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Research Report

ERP effects and perceived exclusion in the Cyberball paradigm: Correlates of expectancy violation?

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ABSTRACT

A virtual ball-tossing game called Cyberball has allowed the identification of neural structures involved in the processing of social exclusion by using neurocognitive methods. However, there is still an ongoing debate if structures involved are either pain- or exclusion-specific or part of a broader network. In electrophysiological Cyberball studies we have shown that the P3b component is sensitive to exclusion manipulations, possibly modulated by the probability of ball possession of the participant (event "self") or the presumed co-players (event "other"). Since it is known from oddball studies that the P3b is not only modulated by the objective probability of an event, but also by subjective expectancy, we independently manipulated the probability of the events "self" and "other" and the expectancy for these events. Questionnaire data indicate that social need threat is only induced when the expectancy for involvement in the ball-tossing game is violated. Similarly, the P3b amplitude of both "self" and "other" events was a correlate of expectancy violation. We conclude that both the subjective report of exclusion and the P3b effect induced in the Cyberball paradigm are primarily based on a cognitive process sensitive to expectancy violations, and that the P3b is not related to the activation of an exclusion-specific neural alarm system.

1. Introduction

Belonging to a group is essential for physical and psychological health (Baumeister and Leary, 1995). Therefore perceiving exclusion at an early stage is necessary to take steps to cope with this experience. Williams and Zadro (2001) established the need-threat model which states that four fundamental social needs – belonging, self-esteem, meaningful existence, and control – are immediately threatened by social exclusion or ostracism. This is perceived as a socially painful event and serves as an early detection system for social exclusion. It motivates a person to restore the satisfaction of the fundamental needs (Williams, 2007; Williams and Zadro, 2005).

Most studies on ostracism use the Cyberball paradigm (Williams et al., 2000; Williams and Jarvis, 2006) to investigate social exclusion in a controlled environment: participants are told to play a virtual ball-tossing game with presumed co-players connected via internet which are actually computer-generated. The possibility of receiving the ball is experimentally manipulated. In an inclusion condition there is an even

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distribution of ball possession between the players, and in an exclusion condition the participant hardly ever receives the ball. To measure the effects of social exclusion, the Need Threat Questionnaire (NTQ, Williams et al., 2000) is given to the participants afterwards to quantify the perceived threat of the fundamental social needs.

Online measurements such as the recording of cerebral blood flow (Eisenberger et al., 2003; Somerville et al., 2006) or electrophysiological signals (Gutz et al., 2011; Kawamoto et al., 2013; Themanson et al., 2012; Weschke and Niedeggen, 2013) during the Cyberball game gave further insight into the cognitive and affective mechanisms determining the processing of social exclusion. The first neuroimaging studies (Eisenberger, 2012; Eisenberger et al., 2003) suggested that the processing of social and physical pain relies on shared neural substrates like the dorsal anterior cingulate cortex (dACC) and the anterior insula. In a more cognitive interpretation, these regions are rather involved in the processing of expectancy violation (Somerville et al., 2006) or represent pain-unspecific structures which are part of a "saliency network" (Iannetti et al., 2013). A recent meta-analysis emphasized the activation of the anterior insula, the left ACC, and left inferior orbito-frontal cortex while experiencing social exclusion (Cacioppo et al., 2013). Following the authors of the meta-analysis, the joint activation pattern signals social uncertainty, rumination, distress, and craving during exclusion, but not social pain per se.

Through its high temporal resolution electroencephalography provides another way to investigate the processing of social exclusion. As demonstrated in our previous studies, the analysis of event-related brain potentials (ERPs) allows us to identify covert processes not detected by retrospective questionnaires (Niedeggen et al., 2014; Weschke and Niedeggen, 2013). In most studies, analyses were focused on the exclusionary events, i.e. ball possession of a co-player (event "other"). Earlier ERP components like N2 and P3 were associated with the activation of the neural alarm system within the Cyberball framework (Crowley et al., 2010; Kawamoto et al., 2013; Themanson et al., 2012). A late (>400 ms) prefrontal positivity was identified supposed to signal coping mechanisms (Crowley et al., 2009).

Kawamoto et al. (2013), picking up the diverse interpretations of previous fMRI studies, noticed that there is an ongoing debate on which factors, social pain or the probability of ball reception, reflect the processing of ostracism. In ERP literature, the processing of stimulus probability is usually examined by using an oddball paradigm (Duncan-Johnson and Donchin, 1977; Polich and Margala, 1997). Here, the frequency of a task-relevant event is varied systematically. Following this approach, we used a partial exclusion condition in our previous studies allowing a separate analysis of ERP responses to the event "self" (=ball possession of the participant). In line with an early Cyberball study (Williams et al., 2000), partial exclusion was found to be sufficient to trigger need threat and negative feelings (Gutz et al., 2011). Transferring the language of the Cyberball to the oddball paradigm, the event "self" served as target stimulus because it requires a reaction from the participant, whereas the event "other" served as standard or non-target stimulus. In line with the established ERP signatures identified in the oddball paradigm (Katayama and Polich, 1996), the parietal P3 (P300 or P3b) amplitudes were more expressed for target stimuli (event "self") compared to non-targets (event "other"). For the event "self", the P3b amplitude was affected by stimulus

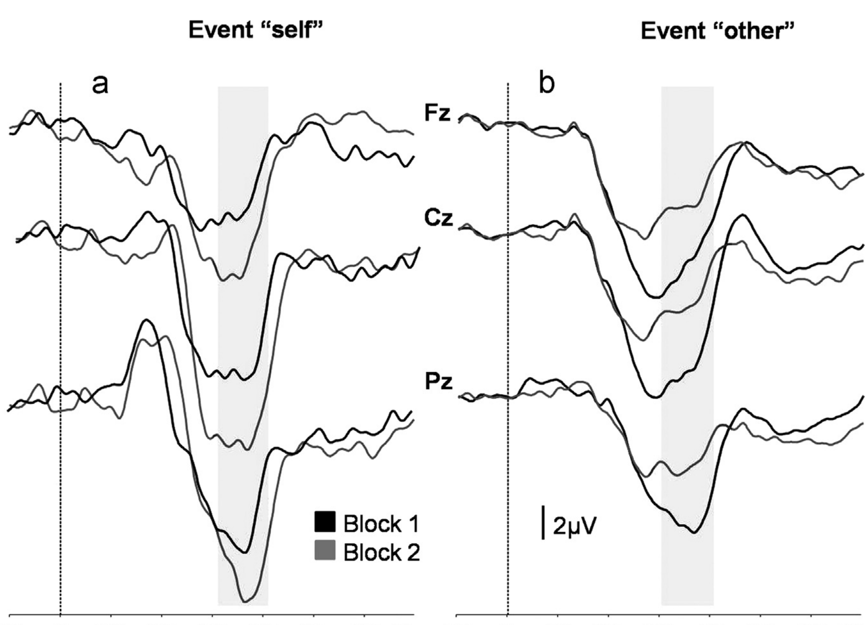

Fig. 1 – Midline ERPs of the "exclusion" group for the events "ball possession" (a) and "ball possession of a co-player" (b), which were presented at 0 ms. Positive voltage is plotted downwards. The probability of the event "self" (a) was 33% in block 1 and 17% in block 2. A negativity at about 160 ms was followed by a more frontally located (P3a: 240–310 ms) and a parietocentral positivity (P3b: 310–410 ms, highlighted) which was mostly pronounced at Pz. The probability of the event "other" (b) was 33% in block 1 and 66% in block 2. A frontocentral P3 at about 240–310 ms was followed by a parietal positivity at about 310–410 ms (highlighted).