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Proprioceptive event related potentials: gating and task effects☆

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Abstract

Objective: The integration of proprioception with vision, touch or audition is considered basic to the developmental formation of perceptions, conceptual objects and the creation of cognitive schemes. Thus, mapping of proprioceptive information processing is important in cognitive research. A stimulus of a brisk change of weight on a hand held load elicit a proprioceptive evoked potential (PEP). Here this is used to examine early and late information processing related to weight discrimination by event related potentials (ERP).

Methods: A gating paradigm having 1 s between the proprioceptive stimuli of 100 g weight increase was recorded in 12 runs of 40 pairs and an 1:4 oddball task of discriminating between 40 and 100 g weight increase was both recorded in 24 healthy men. The subjects were stratified in 3 groups according to their discrimination errors.

Results: The proprioceptive event related potential (PERP) consisted of a contralateral parietal P60, frontal N70, midline P100, initial contralateral later widespread N160, vertex P200, parietal N290 and target related widespread P360 and posterior N500. The target related components were augmented in the best performers, while the bad performers had delayed P60 and attenuated N70. The amplitudes of N160, P200 and N290 were unrelated to performance. Gating was seen as attenuation of P100, N160 and P200 amplitude.

Conclusions: The proprioceptive stimulus feature processing seem to be accomplished in the first 100 ms, while later components are modified by context as expected from previous findings in the somatosensory modality.

Significance: The PERP could be a useful research tool in the investigation of bodily information processing in neuropsychiatric disorders.
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Keywords: Proprioception; Weight discrimination; Somatosensory information processing; Event related potential; Orienting

1. Introduction

Sensory motor operations is basic to the developmental formation of perceptions, conceptual objects and the creation of cognitive schemes (Barsalou, 1999). Even the development of a sense of self is considered to rely on the establishment of sensory motor equivalencies and on perceptual integration (Aitken and Trevarthen, 1997). The motor command output and the proprioceptive feedback input is viewed as integral parts of the sensory motor loop (Savitzky, 1999). Yet, it is of theoretical interest to isolate the information processing related to proprioception (Rado, 1953), when investigating cognitive disorders, like schizophrenia, where anomalies of self-experience are frequent (Parnas et al., 2003).

Proprioception could be defined as the sensation of passive and active movements of the body, the appreciation of body position in space and the appreciation of force applied (Roland and Ladegaard-Pedersen, 1977). Passive movements have been examined aimed at a selective mapping of muscle spindle input as a mean of investigating neurological disorders (Alary et al., 1998; Mima et al., 1996, 1997; Seiss et al., 2002). These passive movement potentials have been named proprioception related EPs. When investigating proprioception as the sense basic to the developmental conceptualisation of objects, it is more important to be able to isolate the dimension of proprioception which is not in every day life continuously updated and refreshed by sensory input from the visual modality (Bedford, 1999). For this reason, another type of

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proprioceptive stimulus has been developed to resemble a sudden inadequacy of maintained muscle contraction, in this manner involving the proprioceptive dimension of appreciation of force applied. A brisk change of weight of a hand held load elicits an EP which has been named the proprioceptive evoked potential (PEP) (Arnfred et al., 2000). The stimulus is a natural compound stimulus triggering firing of both deep and superficial tactile receptors as well as tendon organ and muscle stretch receptors, but it does not lead to a change of limb position. This makes the stimulus well suited for examination of natural information processing related to a proprioceptive task avoiding elements of spatial discrimination, which has been thoroughly investigated (Desmedt, 1990; Desmedt et al., 1977b; Ito et al., 1992; Josiassen et al., 1981; Kida et al., 2003; Nakata et al., 2004; Polich et al., 1991; Yamaguchi and Knight, 1991a,b). The task consists of weight discrimination between load increments of 40 and 100 g.

The event related potential (ERP) component P300 has been demonstrated in all modalities (Polich et al., 1991); in the somatosensory modality the tasks have mostly been of localisation of electrical stimulation (Desmedt, 1990; Desmedt et al., 1977b; Ito et al., 1992; Josiassen et al., 1981; Kida et al., 2003; Nakata et al., 2004; Polich et al., 1991) or touch (Yamaguchi and Knight 1991a,b). As such, this is, to my knowledge, the first time P300 is investigated in relation to a proprioceptive stimulus. Gating or repetition effect on middle latency ERP components has mostly been investigated in the auditory modality as P50 gating. The gating theories of schizophrenia posit that defects of early information processing as indexed by P50 gating are causal to later information processing deficits, cognitive fragmentation and symptoms of schizophrenia (Freedman et al., 1987). The relationship between P50 gating and P300 has, however, only been examined once, finding no such association but only associations between gating at later components (N100 and P200) and the P300 amplitude (Boutros et al., 2004). Using trains of tactile stimuli, it has been shown that the major decrement of somatosensory P50 and N100 happens from the first stimulus (S1) to the second stimulus (S2) (Kekoni et al., 1992, 1997). A modification of the P50 gating paradigm (Arnfred et al., 2001) is employed to map the manifestations of early information processing in the proprioceptive event related potential (PERP) and relate this to later cognitive components.

Incidentally, the term gating of the somatosensory EP (SEP) is mostly used in the context of the modulation of the SEP by movements or other simultaneous stimuli (Rushton et al., 1981) and should not be confused with the present use related to cognitive research and simple stimulus repetition.

Accordingly, this is the first description of the PERP in healthy men, focusing on passive early processing and weight discrimination related late processing of an identical stimulus of a 100 g increment on a hand held load.

2. Methods

2.1. Subjects

Twenty-four physical and mentally healthy men (mean age 29 years, range 19–54) without any former contact to psychiatrist or former psychopharmacological treatment were included. They had no current abuse other than tobacco and no family history of psychiatric disease (first degree relatives). Nine of the subjects smoked more than 10 cigarettes a day. All subjects were right handed. The subjects gave informed consent as approved by the Ethics Committee and they were paid to participate in the experiment. The experiments described here were part of a larger study of somatosensory information processing and only men were included due to large gender variation on other measures of interest. The subjects had Mini Mental Examination scores in the normal range (28–30) as well as reaction times and errors within normal limits in the Danish abbreviated version of the California Computerized Assessment Package™ (CALCAP) reaction time assessment (Miller, 1990).

2.2. Equipment

Silver/silverchloride cup electrodes were placed according to the International 10–20 System at FP1, FP2, Fz, Cz, Pz, C3′, and C4′—the last two placed 2 cm posterior to C3 and C4. They were referenced to linked earlobes. EOG artefacts were registered through an electrode on the right eye upper orbital referenced to the right lateral canthus. The skin was slightly abraded before fastening the electrodes with electrode gel and collodium. Disposable 3M electrodes 3 cm apart were used for the EMG measured at the extensor carpi radialis longus muscle on the forearm. Electrode impedance was below 5 kΩ. We used an integrated system for EEG measurement and stimulus delivery (Contact Precision Instruments (CPI) hardware, PSYLAB®, v.7-software, London, UK), where the 8 channel EEG pre-amplifier (CPI EEG8) was adjacent to the subject in the adjoining room. EEG signals, sampled at 1 kHz with a bandpass of 1–300 Hz, were amplified 50,000 times. EMG was also recorded at a sample rate of 1 kHz, with a bandpass of 1–200 Hz. Dataprocessing was performed off-line and after initial epoching and file format conversion the averaging and further processing of the data was performed in SCAN Edit v 4.2 (Neuroscan Labs®, El Paso, TX, USA). Statistics were performed in SPSS v. 11. The proprioceptive stimulus was delivered by a custom build apparatus (Sv. Christoffersen, Department of Medical Physiology, University of Copenhagen): the subject has a plastic handle in his pronated hand and a minimum static load of 400 g is applied through a nylon wire connected to the handle and an electromagnetic servomotor driving a spool. An additional load of up to100 g is applied with a linear increment of 20 g/10 ms. The hand is supported by a horizontal

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