J Neural Transm (2009) 116:67–70
DOI 10.1007/s00702-008-0125-5

BASIC NEUROSCIENCES, GENETICS AND IMMUNOLOGY - SHORT COMMUNICATION

Change detection related to peripheral facial expression: an electroencephalography study

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Received: 23 November 2007 / Accepted: 5 September 2008 / Published online: 20 September 2008

Abstract The objective is to study the change detection of emotion expression by electroencephalography (EEG). A visual letter task was combined with two neutral faces. After a short break another letter task occurred whilst the peripheral faces remained or randomly changed to joy, anger or disgust. Study participants responded whether they had perceived a change in emotion expression or not. Explicit change detection elicited more positive-going EEG amplitudes than change blindness between 750 and 900 ms. A change to disgust elicited largest effects. Furthermore, evidence for implicit change detection occurred.

Keywords Change detection · Faces · EEG

Introduction

To detect a change in our visual environment is of tremendous evolutionary importance. However, research on this topic showed that we are remarkably bad in doing that if the change happens during a short visual interruption (e.g. Resink et al. 1997).

Beck et al. (2001) investigated change detection and change blindness in a fMRI study. Whilst study participants had to solve a letter task, two flanking images were shown on the display. These images were either faces or places to enable a distinction between category-specific activity and common activity for both categories. Besides common brain activity related to explicit change detection, Beck et al. (2001) also found evidence for implicit detection in the faces category. The fact that such brain activity could only be found in the face category attributes faces a special kind of scientific attraction (see also Downing et al. 2001; Hoshiyama et al. 2003; Kanwisher et al. 1997; Austen and Enns 2003; Ro et al. 2001).

We used a modified version of the experimental design of Beck et al. (2001) and concentrated on the category of faces and their changes in emotion expression. Beck et al. changed the emotional expression of their faces as well as their identity. We decided to present pictures of one person only with controlled emotional expressions (joy, anger and disgust) in order to eliminate differences related to face identity processing. We chose a divided attention task with a one-shot-paradigm and the gap-technique and used the electroencephalography (EEG) in order to describe brain activity elicited by conscious change detection.

Methods

Participants

A total of 30 volunteers (15 females) without neuropathological history participated in our study. The mean age was 23.8 years (range 19–31; SD 3.11). They were all right-handed and had normal or corrected to normal vision (glasses or contact lenses).

Procedure

After a baseline of 500 ms the first visual presentation started. Two lines each of them showing three letters were

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presented for 900 ms. Simultaneously, two neutral faces were presented (one to the left and the other to the right of the two line letter presentation) (see Fig. 1). The task was to decide whether or not the letter X was amongst the letters via button press. This task is referred to as primary task.

After a short interval (black screen for 500 ms) a second presentation started. A second set of letter lines was presented again for 900 ms, whilst the expression of the faces was either the same or had changed during the short break on one side to one of three emotional categories (joy, anger or disgust) (see Fig. 2a showing all emotional categories). Again, the task was to decide whether or not the letter X appeared in the letter strings. After the second presentation a black screen was shown for 500 ms which was followed by a white question-mark shown for 2 s. The question-mark served as a sign for the participants to make a decision if they had noticed a change in one of the two faces or not (secondary task; task of interest) (by button press).

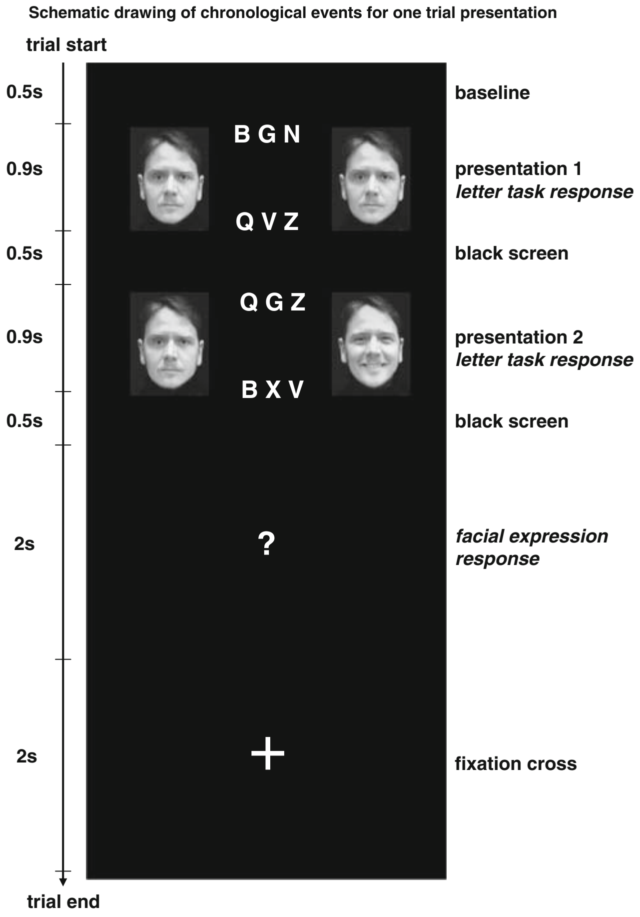


Fig. 1 Schematic drawing of chronological events for one trial presentation. After a baseline period of 500 ms the first presentation started for 900 ms. Two letter strings, each containing three letters, were centrally presented and constituted the primary task. Two pictures of emotionally neutral faces were presented, one to the left and the other to the right of the letter strings. After that a black screen followed for 500 ms. Then, the second presentation appeared for 900 ms again showing a centrally presented primary task (new letter strings). Now, one of the two faces could have changed from neutral to joy, anger or disgust. After a 500 ms black screen break a question-mark appeared for 2 s (secondary task). The secondary task was then to decide whether the emotional expression of one face changed or not, despite mainly concentrating on the primary letter task during the second presentation. Finally, a fixation cross was presented for 2 s

Recordings

Event related potentials were recorded using 40 Ag/AgCl electrodes corresponding to the international 10–20 electrode system locations by Jasper (1958). In order to compensate for eye movement artefacts we also used electrooculography (EOG). All signals were recorded with a 64 channel DC-Amplifier at a sample rate of 250 s^{-1} referenced against a sternovertebral electrode. An online filter from DC to 100 Hz was used. A 500 ms period before the onset of the first presentation served as baseline.

Statistical analysis

The mean amplitudes of 100 ms intervals (overlapping for 50 ms) covering the time range from −50 to 950 ms were determined for each condition (all data were also normalised to correct for amplitude differences). These mean amplitudes were used as dependent variables for analysis of variance (ANOVA) (repeated measures design; Greenhouse-Geisser corrected) calculations. Condition (2 levels), emotion (3 levels) and electrode (40 levels) were used as within subject factors. Analysis of variance (ANOVA) was used to calculate the main effects and interactions between factors for EEG data and behavioural data. In addition, for localising brain activity LORETA (low resolution brain electromagnetic tomography) was used (Pascual-Marqui et al. 1994; Pizzagalli et al. 2002).

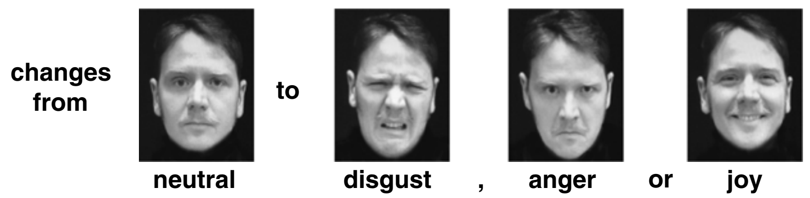
Results

Behavioural data (response times)

Secondary task: change detection versus change blindness

Only trials which were correctly answered with respect to the primary letter task were analysed. The mean response time related to change detection was significantly shorter (RT 383 ms, SD 136) compared to change blindness (RT 529 ms, SD 226) ($P < 0.001$). The mean response time was shortest in case of a change from neutral to “disgust” in both change detection and in change blindness conditions.

a **Pictures of faces used for peripheral visual field stimulation for the *secondary task***



b **LORETA results: Distribution of difference activity between *change detection* and *change blindness* (all study participants)**

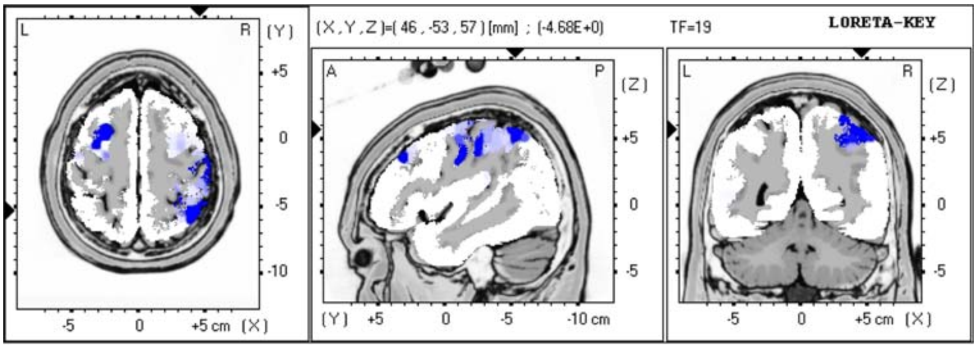


Fig. 2 **a** Pictures of faces used for peripheral visual field stimulation for the secondary task. The emotional expression of one of the two flanking faces could have changed from neutral to joy, anger or disgust. **b** LORETA result related to change detection versus change blindness. Change detection elicited higher brain activity than change blindness at the right parietal area

Secondary task: change blindness versus no change correct

The mean response time related to no change correct was shorter (RT 435 ms, SD 157) than the mean response time related to change blindness (RT 529 ms, SD 226) ($P < 0.001$). This result is interpreted as reflecting implicit change detection.

EEG data

Change detection versus change blindness

Main condition effects were found in the time range between 750 and 900 ms after stimulus onset (four intervals, $P = 0.022$, $P = 0.003$, $P = 0.001$, $P = 0.002$). The mean amplitudes were significantly more positive going in the condition change detection compared to change blindness at the right parietal area (Fig. 2b).

The factor emotion was significant from 500 to 650 ms after stimulus onset (two intervals, $P = 0.04$, $P = 0.017$) and from 750 to 900 ms after stimulus onset (two intervals, $P = 0.006$, $P = 0.016$). The mean amplitudes related to disgust were most positive going followed by anger and joy.

In addition, the emotion factor was calculated for every condition separately by using ANOVA. It was significant in the condition change detection from 550 to 850 ms after stimulus onset (five intervals, $P = 0.032$, $P = 0.011$, $P = 0.028$, $P = 0.028$, $P = 0.035$). The mean amplitudes were most positive related to disgust followed by anger and joy.

Change blindness versus no change correct

An early significant condition main effect in the time range from about 0 to 100 ms after presentation onset was found (three intervals $P = 0.004$, $P = 0.013$, $P = 0.046$). Mean amplitudes were more positive going in the condition no change correct compared to change blindness.

Discussion

Behavioural data

Our results support the idea of unconscious processing of emotion expression. Change blindness was associated with longer reaction times than no change correct. In both cases the explicit answer was “no I have not noticed a change”, but in the change blindness condition actually a change occurred. So, our behavioural data provide strong evidence for implicit change detection related to emotion expression. For instance, Dimberg and colleagues also showed in their studies (Dimberg and Petterson 2000; Dimberg et al. 2000) that participants responded with particular contractions of distinct face muscles when they were shown pictures of happy and angry faces. These specific reactions could be found even when the participants were not aware of seeing these pictures. More particularly, our results demonstrate that the emotion expression of disgust seems to be of distinct importance. This idea is due to the fact that changes from neutral to disgust resulted in shortest reaction times independent from detection accuracy.

EEG data

The significant difference activity between the conditions change detection and change blindness in the time period from 750 to 900 ms after the onset of the second presentation is interpreted as reflecting conscious change detection. This difference activity is located at the right parietal brain area (see Fig. 2b) which is consistent with the current opinion of Beck et al. (2001) that within the process of change detection the parietal cortex is involved. Since we focused on changes in emotion expression our result extends this idea to an involvement of the parietal cortex in change detection of emotion expression.

In the time periods from 500 to 650 ms and from 750 to 900 ms we found significant effects of emotion expression. "Disgust" elicited the most positive EEG amplitude. We therefore interpret that our physiological data provide evidence that disgust somehow represents a dominant emotion, at least as a facial expression. Since our behavioural results led to the same conclusion we want to mention that this evidence might be linked to the idea that the detection of disgust is of great evolutionary importance (avoidance of potential harm). Eimer and Holmes (2003) showed in their study that the processing of emotion expression depends on attention. When their participants were instructed to focus on a face task (figuring out if the expression of two faces is neutral or emotional) then the faces with emotional expressions showed significantly more positive-going mean amplitudes in early time periods (160–215 ms and 220–315 ms) compared to neutral faces. These early fronto-central-effects could not be found when the participants were instructed to focus on a line task (comparing the length of two lines). Thus, we conclude that we did not find effects of emotion expression earlier than starting from 500 ms after stimulus onset because the attention was directed to the primary letter task.

Statistical analysis of EEG data related to change blindness versus no change correct provides vague physiological evidence for implicit detection. We found a significant main effect as early as between 0 and 100 ms after stimulus onset. In contrast, Niedeggen et al. (2001), Turatto et al. (2002) and Koivisto and Revonsuo (2003) found no EEG evidence for implicit detection. The interpretation of our EEG finding is twofold. On one hand, we tend to neglect the early effect mentioned above because of its quite early occurrence and on the other hand we believe that implicit change detection should be a fast process with an early occurence.

Acknowledgments The authors want to thank the professional actor who supported this study by being at our disposal for demonstrating his wonderful ability to change his facial expression whilst being photographed. Thank you very much for your time! We also want to thank Florian Ph.S. Fischmeister for his support related to statistical analysis.

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