Neuropsychologia 46 (2008) 2265–2273

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Normalisation and increase of abnormal ERP patterns accompany recovery from aphasia in the post-acute stage

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ARTICLE INFO

Article history:
Received 28 August 2007
Received in revised form 27 December 2007
Accepted 7 February 2008
Available online 10 March 2008

Keywords:
Aphasia
Anomia
ERP
Recovery

ABSTRACT

Electrophysiological correlates of recovery from anomia were analysed in four aphasic patients in the post-acute stage. Event-related potentials (ERPs) were recorded during picture naming at baseline and after a period of therapy for anomia. All patients had severe anomia at baseline assessment and improved significantly in naming during the study period. Waveform analyses and temporal segmentation were carried out on the ERPs of each patient in comparison with 15 healthy control subjects. Normalisation as well as an increase of abnormal electrophysiological correlates accompanied recovery. An increase of abnormal amplitudes appeared in a patient with semantic impairment during the first 300 ms after picture onset, while only normalisation of amplitudes and topographic maps accompanied recovery in the three patients with lexical–phonological impairment in this early time-window. Abnormal amplitudes and topographic maps emerged during recovery in the patients with lexical–phonological impairment in later time-windows, starting between 250 and 300 ms. Follow-up ERP recordings carried out 6 months later in two of them showed normalisation of amplitudes and persistence of abnormal maps.

The results suggest that electrophysiological changes accompanying recovery from anomia in the post-acute stage are observed in specific time-windows, probably corresponding to different encoding processes and that recovery correlates with normalisation of EEG patterns as well as with the emergence of abnormalities, which presumably indicates compensation mechanisms of specific encoding processes.

1. Introduction

In the last 10 years there has been an increasing interest in the investigation of reorganization of language after stroke. Neuroimaging studies have first tracked the regions involved in reorganization of language through the analysis of patterns of activation in different language tasks in chronic aphasic speakers relative to control groups (Cappa et al., 1997; Heiss, Kessler, Karbe, Fink, & Pawlik, 1993; Karbe, Kessler, Herholz, Fink, & Heiss, 1995; Weiller et al., 1995). Afterwards, investigations have focused on therapy-induced changes in aphasia and performed repeated measurements in patients before and after treatment (Belin et al., 1996; Leger et al., 2002; Musso et al., 1999; Pulvermüller, Hauk, Zohsel, Neininger, & Mohr, 2005; Thompson, 2000). Several brain regions have been identified, including left perilesional areas (fMRI studies by Belin et al., 1996; Leger et al., 2002; MEG study by Cornelissen et al., 2003) as well as right hemisphere regions (fMRI studies by Musso et al., 1999; Saur et al., 2006; Thompson, 2000). In the longitudinal study by Saur et al. (2006) the right hemisphere activation was observed especially in the post-acute stage and activation shifted back to left hemisphere language areas in the chronic stage.

Changes in temporal course of specific language processes may also accompany recovery from aphasia. Most neuroimaging studies on recovery were carried out with PET or fMRI, thus limiting the description to spatial reorganization after brain damage, without information on the time course of the encoding or decoding processes. Magnetoencephalography (MEG) and electroencephalography (EEG) investigations on language recovery in aphasia are rare, especially when it comes to language production (Salmelin, 2007). Hensel, Rockstroh, Berg, and Schonle (2004) and Meinzer et al. (2004) have analysed the electrophysiological changes accompanying recovery from aphasia and only a few studies have investigated the temporal course of changes accompanying reorganization of language production after stroke. Event-related potential (ERP) patterns have been analysed with semantic and phonological categorization tasks in chronic aphasic patients with partial recovery by Angrilli, Elbert, Cusumanu, Stegagno, and Rockstroh (2003) and Dobel et al. (2001). The mean amplitudes of five electrodes from four regions were compared to those of a healthy control group. Different activation patterns

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0028-3932/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.neuropsychologia.2008.02.013

in the patients relative to the control group were observed starting at about 300 ms after stimulus presentation. With regard to therapy-induced changes in language production, Cornelissen et al. (2003) analysed spatio-temporal changes with MEG in three chronic anomic patients. Pre- and post-treatment differed in a time-window between 300 and 700 ms after picture onset in a naming task. This time-window has been estimated to correspond to post-lexical encoding during picture naming in healthy speakers (Indefrey & Levelt, 2004), which is compatible with the lexical–phonological impairment of the patients in that study.

The electrophysiological processes underlying picture naming have been tracked with magnetoencephalographic investigations in healthy speakers (Salmelin et al., 1994; Levelt et al., 1998; Vihla et al., 2006). The results suggested that activation during picture naming proceeds from occipital visual areas to bilateral parietal and left temporal areas, then to premotor frontal areas in the first 400–500 ms following picture presentation. Some studies tried to derive specific spatio-temporal correlates of the different processes during these first 500 ms, with tasks tapping into semantic or phonological encoding processes. For instance, Maess, Friederici, Damian, Meyer, and Levelt (2002) tracked semantic encoding with a semantic interference task in picture naming. Semantic processes linked to semantic interference were found to occur between 150 and 225 ms after picture presentation and were characterised by a left temporal source. Vihla et al. (2006) compared tasks requiring phonological processing (picture naming and phonological judgments from pictures) to a semantic categorization task. Differences in activation between tasks appeared at about 300 ms, suggesting that semantic processes, common to all these tasks, take place before 300 ms.

Since the different processes involved in word production seem to be related to electrophysiological correlates in different time-windows, it is likely that electrophysiological changes linked to reorganisation of language after stroke occur in different time-windows in patients recovering from impairment at different levels of processing, for example patients with semantic impairment relative to patients with impaired phonological processes.

In the present study we analysed the electrophysiological correlates of recovery from anomia in post-acute aphasic patients. ERPs were measured at baseline and after a period of therapy in four aphasic subjects and the data of each patient were compared to a healthy control group.

2. Methods

2.1. Participants

2.1.1. Aphasic participants

Four aphasic in-patients who underwent an ERP during baseline picture naming assessment and who displayed significant improvement after a short period of treatment for anomia were included in the present study. They were all native French-speaking patients in a post-acute stage, who suffered from anomia among other aphasic symptoms.

- *P1* was a 79-year-old woman who suffered an ischemic stroke affecting the left parietal region (Fig. 1) 1 month before the beginning of the study. She rapidly evolved from Wernicke to conduction aphasia with fluent and mostly informative speech despite many phonological paraphasias, which were observed in all production tasks. Auditory and written comprehension was unimpaired at Montreal-Toulouse 86 Aphasia Battery (Nespoulous et al., 1992) and writing was correct for isolated words and simple sentences. Performances were unimpaired in semantic tasks (Pyramid and Palm Trees Test, Howard & Patterson, 1992).
- *P2* was a 55-year-old French speaking but multilingual man, who suffered a left ischemic stroke 4 months before the study with temporal–parietal lesions. The first language assessment revealed very limited speech production with verbal stereotypes and impaired repetition. Four-month post-onset he presented typical conduction aphasia with fluent speech characterized by many phonological transformations and phonologically oriented sequences. Auditory and written comprehension was preserved for words and simple sentences. Writing was not errorless but was superior to oral production and presented some syntactic errors. Semantic assessment (Pyramid and Palm Trees Test, Howard & Patterson, 1992) revealed normal performances with pictures and with words.
- *P3* was a 54-year-old French-speaking woman diagnosed with herpes encephalitis 2 months before the study. MRI showed predominantly left-sided medial–temporal damage as well as damage to the orbito-frontal and cingulate gyrus. Neuropsychological investigation revealed transcortical sensory aphasia accompanied by amnesia and discrete executive dysfunction. Language production was fluent, with many semantic paraphasias and word searching difficulties. Repetition and reading aloud were performed correctly. Oral and written comprehension was unimpaired for words and sentences on a screening aphasia assessment test (Montreal-Toulouse 86 Aphasia Battery), but a semantic impairment was observed in the Pyramids and Palm Trees test and in an intracategorical word-to-picture matching task (French adaptation of Laiacona, Capitani, & Barbarotto, 1993). A moderate surface dysgraphia was also objectivised.
- *P4* was a 57-year-old woman who suffered a hemorrhagic stroke 2.5 months before the beginning of the study with left temporal–parietal–occipital damage. She presented aphasia with alexia and agraphia. Her spontaneous speech was fluent and mostly informative with many word finding difficulties and some phonological paraphasias and phonologically oriented sequences. Repetition was correct for words and short sentences. Comprehension was impaired only for complex sentences at Montreal-Toulouse 86 Aphasia Battery and no semantic impairment was objectivised.

2.1.2. Control group

Fifteen healthy control volunteers aged from 32 to 73 (mean: 56 years, S.D.: 10.9), underwent the picture naming task in a single session.

All study subjects signed an informed consent which was approved by the local ethical committee.

2.2. Procedure

Two baseline assessments with a week interval in-between preceded the treatment period. Post-treatment assessment was performed immediately after the treatment period (post-treatment) and a follow-up assessment was carried out 2–4 weeks later. EEG was recorded during a delayed picture naming task at the second baseline assessment and after treatment (post-treatment), 21–30 days after the baseline recording. The same assessment material was used at baseline and post-treatment recordings. It was composed of 144 line drawings selected from French databases (Alario & Ferrand, 1999; Bonin, Peerman, Malardier, Méot, & Chalard, 2003). Between the two EEG recordings, each patient underwent 3–5 weekly sessions of computer-assisted therapy for anomia. Details of the computer treatment and of the assessment material are described in Laganaro, Di Pietro, and Schnider (2003, 2006).

Each trial had the following structure: first a "+" sign was presented for 500 ms, then a picture appeared on screen for 2000 ms, followed by a response cue (question mark). The participants were asked to prepare the word and to name aloud the picture only when the question mark appeared on the screen.

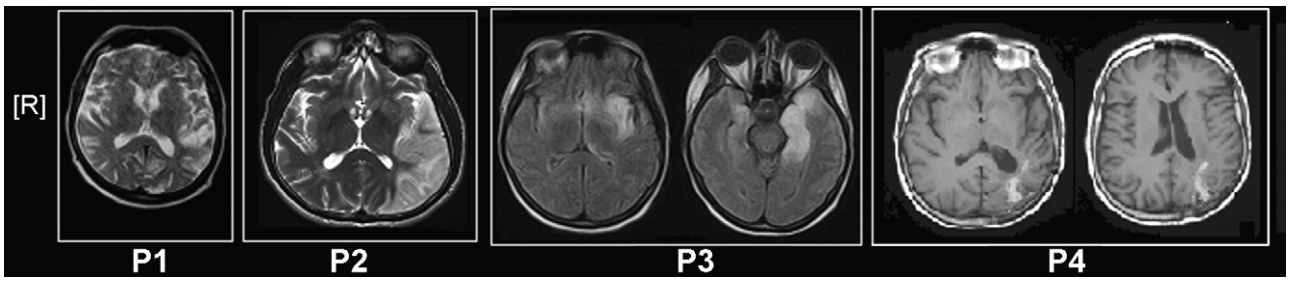

Fig. 1. Site of lesion of each patient (MRI). Detailed descriptions are provided in the text.