PEER COMMENTARY

The Revised Hierarchical Model: A critical review and assessment*

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Brysbaert and Duyck (this issue) suggest that it is time to abandon the Revised Hierarchical Model (Kroll and Stewart, 1994) in favor of connectionist models such as BIA+ (Dijkstra and Van Heuven, 2002) that more accurately account for the recent evidence on non-selective access in bilingual word recognition. In this brief response, we first review the history of the Revised Hierarchical Model (RHM), consider the set of issues that it was proposed to address and then evaluate the evidence that supports and fails to support the initial claims of the model. Although fifteen years of new research findings require a number of revisions to the RHM, we argue that the central issues to which the model was addressed, the way in which new lexical forms are mapped to meaning and the consequence of language learning history for lexical processing, cannot be accounted for solely within models of word recognition.

The Revised Hierarchical Model (RHM; Kroll and Stewart, 1994) was initially proposed to account for observed asymmetries in translation performance by late bilinguals who acquired the second language (L2) after early childhood and for whom the first language (L1) remains the dominant language. The RHM effectively merged the alternative models of word association and concept mediation described by Potter, So, Von Eckardt and Feldman (1984) into a single developmental model. The RHM explained longer translation latencies from L1 to L2 (forward translation) than from L2 to L1 (backward translation) as an underlying asymmetry in the strength of the links between words and concepts in each of the bilingual's languages. The L1 was hypothesized to have privileged access to meaning, whereas the L2 was thought to be more likely to require mediation via the L1 translation equivalent until the bilingual acquired sufficient skill in the L2 to access meaning directly. On this account, translation from L2 to L1 could be accomplished lexically, without semantic access, if the L2 word enabled lexically mediated retrieval of the translation. In contrast, L1 to L2 translation would necessarily be semantically mediated because of the strong L1 link to meaning. Evidence for the proposed asymmetry was reported in a series of experiments that showed that forward translation, from L1 to L2, was more likely to engage semantics than backward translation, from L2 to L1 (e.g., Kroll and Stewart, 1994; Sholl, Sankaranarayanan and Kroll, 1995).

Brysbaert and Duyck (this issue) argue that the RHM is no longer a useful characterization of the way in which bilinguals process words and concepts in each of their two languages. Their proposal to leave the model behind is based on findings in the research reported in the last fifteen years that appear to refute the model's assumptions and predictions. In what follows, we review their claims and consider the evidence that both supports and fails to support the model. In the last fifteen years there have been a number of important discoveries that

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require that the model be revised. However, contrary to the conclusion that Brysbaert and Duyck reach, that a model of bilingual word recognition such as the BIA+ model (Dijkstra and Van Heuven, 2002) does a better job of accounting for the available data, we argue that the RHM was not primarily a model of word recognition but a model of word production. Furthermore, with respect to two of the model's central claims, one in regard to asymmetries between the two languages and the other concerning the consequences of L2 learning history, there remain enduring questions about development and control that can neither be answered within a narrow model of word recognition nor be left behind.

Language non-selectivity

In the fifteen years since the RHM was published, there has been overwhelming evidence to demonstrate that lexical access is non-selective with respect to language. The parallel activity of the bilingual's two languages has been shown in visual word recognition (e.g., Dijkstra, 2005), in spoken word recognition (Marian and Spivey, 2003) and in spoken word production (e.g., Kroll, Bobb and Wodniecka, 2006). The discovery of pervasive non-selectivity of lexical access, even when context should logically provide constraints to enable selective access (e.g., Duyck, Van Assche, Drieghe and Hartsuiker; 2007; Libben and Titone, 2009; Schwartz and Kroll, 2006; Van Hell and De Groot, 2008), has been critically important in reformulating models of language processing. There are two implications of this observation for the present discussion. First, Brysbaert and Duyck are quite right that the original version of the RHM did not assume lexical non-selectivity. The critical evidence on this issue appeared after the RHM was published. Although there were a few early studies in the literature that suggested that bilingual lexical access might be language non-selective (e.g., Altenberg and Cairns, 1983; Nas, 1983), there was also evidence at the time that appeared to strongly favor selective access (e.g., Gerard and Scarborough, 1989). Indeed, soon after the RHM was published, Kroll and De Groot (1997) addressed the issue of how the model might accommodate the emerging evidence for non-selectivity. But Brysbaert and Duyck's claim that "the RHM was attractive to those researchers who saw selective access as a means of language control in bilinguals" (p. 361) wrongly suggests that language selectivity was the focal issue in the model when it clearly was not.

Furthermore, Brysbaert and Duyck's critique of the RHM on these grounds fails to acknowledge that evidence for parallel access does not necessarily imply an integrated lexicon (Van Heuven, Dijkstra and Grainger, 1998). They state that "the picture emerging . . . is that of L1 and L2 words acting very much as if they are words of the same language" (p. 364). The only evidence that technically requires the assumption of an integrated lexicon comes from the effects of cross-language neighbors, arguably the most fragile data among the demonstrations for parallel activation. It could very well be the case that the two lexicons are functionally separate but with parallel access and sublexical activation that creates resonance among shared lexical features (e.g., Jared and Kroll, 2001; Schwartz, Kroll and Diaz, 2007). Studies of lexical access in bilinguals for whom the two languages do not share the same written script or mode of articulation suggest that the parallel activation of the two languages is a general feature of lexical access in both comprehension and production that is observed even when lexical items clearly cannot act as if they were from the same language (e.g., Emmorey, Borinstein, Thompson and Gollan, 2008; Gollan, Forster and Frost, 1997; Hoshino and Kroll, 2008; Jiang, 1999; Kim and Davis, 2003; Thierry and Wu, 2007). Given what we now know after fifteen years of research, the assumption of parallel activation can be incorporated into the RHM to be able to also account for word recognition data (e.g., Kroll and De Groot, 1997; Kroll and Dijkstra, 2002). But the assumption of functional separation of the bilingual's lexicons is not necessarily a problem, and may in fact better accommodate the wider range of evidence for parallel access in same-script, different-script and sign-speech bilinguals. At best, the evidence is equivocal on this issue.

A more serious problem in Brysbaert and Duyck's analysis is that they fail to distinguish the consequences of parallel activity for word recognition vs. word production. As noted above, the RHM is fundamentally a model of word production, proposed to account for performance in translation production. Indeed, there is a literature on bilingual lexical production (e.g., Costa, 2005; Kroll et al., 2006) that is not discussed in Brysbaert and Duyck. In word recognition, there is evidence for bottom-up parallel activation of word form information (e.g., orthography and/or phonology) in both languages. In word production, there is evidence for top-down activation of meaning-related neighbors (e.g., semantic relatives in both languages, including translations). Within the RHM, what is hypothesized to be active when processing the L2 word for translation is the L1 translation equivalent, not word form neighbors. Within BIA-type word recognition models, what is active in L1 are precisely those word form neighbors.[1] To our knowledge, there is only one published empirical paper that has attempted to directly test the predictions of the RHM against the predictions of the BIA/BIA+ model (Sunderman and Kroll, 2006)

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[1] Translation production is an interesting task in the sense that it combines features of word recognition and production, since a word is the event that initiates speech planning. Comparisons of translation to picture naming, a more obviously conceptually driven task, suggest that translation and picture naming share most of the same processes (e.g., Kroll and Stewart, 1994; Potter et al., 1984), although there is also evidence that by virtue of the presence of a target word in one language alone, translation provides additional cues to language selection not available in picture naming (e.g., Miller and Kroll, 2002).

and a chapter that explicitly compares the models directly (Kroll and Dijkstra, 2002). Sunderman and Kroll compared the performance of less and more proficient L2 learners on a translation recognition task in which foils were related to target words by virtue of lexical form similarity, similarity to the form of the translation equivalent, or meaning. Brysbaert and Duyck mention the Sunderman and Kroll study because the results show that even less proficient L2 learners are able to access the semantics of L2 words. We return to that issue. The more critical finding in that study was that only learners at early stages of L2 acquisition showed evidence for activating the L1 translation equivalent in a translation recognition task. Once learners have acquired skill in the L2, they appear not to be sensitive to words that resemble the translation (and see Talamas, Kroll and Dufour, 1999). The differential sensitivity to the translation equivalent supports the claim of the RHM that learners for whom the L2 is relatively weak will exploit the L1 translation equivalent for the purpose of accessing meaning. Interestingly, Sunderman and Kroll found that both less and more proficient learners revealed sensitivity to lexical form neighbors as predicted by the BIA/BIA+ model.

There are two implications of the Sunderman and Kroll (2006) results for the present discussion. First, whether the translation equivalent in the L1 is active appears to depend on proficiency in the L2. In contrast, form relatives of target words are active for both less and more proficient L2 users. Although the magnitude of the lexical form effects may vary as a function of L2 proficiency (e.g., see Kroll, Michael, Tokowicz and Dufour (2002) for a demonstration that cognate effects are larger in word naming for less than more proficient learners), the lexical form effects are present for all groups. Second, it is precisely the difference between these two types of cross-language activity, the translation equivalent vs. lexical form relatives, that distinguishes the way that language non-selectivity is manifest in production vs. comprehension. Production and comprehension differ with respect to what is active in the non-target language and the hypothesized time course of processing. The same lexicon may be accessed in both production and comprehension but the events that initiate processing, the representation of the meaning of the intended utterance in planning speech, the written form of a printed word in reading, and the sound of a spoken word in listening, will determine the nature of the activated candidates and the order in which lexical codes are engaged. Without considering the implications of these differences, it's not clear how to interpret the arguments that are presented.

Conceptual access for L2 words

The RHM has been criticized on the grounds that understanding the meaning of words in the L2 does not necessarily require mediation via the L1 translation equivalent. In a paper that appeared just after the RHM was published but that is not cited by Brysbaert and Duyck, Dufour and Kroll (1995) demonstrated that it was possible for even less proficient learners to understand the meaning of L2 words directly in a categorization task. As Brysbaert and Duyck note, Sunderman and Kroll (2006) also reported semantic sensitivity by less as well as more proficient L2 learners, and many other papers, too many to cite in this brief response, have shown the same result. It became clear early on that the RHM's assumption of L1 translation mediation for comprehending the meaning of the L2 word was incorrect.[2] Again, the distinction that is absent in Brysbaert and Duyck's critique is that learners at relatively low levels of L2 proficiency, who appear able to directly access the meaning of at least some L2 words in word recognition tasks, are unable to reliably lexicalize concepts into L2 words in production, in even relatively simple production tasks such as picture naming. The RHM initially proposed a weak link between the L2 word and concept, and there is indeed a weak link, but it is asymmetric in the sense that access from words to concepts may be accomplished easily when, for the same L2 learners, access from concepts to words is more effortful. The RHM incorrectly assumed that the weak link was bidirectional. The evidence suggests that the asymmetry is more critical for lexicalization during production than for word recognition. Developmental data show clearly that it is production in the L2 that changes most dramatically with increasing proficiency and that those changes cannot be explained entirely on the basis of achieving higher levels of fluency in using the L2 phonology (e.g., Kroll et al., 2002; Schweiter and Sunderman, 2009). In the recent behavioral and neurocognitive literature on L2 production, this problem has been understood as a consequence of competition for lexical selection that potentially imposes increased processing demands for reducing the activity of candidates in the non-target language (e.g., Abutalebi and Green, 2007; Green, 1998; Kroll, Bobb, Misra and Guo, 2008; Kroll et al., 2006): the less proficient in L2, the more asymmetric the demands for control to enable production (e.g., Costa and Santesteban, 2004). These phenomena cannot be understood adequately within the constraints of a word recognition model such as BIA+, but require a model that specifically addresses the conceptually

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[2] A number of comprehension studies (e.g., Kotz and Elston-Güttler, 2004; Silverberg and Samuel, 2004) suggest that there are limits for even highly proficient bilinguals in how completely they are able to access semantics directly for L2 words. Those limits appear to be a function of learning history (i.e., whether the bilingual acquired the L2 in early childhood or later as an adult) and the type of semantic relation (e.g., Ferré, Sánchez-Casas and Gausch, 2006). So even restricting ourselves to comprehension alone, the available evidence is equivocal on the issue of whether L2 meaning can be accessed directly.

initiated processes engaged during bilingual speech planning (e.g., Hermans, 2000).

Translating from L2 to L1

The evidence that has been taken to be most problematic for the RHM comes from studies of translation production that show that translation in both directions appears to be conceptually mediated. According to the model, the L1 should be more likely to engage the semantics directly than the L2 and therefore translation from L1 to L2 should be conceptually mediated more reliably than translation from L2 to L1. A number of studies using the translation production task have shown that under many circumstances there are reliable effects of semantic variables on translation from L2 to L1 that would appear to fail to support the predictions of the RHM. We summarize this evidence briefly, but for more extensive reviews see Kroll and De Groot (1997) and Kroll and Tokowicz (2001, 2005). One series of experiments reported by De Groot, Van Hell and their colleagues (e.g., De Groot, Dannenburg and Van Hell, 1994; Van Hell and De Groot, 1998a) demonstrated that translation in both directions was sensitive to the effects of word concreteness. If concreteness is taken to be a conceptual variable, then finding concreteness effects in both directions of translation would seem to undermine the claims of the RHM. Crucially, most of the evidence for conceptually mediated translation based on the performance of relatively proficient bilinguals is perfectly consistent with the predictions of the RHM. The need to lexically mediate L2 to L1 translation should be greatest when the L2 is relatively weak. As individuals become more skilled in the L2, the RHM predicts that the two directions of translation become more similar to one another (Kroll et al., 2002). It is therefore not surprising to discover that both directions of translation are sensitive to semantics in relatively proficient bilinguals. The evidence that is more critical in evaluating the model comes from learners who are not highly proficient in the L2. De Groot and Poot (1997) demonstrated that even L2 learners produce concreteness effects in L2 to L1 translation, contrary to the predictions of the model. Likewise, Duyck and Brysbaert (2004, 2008) reported that number magnitude effects, thought to reflect semantic processing, are observed in number translation for both directions of translation even when individuals were taught number words in a new language. Translating new words might render them L2 learners rather than proficient bilinguals and, again, finding semantic effects in L2 to L1 translation at low levels of L2 proficiency is a problematic result for the RHM.

Why then did the relatively proficient Dutch–English bilinguals in the Kroll and Stewart (1994) experiment show differential semantic effects in the two directions of translation? One way to understand these apparently contradictory results in the literature is that the actual items to be translated in the Kroll and Stewart study may have been of lower frequency than those in the other studies. Other studies have also shown that even highly proficient bilinguals tend to show longer forward than backward translation times when translating difficult words, such as abstract non-cognates (Van Hell and De Groot, 2008). We have argued (Kroll and Tokowicz, 2005) that the ease or difficulty of item processing may simulate the effects of language skill so that a given bilingual, although highly skilled in the L2, may vary in the accessibility of processing components depending on the properties of the items and the context of the task.

Demonstrating that semantic processing is possible for the L2 does not itself refute the RHM. The model did not assume that L2 was not able to access meaning at all, only that the connections were weaker for L2 than for L1 and that the asymmetry that resulted had consequences for processing. The question that is intellectually interesting is not whether an extreme version of the RHM can be rejected, but rather under what circumstances each alternative processing scheme might hold. Training studies in which individuals learn a new set of words in an unknown language using a small vocabulary that is highly practiced (e.g., as in Altarriba and Mathis, 1997; Duyck and Brysbaert, 2004) are likely to produce semantic effects that may be unrepresentative of actual L2 learning. Likewise, the evidence on concreteness effects on translation performance may be less clear-cut than it appears because word concreteness may engage both lexical and semantic factors in parallel (e.g., Reilly and Kean, 2007).

One line of research that has attempted to understand the apparently discrepant results was reported by La Heij, Hooglander, Kerling and Van der Velden (1996), who showed that translation in both directions is influenced by the presence of a semantically related picture. Like a number of the earlier studies, La Heij et al. tested relatively proficient Dutch–English bilinguals who would be expected to be able to process the L2 for meaning and that is what they reported.[3] But La Heij et al. also

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[3] Brysbaert and Duyck mischaracterize the Dutch–English bilinguals who have contributed significant data to the literature on both bilingual translation and also word recognition (e.g., Dijkstra, 2005). They state: "Importantly, these were not data from balanced bilinguals, as could be assumed from the developmental hypothesis of RHM, but from unbalanced bilinguals with limited fluency in their second language. Even for them conceptual mediation played a significant role in L2–L1 translation" (p. 366). We would argue that these are not bilinguals with limited fluency. Dutch–English university students are technically late bilinguals because Dutch children begin to learn English formally at the age of ten in school. They are immersed in the Dutch L1 environment and are therefore unbalanced bilinguals in the sense that Dutch remains more skilled than English. However, they are highly proficient in English as the L2, with university education in both languages and with English featured prominently in the media.

speculated on how it might be possible to explain the findings that support the RHM. To illustrate, Sholl et al. (1995) found that only translation from L1 to L2, but not translation from L2 to L1, revealed priming from a semantically driven picture-naming task. Sholl et al. argued that the priming asymmetry reflected the greater reliance on semantics for L1 to L2 translation as the RHM initially proposed. La Heij et al. argued that the picture-naming task used to assess priming was likely to have influenced only the shared lexicalization component from concept to word. That may be the weak link in L1 to L2 translation, but in L2 to L1 translation they hypothesized that the weak link may be access to the concept from the L2 word. The picture-priming task would be unlikely to have any effect on that process because the L2 words were not primed directly. La Heij et al.'s analysis requires additional empirical testing, but provides a constructive approach to beginning to understand the mechanisms that determine the circumstances under which symmetries or asymmetries across the two languages are observed (see Van Hell and De Groot (2008) for recent evidence on this issue).

On the nature of the semantics

The RHM assumed a shared conceptual system across the bilingual's two languages. Although L2 proficiency was thought to determine the degree to which access to meaning for the L2 was complete, the model assumed that, once a bilingual was highly proficient in the L2, the same underlying semantics would be accessed. It is absolutely true that the model in its initial form did not specify the architecture of semantic or conceptual representations in any detail (but see Kroll and De Groot, 1997). Brysbaert and Duyck argue that the assumption that semantics are shared is a problem for the RHM and that, instead, it is necessary to distinguish between language independent and language dependent semantics. The way in which meanings are lexicalized into word forms will differ across languages (e.g., Van Hell and De Groot, 1998b) and the consequences of many-to-one and one-to-many mappings from meaning to word forms will influence cross-language tasks such as translation and picture naming (e.g., Malt and Sloman, 2003; Tokowicz and Kroll, 2007). But the absence of one-to-one translation equivalents across languages does not imply different conceptual systems. Instead, the way in which conceptual features are sampled and linked to word forms may differ and may be influenced by the structure and context of language use, but the pool of features that link to those word forms may be the same. The recent neuroimaging data suggest that it is the same neural tissue that supports the two languages (e.g., Abutalebi, Cappa and Perani, 2005). Where differences emerge, they tend to reflect aspects of control rather than representation (e.g., Abutalebi and Green, 2007).

There are at least two different questions about the semantics that will ultimately need to be addressed in any comprehensive model of the bilingual lexicon. One is the question raised above, of whether the bilingual's two languages draw on semantic representations that are fundamentally shared. The second is a question about access, because even if the semantics are shared, bilinguals may not have equivalent access if they are not equally proficient in the two languages. There is still debate in the literature as to whether even highly proficient late bilinguals are able to fully access semantic information for the L2 (see footnote 2). Little is known about how different categories of meaning and types of semantic relations intersect with the proficiency issue. To begin to fully model bilingual semantics will require a more thorough understanding of the implications of acquiring L2 access for semantic domains that may have special properties, such as numbers (e.g., Dehaene, Spelke, Pinel, Stanescu and Tsivkin, 1999), that may differ in the age at which they are acquired (e.g., Izura and Ellis, 2004) and that may or may not be open to the influence of language contact (e.g., Malt and Sloman, 2003).

Other challenges to the RHM's account

Brysbaert and Duyck cite the Thierry and Wu (2007) study as evidence contrary to the RHM in that it shows that there is cross-language activation of the translation equivalent in event related potential (ERP) measures for relatively proficient Chinese–English bilinguals when they perform a semantic relatedness task in their L2. The Thierry and Wu data are indeed problematic for the RHM because the RHM assumes that only learners at early stages of L2 acquisition will need to exploit the L1 translation equivalent for the purpose of accessing meaning. However, Brysbaert and Duyck go to some length to demonstrate that the L2 can be processed conceptually without lexical mediation. The Thierry and Wu data are therefore problematic for their account as well, because the Chinese–English bilinguals in that study were immersed in English as the L2 and should by all accounts be able to process English without access to the Chinese translation equivalent. The main results of the Thierry and Wu study were recently replicated in a behavioral study with deaf signers reading English as their L2 (Morford, Wilkinson, Villwock, Piñar and Kroll, under review). Again, the result was that there was evidence for activation of the translation equivalent, in this study in American Sign Language when reading written words in English. Like Thierry and Wu, the Morford et al. study found the translation effect for highly proficient L2 readers.

To better understand the role of the translation equivalent, Guo, Misra, Tam and Kroll (under review) performed a series of translation recognition experiments with Chinese–English bilinguals like those in the Thierry and Wu (2007) study, using both ERP and behavioral

measures. The logic was similar to the Sunderman and Kroll (2006) study with some word pairs that were correct translations and others that were not correct translations but similar in phonology to the translation or related in meaning. The behavioral results replicated both Thierry and Wu (2007) and Morford et al. (under review) in revealing activation of the L1 translation equivalent when processing the L2 word for meaning. However, a comparison of the time course of the activation of the translation equivalent relative to semantic distractors revealed different ERP patterns. The difference was interpreted to mean that, for these relatively proficient bilinguals, the translation equivalent was accessed after the L2 word was understood. To further test this hypothesis, Guo et al. performed a second behavioral experiment in which a short stimulus onset asynchrony (SOA) separated the two words for translation recognition. Under conditions of limited time, there were semantic effects but not translation effects, supporting the idea that proficient bilinguals may access the translation equivalent after they understand the meaning of the L2 word. The temporal parameters and demand characteristics of the task may determine whether proficient bilinguals engage the translation equivalent. Critically, both the Thierry and Wu and Morford et al. studies used long SOAs that may have encouraged activation of the L1 translation. This analysis leads to a prediction based on the RHM that has not yet been tested, namely that for less proficient L2 learners, there should be evidence for activation of the translation equivalent before semantics are available. The evidence to date suggests that more proficient bilinguals, in keeping with the predictions of the RHM, do not use the translation equivalent as a mediator to retrieve the meaning of the L2 word.

The dynamics of L2 development, cognitive control and language change

In the fifteen years since the RHM was published, there has not only been research on bilingual word recognition and production but also on the dynamics of L2 development, on the cognitive processes that control language selection and on the consequences of cross-language interaction and change for the L1 and for cognition more generally. In many respects, the RHM provided a first step towards acknowledging that models of the bilingual lexicon had to include a mechanism to account for developmental change. There is a rich history of research within the field of second language acquisition that examines the role of transfer of the L1 grammar to the emerging L2 (e.g., see the evidence on the Competition Model; MacWhinney, 2005). The RHM was similarly a model of transfer at the lexical level, assuming that reliance on the L1 translation equivalent diminished with increased proficiency in the L2. The BIA+ model that Brysbaert and Duyck propose as a preferred alternative to the RHM can handle details of visual word recognition but, without additional assumptions, the BIA+ has little to say about the changes that occur during L2 development. Other recent connectionist models more directly address the dynamics of lexical development (e.g., French and Jacquet, 2004; Hernandez, Li and MacWhinney, 2005; Li, Farkas and MacWhinney, 2004; Thomas and Van Heuven, 2005). None of these models provides a fully comprehensive account of bilingual language processing and development. Yet we would argue that none should be left behind; each contributes an important set of insights that provide the foundational constraints for a fully comprehensive model.

In the past fifteen years, not only has there been evidence for language non-selectivity and cross-language interaction, but there has also been considerable evidence to suggest that bilingual language experience confers advantages in the realm of executive function (e.g., Bialystok, 2005). It is tempting to argue that the parallel activity of the bilingual's two languages creates competition that then requires increased cognitive control to ensure that the intended language is selected. A lifetime of resolving cross-language competition is hypothesized to create expertise that is functionally domain general, spilling over to attentional control mechanisms that are engaged beyond language processing itself (e.g., Bialystok, Craik, Klein and Viswanathan, 2004). The available data on this issue remain largely correlational, and a clear goal for future research will be to identify the causal mechanisms that map language processing onto their cognitive consequences. Although the discovery of a bilingualism advantage in executive function has brought the issue of cognitive control into focus in the recent literature, long before these results were available, Green (1986, 1998) identified the need to include attentional control mechanisms within models of bilingual processing. The Inhibitory Control (IC) Model (Green, 1998) used the RHM as an illustrative model of the bilingual lexicon to which assumptions about control must be added to enable bilinguals to act. The IC model provided an alternative interpretation of the translation asymmetries at the core of the RHM. According to the IC model, translation from L1 to L2 is slower and more error prone than translation from L2 to L1 because it is more difficult to overcome the tendency to produce the more dominant L1 word. The IC model offered a reinterpretation of the empirical data at the heart of the RHM that is congenial with current connectionist approaches in which multiple candidates compete for selection. On this view, the link from concepts to L2 is indeed a weak link, but not simply because there is less activation of the L2 words but because there is increased competition among lexical alternatives in both L2 and L1. It is beyond the scope of the present response to discuss the evidence for inhibitory processes in detail, but a set

of recent papers suggests that inhibitory processes may differ in word recognition and production (e.g., Kroll et al., 2008; Martín, Macizo and Bajo, in press), again demonstrating that a model of word recognition alone will not provide a complete account of control processes. The point for the current discussion is that the RHM identified an asymmetry that is central to current developments on issues of bilingual control.

A contribution of the RHM was to identify the relative strength of the connections between words and concepts as important to understanding the way in which L2 learners and bilinguals perform ordinary language processing tasks. The recent literature provides ample evidence to suggest that there is a high level of permeability across the bilingual's two languages, with shifts in language dominance that have implications for performance. At the lexical level, Heredia (1997) demonstrated that native Spanish speakers who have become dominant in English, their L2, produce a pattern of translation performance perfectly in line with the predictions of the RHM if we assume that L2 is the dominant language rather than the native language. A recent study in our lab (Linck, Kroll and Sunderman, 2009) examined the performance of a group of native English-speaking students learning Spanish as their L2 while studying abroad in Spain. Under conditions of immersion, intermediate L2 learners begin to reveal a shift towards the L2 by inhibiting the L1. That process is not complete within a six-month study abroad experience, but studies of proficient bilinguals immersed in the L2 show that there is a marked change in performance with L2 becoming more skilled and automatic (e.g., Segalowitz and Hulstijn, 2005) and with L1 starting to be processed like the L2 at the level of the lexicon and the grammar (e.g., Dussias, 2003; Nosarti, Mechelli, Green and Price, 2010). Identifying the behavioral and neural mechanisms that enable and also constrain these changes in language use will be an important area of future research.

Conclusions

Brysbaert and Duyck (this issue) have reviewed a number of different empirical results and arguments that they consider problematic for the RHM. In fifteen years of research, one hopes that new discoveries are reported. During this period we have learned a great deal about bilingual development and performance that requires revision to the RHM, and indeed to all models of bilingual language processing. In this brief response, we have attempted to capture at least the spirit of these developments. The RHM had the appealing feature of being a testable model and the more than 300 citations of the Kroll and Stewart (1994) paper that now appear in the Web of Science include a range of studies that have tested the model, extended the model and applied the model more broadly. Contrary to Brysbaert and Duyck's

claim, the RHM was not intended to be a model of visual word recognition, and in focusing the discussion narrowly, we believe that Brysbaert and Duyck have lost sight of the larger picture. In a constructive science, the presence of divergent results provides an opportunity for theoretical advancement. Our goal is not only to test and reject specific models but to provide a synthesis of the available evidence that will enable the development of a more comprehensive account. We owe an intellectual debt to the field and to ourselves to understand the range of phenomena that have been identified. Models provide a means to approach problem solving and to refine our own thinking. In this sense, no model should be left behind.

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