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Cognitive control, word retrieval and bilingual aphasia: Is there a relationship?

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ABSTRACT

It is proposed that successful word retrieval involves lateral inhibition of lexical competitors, and suppression of the non-target language in bilingual speakers. Thus cognitive control is crucial for word production. Given that word retrieval difficulty is a hallmark feature of aphasia, the relationship between word retrieval and cognitive control in aphasia has not been sufficiently explored. This study examined whether persons with aphasia show 1) evidence of a cognitive control deficit, 2) bilingual status interacts with cognitive control deficit in persons with aphasia, and (3) a relationship between measures of word naming and cognitive control. Thirty-eight persons with aphasia were administered a task of cognitive control (Stroop color-word task) and two word production tasks (picture naming and category fluency). We found weakened cognitive control in aphasia relative to age-matched neurologically healthy adults. A bilingual advantage in cognitive control was found in neurologically healthy adults and in one group of bilingual speakers with aphasia, but not the other group. Word retrieval in persons with aphasia was not correlated with Stroop task performance. These findings show that cognitive control performance (as measured by the Stroop task) is compromised in persons with aphasia, irrespective of bilingual status. There was a bilingual advantage in two out of three groups, showing a general support for the bilingual inhibitory control advantage (BICA) hypothesis.

1. Introduction

The cognitive processes underlying word production involve selecting a target lexical representation from numerous similar representations. For example, if a speaker wants to produce the word *horse*, the lexical representations of *saddle, stable, dog, mule, stallion*, etc. are co-activated. The mechanism by which a specific target word is rapidly narrowed down for production is debated. One prominent view proposes that lexical selection involves competition between co-activated semantically related representations (Levelt, 2001; Rahman & Melinger, 2009; Roelofs & Piai, 2015). Alternately, lexical selection is viewed as a non-competitive process, where the overall cumulative activation level of lexical representations

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determines which word is eventually articulated (Dell, 1986; Finkbeiner & Caramazza, 2006; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007; Miozzo & Caramazza, 2003). Irrespective of whether lexical selection proceeds via competition among related representations or not, it is assumed that lexical selection involves some level of interference resolution of unwanted candidates. Some authors propose that this occurs via an early top-down cognitive control mechanism triggered by language schema or contextual demands (Green, 1998). Others propose that unwanted lexical candidates are subdued by local inhibitory connections between lexical representations, also called lateral inhibition (Colzato et al., 2008; Dijkstra & Van Heuven, 1998; La Heij, 2005). Thus, cognitive control, which refers to processes of detection and resolution of interference and maintenance of goal-relevant representations, is crucial for word production.

This study aims to elucidate the relationship between word retrieval and cognitive control by focusing on two variables: one that negatively influences word retrieval (aphasia) and the other supposedly poses cognitive control advantages (bilingualism). Lexical selection is especially vulnerable in persons with aphasia (PWA), a language impairment resulting from brain damage. PWA frequently report that the target word is at the tip-of-their tongue, and produce semantic paraphasias, which are semantic errors such as *dog* for *horse*. Such semantic paraphasias are indicative of a difficulty in lexical selection, perhaps due to insufficient resolution of the interference caused by related non-target lexical representations (Biegler, Crowther, & Martin, 2008). Could lexical selection difficulties in aphasia be a manifestation of weak interference resolution of lexical competitors? The primary goal of this study is to examine cognitive control in aphasia and its relationship with word retrieval success. For bilinguals (speakers of multiple languages), cognitive control is claimed to play an even larger role in word retrieval because of the additional need to suppress the lexical representations of the non-target language (Green's inhibitory control model, 1998). Hence, a secondary goal of this study is to investigate cognitive control in bilingual aphasia, given the recent debate on cognitive advantages in neurologically healthy bilingual speakers (Hilchey & Klein, 2011; Paap & Greenberg, 2013). In the following sections, we will examine the evidence for the role of cognitive control in word retrieval, aphasia and bilingualism.

1.1. Cognitive control and word retrieval

One approach to establishing a connection between cognitive control and word retrieval is based on identifying overlap in neural activation in functional brain imaging studies. The middle-to-inferior prefrontal cortex and dorsal anterior cingulate cortex are two regions frequently associated with tasks involving both domain general cognitive control and lexical selection (Bokde, Tagamets, Friedman, & Horwitz, 2005; Braver, 2012; Kerns et al., 2004; Piai, Roelofs, Acheson, & Takashima, 2013; de Zubicaray, McMahon, Eastburn, & Pringle, 2006; ; evidence reviewed in Abutalebi & Green, 2007 and Green & Abutalabi, 2013). Piai et al. (2013) examined neural correlates of picture word interference (PWI) and Stroop (Golden, 1978; Stroop, 1935) tasks in the same group of participants. Both PWI and Stroop have conflict conditions that demand higher cognitive control (semantically related distractors in PWI and incongruent trials in Stroop). Piai et al. (2013) found activation of anterior cingulate cortex in both tasks for only the conflict conditions, suggesting recruitment of similar cognitive control networks. The prefrontal and dorsal anterior cingulate regions are also found to be recruited by bilingual speakers who constantly negotiate cross-language competition, especially during language switching (Abutalebi et al., 2012; Crinion et al., 2006).

The connection between cognitive control and word retrieval has also been investigated using an individual differences approach: performance on tasks known to tap cognitive control is correlated with performance on word retrieval. Bialystok, Craik, and Luk (2008) examined cognitive control using an adaptation of the Simon task that used arrows and Stroop color naming tasks, and word retrieval using verbal fluency (category and letter) and naming-to-definition tasks. In both the Simon arrows and Stroop color naming tasks, there are congruent and incongruent trials. The incongruent trials are designed to tap cognitive control, and the relative performance between incongruent and congruent trials is a measure of inhibition. In Simon arrows, participants indicate the direction of an arrow by pressing left and right arrow keys. In congruent trials the response key is in the same direction as the arrow and incongruent trials require pressing of the right arrow key for left pointing arrows and vice versa. In the Stroop task, participants name the font color of words, congruent trials show the word (e.g., GREEN) in the same font color, and incongruent trials show the word in a different font color (e.g., red). Bialystok et al. (2008) did not find a correlation between cognitive control and word retrieval measures in young or old monolingual or bilingual speakers. In contrast, Shao, Roelofs, and Meyer (2012) found a significant positive correlation between speed of lexical access and cognitive control in young adults. They examined cognitive control using the stop-signal task, in which participants respond to shapes (circle or square) by pressing specific keys on a keyboard, but have to withhold their response if they hear an auditory tone. Not only did Bialystok et al. (2008) and Shao et al. (2012) use different cognitive control and lexical tasks, but more crucially, they used different metrics for lexical access: speed and accuracy. While these differences could have accounted for the contradictory findings of the two studies, whether cognitive control correlates with lexical selection remains an open question.

1.1.1. Dual mechanisms of cognitive control

For the sake of simplicity, until this point in the paper, we have treated cognitive control as a unitary concept. In reality, at least two types of mechanisms are identified (although the specifics of this division differ across authors and are beyond the scope of this paper): 1) a *conscious* level, used, for example, to actively maintain an abstract goal or task set, and 2) a more *automatic* (and sometimes local) mechanism that resolves interference arising during any cognitive process. The former cognitive control mechanism is can be thought of as 'Do not do X' (Munakata et al., 2011) and is implemented in anticipation

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