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Similarity-based competition in relative clause production and comprehension

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ABSTRACT

This work investigates the role of semantic similarity in sentence production and comprehension. Previous research suggests that animacy and conceptual similarity of the noun concepts within complex descriptive phrases modulate structural preferences in production, and processing cost in comprehension. For example, animate-head phrases such as *the girl that the boy is pulling* are rare in production and more difficult to understand in comprehension. In contrast, phrases with passive clauses such as *the girl being pulled by the boy* are commonly produced and more easily understood, as are inanimate-head structures such as *the truck the boy is pulling*. In three picture-based studies, we examined the mechanisms underlying semantic similarity effects in producing and comprehending these phrases. Study 1 investigated structural preferences in production, whereas Study 2 investigated processing cost in comprehension. Study 3 used eye-tracking to examine the time-course of production processes. The results showed that semantic similarity elicited competition during phrase planning, influenced the choice of syntactic structure in production, and engendered comprehension difficulty in animate-head active configurations. Structural preferences, fixation probabilities reflecting production planning processes and comprehension cost significantly correlated with measures of conceptual similarity across the three studies. We argue that similarity-based competition modulates sentence production and comprehension processes when verbs are planned or interpreted, i.e., when event-based semantic or syntactic roles are determined. In addition to task-specific processes, we suggest that a similar and shared semantic competition mechanism underlies both production and comprehension, a view consistent with existing evidence for common brain regions recruited in both tasks.

Introduction

Traditionally, psycholinguistic research has studied production and comprehension as separate processing systems (Bock & Levelt, 1994; MacDonald, Pearlmutter, & Seidenberg, 1994). This appeared necessary because production and comprehension do involve different processes such as word retrieval vs. recognition, or motor planning vs. sensory analysis. More recently, however, researchers have started to investigate relationships between these two processing systems and what they have in common (Bock, Dell, Chang, & Onishi, 2007; Chang, Dell, & Bock, 2006; Gennari & MacDonald, 2009; Humphreys & Gennari, 2014; MacDonald, 2013; Menenti, Gierhan, Segaert, & Hagoort, 2011; Pickering & Garrod, 2007). Chang et al. (2006), for example, suggest that the learner's

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experience shapes production processes, and that learning and production share the same computational architecture and the abstract structural knowledge underlying these processes. Gennari and MacDonald (2009) further suggest that the mapping of semantic roles into syntactic arguments may be shared across production and comprehension, in part because both abilities emerge from experience-based learning, which extracts common patterns of mapping words to meanings. More generally, MacDonald (2013) argues that production mechanisms play a significant role in shaping comprehension processes because they determine the input that learners and comprehenders are exposed to. Taken together, these accounts converge in suggesting that production and comprehension share a common knowledge base, which contains lexical knowledge and abstract mapping patterns extracted from linguistic experience.

Beyond shared knowledge, however, it remains an open issue whether sentence production and comprehension also share specific processing mechanisms. Previous behavioral evidence has shown strikingly similar processes in both tasks, and thus suggests potential candidate mechanisms. For example, in sentence comprehension research, multiple studies have shown that relative clauses such as those in (2) are difficult to comprehend and that this comprehension difficulty is modulated by animacy and conceptual similarity (Gennari & MacDonald, 2008, 2009; Mak, Vonk, & Schriefers, 2002, 2006; Traxler, Morris, & Seely, 2002). Object relative clauses with two animate nouns as in (2) are harder to understand than those with nouns of different animacy as in (4), and increased similarity between the two animate nouns leads to increased difficulty (Gordon, Hendrick, & Johnson, 2001; Gordon, Hendrick, Johnson, & Lee, 2006). This comprehension difficulty has been attributed to different mechanisms. Some authors have argued for similarity-based interference in working memory as two similar nouns (e.g., *man* and *woman* in (2)) must be retrieved and integrated with the upcoming verb (Gordon et al., 2001). Others have argued for competition between incoming and expected alternative structures and interpretations as the relative clause unfolds (Gennari & MacDonald, 2008, 2009). These two views are not mutually exclusive, because different types of linguistic information may contribute to competition between interpretations and/or retrieval interference in working memory (Staub, 2010).

(1) Animate Head, Passive: *The man who's being punched by the woman.*
(2) Animate Head, Active: *The man that the woman is punching.*
(3) Inanimate Head, Passive: *The sandbag that's being punched by the woman.*
(4) Inanimate Head, Active: *The sandbag that the woman is punching.*

Similarly, in production research, studies have shown that speakers and writers select relative clause structures according to animacy and conceptual similarity. Producers very rarely use structures such as (2), whereas they are more likely to use the ones in (1) and (4) (Gennari & MacDonald, 2009; Gennari, Mirković, & MacDonald, 2012; Roland, Dick, & Elman, 2007). For example, a sentence elicitation task using pictures such as that in the left panel of Fig. 1 indicated that in response to a question, e.g. *Who is bald?,* speakers overwhelmingly prefer structure (1) rather than (2). In contrast, in response to *What is orange?*, speakers are equally likely to use (3) or (4) (Gennari et al., 2012). These findings indicate that animacy influences production choices. Moreover, in animate-head cases such as (1) the conceptual similarity between the nouns of the relative clause positively correlated with the rate of agent omissions: for the case of man and woman in (1), the preference for agent omission is relatively large (e.g., *the man being punched*), whereas for cases where the similarity is lower as in *the baby being held by the woman* (Fig. 1, right panel), this preference is reduced (Gennari et al., 2012). This graded similarity effect clearly indicated that specific semantic features of the nouns played a role, rather than only categorical animacy. The authors argued that conceptual similarity may cause interference between alternative concepts or words to be produced. In planning relative clauses with two animate nouns, where the second noun could potentially follow the first noun, sentence planning may involve some temporal overlap in the preparation of the two nouns, and hence there is potential for interference or competition between their meanings, as in comprehension of object relative clauses. This interference or competition may result in inhibition or reduced activation of the agent concept following lexical selection of the head noun *man*, leading to the use of a passive construction in which the agent noun is mentioned last or omitted altogether.

More generally, outside of the domain of relative clauses, much research has also demonstrated the role of similarity-based interference in many language behaviors, including production, comprehension and verbal working memory (Baddeley, 1986; Baddeley & Hitch, 1974; Freedman, Martin, & Biegler, 2004). For example, production studies investigating factors that modulate choices of referential expressions (e.g., pronouns vs. definite descriptions) suggest that the conceptual similarity between the characters to be described influences the choice of referential expressions (Arnold & Griffin, 2007; Fukumura, van Gompel, Harley, & Pickering, 2011; Slevc, 2011; Smith & Wheeldon, 2004). These findings are consistent with Smith and Wheeldon's proposal that some temporal overlap exists, if only at a conceptual level, in the planning of two nouns to be produced in sequence, thus leading to semantic interference (see also picture-word interference effects between distractors and targets, e.g. Costa, Alario, & Caramazza, 2005; Glaser & Düngelhoff, 1984; Glaser & Glaser, 1989; Schriefers, Meyer, & Levelt, 1990). Further, models of sentence comprehension inspired by working memory research suggest that similarity-based interference pervades many aspects of sentence comprehension and leads to a greater processing cost when the target to be retrieved from memory syntactically or semantically overlaps with distractors available in working memory (Gordon, Hendrick, & Johnson, 2004; Gordon et al., 2001; Lewis & Vasishth, 2005; Van Dyke, 2007; Van Dyke, Johns, & Kukona, 2014; Van Dyke & McElree, 2011).