The proof of the existence of specific reaction related brain potentials

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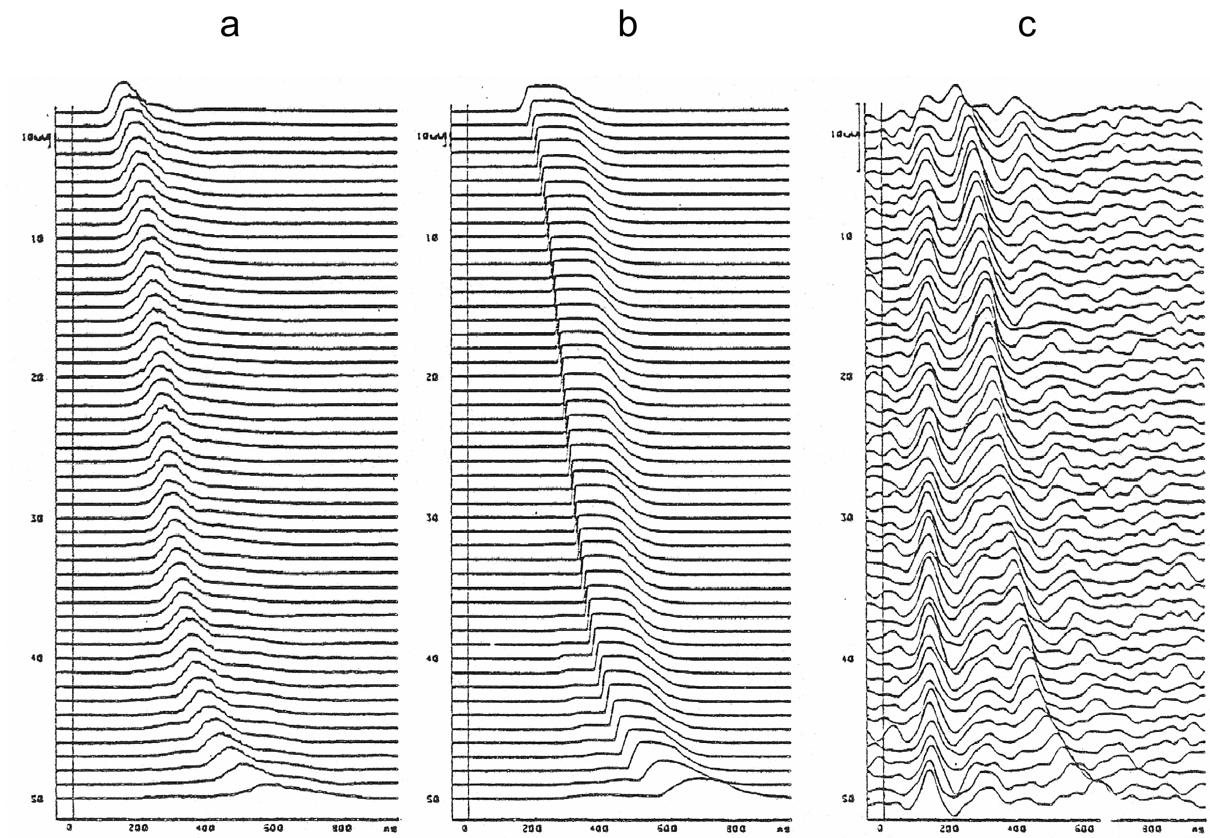

Fig.1 For the details of this figure please read the following text

Introduction

Figure 1 displays a perfect 1:1 parallel association between peripheral events and brain events. It is taken from the monograph on “The predictive brain. Prediction theory of conscious behavior.” (in prepare) and shows the association between reaction correlated EMG (fig. 1a), reaction correlated movement onset and offset flags (fig. 1b) and reaction correlated, movement specific brain potentials (fig. 1 c, right side as to the preceding perception related brain potentials with invariant latencies per either line). This picture is the proof of the existence of the reaction correlated, motor specfic brain potentials.

Study design

A P3-oddball Go/NoGo reaction time paradigm (Bernoulli order, random ISI 1.1 to 4.1 sec) with auditory stimuli was applied. 24 Ss (25.2 to 29.8 years, 15 males, 9 females) were instructed to respond to the frequent (Go-) stimulus (85 %, 800 Hz, 65 dB, 40 ms), but not to the rare (NoGo-) stimulus (15 %, 1400 Hz, 65 dB, 40 ms). Ss were supposed to lift as quick as possible the rightsided indexfinger and to return the finger immediately back to the initial “readiness”-position as Go-reaction. The movements gave rise to extension onset and flexion offset flags. In parallel with the stimulus response behavior recordings were performed by means of 11 EEG channels

(10/20 system) plus 5 monitor channels (2 EOG, EMG, linked ear reference, movement channel). Collodium Ag/AgCl-electrodes were used. From each subject 1000 Go-reactions were collected, i.e. per subject finally 16000 recordings of 1000 epochs due to stimulus response behavior were available for analytical purposes.

From the 24 Ss a total of 24.000 Go-reactions was collected. We performed an extremely strong artefact rejection. Neither in one of the EEG channels nor in any of the monitor channels any contamination by technical or biological artefacts was allowed. The artefact rejection was performed automatically, but all cases were controlled via a graphical EDP-display. Finally from the 24.000 Go-reactions a total of 14.459 Go-reactions with completely artefactfree recordings remained with an average of 603 Go-reactions per subject (range from 486 to 937).

Movement onset and offset recordings
Either reaction was basically recorded in terms of a time interval beginning 50 ms prior to the auditory stimulus onset and lasting over a period of 912 ms (see fig. 1b). Within this interval the reaction correlated movement onset flag indicated the reaction time. The completion of the movement was indicated by the succeeding movement offset flag. The onset flag was the up deflection and the offset flag the down deflection of a rectangular shape within the reaction related time interval.

Ranking by reaction time, not by subjects
The data pool of the totally 14.459 recordings of reaction related time intervals was used to create a ranking order due to reaction time. This ranking was governed by reaction time only, regardless which subject contributed a certain recording. The ranking order of the 14.459 recordings was divided into 50 classes, with increasing reaction times from class 1 to class 50 (arranged from top to bottom in fig. 1b). Each class was constituted by 289 reactions. In class 1 the extraordinary fast and in class 49 and 50 the extremely slow reactions were found. We do not consider them here. From class 2 to class 48 the covered range of reaction times was from 188 ms to 538 ms (range 350 ms), i. e. the average time increment from class to class was 7.4 ms. Thus the average difference in reaction time between the 289 reactions per class did not exceed 7.4 ms. From this we may say, that in either of the considered reaction time classes there were always 289 reaction with at least very similar (or identical) reaction times.

Therefore about 94% of the 50 classes shown in fig. 1b display averages of the movement onset flags in a very steep fashion because of the only minor variability of the reaction times per class (except for the extreme outside classes 1, 49 and 50 not considered here). In contrast to the averages of the movement onsets, the averages of the movement offsets were obviously influenced in either class by a high variability of the movement times (due to the well known independency of reaction time and movement time). Thus, the averages of the movement offsets in either class are displayed in terms of oblique bounds in Fig. 1b.

Important remark
The procedure in order to establish the particular arrangement of the reaction correlated movement onsets and offsets in fig. 1b was extensively discussed because the procedure to establish the EMG recordings of the reacting right indexfinger movement shown in figure 1a and for the arrangements of the brain signal recordings shown in figure 1c follows exactly the same principles outlined

before. One must be aware that for each recording of a reaction in terms of movement onset and offset there exists the simultaneous recordings of the extensor EMG of the right indexfinger and of the electrical brain activity. Therefore the brain signal recordings and the EMG recordings are processed accordingly as to the procedure demonstrated in detail for the movement on- and offsets. Moreover the sequentiell structure of fig. 1a, fig. 1b and fig 1c displays parallel activities of the EMG, the movement and the brain signals due to stimulus response behaviour. For instance the averages of class 30 of the EMG recordings, of the movement on-/offset recordings and of the brain signal recordings represent simultaneously appearing forms of activity. They therefore are reflecting a 1:1 parallel association between peripheral and brain events.

EMG recordings of the reacting indexfinger movement
In fig. 1a the 50 averages of the corresponding recordings of the surface EMG of the m. extensor indici of the reacting (rightsided) indexfinger are displayed. They were processed (from the same total of 14.459 recordings) in accordance with the procedure described for the reaction correlated movement onset and offset in fig. 1b. The EMGs are always preceding the finger lift reaction, with an average of 28 ms from the EMG peak to movement-onset (and a very minor variability of this measure in 90 % of the classes with $r=0.92$, $p>0.001$)

Brain signal recordings due to stimulus response behavior
In fig. 1 c the 50 averages of the corresponding brain signal recordings depicted by bipolar precentral-parietal leads (F3-P3, single sweep time 912 ms, 612 scans per sweep) are shown. The total of 14.459 single sweep recordings was processed according to the procedure used to yield the averages of the EMG- and the movement on-/off-recordings.

Three fundamentals of brain functions due to stimulus response behavior
The results for the brain signals shown in fig.1 c demonstrate the three fundamentals of brain functions due to stimulus response behavior:

<u>Firstly</u>, the perception related brain potentials are appearing invariant with stable latencies over all 50 reaction time classes indicating a linear correlation of perception with stimulus onset; on the other hand these potentials show absolutely no linear correlation with the reaction correlated events.

<u>Secondly</u>, reaction correlated motor potentials definitly exist. They show a linear correlation with the reaction related movement onsets (in fig. 1b) and the movement EMG (fig. 1a).

<u>Thirdly</u>, there is a nonlinear gap between perception and behavior related brain potentials. We propose cognition to be responsible for this nonlinear gap. A linear estimate of the cognitive top down function controlling the bottom up processes of perception and behavior is demonstrated in the paper “The cognitive CDA-Potential”. The estimate of cognition will be shown to appear in terms of a bioelectrical negativity in parallel with perception and behavior due to top down control of stimulus and reaction related activity.