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Semantic processing during language production: An update of the swinging lexical network

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Abstract

Semantic processing in language production includes different meaning relations determining the selection of lexical representations that best express the intended message. Here, we discuss assumptions of the swinging lexical network proposal (SLN), proposed to account for effects of different semantic relations in a variety of experimental paradigms, with effects ranging from semantic facilitation to interference. The SLN is based on two assumptions. First, conceptual and lexical processing proceed in parallel and may exhibit opposite effects of conceptual priming and lexical competition. Second, the amount of lexical competition is determined by the co-activation of an inter-related lexical cohort and is thus sensitive to the number and strength of active competitors. We discuss behavioral effects across different experimental paradigms and semantic relations in light of the SLN and suggest that by adopting the basic assumptions we can account for a wide range of semantic facilitation and interference effects in language production.

Keywords: semantic context effects, language production, lexical selection

Semantic processing during language production: An update of the swinging lexical network proposal

When we produce language, we translate preverbal thoughts into articulated speech. One of the core tasks during initial planning stages of language production is to select a lexical representation that best expresses the meaning of an intended message with its semantic attributes and associations (e.g., Dell, 1986; Levelt, 1989; Levelt et al., 1999; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007; Roelofs, 1992; 2018). This semantic aspect of lexicalization has been investigated in several different experimental paradigms by examining picture naming within some sort of semantic context. In the picture-word interference paradigm, a picture of an object is presented for a naming response together with a related or unrelated word distractor which should be ignored (e.g., Damian & Bowers, 2003; Glaser & Dungelhoff, 1984; Glaser & Glaser, 1989; Hantsch, Jescheniak, & Schriefers, 2005; La Heij, 1988; Schriefers, Meyer, & Levelt, 1990; Vitkovitch & Tyrrell, 1999). In the cyclic blocking paradigm, pictures are repeatedly presented in blocks consisting of semantically homogeneous or heterogeneous objects (e.g., Belke, Meyer, & Damian, 2005; Damian & Als, 2005; Damian, Vigliocco, & Levelt, 2001; Kroll & Stewart, 1994; Schnur, Schwartz, Brecher, & Hodgson, 2006; Vigliocco, Vinson, Damian, & Levelt, 2002). In the continuous naming task, pictures of related objects are embedded randomly in a sequence of unrelated objects (e.g., Belke, 2013; Belke & Stielow, 2013; Costa, Strijkers, Martin, & Thierry, 2009; Howard et al., 2006; Navarrete, Mahon, & Caramazza, 2010; but see: Navarrete et al., 2012; Navarrete, Del Prato, Peressotti, & Mahon, 2014; Schnur et al., 2006).

For categorical relations, semantic interference, i.e., longer naming times for related relative to unrelated contexts, has been reported in all paradigms (see above for evidence within the different tasks). According to models assuming competition at the level of lexical selection (cf. Bloem & La Heij, 2003; Bloem, van den Boogaard, & La Heij, 2004; La Heij, Kuipers, & Starreveld, 2006; Levelt, 1992; Levelt, Roelofs, & Meyer, 1999; Roelofs, 2018), these effects reflect delayed lexical selection due to the co-activation of categorically related items that directly compete with the target for selection. Empirical reports of interference from non-categorical semantic relations such as associations and thematic links are comparatively rare, and instead facilitation has often been reported (e.g., Abdel Rahman & Melinger, 2007; Alario, Segui, & Ferrand, 2000; Aristei, Melinger, & Abdel Rahman, 2010; Costa, Alario, & Caramazza, 2005; de Zubicaray, Hansen, & McMahon, 2013; La Heij, Dirkx, & Kramer, 1990; Costa et al, part-whole; for recent discussions, see Mahon, et al, 2007; Mahon, Garcea, & Navarette, 2012; Navarrete et al, 2012, 2014; Roelofs & Piai, 2013, 2015). It has been argued that opposing effects from different types of semantic relations and context are problematic for competition models, and alternative models have been proposed that do not rely on lexical competition but instead focus on task-specific mechanisms. For the PWI task, Mahon and colleagues (2007) have suggested that distractor words block the articulatory output-buffer, with potentially response-relevant categorically related words being more slowly removed than less task relevant unrelated words. Interference in cyclic blocking and continuous naming tasks has been explained with a learning mechanism: lexical selection of a target leads to subsequent weakening of the connections between semantic and lexical representations of co-activated non-target items, rendering them harder to retrieve (Oppenheim et al., 2010). However, each of these individual proposals is limited in their explanatory scope.

Although semantic facilitation has often been discussed as incompatible with traditional competition models, Roelofs and Piai (2015) have demonstrated that this is not the case by simulating facilitation for associatively related distractors in a Stroop task in WEAVER++ (for more details see Mahon, Garcea, & Navarette, 2012; Mahon & Navarrete, 2014; Roelofs & Piai, 2013, 2015). Indeed, facilitation and interference can be captured by lexical competition models that incorporate concurrent activation with priming at the conceptual level and interference at the lexical level (e.g., Belke, 2013; Levelt et al., 1999; Roelofs, 1992; Roelofs, 2018).

While almost every model of lexical selection acknowledges the need for unrestricted bidirectional connections between conceptual and lexical levels of representation (cf. Bloem & La Heij, 2003; Caramazza & Miozzo, 1997 for notable exceptions), the importance of concurrent activation has been highlighted most explicitly in the Swinging Lexical Network proposal (SLN; Abdel Rahman & Melinger, 2009a, b). This proposal, which grew out of traditional competitive selection models, was designed to account for facilitatory and inhibitory effects of different types of semantic relations. While not yet implemented computationally, this proposal aims to provide a general framework to account for the polarity of semantic effects across a range of tasks and semantic relations.

In the present paper, we provide a review of the recent empirical developments relevant for SLN. This review takes into account context effects from different categorical and non-categorical relations and the effects of semantic distance as critical tests for lexical competition models. In addition to exogenously induced semantic context effects, we also discuss influences of endogenous factors arising from the inherent semantic richness of a message and the specific neighbourhoods concepts inhabit. These latter findings provide insights into context-free semantic activation spread and lexical selection. We conclude with a description of the original model in light of the new evidence and highlight the value of investigating different meaning relations besides categories for a comprehensive understanding of lexical-semantic processing during language production. We end with a discussion of open questions and the future for the SLN.

The swinging lexical network: basic assumptions

The SLN is based on two basic assumptions. Our first assumption is that during relatively early stages of speech planning, conceptual processing and lexical activation proceed in parallel, thereby allowing for temporally overlapping context effects at both stages (Abdel Rahman, Sommer & Schweinberger, 2002a, b; Abdel Rahman, van Turennout & Levelt, 2003; Strijkers, Costa & Pulvermüller, 2017). Specifically, semantic activation spread and continuous bidirectional transmission of information between the conceptual and lexical stages results in the mutual activation of the intended meaning and related concepts as well as their respective lexical representations. Thus, the target concept, its different meaning facets and relations are active simultaneously at the conceptual and at the lexical level. In this time window of parallel conceptual and lexical activation, before the selection of a lexical item, semantic contexts may simultaneously affect conceptual and lexical processing. At the conceptual level, semantic contexts (e.g., the presentation of a categorically related distractor word) enhance the spread of activation within the semantic network, resulting in the stronger co-activation of the target concept and related items, semantic features, and associations. For instance, when the word ‘cat’ is presented as a distractor stimulus shortly before or simultaneously with a to-be-named-picture of a dog, ‘cat’ and ‘dog’ conceptual representations co-activate each other, semantic attributes like “is an animal”, “has four legs”, “likes meat”, etc., as well as category coordinates such as ‘horse’ and associations such as ‘whiskers’ etc. These active conceptual items in turn co-activate their affiliated lexical representations. Hence, in our simplified example, the word ‘cat’ will prime ‘dog’, ‘whiskers’, ‘horse’, etc. at the conceptual level, and will therefore also prime the target dog at the lexical level, but at the same time, ‘cat’, ‘whiskers’, ‘horse, etc. will interfere with the selection of ‘dog’ at the lexical level.

These two opposing effects tradeoff to determine language production times and observable facilitation or interference effects. If the context strongly primes the target concept and affiliated lexical representation but fails to strongly activate related lexical competitors, facilitation will be observed. However, if the context results in the strong activation of lexical alternatives, competition will be strong and it should outweigh the concomitant conceptual priming, resulting in overall interference. We assume that active lexical alternatives have a stronger impact than active conceptual relations because an explicit decision is only needed at the lexical stage, namely the selection of one item from amongst many alternatives.

This leads us to the second core assumption of the SLN – the amount of lexical competition is influenced by the activation of an inter-related and co-activated lexical cohort. This assumption is derived from language production models implementing competitive selection mechanisms such as the Luce ratio or a critical difference (Bloem & La Heij, 2003;

Levelt et al., 1999; Luce, 1959; Roelofs, 1992; 1993; Starreveld & La Heij, 1996). Specifically, the probability of selecting a target lexical item depends on the state of its activation divided by the sum activation of all other active nodes (cf. Roelofs, 1992, 1997). In other words, both the number of competitors and the strength of their activation should contribute to the magnitude of the competition effect. The number and strength of active candidates depends, in part, on the pattern of activation flow at the conceptual level. Mutually inter-related representations will enhance each other's activation level, conserving the activation amongst themselves (e.g., cat activates the target dog, but also activates horse, which in turn also activates dog). This resonance within the semantic network and between the semantic and lexical levels is what we refer to as *swinging*. In contrast, representations that are not mutually related will distribute their activation more broadly, weakly activating many other representations that may be unrelated to the initial target concept (e.g., whiskers activates cat but also activates bristles, which is unrelated to cat). Thus, the more inter-related competitors are active, the more strongly they activate each other, and the more competition they induce. When the network is swinging and a cohort of lexical alternatives becomes strongly activated, the resulting competition should outweigh conceptual facilitation. In contrast, if the network is not swinging and only a single isolated competitor becomes strongly activated, the resulting competition is unlikely to outweigh parallel conceptual facilitation, resulting in a net semantic facilitation effect. Semantic facilitation and interference can therefore be viewed as two sides of the same coin.

With these two core assumptions, we have derived several predictions for when we should observe faster or slower lexical selection times. First, interference should be observed if a) a cohort is generated due to the inter-relatedness of the target and context, b) single competitors are strongly activated directly at the lexical level, bypassing the conceptual level, or c) the number of active lexical alternatives is increased. Facilitation is predicted when a) the target and semantic context do not form an inter-woven network of semantic relations, b) conceptual processing is enhanced without associated enhancement of competing lexical representations. These predictions are not task specific, allowing the SLN to bring a broad range of explanatory value to the domain of lexical selection.

In what follows, we discuss evidence supporting these predictions. Our discussion will focus on evidence derived from an examination of non-categorical semantic relations, effects of semantic distance, and endogenously induced semantic effects. Across these topics, we will focus on the argument that the polarity of semantic context effects should depend on the trade-off between conceptual facilitation and lexical competition and that competition is sensitive to the interactive influences of the number and strength of active competitors.

Categorical vs. non-categorical relations and lexical cohort activation

Many models that were developed to account for semantic context effects in Stroop and PWI-like tasks explain semantic interference effects by contrasting the activation level of a related distractor word to that of an unrelated word. In these discussions, competition is couched in terms of these two alternatives, and by implication restrict the contribution of other active representations. For instance, to account for the observation that low frequency distractor words slowed target naming times more than high frequency distractor words, Miozzo and Caramazza (2003) proposed that distractor words need to be actively blocked before a target word can be produced, pitting the target word against the distractor word and ignoring other active representations. Non-competitive models of semantic interference, such as the Response Exclusion Hypothesis (Mahon et al., 2007), similarly attend only to properties of the distractor word; no other representation should negatively impact response times. Competitive selection rules based only on the single most active competitor approach have also extended to accounts of other types of data, such as error detection (Nozari, Dell, & Schwartz, 2011).

The SLN is necessarily sensitive to the activation levels across the entire network. This is consistent with several prominent computationally-implemented models of lexical selection which incorporate the broader network of active representations into the calculation of response times (Levelt, et al, 1999; Roelofs, 1992; Starreveld & LaHeij, 1996; Howard et al, 2006). Clearly, the debate regarding how the selection threshold should be operationalized and what contribution the broader network plays in determining response times continues. Hence, we aimed to find direct evidence for the role of the wider network.

Direct evidence that the number of active lexical competitors impacts the magnitude of semantic interference effects comes from a task in which the PWI paradigm was modulated to include double distractors. Abdel Rahman and Melinger (2008) found that presenting two different categorically related distractor words (e.g., presenting 'camel' and 'sheep' together with the picture elephant, relative to two unrelated words) slows down picture naming more than presenting only a single categorically related distractor (e.g., only 'camel', relative to a single unrelated word). Numerically, the interference effect was almost doubled in size. This finding demonstrates that having two highly active semantic competitors within the cohort slows naming times more than one highly active semantic competitor. This result is difficult to explain if competition is determined only by the most active competitor. For example, models that assume the distractor word must be blocked before the target can be named would need to assume blocking occurs serial, i.e., blocking of the second distractor would need to wait until the first distractor was blocked. The same logic would apply to models that assume the distractors must be purged from the response buffer, one at a time. In contrast, this result was predicted by the cohort assumption of the SLN.

The vast majority of investigations of semantic context effects in production have focused on categorical relations, despite the fact that word meaning is composed of many types of semantic relations, including associative and thematic relations (Barsalou, 1993; de

Zubicaray, Hansen, & McMahon, 2013; Estes, Golonka, & Jones, 2011; McRae, Khalkhali, & Hare, 2012; Mirman, Landrigan & Britt, 2017). In contrast to category members that share semantic features and category nodes, thematically and associatively related concepts are linked by a common situation or thematic context, but often have little or no overlap between their semantic features (e.g., salad and plate) (Abdel Rahman & Melinger, 2007, 2011; Barsalou, 1983; Estes et al., 2011). Such relations may help us to communicate and interact appropriately with our environment, for instance, by generating hypotheses about what to expect in specific situations or during conversations (e.g., Estes et al., 2011; McRae et al., 2012; van der Meer, 1991; Bar, 2004; Bar & Aminoff, 2003; Kveraga et al., 2011). In the context of single word production, however, most PWI studies found that associatively related distractors have no effect or facilitate naming, in contrast to the interference robustly observed for categorically related words (Abdel Rahman & Melinger, 2007; Alario, Segui, & Ferrand, 2000; Aristei, Melinger, & Abdel Rahman, 2010; Costa, Alario, & Caramazza, 2005; de Zubicaray et al., 2013; La Heij, Dirkx, & Kramer, 1990). As discussed above, the absence of interference effects for these semantic relations posed a challenge for competitive models of lexical selection for many years.

Thinking about these findings within the context of the SLN, Abdel Rahman and Melinger (2009a) argued that there is no principled difference between associatively and categorically related concepts, but that they differ systematically in their capacity to make the network swing. Because categorical relations (e.g., dog and hamster) share semantic features (e.g., fur, four legs, etc.) and category nodes (animals), their activation automatically converges, co-activating other category members sharing these features, which in turn form an inter-related lexical cohort (Abdel Rahman & Melinger, 2007; Estes et al., 2011; McRae et al., 2012; Rabovsky, Schad & Abdel Rahman, 2016). In contrast, non-categorically related concepts (e.g., salad and plate) serve complementary roles within situations or themes, but they do not share category nodes or semantic features (cf. Muehlhaus et al., 2014). Therefore, the activation from target and distractor diverges across the semantic network and consequently no lexical cohort is generated. Without a strong lexical cohort, conceptual facilitation typically dominates (Abdel Rahman & Melinger, 2007; de Zubicaray, Hansen, et al., 2013; see also Vieth et al., 2014; Sailor & Brooks, 2008).

Given this explanation for associative facilitation in the PWI paradigm, Abdel Rahman and Melinger (2007) reasoned that the polarity of a non-categorical semantic context effect should reverse if a set of interconnected semantic associates were presented rather than just a single associatively-related distractor word. To test this hypothesis, they used the cyclic blocking paradigm and presented pictures of thematically interconnected but categorically distinct concepts (e.g., deer, roast shank, hide, rifle, hunter) in either homogeneous or heterogeneous blocks. In line with these predictions, pictures were named more slowly in the homogeneous blocks, which bound the concepts together and facilitated the generation of a lexical cohort, compared to the heterogeneous blocks. Crucially, the same stimuli produced semantic facilitation when presented in the PWI task, which highlights the one-to-one relationship between target and distractor word. In other words, although deer and rifle do not share a common category or many semantic features, their relationship is grounded in the underlying theme, which is supported by the blocking task. In contrast, when a picture is paired with a single thematically-related distractor word in the PWI paradigm, the wider underlying theme is not strongly engendered. Instead, two concepts are activated and they mutually enhance each other and then two activated lemmas compete for selection in a oneto-one fashion. In this situation, conceptual facilitation will outweigh the lexical competition. Thus, Abdel Rahman and Melinger argued that the polarity of semantic context effects depends not on the nature of the semantic relations, per se, but rather on the activation of a lexical cohort.

The tradeoff assumption of the SLN also makes the explicit prediction that small oneto-one lexical competition effects can be observed if the (typically co-present) conceptual facilitation can be reduced. To test this prediction, Melinger and Abdel Rahman (2013) used their double distractor version of the PWI task, presenting distractor word pairs that were indirectly orthographically related to the name of a semantic associate of the target picture (distractors: camera bagel; target: pyramid, an associate of camel), or unrelated. Critical to this experiment is the fact that neither distractor word was related to the target and hence no semantic priming was expected. Following on from previous research that obtained orthographically-mediated semantic interference effects for near synonyms (e.g., soda, related to sofa, slowed the production of couch; Jescheniak & Schriefers, 1998) Melinger and Abdel Rahman predicted that the distractor words should boost the lexical activation of the associatively related competitor, in this case camel, without boosting its corresponding conceptual representation. No effects were found when only indirect relations were presented in an experimental context. However, when the associates were also included as naming trials within the experiment, indirect, orthographically mediated activation of associates produced reliable interference, demonstrating that small competition effects can be detected if they are not offset by conceptual priming. This finding therefore supports the prediction that semantic interference can be observed even when there is only one strong competitor, so long as the concomitant conceptual priming is minimized.

Another under-explored non-categorical semantic relation is meronomy or part-whole relations. Like other non-categorical relations, semantic context effects resulting from meronomic relations can be facilitative (Costa, Alario, & Caramazza, 2005) or interfering. Sailor and Brooks (2014) compared semantic context effects in the PWI paradigm from parts that were associated to their wholes (e.g., siren – ambulance) to parts that were unassociated (e.g., dashboard – ambulance). They observed that associated parts facilitated picture naming while unassociated parts interfered with picture naming. Given that their conditions were matched on semantic distance and density, informed by LSA values, they argued that their distractor conditions should have activated similarly sized lexical cohorts. Indeed, these results illustrate that size is not the only determinant of semantic context effects; strength of the cohort is at least as important. Meronomic distractor words, like other non-categorically related distractors, are unlikely to activate a set of interconnected concepts because the activation at the semantic level will diverge and dissipate across the network. If the semantic facilitation induced by the distractor is also weak, as is potentially the case for the nonassociated parts, then the interference arising from a weakly activated cohort could still win the day. But, if the semantic facilitation is strong, as should be the case in the associated parts condition, then facilitation will win out. These results are important in that they highlight that the number of competitors is only part of the equation; strength of activation is also critical, as we discuss further below.

Note that the effects of non-categorical relations were relatively small in the blocking as well as in the PWI paradigm. In line with our assumption that the number of active competitors determines, in part, the polarity and/or the magnitude of semantic context effects, we note that associates would still co-activate smaller cohorts at the lexical level compared to category members, and thus also weaker competition. Indeed, de Zubicaray and colleagues (2014) did not report interference in the cyclic naming task (for details, see below). The situation is different in the third major context paradigm, the continuous naming task. In this paradigm, categorically related objects are presented randomly in a sequence of unrelated objects. Naming times increase linearly with each new member of the category being named, that is, with the ordinal position of an object within the presented category (Howard et al., 2006).

To account for cumulative interference effects in both competitive and noncompetitive models, additional learning mechanisms have been proposed (Belke, 2013; Howard et al., 2006; Oppenheim, Dell, & Schwartz, 2010). According to these proposals, when a word is produced, e.g., cat, its connections to its semantic features (Belke, 2013) or its lexical counterpart (Howard et al., 2006) are strengthened, making it easier to produce in the future. When a picture from the same category is subsequently presented, e.g., horse, related concepts are coactivated as usual, including the previously retrieved concepts, now with strengthened connections. These pre-potent items will therefore activate their lexical representations more strongly than those of previously unnamed objects, thereby slowing the selection of the target picture's appropriate lexical representation. Each additional picture from the category adds another enhanced competitor into the cohort. As a result, the number of strongly active competitors in the lexical cohort steadily increases with each new member of the category, resulting in cumulative semantic interference.

The SLN does not explicitly include a learning mechanism, but incorporating this mechanism is consistent with the assumption of dynamic context adaptations of the language production system, discussed below (Abdel Rahman & Melinger, 2009a, b; Abdel Rahman & Melinger, 2010; Rose, Spalek, & Abdel Rahman, 2015). In their computational models, both Howard et al. (2006) and Oppenheim et al (2010) implement the learning mechanism at the semantic-lexical interface, directly adjusting the links between concepts and their associated lexical representations. However, Belke (2013) presented empirical evidence that the learning mechanism is implemented within the conceptual level. Specifically, she demonstrated that the incremental facilitation in a classification task and incremental interference in a naming task interact, suggesting a common origin at the conceptual level.

The cumulative interference paradigm allows experimental manipulation of the number of active competitors, for both categorical and non-categorical relationships. The SLN, augmented with a conceptual level learning mechanism, predicts strong cumulative *associative* interference because the number and strength of active competitors (the interrelated lexical cohort) is systematically increasing with each newly named member of a given semantic context. Adjustments of the connection weights between concepts and semantic features upon naming cause each previously named related object to contribute to and strengthen the lexical cohort that competes for selection. This should hold in a qualitatively and quantitatively similar way for category members and associates. Indeed, Rose and Abdel Rahman (2016; see also Roelofs, 2018) showed robust cumulative interference with linearly increasing naming times for each newly named member of a thematic category (e.g., football, goal, stadium, whistle, jersey) that are comparable to the effects reported for categorical relations. The observation that non-categorical interference effects are comparable to effects reported for categorical relations in the continuous naming task but smaller in the PWI and cyclic blocking tasks again reinforces the contribution that multiple competitors play in lexical selection.

Together, the reviewed findings from experiments with multiple and indirectly related distractors, and from cumulative semantic interference with categorical and non-categorical relations demonstrate that lexical cohort activation modulates the speed of speech production and that non-categorical relations can induce interference when either a) a cohort of items is interrelated in a meaningful way or b) conceptual priming can be minimized, supporting the key assumptions of the SLN. Furthermore, these results highlight the novel empirical insights and theoretical developments that arise when one investigates different types of semantic relations.

Effects of semantic distance

One assumption derived from lexical competition models is that competitive selection, and therefore semantic interference, depends on the degree of semantic similarity between representations and that highly related co-activated representations should compete more than loosely related representations due to high feature overlap (Dell, 1986; Roelofs, 1992; Vigliocco, Vinson, Damian, & Levelt, 2002; Vigliocco, Vinson, Lewis, & Garrett, 2004). In line with this idea, Vigliocco and colleagues (2004, Exps 3 & 4) reported enhanced interference in the PWI task, with close distractors inducing stronger interference than more distantly related words (see also evidence in subsequent studies using different naming paradigms; Aristei & Abdel Rahman, 2013; Navarrete, Del Prato, & Mahon, 2012, Experiment 3a and b; Vieth et al., 2014, Experiment 2). However, it must be acknowledged that several studies have found equally robust interference effects for close and distant category members (Hutson & Damian, 2014; Navarrete et al., 2012, Experiment 2; Vieth et al., 2014a, Experiment 1), and some have even found faster naming in the context of close relative to distantly related distractors (Mahon, Costa, Peterson, Vargas, & Caramazza, 2007). These latter results challenge competitive models of lexical selection.

In an attempt to account for the effects reported by Mahon and colleagues (2007) within a competitive framework, Abdel Rahman and Melinger (2009a, 2009b) argued that closely related target-distractor pairs (e.g., birds: owl, hawk) may co-activate lexical cohorts that consist of fewer members than categories co-activated by more distant target-distractor pairs (e.g., animals: owl, tiger), resulting in a narrower set of competitors in the cohort and thus smaller interference. Supporting the idea that different members might activate broader or narrower categories, Alario and Moscoso del Prado Martin (2010) reanalysed Howard et al's (2006) data, examining whether supra-categories contributed to the observed cumulative semantic interference effect. By regrouping small categories (e.g., farm animal and zoo animals) into supra-categories (e.g., mammals), the authors demonstrated an effect of the supra-category that was above and beyond the individual contributions of the sub-categories. However, their analysis did not support the further claim that the original effects could be subsumed by the supra-category effect. Rather, their results demonstrated a multi-tiered model that includes effects at both levels of the taxonomic hierarchy. This finding aligns with the proposal within the SLN that close neighbours will activate a different, possibly smaller, cohort than distant neighbours.

This original SLN explanation for the semantic distance effect observed by Mahon and colleagues (2007) relies on the assumption that the size of a cohort matters, but this assumption does not explain the diversity of findings across experiments. Some of the diversity may rest on the way semantic distance was operationalized within each study. Specifically, the nature of semantic relations between items and the specific measures used to define semantic relations differ across studies. For instance, stimuli from different categories may be classified as closely related if selection criteria emphasize isolated shared features (Mahon et al., 2007; Hutson & Damian, 2014, Experiment 1; Vieth et al., 2014a, Experiment 2; Vigliocco et al., 2002). For example, Mahon et al argued that ‘strawberry’ and ‘lobster’ were as semantically similar as ‘strawberry’ and ‘lemon’, as the former pair share a dominant visual property, namely their colour (Exp 4). In contrast, pairs such as these would be viewed as distantly related if selection criteria emphasize semantic similarity ratings that may underestimate the contribution of distinctive features (Cree & McRae, 2003; Hutson & Damian, 2014, Experiment 2; Mahon et al., 2007; Vieth et al., 2014a, Experiment 1). These differences in how similarity is defined, especially when defined independently of the taxonomic heirarchy, could have consequences for observed semantic context effects, accounting for the divergent findings reported in the literature. Therefore, Rose, Aristei, Melinger and Abdel Rahman (2018) manipulated semantic distance in the sense of shared semantic features systematically within taxonomic hierarchies (cf. Aristei & Abdel Rahman, 2013; Navarrete et al., 2012; Rose & Abdel Rahman, 2016). In a PWI task, the number of shared semantic features was systematically manipulated while superordinate category membership was held constant. In the distant condition, target and distractor were members of a superordinate category, but shared few semantic features and stemmed from different basic level categories (e.g., orangutan and horse). In contrast, in the close condition, target and distractor stemmed from a common basic level category, sharing many features (e.g., orangutan and gorilla). Close relations should strongly co-activate a relatively small lexical cohort while distant relations should induce a broader but shallow cohort. Here, a gradual increase of interference was observed with decreasing levels of semantic distance, with the slowest naming times associated with closely related distractors, intermediate naming times with distantly related distractors, and the fastest naming with unrelated words. Similar effects with stronger interference for close relative to distant relations were found with the same materials in the continuous naming task (Rose & Abdel Rahman, 2017) and in the cyclic blocking task (Aristei et al., in preparation). This pattern is at variance with the observations of Mahon and colleagues (2007), but converges with other previous reports of similar findings in different paradigms which also used a definition of semantic similarity that emphasizes total number of shared features and category membership (Vigliocco et al., 2004; Aristei & Abdel Rahman, 2013 in the PWI task; see also Navarrete et al., 2012 Experiment 3; Vigliocco et al., 2002 in blocked cyclic naming,).

This finding demonstrates that the strength of lexical co-activation, even of a relatively small cohort, is crucial. If an increasing cohort size goes along with a decrease in the strength of mutual co-activation, the effect will be weaker than the competition induced by a smaller cohort of highly active competitors. This is the case for loosely related members of broad categories. We conclude that it is the combined effect of cohort size and activation strength, rather than either of these effects alone, that can explain the slower naming times associated with close compared to distant distractors: closely related items share many specific features and their activation spread converges on a small assembly of strongly interrelated and coactivated lexical representations, inducing strong lexical competition. In contrast, distantly related items share fewer and more global features, inducing a wide but relatively unspecific co-activation between many loosely connected concepts. Consistent with this view, there is a growing body of evidence demonstrating both the independent importance of cohort size and activation strength (e.g., Rose & Abdel Rahman, 2016; Rabovsky, et al., 2016) as well as the interplay between the two (Fieder, Wartenburger & Abdel Rahman, 2018). These observations illuminate the interplay between cohort size and activation strength, thereby clarifying the SLN account.

Semantic co-activation without context manipulations: Endogenous interference and facilitation

The richness of semantic information contained in verbal messages and the density they inhabit in semantic space varies, and such variations should affect conceptual and lexical planning stages. At the level of single words, verbal messages can be associated with a relatively high or low number of semantic features, a variable referred to as the *semantic richness* of a concept or verbal message (McRae, Cree, Seidenberg, & McNorgan, 2005; Pexman, Holyk, & Monfils, 2003; Pexman, Lupker, & Hino, 2002; Rabovsky, Sommer, & Abdel Rahman, 2012a, 2012b). Likewise, verbal messages may be associated with a relatively large or small number of lexical neighbours, a variable referred to as *semantic density*, for which a variety of measures have been employed (e.g., Bormann, 2008; Fieder et al., 2016; Hameau, Biedermann, & Nickels, submitted; Hameau, 2017; McRae et al., 2005; Mirman, 2011; 2011; Rabovsky et al., 2016). According to the SLN, endogenous factors specific to the message, such as semantic richness and density, should affect conceptual and lexical processing in similar ways as context stimuli.

Specifically, an increasing number of semantic features associated with a concept should elicit enhanced spread of activation in the semantic network, and should therefore prime the target concept, enhancing the activation of the target lexical entry. Rich messages, associated with a larger number of semantic features, should also co-activate a larger number of competitors in the course of speech planning. However, because not all semantic features correspond to lexical items, the effect of the conceptual facilitation should outweigh the interference induced by the cohort at the lexical level. In line with this assumption, semantic richness has been shown to facilitate picture naming, with faster naming times and fewer errors associated with increasing levels of semantic richness (Rabovsky, Schad & Abdel Rahman, 2016, in preparation).

In contrast, lexical neighborhood density, which specifically references the number of lexical neighbours rather than the number of semantic features, should impact the activation of a semantic cohort at the lexical level, according to the SLN -- concepts in dense lexical neighbourhoods will activate larger cohorts, slowing naming times relative to concepts in sparse neighbourhoods, which will activate smaller cohorts. As for exogenously-induced context effects, the SLN assumes that inhibitory influences induced by lexical competition will outweigh facilitation at the conceptual level when a lexical cohort of sufficient size and activation strength is activated because an explicit selection is only required at the lexical level. Indeed, the predicted inhibitory effect of lexical neighborhood size, measured as correlational feature density (McRae et al., 2005) has been observed in the studies by Rabovsky et al (2016; in preparation) for the same participants that showed facilitation caused by semantic richness, confirming the predictions derived from the SLN, namely that strong cohort-related activation will result in inhibition-dominant semantic effects. Using different measures of neighborhood density, other studies have reported similar findings (e.g., Mirman, 2011; Fieder et al., 2016; but see e.g. Kittredge, Dell, and Schwartz, 2007 for different effects).

Another recent study investigated influences of the number of related lexical neighbours, effects of the semantic distance of the neighbours, and how these factors interact (Fieder, Wartenburger, & Abdel Rahman, 2018). Similar to semantic distance effects in context paradigms with slower naming for close relative to distantly related contexts (see discussion above), interference induced by semantic neighbourhood similarity was observed with less accurate naming for similar relative to more distant lexical neighbours. This finding yields additional evidence that the increasing strength of semantic co-activation due to increasing levels of similarity results in enhanced interference. Furthermore, while no main effect of semantic neighbourhood density was found when relatively distantly related neighbours were also included, this factor did affect naming when a certain degree of semantic similarity is exceeded: For semantically close neighbours, a density effect was found, with longer naming latencies and higher error rates associated with an increasing number of close neighbours, whereas density had no effect when the neighbours were semantically distant. These observations demonstrate that attributes such as semantic similarity and the lexical cohort size of closely related items directly modulate lexical selection, supporting theories of competitive lexical processing.

To summarize, endogenous attributes like semantic richness and lexical neighbourhood density influence conceptual and lexical processing and affect the tradeoff between conceptual priming and lexical cohort-induced competition in the same ways as is seen for exogenous manipulations of semantic context. Semantic richness affects activation patterns at the conceptual level but does not necessarily induce corresponding strong changes at the lexical level. Therefore, faciliatory effect prevail. Semantic neighbourhood density, in contrast, does relate directly to the size of the lexical cohort, leading to the dominance of lexical interference effects. Both factors reveal valuable additional evidence on the generalizability of semantic variables such as similarity and cohort size as revealed by context paradigms. However, they do not have to deal with potentially confounding influences that have been discussed for context paradigms. No strategies or differences in expectation or predictability as in the cyclic blocking or post-lexical effects due to distractor presentation play a role. Furthermore, learning mechanisms (Oppenheim et al., 2010) are not directly relevant because the effects are endogenous and are measured directly and upon first object naming. Note, however, that long-term connection weight adjustments as a result of semantic richness and density are conceivable. Future research could test this idea.

Neurocognitive evidence

While the behavioural findings reported above provide valuable evidence into how lexicalsemantic mapping feeds lexical selection for different tasks and different types of semantic relations, additional insights can be revealed by examining the neuroimaging and electrophysiological literature. Here, we do not attempt to provide a comprehensive review of the rapidly growing literature on neuroimaging and electrophysiological evidence (for recent reviews and discussions, please see e.g. Zubicaray & Piai, 2019; Indefrey & Levelt, 2011; Indefrey, 2016; Munding et al., 2016; Piai, Riès, and Knight, 2015; Piai, 2016; Strijkers K. & Costa A., 2016). Instead, we selectively discuss neuro-cognitive evidence revealing additional information to evaluate the assumptions on semantic processing and the trade-off and temporal overlap between conceptual priming and competitive lexical selection. We also derive concrete predictions from our core assumptions where direct evidence is not yet available.

Concerning different types of semantic relations, functional and neural dissociations with distinct patterns of brain activation have been reported (e.g., Mirman et al., 2017; Schwartz et al., 2011). De Zubicaray and colleagues (2013) have shown that the presentation of both thematically and categorically related distractor words activates the left middle temporal gyrus (MTG), taken to reflect the retrieval of conceptual or lexical representations. Additionally, thematic relations involved the activation of the left angular gyrus, whereas only categorical relations were associated with activation of the posterior left MTG, taken by the authors to reflect the retrieval of lexical cohorts. While these results converge with the cohort assumptions discussed above, another MRI experiment employing the cyclic blocking paradigm (de Zubicaray et al., 2014) only revealed semantic interference for categorically related blocks of pictures, with neural activation including the left middle and posterior lateral temporal cortex and the hippocampus. Thematically related blocks of pictures only yielded a behavioural facilitatory effect in the first cycle, but no other effects, providing no support for the assumption that thematic relations are active lexical competitors, in contrast to the behavioural findings of Abdel Rahman and Melinger (2007).

As discussed above, behavioural effects for thematic relations in the cyclic blocking paradigm and when indirect activated in the PWI paradigm tend to be weak, and small variances, e.g., in semantic distance (Rose & Abdel Rahman, 2016a; Rose et al., 2018) may obliterate them. It would therefore be beneficial to present thematic relations in the continuous naming task because this task reveals robust interference in the form of cumulatively increasing naming times. As discussed in Rose and Abdel Rahman (2016b), cumulative interference for thematic relations should be comparable to the interference reported for categorical relations due to the identical learning mechanisms contributing to the activation of a cumulatively increasing cohort size. Along with behavioural interference, in fMRI experiments we predict modulated activation in brain areas that have been related to lexical selection, specifically in the left middle MTG, as found for categorical relations in the continuous task (de Zubicaray et al., 2015). For ERP data we predict a posterior positivity within a latency range of about 200 to 300 ms, as reported for categorical relations (for details, please see below).

Concerning the time course of lexical-semantic processing, several EEG / MEG studies have reported that lexical factors affect processing relatively early, within around 200 and 400 ms (e.g., Aristei, Melinger, & Abdel Rahman, 2011; Costa, Strijkers, Martin, & Thierry, 2009; Dell'Acqua et al., 2010; Maess, Friederici, Damian, Meyer, & Levelt, 2002; see also Indefrey & Levelt, 2004; Python et al., 2018; Rose & Abdel Rahman, 2016; Rose et al., 2018; Strijkers, Costa, & Thierry, 2010). While the temporal information alone may only allow for relatively coarse conclusions about the origins of the effects, electrophysiological data can also be employed to investigate the *relative* time course of different involved processes and their serial or parallel organization. Of specific interest for the present purpose is information on the presumed parallel processing and temporal overlap between ongoing conceptual and lexical processes (or between lexical activation and lexical selection; Piai, et al., 2014; Ries et al., 2017). For instance, employing the lateralized readiness potential (LRP), Abdel Rahman and Sommer (2003) and Abdel Rahman, von Turennout and Levelt (2003) provided some evidence for parallel retrieval of conceptual-semantic information on the one hand and lexical and morpho-phonological processing on the other. Similarly, Strijkers, Costa and Pulvermüller (2017) have reported lexico-semantic and phonological-articulatory processes emerging together, recruiting the frontal and temporal cortex within 200 ms.

Theoretically, the assumed temporal overlap between priming and competition should also result in temporally overlapping ERP modulations associated with conceptual priming and lexical competition. Assuming that these strongly related modulations overlap not only in time but also to some degree in their scalp distributions, similar overall topographical distributions and time courses of ERP effects may be associated with overall facilitatory and inhibitory behavioural effects. Such an overlay of ERP modulations may be decomposed by relating them directly to behaviour - for instance, differential patterns for correlations with naming times should be found. Additionally, the signal may be decomposed into separate components (Ouyang, Guang, Sommer & Zhou et al., 2015). Indeed, ERP effects of endogeneous variations of semantic richness and neighborhood density, Rabovsky et al (in preparation) have found a modulation suggesting considerable temporal overlap and parallel processing. Since here, endogeneously co-activated semantic features and lexical neighbors are relevant, contextinduced confounds should pay no role.

Conclusions

In this paper we discuss central assumptions of the SLN, derived from the family of lexical competition models assuming that the selection of a lexical entry depends on the activation status of related alternatives. We assume that (1) semantic activation spread at the conceptual and lexical levels overlap in time, with predominantly facilitatory influences of semantic factors originating at the conceptual level, and predominantly inhibitory mechanisms of selection in the form of competition from co-activated representations at the lexical level. These two overlapping effects tradeoff to determine overall selection durations and thus naming times. The tradeoff is influenced by semantic factors, especially those that affect the activation of lexical cohorts: many related items forming an interactive network of mutual coactivation, the swinging network, with enhanced levels of activation. In the original formulation of the SLN we assumed that (2) each individual co-activated cohort member will contribute to the overall competition, with larger cohorts delaying the naming response more than smaller cohorts. Over the last decade however, the empirical evidence has made clear that the size of the cohort is only half of the story – the strength of the cohort is equally, if not more, important to determining the polarity and magnitude of semantic context effects. Cohort size and the activation levels of the involved items within the network should interact, with stronger effects of mutual co-activation – and a more strongly swinging network - in bigger cohorts for strongly relative to weakly related items.

From this perspective, we view semantic facilitation and interference as two sides of the same coin, reflecting differential contributions of conceptual priming and lexical competition that may vary depending on semantic factors or task demands. Specifically, factors that enhance conceptual-semantic priming or factors that diminish lexical competition should induce faster naming. Conversely, factors that enhance lexical cohort activation and competition or factors that decrease conceptual priming should induce slower naming. These predictions should hold across different naming paradigms and semantic relations. We have summarized evidence from semantic manipulations in context paradigms, such as PWI, cyclic blocking and continuous naming, and from variations of endogenous semantic factors, such as the richness of the message or the distance and density of co-activated lexical-semantic neighbourhoods, revealing how the SLN can integrate seemingly heterogeneous findings from across the literature. For instance, associative / thematic relations tend to yield facilitation in the PWI task, a task that does not include the activation of associative lexical cohorts. However, the same relations induce interference in the cyclic blocking and the continuous naming tasks because blocking and the presumed learning mechanism in continuous naming are assumed to promote lexical cohort activation, including strong co-activations between items, that should outweigh concomitant conceptual priming.

Abdel Rahman and Melinger (2009) also tried to explain the semantic distance effects reported by Mahon and colleagues (2007) where they observed shorter naming times for pictures paired with close relative to distantly related distractors. Specifically, we proposed that distant relations would co-activate a broader, and therefore larger, cohort than close relations. However, this reported semantic distance effect was not found in subsequent experiments that systematically manipulated semantic distance in terms of the number of shared features within taxonomic hierarchies. Instead, we found stronger interference for closer relative to more distant distractors in PWI, cyclic blocking and continuous naming (cf. discussion above). This demonstrates that the strength of activation of individual competitors is the major determinant, as predicted by competition models such as (WEAVER; Levelt et al., 1999; Roelofs, 2018). Competitors that are strongly co-activated in small cohorts of highly related items produce more competition than more weakly activated competitors in broader cohorts with more distant relations. Crucially, in line with the findings of semantic distance in semantic context paradigms, similar effects have been reported in context-free tasks where close co-activated lexical-semantic neighbours induce longer naming times than distantly related neighbours. Thus, we find converging evidence for increasing interference for closer relations across very different paradigms.

As discussed before (Roelofs, 2018; Rose & Abdel Rahman, 2016), lexical competition models, including the SLN, provide a comprehensive general explanation for semantic context effects in different paradigms. Roelofs (2018) has presented a unified account of context effects in the PWI, cyclic blocking and continuous naming task, arguing that available evidence from electrophysiological, hemodynamic and patient studies speaks in favour of a common locus of semantic context effects at the level of lexical selection. Such a unitary account is valuable because it provides a relatively simple explanation for interference effects across paradigms. Here, we additionally emphasize that consideration of the relative contributions of temporally overlapping conceptual priming (resulting in enhanced activation levels of the target concept and lexical entry) and lexical competition (resulting in delayed selection) can explain a variety of semantic effects. Indeed, the whole spectrum of behavioural effects ranging from facilitation to interference is in line with lexical competition models because both effects are integral components of early planning stages of language production. In this context, lexical cohorts play a special role, with flexible adjustments of coactivations depending on the semantic relations and situational requirements as well as internal modulations without additional contexts.

To summarize, we argue that, by taking the trade-off between facilitation and interference and the role of co-activating lexical cohorts and activation strength into account, the SLN can explain diverse findings for different semantic relations, polarity reversals and semantic effects revealed by context manipulations and endogenous variations. As such, the SLN provides wider explanatory power than models like the REH (Mahon et al, 2007), the dark side model (Oppenheim et al, 2010), many of which were developed to account for task specific effects.

Open questions and future directions

There are several open issues concerning the SLN as well as potential questions and directions for future research. The SLN was developed as a competition model that capitalizes on the implications of the Luce ratio. However, are the SLN's assumptions consistent with models that implement competition via inhibitory links between active lexical representations (e.g., Caramazza, 1997; Harley, 1993a, 1993b; Howard, Nickels, Coltheart, & Cole-Virtue, 2006; Stemberger, 1985)? To our knowledge, all models that implement lateral inhibitory at the lexical level assume unrestricted bidirectional flow of activation, which means these models are naturally sensitive to the activation levels across the network. However, for these models, semantic and lexical patterns of activation are mirrors of each other -- interconnected concepts mutually enhance each others' level of activation while interconnected lexical representations mutually inhibit each other. Given the bi-directional nature of the links between levels, this means the inhibited lexical representations feedback to the conceptual level, potentially dampening the resonance at the conceptual level. In other words, we do not believe that a model with lateral inhibition would create the sort of 'swinging network' that we argue underpins lexical selection processes. That said, without computational modelling, it is very difficult to track the specific consequences of lateral inhibition and bidirectional parallel activation.

Although it is difficult to pull out specific predictions that will help differentiate between models based on lateral inhibition vs. competition for selection, a few key points can be drawn out. For instance, a Luce-like selection rule depends on a large differential in activation between the target word and the rest of the network. Slower selection times are attributed to the time needed for the target activation to increase while the rest of the network's activation decreases, presumably due to accumulating evidence for the target. In contrast, inhibition models set an activation threshold rather than a differential. If a representation crosses this threshold, it is selected, even if another representation is also very close to crossing the threshold. Slower selection times are attributed to the tug-of-war between representation. An experiment that could manipulate the activation differential should be able to discriminate between these two alternative competition mechanisms.

Another question concerns the effects of cohort activation. We have proposed two effects. Activation of mutually interconnected concepts should result in the swinging of the network, inducing enhanced activation of affiliated lexical representations, i.e., the lexical cohort, and thus strong competition. Additionally, we assume that each individual competitor contributes to the overall competition, taking the activation levels of the entire network into account. It is an open question whether and how the contributions of the two effects can be distinguished. One shortcoming is that the assumptions of the SLN are thus far described only at a general level, and it should be implemented and modelled computationally to better understand and test the predictions derived from the SLN.

Similarly, to account for cumulative semantic interference, we proposed incorporating a learning mechanism into the SLN. Two specific options have been proposed. Two computationally implemented models which aimed to capture early observations from cumulative semantic interference experiments proposed that links between conceptual representations and their associated lexical representations could be adjusted, strengthening representations that were recently selected (Howard et al, 2006; Oppenheim et al., 2010). More recently, Belke (2013) explored the predictions of the Conceptual Accumulation Hypothesis, which proposes that semantic context effects in blocked and continuous naming paradigms both have their origin (as opposed to the locus) at the conceptual level. Her exploration produced evidence that the learning mechanism is best captured by adjusting links between conceptual representations and their associated semantic features. The view that the learning mechanism was best modelled at the conceptual level, rather than at the semanticlexical mapping, was later implemented by Roelofs (2018) by means of a response bias. The empirical evidence presented by Belke, namely showing a) the necessary involvement of conceptual representations in semantic blocking and continuous naming paradigms and b) that facilitation and interference effects both have their origins at the same level of representation, even if the behavioural effects might emerge at different levels of representation, fit perfectly with the core assumptions of the SLN. Her experiments were designed to localize where learning takes place and, being fully consistent with the core assumptions of the SLN, are our preferred implementation. However, to take a stronger stand on this issue, we again must await a computational implementation of the SLN to ensure full compatibility with our proposal.

We believe that the SLN can account for semantic context effects from same and different category competitors across PWI, cyclic blocking and continuous naming paradigms. It can also explain endogenous semantic effects. Its core assumption of parallel semantic and lexical activation is supported by the extant ERP investigations (e.g., Abdel Rahman & Sommer, 2003; Abdel Rahman, von Turennout & Levelt, 2003; Strijkers, Costa, & Pulvermüller, 2017)). Thus, we feel that the SLN gives broad explanatory coverage and goes beyond most proposals that either are designed to account for task-specific effects, such as the Response Exclusion Hypothesis (Mahon et al, 2007) which is designed to account for PWI effects or the Dark Side model (Oppenheim et al, 2010), which is designed to account for continuous and blocked naming. However, the SLN does not yet provide an explanation for all relevant findings. For example, we do not think lexical cohort activation can explain why distractors at different levels of specificity do not reliably induce semantic interference (Vitkovitch & Tyrrell, 1999; Kuipers, La Heij, & Costa, 2006, but see Hantsch, Jescheniak, & Schriefers, 2005). We also cannot explain why picture distractors do not induce semantic interference as effectively as word distractors (Aristei et al., 2012; Damian and Bowers, 2003; Jescheniak et al., 2009; 2014). And, we have also never explored the explanatory power of the SLN for patient data. Finally, we have not discussed the effects of individual variability. For instance, healthy ageing, bilingualism, semantic or lexical processing deficits may directly affect the trade-off between conceptual priming and lexical competition. Hence, there is yet more work to do in developing the SLN and much of that work will require computational modelling.

For future research, we would like to advocate for a broader investigation of meaning aspects in language production for a comprehensive understanding of conceptual and lexical planning stages. The meaning of verbal messages is not only composed of categorical relations. It may be influenced by factors like semantic richness and density, and may include associations, part-whole relations, thematic links and ad-hoc relations.

We have discussed evidence from studies investigating endogenous semantic variations as a complement to classic semantic context manipulations. Because no semantic contexts or distractor stimuli are involved, such studies provide insight into natural and unbiased meaning processing during speech planning, avoiding confounding influences of attention, response strategies and semantic biases. Notably, endogenous and exogenous manipulations have revealed remarkably similar types of effects. For instance, semantically close relations, whether activated by contexts (Rose & Abdel Rahman, 2017; Rose et al., 2018; Aristei et al., in preparation) or endogenously upon lexical-semantic processing (Fieder et al., in press), interfere more with target naming than distant relations, and inhibitory effects have been reported caused both by contexts or semantic relations that induce the co-activation of inter-related items (Abdel Rahman & Melinger, 2007) or by inherent effects of semantic neighbourhood density (Fieder et al., in press).

A broader definition of meaning beyond categories also includes associations and thematic relations that are highly relevant for communicating and interacting with our environment. Such relations may differ in many ways from categorical links. Specifically, they may differ in their potential to induce cohort activation. While category members more or less automatically co-activate each other via shared features and category nodes, associates may co-activate related items to a lesser degree, only when prompted or in specific contexts. Nevertheless, the evidence reviewed here suggests that the differences between category members and associates in terms of conceptual priming and lexical competition are quantitative and related to the trade-off between facilitation and interference, rather than qualitative in nature.

Finally, little research has been dedicated to social and emotional meaning aspects, despite their high relevance for verbal and non-verbal human communication and their high personal and social relevance (e.g., Baus et al., 2014; D'Hooge & Hartsuicker, 2011; Gambi et al., 2015; Hoedemaker & Meyer, 2018; Hansen et al., 2016; Hoedemaker et al., 2017; Kuhlen & Abdel Rahman, 2017; Rohr & Abdel Rahman, 2015; 2018; Schindler et al., 2014; 2015). Social and emotional meaning may modulate conceptual and lexical processing and cohort activation and should contribute to a comprehensive view on meaning-based language production and to better understand how we select our words to express what we mean to say.

In sum, ten years after the original proposal of the SLN, a wide variety of behavioural effects from across the literature find an explanation in our extension of a traditional competition model. Our exploration into non-categorical semantic context effects and endogenous semantic effects have informed the modification of the proposal to more accurately reflect the empirical evidence. We hope the next ten years will see more researchers investigating a broader set of semantic relationship in the hopes of finding better answers to the fundamental question of how we select words that correspond to our intended message.

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