Cognitive Effort and Aphasia

Introduction

According to the resource allocation theory, impaired performance by individuals with aphasia (IWA) on language tasks may be partially due to an impaired ability to allocate cognitive resources to the tasks (McNeil, 1980, McNeil et al., 1991). This theory has been popularly applied to aphasia because it explains the moment-to-moment variability in language performance by IWA. However, the term "resources" represents a vague construct that is difficult to directly measure. Others have better explained this deficit as an impaired ability to match effort with task demands (e.g. Clark & Robin, 1991). In fact the terms "effort" and "resources" are frequently used interchangeably (Kahneman, 1973). If language performance by IWA is affected by effort allocated, this could have important clinical implications.

Clark and Robin (1991) found that their participants with aphasia, compared to control participants, had no change in sense of effort with increased reaction time to a lexical decision task that increased in difficulty. Murray and colleagues (1997) assessed IWA's ratings of task difficulty. They also compared participants' performance on a lexical decision task to performance on the lexical decision task when combined with a semantic distractor task. Although performance declined in the dual task condition, IWA's ratings of task difficulty did not change. Findings from these studies suggest that IWA do not invest effort appropriately because they mis-perceive the task demands.

A direct, physiological measure of effort is needed to further explore this disconnect between performance and IWA's ratings of perceived effort and task difficulty. The physiological stress response is an indicator of the amount of cognitive effort allocated to tasks (Aasman et al., 1987). Laures-Gore and colleagues (2003, 2007) have attempted to objectively quantify physiological stress experienced by IWA using salivary cortisol measurements. They investigated change in cortisol during a vigilance task (2003) and during a public speaking task (2007). In spite of poorer performance than control participants, IWA did not display cortisol reactivity during these tasks. Similarly, Laures-Gore and colleagues (2010) found no relationship between the frequency of word errors made by individuals with aphasia and salivary cortisol measurements. However, they did find a positive relationship between cortisol concentrations and another language measure – word productivity. These studies provide conflicting results about the relation between performance and a physiological measure of stress for IWA (2003). Although salivary cortisol measurements indicate stress experienced, cortisol concentrations may not be the best measure of effort allocated during short experimental tasks frequently used with IWA. For example, it has been suggested that the mechanism involved in the production of cortisol, the hypothalamic-pituitary-adrenal (HPA) axis, is impaired in brain injured populations (e.g. Franceshini et al., 2001). Further, cortisol takes time to build up in the bloodstream and is a slower responding measure of stress than other physiological measures (Bishop, 1994).

An alternative, well-studied measure of effort allocated to cognitively demanding tasks is heart rate variability (HRV). HRV is the amount of fluctuation around the mean heart rate. It has been shown to reflect the mental workload required during cognitive tasks (Hansen et al., 2003) and is a commonly used measure of effort (Aasman et al., 1987). Cognitively challenging tasks elicit a stress response measured as a drop in HRV from baseline to task conditions (Kalsbeek, 1971). This decrease in HRV occurs because the parasympathetic system, normally working to slow the heart in opposition to the sympathetic system which speeds heart rate, is inhibited during cognitively challenging tasks. The resulting decrease in HRV, provides an objective physiological measure of the effort allocated to the tasks and should provide insight into the effort allocated by IWA to a verbal working memory task. In this study effort is operationally defined as the difference in HRV measured during an n-back working memory task from HRV measured during a resting state. The objective of this study is (1) to quantify the cognitive effort IWA dedicate to a verbal working memory task through a physiological measure (HRV) and (2) to investigate the relationship among perceptions of task demands, behavioral performance, and effort allocated to a verbal working memory task by including all three measures in one study.

<u>Method</u>

Participants

Currently only preliminary data with 3 IWA has been collected. Participants will include 10 IWA. All participants will demonstrate hearing and vision within normal limits. Additional inclusion criteria include presence of aphasia as indicated by performance on the Western Aphasia Battery-Revised (WAB-R; Kertesz, 2007) and no other neurological deficits.

Tasks

The experimental tasks include verbal n-back tasks that vary in processing load. The n-back task requires participants to decide whether each stimulus in a sequence matches the one that appeared *n* items ago. Therefore, it requires temporary storage and manipulation of information, while, continuously updating the contents in their working memory (Jonides, et al., 2007).

All participants complete three n-back tasks – a 0-back, 1-back, and 2-back. The task consists of an adaptation of Wright et al.'s (2007) n-back task with fruit as stimuli. The stimuli consist of eight familiar fruit stimuli presented visually. Each n-back contains a practice block of 10 items with two targets. The test conditions include 33 targets presented in a single block containing 100 stimuli. This adaptation from the multiple block presentation in Wright et al. (2007) is necessary due to continuous HRV recording.

Task difficulty order is counterbalanced. Each n-back is preceded and followed by a 5 minute baseline rest period during which baseline HRV data are recorded.

Procedures

Participants are asked to avoid smoking, caffeine, alcohol, and strenuous exercising on the day of testing. They complete a brief questionnaire describing any deviations from that request upon their arrival. Prior to testing 3 surface electrodes are placed on their torso to record ECG activity during testing. ECG activity is recorded using BIOPAC Student Labs (BSL) PRO MP35 recording unit with BSLPro software (500 samples/second, Filter .05 - .35 Hz). Participants sit in a comfortable, high back chair during recording.

During 5 minute pre- and post-task baseline conditions, participants are instructed to rest quietly with their eyes open. After completion of the experimental n-back tasks, immediately before the post-test baseline condition, participants are informed that they have completed the experimental procedure. Possible pre-test anxiety is assessed by measuring the difference between the pre- and post-test HRV recordings. The average baseline HRV is used to calculate the change in HRV to minimize any effects of pre-test anxiety.

<u>Results and Conclusions</u>

Preliminary results indicate that IWA allocated effort to the experimental tasks as demonstrated by a drop in HRV. However, they did not allocate effort differentially according to task demands. That is, although differences in behavioral performance were found across the n-back tasks, participants did not allocate additional effort to the more difficult task (i.e. 2-back). In contrast, ratings of task difficulty were consistent with behavioral performance indicating that these participants were able to perceive the difficulty of the tasks, but were not able to adjust their allocation of effort to meet the task demands.

If individuals with aphasia are not able to properly adjust the effort they invest to tasks that vary in their cognitive demands, this could influence current theories of aphasia. Further, being able to quantify the physiological stress experienced during cognitively challenging tasks could have important health and treatment implications for IWA.