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Word Selection Deficits and Multiword Speech

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Abstract

Through computational modelling of language behaviour in both healthy and brain-damaged individuals, Anders, Riès, van Maanen and Alario (in press) propose that to facilitate word selection when alternatives compete for production, the left lateral prefrontal cortex (PFC) changes the threshold for word selection. Because selecting a word during multiword speech involves resolving competition from target-related competitors as well as words produced in the past and future, a word-selection deficit caused by damage to the left PFC may result in difficulties in producing multiword speech. I review evidence in support of this hypothesis and discuss alternative explanations. Future work should extend Anders and colleagues' conclusions to understand whether a deficit in word selection when producing single words accounts for failures to communicate via multiword speech.

When we produce speech, we select two to three words per second out of an active vocabulary of 40,000 words and yet we make a mistake only one in a thousand words (Levelt, 1989). The ability to select a representation in the face of myriad competitors is a critical process not only in language production but across other domains including language comprehension (e.g., Novick, Trueswell, & Thompson-Schill, 2005), memory retrieval (e.g., Anderson, Bjork, & Bjork, 1994), action planning (e.g., Watson & Buxbaum, 2015) and decision making (e.g., Miller & Cohen, 2001). Anders, Riès, van Maanen and Alario's (in press) computational work provides a framework with which to understand how we select a word when semantically related words compete for production. This advance is particularly important in its proposals for how this process breaks down in those with language deficits as a result of brain damage. The research focuses on single word production, a general focus of language theories to date (e.g., Caramazza, 1997; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Levelt, Roelofs, & Meyer, 1999; Rapp & Goldrick, 2000). However, a next step will be to understand how the Anders and colleagues' model explains why selecting words fails for persons with aphasia during real world contexts like discourse, starting with multiword speech.

The work from Anders and colleagues (in press) suggests that when selection occurs in situations of competition, the selection process changes in at least two ways. First, lexical representations more slowly accumulate activation in situations of competition (for reasons that continue to be explored, for example see Snyder and colleagues, 2010). Second, the system increases the amount of activation required for selection (a change in selection

threshold) so that it does not misselect one of the competitors. Anders and colleagues propose that damage to the left prefrontal cortex (PFC) and the left inferior frontal gyrus (LIFG) in particular create a deficit in adjusting the selection threshold upward in the presence of competing alternatives. This deficit in adjusting the selection threshold during competition from alternatives results in naming errors. Does this type of word production failure in a serial picture naming task like blocked-cyclic naming extend to explain difficulties in producing words in multiword speech?

Speech error evidence suggests that word selection is susceptible to competition from multiple sources. In experimental tasks like blocked-cyclic and serial picture naming, naming errors include misselecting words semantically related to the target (e.g., Schnur, Schwartz, Brecher, & Hodgson, 2006) and misselecting semantically related words produced in the past (e.g., Vitkovitch & Humphreys, 1991; Hsiao, Schwartz, Schnur, & Dell, 2009). In narrative production, we make errors by repeating words said in the past (perseverations), producing semantically or phonologically related word substitutions or omissions for our target, or exchanging our target with a word to be produced in the future (for examples, see Garrett, 1975). These errors occur at one or more levels in the language system. For example, errors are possible when activating the concepts associated with the message we wish to convey (conceptual level), selecting the words associated with those concepts (lexical level), or selecting the sounds associated with words (phonological level). However, the degree to which selection during speech is competitive and at which levels is an ongoing research question (e.g., Levelt, et al., 1999, Bloem & la Heij, 2003; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007; Navarette, del Prado, Peressotti, & Mahon, 2014; Breining, Nozari, & Rapp, 2016). Because selecting a word in a multiword context requires ignoring words produced in the past, ignoring words semantically related to the target, and ignoring words to be produced in the future (e.g., Gordon & Dell, 2003; Dell, Oppenheim, & Kittredge, 2008) a word selection deficit may impact selection when competition arises from these sources during multiword speech.

Support for a selection deficit contributing to a deficit in multiword speech comes from evidence from persons with chronic aphasia. In a group study of blocked-cyclic naming in 12 individuals with aphasia following stroke (Schnur et al., 2006), the more errors produced in semantically homogeneous versus heterogeneous picture naming (the same measure of selection deficit as in Anders and colleagues, in press) the fewer words produced in sentences and the fewer overall words per minute produced during narrative speech (i.e., a retelling of the Cinderella fairy tale analyzed using the Quantitative Production Analysis; Rochon, Saffran, Berndt, & Schwartz, 2000). Speer and Wilshire (2014) found a similar set of results in a study of sentence production in five speakers with non-fluent aphasia (usually coincidental with left frontal damage) and four speakers with fluent aphasia (associated with damage to left posterior brain regions). The non-fluent group was worse than the fluent group when producing nouns in sentences (e.g., the nurse is kicking the pig) compared to producing the same nouns in isolation. This group difference emerged again when the nouns in the sentences (the subject and object) were semantically related (a condition of higher competition during selection) vs. unrelated. Similar to Schnur and colleagues, the more errors produced in the semantically related vs. unrelated sentences, the fewer overall words produced per minute when recounting the Cinderella story. Single-case studies also report

individuals with aphasia who have difficulties in producing words in context compared to in isolation (see Schwartz & Hodgson, 2002; Scott & Wilshire, 2010).

Evidence from subjects based on the location of their anatomical damage also suggests a relationship between a selection deficit caused by damage to the left PFC and impairments in multiword production. For example, two subjects (CBD and TB) with damage as a result of stroke to the left PFC and premotor cortex (Brodmann Areas (BAs) 44 and 6) had more difficulty producing two-word utterances (e.g., the eye and the pencil → ____ and the pencil) and producing sentences that were well-formed (for example, the error “Cinderella had to what was going to the ball”) in comparison to subjects with damage more anteriorly (BAs 45/47; Thothathiri, Schwartz & Thompson-Schill, 2010). LIFG damage is also related to deficits in generating sentences from nouns which do not constrain selection alternatives either at the conceptual and/or lexical levels of production. In a single-case study, ANG had difficulty producing words, phrases and sentences when there were many competitors for output as a result of a left frontal meningioma affecting BA 45 (Robinson, Blair, & Ciolotti, 1998). For example, ANG was significantly impaired producing sentences from common nouns (e.g., teeth) in comparison to nouns which constrained the number of sentences possible (e.g., proper nouns like “Oliver Sacks”). In another single case study, CH who had atrophy to both the LIFG (BA 44) and left temporal cortex (BA 21), also exhibited a similar pattern in sentence generation (Robinson, Shallice, & Ciolotti, 2005). In a group study of subjects with brain damage as result of stroke or tumor, compared to six subjects with damage restricted to the left temporal cortex, 12 subjects with isolated LIFG damage demonstrated greater difficulty in generating sentences from high frequency nouns (Robinson, Shallice, Bozzali, & Ciolotti, 2010). In sum, group and single case studies of speakers with aphasia suggest a relationship between successful multiword production, the ability to select representations in the face of competition, and the left PFC.

Although the evidence is suggestive, there are alternative explanations for why producing multiple words in sequence fails as a result of left PFC damage. For example, semantic short-term memory deficits associated with left frontal damage create impairments in multiword speech (e.g., Martin & Freedman, 2001; Martin & Slevc, 2014; Martin, Schnur, & Anderson, 2016). It is also unclear the degree to which difficulties in producing words in situations of competition (in isolation or context) is a result of damage to a selection mechanism in the left PFC and/or damage or access to representations stored in the left temporal cortex (e.g., Noonan, Jefferies, Visser, & Ralph, 2013; Harvey & Schnur, 2015). Of the six patients with left PFC damage reported by Anders and colleagues (in press), three of the six had around 20% damage or more to the left temporal cortex. We should also consider the role of the left PFC in grammatical and phonological encoding required for multiword speech (e.g., Bookheimer, 2002; Hagoort, 2005). Failures to produce multiword speech occur for multiple reasons, but if the left PFC is critical for resolving selection competition during word production, it should be necessary in competitive selection scenarios like multiword speech.

Converging methodologies can provide evidence of the relationship between left frontal regions, selection mechanisms, and multiword speech. Some examples include transcranial magnetic stimulation (e.g., Pisoni, Papagno, & Cattaneo, 2012; Krieger-Redwood, &

Jefferies, 2014) anodal transcranial direct current stimulation (Meinzer, Yetim, McMahon, & Zubizaray, 2016; cf. Westwood, Olson, Miall, Nappo, & Romani, 2017), and functional MRI (Schnur et al. 2009; de Zubizaray, McMahon, & Howard, 2013; Thothathiri, Rattinger, & Trivedi, 2017). In addition, as seen in Anders and colleagues (in press) and elsewhere (e.g., Oppenheim, Dell, & Schwartz, 2010; Dell, Schwartz, Nozari, Faseyitan, & Coslett, 2013), combining computational modeling, cognitive neuropsychology, and neuroimaging gives insight into the mechanisms involved in lexical selection. Through these avenues we can understand how selection deficits in single word production contribute to failures to communicate via multiword speech.

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