Metacognitive deficits in categorization tasks in a population with impaired inner speech

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ABSTRACT

This study examines the relation of language use to a person's ability to perform categorization tasks and to assess their own abilities in those categorization tasks. A silent rhyming task was used to confirm that a group of people with post-stroke aphasia (PWA) had corresponding covert language production (or "inner speech") impairments. The performance of the PWA was then compared to that of age- and education-matched healthy controls on three kinds of categorization tasks and on metacognitive self-assessments of their performance on those tasks. The PWA showed no deficits in their ability to categorize objects for any of the three trial types (visual, thematic, and categorial). However, on the categorial trials, their metacognitive assessments of whether they had categorized correctly were less reliable than those of the control group. The categorial trials were distinguished from the others by the fact that the categorization could not be based on some immediately perceptible feature or on the objects' being found together in a type of scenario or setting. This result offers preliminary evidence for a link between covert language use and a specific form of metacognition.

1. Introduction

The most obvious function of language is that it facilitates communication. Yet there is increasing evidence that language has important *extra-communicative* cognitive functions as well, insofar as covert uses of language appear to influence performance on a diverse set of tasks unrelated to interpersonal communication. Some of these include categorization tasks (Lupyan & Mirman, 2013; Plunkett, Hu, & Cohen, 2008), memory tasks (Loewenstein & Gentner, 2005; Papafragou, Hulbert, & Trueswell, 2008), object individuation (Xu, 2002), relational judgments (Kotovsky & Gentner, 1996), event categorization (Papafragou & Selimis, 2010), task switching (Laurent et al., 2016), and theory of mind judgments (Newton & de Villiers, 2007).

Some studies have investigated the cognitive functions of language by looking at the particular cognitive disabilities of people with aphasia (PWA), who have acquired language impairments due to stroke. For instance, some of these studies show that PWA have difficulties attending to specific dimensions of similarity when making taxonomic judgments during categorization (Cohen, Kelter, & Woll, 1980;

Lupyan & Mirman, 2013; Noppeney & Wallesch, 2000); others reveal an influence of language on working memory capacity (Caspari, Parkinson, LaPointe, & Katz, 1998) or attention (Murray, 2012). In some cases, these results from PWA have been corroborated in neurotypical populations under verbal interference (Lupyan, 2009). While some PWA have cognitive impairments that extend beyond their impaired linguistic systems (Glosser & Goodglass, 1990; Purdy & Dietz, 2010; Murray, 1999), the above studies are of special interest in that they attempt to show that impaired task performance results specifically from damage to linguistic centers of the brain.

To date, however, there has been relatively little examination—in neurotypical or PWA populations—of the role that language may play in metacognition. A number of theorists have speculated that covert language production—in the form of "inner speech" (Alderson-Day & Fernyhough, 2015)—may play an important role in bringing thoughts to consciousness (Bermudez, 2003; Carruthers, 1996; Clark, 1998; Jackendoff, 1996; Morin, 2009) and in allowing for critical reflection on one's own judgments and attitudes (Carruthers, 2011; Martínez-Manrique & Vicente, 2015). Yet there have been no quantitative empirical studies of this hypothesis as yet. In a similar vein,

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others have hypothesized that abnormalities in inner speech may lead to deficits in self-awareness; however, these reports pertain primarily to the auditory verbal hallucinations experienced by people with schizophrenia (Fernyhough, 2004; Frith, 1992; Langland-Hassan, 2008). As such, these speculative proposals do not directly speak to the role of language in normal cognition, including metacognition.

This study seeks to fill these gaps in the empirical literature by examining specifically the relation of language to a person's ability to perform categorization tasks and to assess their own abilities in those categorization tasks. In the study described here, participants performed a task in which they were called upon both to categorize objects and to judge whether they had done so correctly. The performance of control participants was compared to the performance of PWA who demonstrated an impairment with respect to inner speech, but who otherwise approached normal levels in other tests of cognitive abilities. The purpose of the study was twofold: first, to assess the extent to which language is needed for certain types of categorizations, and, second, to assess whether language plays a metacognitive role in enabling awareness of one's success in these types of categorizations.

1.1. Nonverbal tests of metacognition

Our means for testing metacognition in a language-impaired population was modeled in part on previous studies of metacognition with nonhuman animals. These studies have had the following structure: The subject is presented with tasks of varying difficulty, with known rewards and penalties for answering correctly or incorrectly (Hampton, 2001; Kornell, Son, & Terrace, 2007; Smith, Beran, Couchman, & Coutinho, 2008; Smith, Shields, Schull, & Washburn, 1997; Smith & Washburn, 2005). The actual abilities of the animal are typically assessed during an initial forced-choice condition. Subsequently, subjects are provided with a means for *opting out* of answering the prompt (typically by pressing a button designated as the opt-out choice). Opting out results in a lesser reward than answering the prompt correctly, but is preferable to the penalty (typically a time delay) received for answering incorrectly. Use of the opt-out key is said to be adaptive, and to indicate appropriate self-assessment, if it occurs on trials in which the subject would be expected to answer incorrectly, based on its prior performance.

In view of the similarity between the present study and these previous animal studies, we describe the present study as an investigation into metacognition. But in so describing it, we need to draw a distinction. Metacognition is often conceived of as the ability to have thoughts about thoughts, either one's own thoughts or the thoughts of others (Bermudez, 2003; Carruthers, 2011). Whether the tests of opt-out behavior are indeed proper tests of metacognition in this sense is a matter of some dispute. While most agree that the abilities possessed by species that can learn to use the opt-out key adaptively are of significant theoretical interest, some deny that they support the presence of metacognition on the grounds that they may not require the animal to form a representation of its own cognitive representations (Carruthers, 2008, 2011; Perner, 2012). Others reject this stringent standard for the use of the term "metacognition", on the grounds that cognition can have a metacognitive *function* even if it does not strictly involve forming a representation of a mental state (Proust, 2013). We will describe the experiment as a test of metacognition with the proviso that we do not assume that metacognition necessarily involves thoughts about other thoughts.

1.2. Covert language use and "inner speech"

It has been shown that the overt language deficits of PWA are not always mirrored by corresponding deficits in occurrent[1] covert language use (or "inner speech") (Geva, Bennett, Warburton, & Patterson, 2011; Stark, Geva, & Warburton, 2017) and that the relationship between inner and outer speech capacities in PWA is complex and variable (Fama, Hayward, Snider, Friedman, & Turkeltaub, 2017). Therefore, to draw any conclusions about the role of occurrent covert language use from a population of PWA, it is important to establish that the population of PWA in fact have deficits in the covert use of language, or inner speech. We follow others in using silent rhyming abilities as a test for inner speech capacity (Feinberg, Gonzalez Rothi & Heilman, 1986; Geva et al., 2011; Levine, Calvano, & Popovics, 1982). These earlier studies have confirmed that people with aphasia often experience impaired inner speech. We incorporated a similar silent rhyming task into the present study in order to assess covert language use, while also confirming, via other cognitive screening tests (described below), that cognitive abilities of the PWA were normal or near normal in other respects. (Langland-Hassan, Faries, Richardson, & Dietz, 2015 contains a detailed examination of correlations among of the silent rhyming abilities of our population[2] and their abilities on non-linguistic cognitive tasks).

It might be questioned whether silent rhyming tasks are good tests for a lack of inner speech. In generating normal, overt speech, the mind must execute a number of theoretically separable tasks, including the selection of a grammatical structure and the selection of words to populate the leaf nodes of the grammatical structure. (For one of many analyses, see Pickering & Garrod, 2013). A presumably late stage is the selection of a phonemic realization of the sentence or phrase to be spoken. An even later stage is the planning of muscle movements that generate the utterance, followed by the actual execution of the plan. During covert language use, the production does not get as far as actual movements of the vocal apparatus, but may include the generation of an iconic representation of the sound of a spoken utterance, which we will call the auditory imagery of inner speech. The phenomenon of inner speech might also include, as an additional step, an experience of "hearing", or processing, the inner speech that has been generated. Thus, a judgment of whether two words rhyme may presuppose yet a further level of articulation and comparison. How much of normal speech production is executed in inner speech is an open question, and the answer may vary from one occasion to another and between one person and another (Oppenheim & Dell, 2010; Perrone-Bertolotti, Rapin, Lachaux, Baciu, & Lœvenbruck, 2014). For purposes of this study, we simply define inner speech operationally as *whatever capacity for occurrent covert language use is needed to pass the silent rhyming task*. This task is described in more detail below.

2. Methods

2.1. Participants

We recruited 13 participants with chronic post-stroke aphasia from a database held at the University of Cincinnati Augmentative and Alternative Communication and Aphasia Lab. Because we were primarily interested in the effect of inner speech deficits on metacognition, we selected individuals with conduction, anomic, or Broca's aphasia. In such patients, language comprehension is relatively strong, while overt language production is moderately-to-severely impaired. Eleven adults

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[1] By 'occurrent' language use we mean what is sometimes called 'online' language use (Lupyan, 2009). These terms serve to distinguish the active exploitation of language production and processing capacities (which are 'occurrent' and 'online' uses of language), from the dispositional and structural changes to a cognitive system that may result from mastering a language. The latter may influence one's performance on a task—and thus be an effect of language—without requiring one to actively generate or comprehend new linguistic material.

[2] The population of PWA in Langland-Hassan et al. (2015) includes two participants who were excluded from the tests of categorization and metacognition reported here, due to their inability to follow instructions for those tasks.