kohonen, 2001) and Hebbian Learning (Hebb, 1949), DevLex-II can explicitly model the development of bilingual lexical representation and empirical patterns of priming (Zhao & Li, 2013), key aspects that the OM is designed for explaining. Connectionist models, including DevLex-II and others starting from the late 1990's (e.g., Thomas, 1997; French, 1998), have aimed to provide the kind of computational mechanisms that the OM currently lacks, particularly with regard to such concepts as the word association networks within (OM's IntraNetwork) and between languages (OM's InterNetwork).

Finally, a crucial concept of the OM is its Fuzzy Lexical Representation (FLR) account. This view is highly consistent with what has been proposed by many connectionist language development models, in both L1 (e.g. Plunkett & Marchman, 1996; Li et al, 2007) and L2 (Hernandez, Li, & MacWhinney, 2005; Li & Zhao, 2013; Zhao & Li, 2021). Specifically, Hernandez et al. (2005; see Fig. 1) proposed the concept of 'parasitism', according to which factors such age of acquisition, proficiency, and in particular competition/interaction between L1 and L2, are responsible for fuzzy L2 lexical-semantic representations which in turn lead to inaccurate lexical comprehension and production in both semantic and phonological domains. This leads to the question of why OM chooses to ignore L1-L2 interaction, given that the dynamic interaction of L2 with L1 is a core process that drives the outcome fuzzy L2 representation, based on both theoretical perspectives and neurocognitive evidence (e.g., Claussenius-Kalman, Hernandez, & Li, 2021; Zhang, Yang, Wang & Li, 2020).

Despite our defending connectionism in this commentary, we believe that OM provides a good platform for further discussion and investigation of core issues in bilingual lexical representation, but the integration of connectionist principles into its architecture could enhance its plausibility and generalizability.

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