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Processing of emotional words after stroke: An electrophysiological study

E. Ofek *, S.C. Purdy, G. Ali, T. Webster, N. Gharahdaghi, C.M. McCann

Discipline of Speech Science, School of Psychology, Tamaki Campus, The University of Auckland, 261 Morrin Road, Glen Innes, Private Bag 92019, Auckland, New Zealand

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HIGHLIGHTS

- This paper focuses on the neurophysiological processing of personal–emotional words in healthy adults and adults with post-stroke aphasia.
- Personal–emotional words are processed in a different and more preserved way even after stroke.
- This study may support the development of diagnostic and therapeutic tools for people after stroke and for other brain related disorders.

ABSTRACT

Objective: Auditory evoked potentials (EP) were used to examine the neural processing of personal–emotional and neutral words, in a group of 14 people with post-stroke aphasia and an equal sized control group to determine whether the EP differed between groups and word types.
Methods: Effects of the emotional value of the words and participant group were assessed on EP. Latencies and amplitudes of EP were analyzed for the two groups (aphasia and control) in response to word type (emotional and neutral).
Results: N1 amplitudes were smaller and P2 and P3 were delayed in the aphasia group, for both word types, indicating effects of stroke on processing of both neutral and emotional words. P3 amplitudes were larger for emotional words in both groups. These differences in late cortical responses between word types for both groups suggest distinct neural networks involved in the response to emotional and neutral words, even with post-stroke language impairment.
Conclusions: The neurophysiological processing of affective speech in aphasia has been revealed. This opens up the interpretation of these results to the critical assessment and therapeutic identification of emotional language in people with aphasia.
Significance: This study has implications not just for aphasia but allows for further exploration of other neurological conditions.

1. Introduction

This study aims to improve the understanding of emotional language processing in adults with aphasia and to investigate the effects of aphasia and emotional significance on cortical auditory evoked potentials (CAEPs). A stroke often results in aphasia, as a consequence of cortical damage to the left hemisphere (Talvitie et al., 2010). Although the left hemisphere is typically dominant for language, the right hemisphere is thought to play a key role in the perception of emotion in spoken language (Hagoort, 1993; Atchley et al., 2003). As many as a quarter of people following a stroke are diagnosed with aphasia (Doesborgh et al., 2004), though figures vary, and two thirds of people with aphasia continue to have language impairments 1 year after their stroke, despite therapeutic interventions to facilitate communication (Kauhanen et al., 2000). This study aims to understand emotional language processing abilities in aphasia, beyond what is observable from behavioral testing. We aim to characterize the time course of brain activity in response to personal–emotional words and neutral words for a group of people with aphasia and a control group. We predicted delayed latencies and smaller amplitudes of CAEPs in the aphasia group in response to words in general, but that the responses to personal–emotional words would differ less between the two groups, showing a more preserved pattern of response to personal–emotional words than neutral words in the aphasia group.

* Corresponding author. Tel.: +64 9 3737599x89260, +64 22 1757299; fax: +64 9 3737902.
E-mail address: ofek.einat@gmail.com (E. Ofek).

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A growing body of literature has documented the involvement of both the right and left hemisphere in emotional language processing, and suggested unique hemispheric processing pathways for words with emotional versus neutral content (Atchley et al., 2003; Demaree et al., 2005). Despite left hemisphere dominance for language in 95% of people, studies have consistently suggested that the right hemisphere mediates processing of the emotional content in words and plays a key role in the perception of words with emotional valence (positive and negative) (Borod et al., 2002; Atchley et al., 2003). Electrophysiological research into language dysfunction post-stroke also suggests an advantage of emotional words over neutral (Landis et al., 1982; Kotz and Friederici, 2003; Landis, 2006). Distinct cerebral areas in the right hemisphere have been shown to facilitate emotional linguistic processing in both healthy controls and aphasia (Landis, 2006).

For some time the language of aphasia has been assessed using event related potentials (ERPs), allowing non-invasive investigation of covert processes such as emotional language processing without requiring behavioral responses (Viggiano, 1996). More recently, CAEPs have been used to measure passive responses that do not require any behavioral response to the stimulus presentation, (Kotz and Friederici, 2003; Alain and Tremblay, 2007). Differences in brain responses to stimuli with emotional versus neutral connotations have been observed in a number of electrophysiological studies. Proposed explanatory models suggest that information which is emotionally laden has distinct processing pathways, to reflect appraisal or risk, or life threats (Hinojosa, 2009; Kousta et al. (2009)). A common justification for the unique brain response to emotional stimuli is the negativity bias, or the advantage of processing negative stimuli over either positive or neutral. This is thought to represent an evolutionary survival mechanism, where information surveyed as threatening is prioritized in cognitive processing of the stimuli (Kutas and Hillyard, 1984; Borod et al., 2002; Kissler et al., 2007).

Relatively few studies have focused on the emotional connotations of linguistic stimuli (emotional versus neutral) through investigation of auditory obligatory responses that do not require active attention (Hinojosa, 2009). These studies indicate a distinction between emotional and neutral words for mid-latency ERP components (Dillon et al., 2006). The site and size of brain lesions consistent with post-stroke aphasia may distort the mid-latency components of the CAEP waveform, reflecting deficits in individual components of language processing (Kotz and Friederici, 2003). The ERP investigation of meaningful words by Hagoort et al. (1996) found cortical responses, including N400 and P300, had higher amplitudes in the right hemisphere for people with aphasia. More recently Ortigue et al. (2004) used a lexical decision task with visual stimuli and found early cortical differentiation evident in ERP responses to linguistic stimuli before 140 ms and a unique pattern of brain activity in response to emotional words.

There is relatively little research to date examining emotional language processing in an auditory obligatory response paradigm using a passive auditory task. The current study aimed to redress this by examining how individuals with aphasia process the personal–emotional content of spoken words, through a neurophysiological investigation of cortical responses.

Research into emotional processing has largely focused on visual and non-linguistic stimuli such as facial expression (Kissler et al., 2007). Studies focusing on lexical emotional processing are often limited by their use of universal emotional lexical stimuli and their neglect of the personal–emotional content for the individual participant (thereby ignoring the impact of life experience on personal interpretations of words and names) (Hamann and Mao, 2002). Ofek and Pratt's (2005) investigation into the processing of language with subjectively significant (i.e. personal–emotional) content, confirmed a differential brain response to auditory subjectively significant names versus neutral names, in both the location and the pattern of brain activation. Ofek and Pratt subsequently developed a questionnaire to validate the subjective meaning of emotional versus neutral names used in their research. The subjective significance of names was measured by the general emotional significance, negative impact, recency of contact and closeness of people known by these names, to the participant (Ofek and Pratt, 2008). The current study aims to strengthen current knowledge about lexical–emotional processing capabilities in adults by investigating temporal processing of personal–emotional and neutral words, as indicated by ERPs evoked by a wider variety of auditory emotional linguistic stimuli types, not limited to first names. The importance of contextualized stimuli in aphasia therapy was shown by McKelvey et al. (2010), who demonstrated the preference for and effectiveness of the stimuli in communication facilitation programs. The memories and experiences connected with the stimuli provide an additional cue for the development of language associated with the stimuli.

2. Methods

The neural correlates of personal–emotional and neutral words were compared in adults with aphasia and those with no history of neurological deficits, to determine whether distinctive ERP response patterns could be observed between word types and groups. A selection of personal–emotional words relating to important people, personal experiences and important values were used for each participant, to analyze auditory word-evoked responses to personal–emotional words compared to neutral words.

2.1. Subjects

A total of 28 participants took part in the study, comprising equal numbers of participants in the aphasia and control groups. Fourteen adults diagnosed with aphasia following a left hemisphere stroke participated (10 males and four females, mean age = 64.6, SD = 10.9 years, range = 80–37 years). Consistent with other studies we sought to include those with "chronic" aphasia (at least one year post-onset). The average time post-onset was 6 years (M = 6.35, SD = 2.9, range = 11–1 years). Given that we have studied the brain correlates of the language impairment following stroke, and not the stroke directly, this allows for more variance in the number of years since stroke. The control group consisted of fourteen volunteers (10 males and four females, mean age = 62.7, SD = 11.39 years, range = 79–35 years) with no history of neurological disorders. All participants were right-handed native English speakers who were recruited through the study advertisement, or through word of mouth. To ensure adequate hearing for participation in the study, participants' pure tone hearing thresholds were tested using a GSI 39 pure tone audiometer prior to the experiment. Five people with aphasia and four of the control participants showed mild to moderate high frequency hearing loss at 4000–8000 Hz. Hearing thresholds at other frequencies were within the normal range (20 dB HL or better). This did not affect their ability to identify the linguistic stimuli. All other participants showed normal pure-tone thresholds ($\leqslant$20 dB HL) at octave frequencies from 250 to 8000 Hz, and had no history of hearing problems prior to the study. People in the aphasia group undertook the Comprehensive Aphasia Test (CAT, Swinburn et al., 2004, 2005) to determine their language performance profile. The severity of aphasia was calculated by averaging the *t*-scores across the eight language modalities within the CAT. All but one of the participants in the aphasia group had mean scores at or below the threshold of 68.2 indicating a very strong likelihood of an aphasic language impairment (Swinburn et al., 2005, see Table 1). Consistent with many studies of aphasia, the majority of the