



Neurophysiological sensitivity for impaired phonological processing in the acute stage of aphasia



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ABSTRACT

The present study aimed to investigate neurophysiological substrates of phoneme and word processing in 10 patients with acute aphasia (PWA). More specifically, phoneme discrimination was studied in a passive and active oddball task with respect to different phonemic contrasts, while lexical detection was investigated by presenting infrequent pseudowords among frequent words in a passive oddball task. Concerning phoneme discrimination, PWA in the acute stage had smaller MMN and P300 amplitudes than the norm group for voicing, whereas for place and manner they only demonstrated smaller P300 amplitudes. PWA showed a distinct pattern of impaired phonemic contrast sensitivity, with place displaying the largest amplitude and voicing the smallest. Concerning lexical detection, pseudowords elicited larger responses than words in both groups, but with a delay and larger P200 amplitude for pseudowords in PWA compared to the norm group. For clinical practice, passive tasks seem more suitable than active tasks in acute aphasia.

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1. Introduction

Deficits in phonological and lexical input processes can cause a destabilization in the consecutive language process, as they form part of the first processing steps in language comprehension (Pulvermüller, Shtyrov, & Hauk, 2009). The ability to detect and discern different phonemes from each other and subsequently use the outcome of this process in successive stages like word recognition and comprehension is often disturbed in patients with aphasia (Blumstein, Baker, & Goodglass, 1977; Mirman, Yee, Blumstein, & Magnuson, 2011; Robson, Keidel, Lambon Ralph, & Sage, 2012).

Event-related potentials (ERPs), especially the oddball-paradigm based studies, have a great potential in characterizing, evaluating and monitoring these specific phonological problems in patients with aphasia. The pre-attentive Mismatch Negativity (MMN) (Näätänen, Gaillard, & Mäntysalo, 1978) and the attentive P300 potential (Sutton, Braren, Zubin, & John, 1965) are very suitable to gauge auditory discrimination and these ERPs

are already demonstrated to be a good measure for monitoring recovery patterns in early stages of aphasia and long-term follow-up periods (Ilvonen et al., 2003; Nolfé, Cobiañchi, Mossuto-Agatiello, & Giaquinto, 2006). In general, the MMN is more reduced in patients with aphasia for speech sound changes (vowels, phonemes) than tone stimuli differing in frequency or duration, potentially because tone stimuli activate different cortical generators than the speech stimuli (Aaltonen, Tuomainen, Laine, & Niemi, 1993; Csépe, Osman-Sági, Molnár, & Gósy, 2001; Ilvonen et al., 2004; Wertz et al., 1998). Within speech sound discrimination, consonant contrasts elicit a more distorted MMN and attenuated amplitude than vowel contrasts in patients with aphasia (Csépe et al., 2001), perhaps due to the clear acoustic relation between the first three formant frequencies for different vowels. Especially discrimination of the phonemic contrast voicing is neurophysiologically reflected by a total absence of the MMN in patients with aphasia, whereas a difference in place of articulation elicits a MMN, yet heavily distorted and with an abnormal scalp distribution (Csépe et al., 2001). The effect of degree of difference between the standard and deviant stimulus is also reflected in the P300 potential. A study by Becker and Reinvang (2007b) compared patients with aphasia with mild or moderate auditory comprehension impairment and patients with aphasia with severe or very severe auditory comprehension impairment during an active

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auditory discrimination task. No significant differences in P300 amplitude between the two aphasia groups and a healthy control group could be established. This was most likely related to the relatively low difficulty of the behavioural task (every patient completed the task correctly) and the fact that the standard and deviant speech stimuli differed in more than one phonemic contrast, e.g. voicing and place of articulation (Becker & Reinvang, 2007b).

The MMN and P300 have also been applied to evaluate auditory word processing in patients with aphasia. When the neurophysiological response to real words and pseudowords is compared in healthy controls, either a MMN is elicited with a larger negativity to real words during a passive discrimination task or a P300-like ERP emerges with a larger positivity to real words during an active discrimination task, both referred to as a “real word advantage” (Pulvermüller et al., 2001; Shtyrov & Pulvermüller, 2002). The MMN is often attenuated in response to both real words and pseudowords in patients with aphasia, but despite these attenuated responses a similar significant “real word advantage” as previously evidenced in healthy controls is still present (Pettigrew et al., 2005). This is not necessarily the case for the P300 potential, which can be reduced in response to real words in patients with aphasia during a visual word discrimination task, thereby presenting a smaller positivity to real words than to pseudowords (Pulvermüller, Mohr, & Lutzenberger, 2004). The early word-evoked MMN can also be used to monitor neuronal recovery patterns in patients with aphasia, whether or not in the context of treatment effects. Re-enhanced neurophysiological responses to real words after treatment can indicate recovery in chronic patients with aphasia and has even been referred to as an “aphasia recovery potential” (Pulvermüller, Hauk, Zohsel, Neininger, & Mohr, 2005). This is of great relevance, also with respect to laterality patterns as it has been established that different laterality patterns can arise throughout the recovery from stroke (Saur et al., 2006). The MMN and P300 can be used to explore hemispherical distribution of brain activity, which allows for determining potential contralesional contributions to auditory discrimination processes (Becker & Reinvang, 2007a; Becker & Reinvang, 2007b; Ilvonen et al., 2003).

Despite the great knowledge these group studies have provided on the neurophysiological substrate of phonological disorders in patients with aphasia, they do not seem to control for the large heterogeneity existent in such a patient population. Nonetheless, this is a factor to be taken into account, as the structural brain alterations due to the stroke in patients with aphasia can differ significantly from patient to patient. The fact that a group study by Becker and Reinvang (2007a) failed to find significant MMN amplitude reductions to phonemes and tones in patients with aphasia, while this was found in other studies (Ilvonen et al., 2004; Pettigrew et al., 2005; Wertz et al., 1998), might be interpreted as a potential lack of controlling for the large variability among patients with aphasia. This denotes the risk of neglecting the heterogeneity and variability within a group of patients with aphasia, especially when taking into account a general individual variability in healthy functional brain activation patterns (Burton, Noll, & Small, 2001) and recent findings of significant age-related influences on ERPs in healthy subjects (Aerts et al., 2013). When one wants to practically implement event-related potentials in the linguistic evaluation of patients with aphasia and subsequently make justified decisions when interpreting these ERPs, controlling for heterogeneity and variability is an important issue that should not be disregarded. A second remarkable observation from the literature is that only a few studies have investigated patients with aphasia in the acute stage of stroke (e.g. within 2 weeks after stroke) (Ilvonen et al., 2003; Nolfé et al., 2006). Nonetheless, it is highly likely that extensive behavioural evaluation is problematic

or even impossible at this stage of stroke due to severe comprehension problems (Ilvonen et al., 2003). When this is the case, especially the ERPs that can be elicited with a simple passive oddball task in which no explicit cooperation of the patient is required, such as the MMN, can provide a means for counteracting this practical problem.

The present study aims to characterize specific language-related neurophysiological activation patterns in patients with aphasia in the acute stage of stroke (within 2 weeks after stroke), while explicitly controlling for group heterogeneity and variability. First, auditory phoneme discrimination based on three different phonemic contrasts (place of articulation (PoA), manner of articulation (MoA) and voicing) is investigated with a pre-attentive (MMN) and attentive (P300) oddball task, to additionally explore the effects of attention and the possibility of using active oddball tasks in patients with aphasia at the acute stage of stroke. Second, pre-attentive auditory lexical detection is investigated by including a Real Word/Pseudoword pre-attentive discrimination oddball task. Third, it is examined whether a correlation exists between neurophysiological and behavioural results in patients with aphasia at the acute stage of stroke.

2. Material and methods

2.1. Subjects

Ten patients with aphasia (5 men, 5 women) were recruited from the Hospitalization department of Neurology at Ghent University Hospital (Belgium) and were compared to 44 healthy control participants (20 men, 24 women) (Aerts, van Mierlo, Hartsuiker, Santens, & De Letter, 2015). All patients (1) suffering from a first-ever stroke in the left hemisphere, (2) having Dutch as their native language and (3) displaying acute phonological disorders as established with the Psycholinguistic Assessment of Language Processing in Aphasia (PALPA) (Bastiaanse, Bosje, & Visch-Brink, 1995) were included in the study. Patients with aphasia admitted with (1) a recurrent stroke, (2) left handedness, as confirmed with the Dutch Handedness Inventory (DHI) (Van Strien, 1992), (3) indications for comorbid cognitive disorders, which was screened with MMSE (Folstein, Folstein, & McHugh, 1975) in patients above 70 years and (4) severe hearing deficits as reported by patients themselves or judged by the examiner were excluded from the study. The complete test battery (ERP and behavioural tests) was administered in the acute stage (within two weeks after stroke). The mean age of the patients was 69.4 years (± 3.46 SD), ranging between 46 and 85 years. Patient characteristics with regard to gender, age, education, type of aphasia, behavioural test scores, site of lesion, etiology and exact time post injury are represented in Table 1. MRIs of the patients' lesions are displayed in Fig. 1. The norm group showed an equivalent age distribution between men (mean: 45.60 years ± 13.67) and women (mean: 44.46 years ± 13.76). All participants investigated were right-handed, as verified with the Dutch Handedness Inventory (DHI; Van Strien, 1992), and had Dutch as their native language. They reported to have normal hearing and none of them had neurological, psychiatric or speech- and language developmental disorders. At the time of testing, none of the participants was on medication. The study was approved by the Ethics Committee of the University Hospital Ghent and an informed consent was obtained from all the participants (patients and norm group).

2.2. Paradigms and stimuli

2.2.1. Auditory phoneme discrimination (APD)

The first experiment (a phoneme discrimination task) consisted of three different auditory oddball tasks both in a pre-attentive

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