Comparison of Event Related Brain Potentials of Fast and Slow Reacting Human Subjects

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Abstract

In the present study, both the cognitive and motoric processes involved in a stimulus/response (S-R) task were investigated. The cognitive processes were investigated through the P200, N200 and the P300 components in the stimulus locked event related potentials (ERP). The investigation of the motoric processes were based on the response locked lateralised readiness potential (LRP). In a 4 choice reaction task (CRT), the subjects responded with both hands and feet according to a visual stimulus. The relations between performance of the subjects, measured by their reaction time (RT), and the ERP components and the LRP were investigated for both upper and lower extremities. It was found that performance differences were mainly due to differences in the cognitive processes, but weak correlation between RT and the timing of the motor related processes was also present.

Keywords: Event related potentials, lateralized readiness potential, mental chronometry, choice task, hands and feet.

1 Introduction

A firm basic understanding of the functionality of the brain is of clear clinical relevance for e.g. improving rehabilitation techniques and increasing the insight in different neurological diseases. To investigate the functionality of the brain, mental chronometry has been used to identify the underlying processes of tasks involving e.g. movement accuracy, reaction time and attention.

The intra-personal relations between RT for hand responses and the timing as well as the activation level of the cognitive processes in S-R tasks has been investigated in numerous studies e.g. [5] and [1]. Clear relations between RT and the ERP components associated with the underlying processes have been observed. Most of these studies have reported that fast responses where associated with earlier and larger P300 components compared to the slow responses. The relations between RT and motor processes have been evaluated through the LRP by e.g. [6].

Relatively few studies have investigated the inter-personal relations between RT and the underlying cognitive and motoric processes in S-R tasks for hands. Further, the investigation of responses made with the lower extremities is an almost undescribed field in the investigation of the relation between the RT and the involved brain processes. The inter-personal relation between RT and the underlying processes is therefor the topic of the present study. A reaction time performance paradigm, in terms of a 4 choice reaction task involving visual stimulus and response with both finger and toe, was chosen for this purpose.

The hypothesis was that fast subjects have faster cognitive and motoric processes than slow subjects and further that the relations found would be similar for responses made with hands and feet.

The cognitive processes are investigated through an analysis of the P200, N200 and P300 components, which are believed to reflect different cognitive/non-motoric processes [3]. The motoric processes are investigated through the response locked LRP, which reflect the initiation and execution of lateralised movement [4].

2 Methods and material

Seventeen normal subjects (16 males and 1 female, aged 22-27) without any neurological disorder voluntarily participated in the experiment, after giving their informed consent. All subjects had normal or corrected to normal vision.

The visual stimuli were presented at a computer screen located 1 meter in front of the seated subject. The extension of the stimulus was app. 0.5° at a distance of 1 meter. The stimulus symbols were 4 differently oriented arrows presented at the centre of the screen. The 4 different stimuli were associated with 4 different responses, which were key presses made with right and left, index finger and big toe. In addition to the arrow symbols, an “X” was used as a no-response symbol (no-go). The 600 symbols were presented randomly, in blocks of 50 repetitions (trials). The ratio between go and no-go symbols was 0.9/0.1. The subjects were instructed to respond as fast as possible to stimulus, but to avoid making errors. Likewise, the subjects were instructed to avoid

blinking while the stimulus was displayed at the screen to limit the number of artefacts caused by blinks.

Prior to the experiment the subjects went through a practise session to get familiar to the response system and to practise not blinking while the stimulus was displayed at the screen. The practise session consisted of 200 trials. The practise trials were composed similar to the actual CRT experiment, which was consisting of 3 different events. A fixation point was presented on the centre of the screen for a variable duration of 650 to 1650 ms. The fixation was substituted by the stimulus symbol, which was displayed for 1250 ms. The stimulus was followed by blanking of the screen (750 ms), which also indicated that blinking was permitted and that the next trial was about to start.

EEG and EOG were DC recorded using a SynAmp 5083 amplifier. EEG signals were recorded from 7 electrodes (Fz, Cz, Pz, C3, C4, FC1, FC2) placed according to the 10-20 system. Both horizontal and vertical EOG were recorded and all trials contaminated with EOG activity was manually removed off-line. All signals were recorded using linked ear electrodes as reference, and the FPz as ground. Both EEG and EOG were amplified with a gain of 500 and sampled at 200 Hz using a 3rd order antialiasing filter at 40 Hz.

To avoid smearing of the stimulus locked ERPs, caused by time jittering, the fastest 10% of the responses and the slowest 20% of the responses of each subject were removed from the analysis (different percentages were used due to a skew distribution of RTs). Only the subjects' responses closest to their mean reaction time were therefore included in the investigation.

2.1 Analysis of cognitive components

The P200, N200 and P300 latency and amplitude were the targets of the analysis of the components related to the cognitive processes. These latencies and amplitudes are subsequently referred to, as parameters. The component parameters were detected in the ERPs, that is, the averaged EEG of all accepted trials. All components were detected in the EEG obtained from the Pz channel, similar to e.g. [8] and [9], since they are maximally defined parietal. The N200 and P300 were detected after the averaged ERP of each subject was low pass filtered with a 2nd order 6 Hz filter. A 6 Hz filter was used to attenuate EEG activity (primarily alpha activity) outside of the P300 bandwidth. The P200 was detected in the ERP after low pass filtering using a 2nd order 17 Hz filter. A 17 Hz filter was used for the P200 component because the P200 is relatively fast component compared to e.g. the P300.

The P300 was detected as the largest positive peak after stimulus in the time interval 200ms to 1000ms. The N200 was detected as the largest negative peak in the time interval from 175ms to P300 latency, whereas the P200 was detected as the largest positive peak in the interval from 100ms to the instant of the N200 (peak) latency. The component latencies were defined relative to the stimulus and the corresponding peak amplitudes were measured relative to the baseline (mean amplitude of the ERPs in the interval –500 ms to –200 ms prior to stimulus).

The parameters were determined for each of the 4 response possibilities for each subject. The parameters were averaged across hands and likewise averaged across feet. The relationship between RT and the averaged parameters were found using linear regression.

2.2 Analysis of LRP

The relations between RT and the motor related processes were investigated through the response locked LRP. The LRP was defined as the potential difference of C3-C4 for right side response summed with the potential difference of C4-C3 for left side responses [7].

Based on the low pass filtered (17 Hz) LRP, the peak latency, peak amplitude and the onset of the LRP were determined for all subjects for both hands and feet. The peak latency was defined as the time instant of the largest negativity in the interval from –400 ms (relative to the response) to the instant of response. The peak amplitude was measured relative to baseline at the time of the detected LRP peak. Segmented regression, a method suggested by [10], was utilised for onset detection: From the best fit of two straight lines to the LRP waveforms, the segmented regression method calculates the onset as the cross point of the two lines fitted to the LRP waveforms. The interval for the segmented regression was from –600 ms to the time of the LRP peak. In case of erroneous detections, manual corrections were made (12% of the detections).

3 Results

3.1 Performance

The mean reaction times of the subjects were for handed responses in the range 368 ms to 519 ms, with a mean RT of 446 ms and a standard deviation of 45 ms. The range of RTs for feet were from 391 ms to 541, with a mean of 474 ms and a standard deviation of 38 ms. The RTs given are based on the responses where the fastest 10% and the slowest 20% have been removed.

3.2 Cognitive components

The relation between the parameters and RT were investigated through a regression analysis. The result of this analysis is presented in Table 1. The significance of the relations was tested using a F-test. The sign of the correlation coefficient, r, provide

	Hand responses		Foot responses	
	r	p	r	p
P200 latency	0.056	0.810	0.263	0.306
P200 amplitude	0.000	0.999	0.001	0.959
N200 latency	0.589	**0.013**	0.637	**0.006**
N200amplitude	-0.235	0.365	-0.166	0.525
P300 latency	0.663	**0.004**	0.467	0.059
P300 amplitude	-0.461	0.063	-0.546	**0.023**

Table 1: Results of test for significant linear relations between the component parameters and the reaction time. The significant (<0.05) relations are marked with boldface.

information of a positive or negative correlation between the RT and the specific parameter.

The results of Table 1 show significant relationship between RT and the N200 latency for both hands and feet. Likewise, there is a strong tendency that P300 latency and amplitude depend on RT for both hands and feet. These tendencies are illustrated graphically in Figure 1, where the ERPs of the fastest and the slowest subject are shown for both hand and foot responses. The difference in mean RTs of the 2 subjects are 143 ms for hands and 149 ms for feet. A difference in N200 latency, P300 amplitude and P300 latency are observed between the 2 subjects.

3.3 LRP

The relation between the peak latency, peak amplitude and the onset latency of the LRP and RT of the subjects were investigated through linear regression. Similar to the investigation of the cognitive components the statistic used was an F-test. The results are listed in Table 2.

The LRPs of both hand and foot responses of the fastest and slowest subject are presented in Figure 2.

	Hand responses		Foot responses	
	r	p	r	p
Peak latency	-0.084	0.753	-0.474	0.054
Peak amplitude	0.504	**0.039**	+0.161	0.534
Onset latency	-0.409	0.103	-0.422	0.092

Table 2: Linear relations between LRP peak latency, peak amplitude and onset latency and the reaction time of subjects. The significant (<0.05) relations are marked with boldface.

According to the linear regression, as Figure 2 also indicate, the only parameter significantly related to the RT is the LRP peak amplitude for hands (F=51.01, p=0.039), which is increasing (negatively) with a decreasing RT. The LRP onset latency of both hand and foot response is showing weak signs of a likely relation to the RT, but not statistically significant.

4 Discussion

The purpose of the present study was to investigate whether inter-personal performance differences, by means of RT, for both hands and feet were due to differences in both cognitive and motoric processes.

Other studies have found that earlier RTs of hand response are accompanied by an earlier and larger P300. This finding is replicated in the present study and is found also to apply for responses with feet. Further, it is found that both hand and foot responses are having a delay in N200 latency as a consequence of higher RTs. This was also observed in [1], which only measured hand responses, but also reported significant negative correlation between P300 amplitude and RT.

The results of the present study thus suggests that performance differences for both hands and feet are

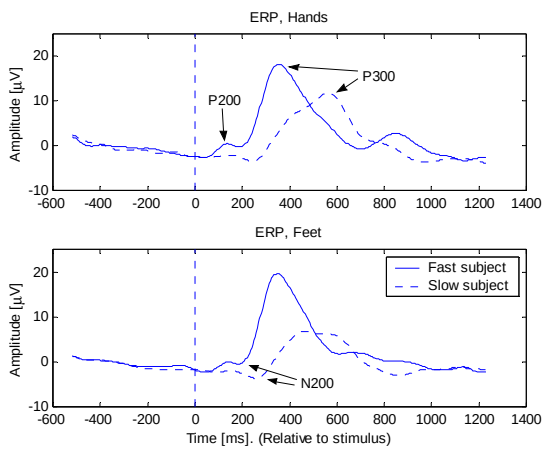

Figure 1: ERP of the fastest and slowest subject. The ERP's are obtained from the Pz electrode and filtered with a 2nd order 6 Hz low pass filter.

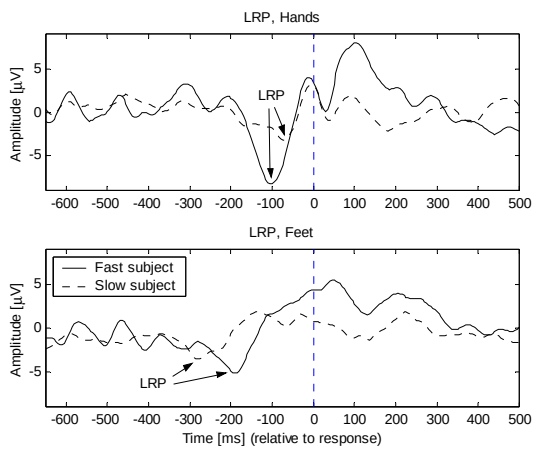

Figure 2: LRP of the fastest and slowest subject. The LRP's are obtained form the C3 and C4 electrodes and filtered with a 2nd order 17 Hz low pass filter.

reflected in the cognitive processes that are related to the N200 and P300 components and that these processes are faster for fast than for slow responding subjects. The results obtained from the response locked LRP did not show a significant relation between the RT and the latency parameters. This indicates that the timing of the motor processes is not depending on the RT. However, weak signs of a relation between RT and the onset latency ($p \approx 0.1$) for both hand and foot responses should be investigated further, before purely rejecting the existence of this relation.

The significant relation between LRP peak amplitude and the RT for hands can be explained by a higher involvement of the related motor areas for fast subjects. The reason that this relation is lacking for the foot responses could be that the recording locations at C3 and C4 are simply not appropriate for investigations of LRP obtained from foot responses. It would be likely that recording sites more central, toward the longitudinal fissure and thereby closer to the motor areas of feet, could be an better recording location. Another explanation for the missing significance for the feet responses is the detection of the LRP. The LRP are detected in the same way for both hands and feet, even though that foot responses should have a maximum ipsilateral activation [2] in contrast to hands responses. This should theoretically have the effect that the LRP for feet should be of opposite polarity to the LRP for hands. This has not been observed in the present study, as is seen in Figure 2, where the LRP for feet are having the same polarity as for hands. Due to this observation, it was determined to detect the LRP for feet in the same manner as for hands. The correctness of this detection can thus be questioned.

The hypothesis that fast subjects have both faster cognitive and motoric processes than slow subjects is based on the current results rejected. The cognitive processes are found to be faster whereas motoric processes are not. This indicates that performance differences between fast and slow responding persons are mainly due to differences in cognitive processes. The second part of the hypothesis, that similar processes are involved in responses with hands and feet, are partly accepted. The only difference in the relation between RT and the component parameters were seen in the LRP, where the peak amplitude showed different results for hands and feet. The reason that this finding does not reject the second part of the hypothesis is that it is believed, that the recording locations for feet were not optimum and further, that the LRP of foot responses showed same polarity as for hands.

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