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Processing lexical ambiguity in sentential context: Eye-tracking data from brain-damaged and non-brain-damaged individuals

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ABSTRACT

The purpose of the present study was to identify general and syndrome-specific deficits in the lexical processing of individuals with non-fluent and fluent aphasia compared to individuals without cognitive, neurological or language impairments. The time course of lexical access, as well as lexical selection and integration was studied using a visual-world paradigm in three groups of Russian speakers: 36 individuals in the control group, 15 individuals with non-fluent aphasia and eight individuals with fluent aphasia. Participants listened to temporarily ambiguous sentences wherein the context biased the interpretation of an ambiguous word toward one of its two meanings. In half of the experimental sentences, a reanalysis was needed upon encountering the disambiguating phrase. The effect of the length of the intervening material between the ambiguous word and the disambiguation point was additionally monitored. All groups of participants showed intact lexical access under slowed speech rate, but non-fluent participants experienced difficulties with timely activation of multiple referents. At later stages of lexical processing, they additionally demonstrated a specific impairment of reanalysis. The deficit in participants with fluent aphasia was not focalized at any specific stage of lexical processing. Rather, the breakdown of lexical processes in fluent aphasia was likely related to difficulties with the inhibition of irrelevant lexical activation, which is further supported by the finding that increased phonological distance between the ambiguous word and ambiguity resolution was influential to the offline performance in this group.

1. Introduction

Language comprehension cannot be achieved outside of sentential context. Nonetheless, the first studies of lexical processing often involved isolated words – a necessary oversimplification that, for many decades, has served as a window to the intricate nature of lexical processing. A shift toward context-considerate language studies is now imperative to bridge the gap between these experimentally manipulated and naturally occurring language segments. Theoretical models typically divide word processing into three stages: lexical access, lexical selection and lexical integration (Friederici et al., 1999; Frauenfelder and Tyler, 1987; Marslen-Wilson, 1987). Critically, all three processes are constantly shaped by the surrounding context during language processing in a natural environment. At the lexical access stage, linguistic input activates a range of interrelated lexical units, with the amount of activation of a particular unit and its meanings being determined by the surrounding context and meaning frequency, among other factors. The meaning which was accessed first is then automatically selected (Duffy et al., 1988; for alternative view, see Rayner and Frazier, 1989) and undergoes integration into context and a transformation into higher-order lexical-semantic and syntactic representations.

However, lexical processing is not necessarily restricted to the three stages described in many theoretical models. Sometimes integration of the selected meaning into the context fails, and the stages of lexical selection and integration are repeated to allow for the selection of a new meaning. That is, a reanalysis occurs. The present study has two primary aims: first, to investigate the time-course of lexical processing and reanalysis in non-brain-damaged speakers of Russian, as well at identifying factors that interfere with it (e.g., contextual bias, intervening phonological material). Additionally, driven by the idea that lexical processes are not uniform across all human populations, this paper focuses on the specific characteristics of lexical processing in individuals with language impairments related to stroke (i.e., non-fluent and fluent aphasia). In the following section, a brief summary of the data on lexical processing in populations without brain damage will be presented, followed by a review of studies on lexical processing in aphasia.

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1.1. Lexical processing in populations without brain-damage

The mechanisms underlying lexical access in individuals without cognitive, neurological or language impairments have been a topic of extensive research. Several theoretical models appeared and later faded away with the emergence of new empirical evidence. Today, the available data (Sereno, 1995; Reichle et al., 2007; Weber and Crocker, 2012) seem to converge with the reordered access model introduced by Duffy et al. (1988). This model postulates that lexical access is exhaustive; that is, all word meanings are accessed during this stage of processing. However, access to meaning is not simultaneous, but rather ordered, i.e. determined by factors like context and meaning frequency. The importance of these factors to lexical access is now a well-accepted phenomena; the presence of a higher-frequency meaning or a stronger contextual bias towards one meaning induces faster lexical access (Sheridan and Reingold, 2012; Sereno et al., 2003). If factor values are balanced (i.e., meanings receive equal contextual support or meanings have similar frequencies of occurrence), lexical access may be delayed due to a pending conflict resolution (Dopkins et al., 1992; Sheridan et al., 2009).

The next stage of lexical processing, lexical selection, has been less studied. In auditory word recognition, it has been monitored using cohort competitors, defined as words with overlapping initial phonemes. In such experiments, the conflict among activated cohort competitors is resolved with the help of the upcoming acoustic and top-down contextual information (Marslen-Wilson and Welsh, 1978). Interestingly, some evidence suggests that lexical selection and integration are in fact cascading processes (i.e., integration begins before the end of the selection process; Van den Brink et al., 2006; Van Petten et al., 1999; Van den Brink and Hagoort, 2004). The reason why lexical selection and integration may have generated less research interest separately could be that these stages are not easy to isolate and manipulate in experimental designs. In fact, in the reviewed studies, the terms “selection” and “integration” are frequently interchangeable. Nonetheless, these studies demonstrate that incoming phonetic and contextual information are critical factors in guiding lexical processing at later stages as well.

Finally, the reanalysis stage of lexical processing has been often investigated using ambiguous words. Reanalysis may be triggered in several ways, for example, it may take place when an ambiguous word has multiple meanings with different frequencies and the ambiguity is resolved towards the subordinate (less frequent) meaning. In this case, the more frequent meaning is selected first upon initially encountering the word but the attempt to integrate it into the context fails, thus necessitating reanalysis (Rayner and Duffy, 1986; Duffy et al., 1988; Rayner and Frazier, 1989; Sheridan et al., 2009). Alternatively, when the ambiguous word is balanced (i.e., has meanings with similar frequencies), the context comes into play. If the context initially biases the interpretation towards one meaning while the ambiguity is later resolved towards the other, reanalysis is also required (Rayner and Frazier, 1989). Reanalysis is typically associated with longer reading times, most likely, due to repeated access to different meanings (Rayner and Duffy, 1986; Duffy et al., 1988; Rayner and Frazier, 1989; Sheridan et al., 2009).

Interestingly, the possibility for reanalysis is always open. For example, Dahan and Tanenhaus (2004) found that, in a visual-world study, participants shifted their gaze to the contextually incongruent referent immediately upon hearing the coarticulation that was consistent with it, but inconsistent with the contextually congruent referent. The lack of delay suggests that the human language processing system is constantly geared for reanalysis, because it remains highly sensitive to input even after the phonology and context have strongly converged on a given word candidate.

In sum, it appears that the three stages of lexical processing (i.e., access, selection and integration) cannot be definitively demarcated. Already during lexical access, selection starts based on the available information (e.g., frequency, context), possibly reflecting the fundamental psychological tendency to eliminate uncertainty. Lexical integration is linked with lexical selection. If a conflict arises, reanalysis is performed giving feedback to the new round of lexical processing. Nonetheless, it appears that clear-cut reference points for lexical processing include (1) initial lexical access, (2) late processing, i.e. lexical selection and integration, as well as ambiguity resolution, and (3) reanalysis. One can potentially dissociate the effects of factors such as frequency and contextual bias at different stages of lexical processing and across populations of individuals without cognitive, neurological or language impairments and in people with a language disorder such as aphasia. This framework is adopted in the present study.

1.2. Lexical processing in aphasia

Language impairments in aphasia often involve difficulties with lexical processing. The underlying deficit in lexical processing has been traditionally tied to the type of aphasia (Hagoort, 1993). For instance, deficits in non-fluent Broca's and agrammatic aphasia, which is typically characterized by agrammatism and a lack of speech fluency, have been associated with impairments that are localized at specific stages of lexical processing. However, identification of these stages has been somewhat problematic; at times, lexical access has been reported to be impaired (Katz, 1988; Hagoort, 1993) whereas other studies have pointed to deficits with lexical selection and/or integration (Swaab et al., 1998; Grindrod and Baum, 2003). In fluent (Wernicke's) aphasia, which is often described in terms of phoneme and word-level deficits but relatively spared syntax, deficits have been ascribed to all stages of lexical processing. More specifically, studies of fluent aphasia have reported atypical behavior at all stages, including a faster-than-normal access to meanings and an inability to promptly suppress the activation of irrelevant referents (Prather et al., 1997; Prather et al., 1992). One goal of the present study was to compare eye-movement behavior in non-fluent and fluent aphasia during lexical processing in all of its stages (lexical access, late processing, ambiguity resolution and reanalysis) and to identify their syndrome-specific deficits.

1.2.1. Non-fluent (Broca's and agrammatic) aphasia

Individuals with non-fluent aphasia have been reported to have an impairment in lexical processing, but the locus of this deficit with respect to the stages of lexical processing is still under debate. Two alternative accounts have been proposed: a slowdown in initial lexical processing (i.e., lexical access), or impaired late processing (i.e., lexical selection and/or integration). The first hypothesis received support from a series of priming studies. For example, Katz (1988) reported five participants with Broca's aphasia showing normal priming patterns, although their reaction times were significantly longer than in the control group. This delay in lexical access has been replicated in studies with Broca's and agrammatic aphasic participants. Delays typically ranged from 400 ms (Thompson and Choy, 2009; Ferrill et al., 2012) to 1500 ms (Prather et al., 1992; Prather et al., 1997). Nonetheless, Hagoort (1993), in an auditory priming study, observed normal priming at 100- and 500-ms interstimulus intervals in Broca's aphasia, but not at 1250-ms intervals, indicating that lexical access is spared and prompt (but see Hagoort (1997) where priming occurred at both 300 ms and 1400 ms, which is longer than the priming interval in control groups). Such inconsistency in results has recently received a tentative explanation: Love et al. (2008)