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Can you feel what you do not see? Using internal feedback to detect briefly presented emotional stimuli

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ABSTRACT

Briefly presented (e.g., 10 ms) emotional stimuli (e.g., angry faces) can influence behavior and physiology. Yet, they are difficult to identify in an emotion detection task. The current study investigated whether identification can be improved by focusing participants on their internal reactions. In addition, we tested how variations in presentation parameters and expression type influence identification rate and facial reactions, measured with electromyography (EMG). Participants made force-choice identifications of brief expressions (happy/angry/neutral). Stimulus and presentation properties were varied (duration, face set, masking-type). In addition, as their identification strategy, one group of participants was instructed to use their bodily and feeling changes. One control group was instructed to focus on visual details, and another group received no strategy instructions. The results revealed distinct EMG responses, with greatest corrugator activity to angry, then neutral, and least to happy faces. All variations in stimulus and presentation properties had robust and parallel effects on both identification and EMG. Corrugator EMG was reliable enough to statistically predict stimulus valence. However, instructions to focus on the internal states did not improve identification rates or change physiological responses. These findings suggest that brief expressions produce a robust bodily signal, which could in principle be used as feedback to improve identification. However, the fact that participants did not improve with internal focus suggests that bodily and feeling reactions are either principally unconscious, or that other ways of training or instruction are necessary to make use of their feedback potential.

1. Introduction

Numerous studies have shown that emotional stimuli influence behavior and physiology when they are presented very briefly, even "subliminally" (i.e., without being consciously perceived). For instance, in a classical paradigm introduced by Niedenthal (1990) and expanded by Murphy and Zajonc (1993), participants are asked to rate how much they like neutral targets (e.g., Chinese ideographs). The targets are preceded by brief (e.g., 10 ms) pictures of emotional faces, which are either positive (usually happy) or negative (usually angry, but sometimes fearful, disgusted or sad). Results show that positive faces enhance ratings of the targets, whereas negative faces lower them (see also Winkielman et al., 1997; Rotteveel et al., 2001; Stapel et al., 2002; Wong and Root, 2003). Interestingly, the effects of subliminal faces go beyond ratings and influence behaviors such as the consumption of a novel beverage (Winkielman et al., 2005b) or the willingness to take risks (Winkielman et al., under review). Furthermore, people react to subliminal smiling faces by smiling themselves and to angry faces by frowning themselves (e.g., Dimberg et al., 2000; Rotteveel et al., 2001). Despite such effects on ratings, behavior, and physiology, participants in those studies remain largely unaware of the brief emotional stimuli, even when informed about their presence and asked to identify them (e.g., Dannlowski et al., 2007; Murphy and Zajonc, 1993; Öhman and Soares, 1993; Winkielman et al., 1997; Wong and Root, 2003). For instance, in a typical "forced-choice awareness procedure", an emotional face is first briefly flashed (e.g., 10 ms), and is then followed by a mask, consisting either of a neutral face or some graphical pattern (e.g., scrambled picture fragments or random dots). Participants are then shown two faces, the previously presented one and a new one, and are asked to indicate which face had been flashed. Typically, participants' performance on this task is around the chance level or barely above it.

These findings are puzzling. After all, the effects on ratings, behavior and physiology suggest that brief emotional stimuli trigger some internal reactions, so that information about them is available "somewhere" in the mental system. Yet, participants cannot identify

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those stimuli in a forced-choice awareness procedure. In our research, we test whether people can deliberately access their internal emotional reactions to improve identification of brief stimuli. Different predictions are possible regarding access to such internal reactions. One prediction is that people, if directed properly, can utilize fluctuations in their subjective feeling and sense their own physiological reactions. If so, they should be able to “feel what they do not see”, that is, discern the valence of a brief emotional stimulus by basing their judgments on their own affective state (physiology and subjective experience). This prediction is consistent with two major theoretical models: (i) the Affect-As-Information model, and (ii) Facial Feedback model of emotion recognition. Here is why.

The Affect-As-Information model (AAI) proposes that people base their judgments on their subjective feelings (Schwarz and Clore, 2003; Clore and Huntsinger, 2007; Clore et al., 2001). On this model, affective priming effects (e.g., Murphy and Zajonc, 1993) occur because subliminal emotional faces elicit subtle, fleeting, but principally detectable changes in phenomenal experience. Subjects, who lack any useful knowledge about ambiguous targets, such as a Chinese ideograph, ask themselves, ‘How do I feel about it’, and rate the ideograph in line with their current feelings. In essence, the AAI model proposes that subjects misattribute their prime-induced feelings to the neutral target (see Schwarz, 1990, p. 538). If this is true, then changes in subjective feeling could be used deliberately to identify briefly presented emotional faces in the forced-choice paradigm.

The Facial Feedback model of emotion recognition proposes that when we see emotional expressions, we engage in spontaneous facial mimicry — involuntarily mirroring the expressions on our own faces (e.g., Achaibou et al., 2008; Dimberg et al., 2000; Hess et al., 1999; McIntosh et al., 2006; Sato and Yoshikawa, 2007). This facial mimicry could facilitate emotion detection via multiple mechanisms. Some researchers propose that the facial movements influence the actual emotion experienced by the subject (Laird, 1974; Zajonc et al., 1989). Others suggest that feedback from one's own facial muscles provides an embodied cue to what expression was actually shown (Goldman and Sripada, 2005). Assuming the outputs from these processes are conscious, then focusing on facial feedback should facilitate identification of brief emotional faces.

The AAI model and the Facial Feedback model predict that focusing participants on their feelings and facial responses should improve identification of brief emotional expressions. An opposing prediction, however, is offered by recent ideas about “unconscious emotion” (e.g., Winkielman et al., 2005a; Berridge and Winkielman, 2003). According to this proposal, briefly presented emotional faces are processed using low-level and automatic mechanisms that run below consciousness. Subliminal emotional priming effects are due to front-end changes in perception of the stimulus' incentive value (e.g., the ideograph “looks” better; the Kool-Aid “seems” tastier). On this account, there are no consciously accessible changes in feelings that could assist in the identification of the briefly presented expressions. Accordingly, the Unconscious Emotion model predicts no effects of the internal focus manipulation.

1.1. Specific research questions and design

Our first question was whether subjects can be instructed to strategically use their physiological reactions or changes in their feelings to discern the valence of a briefly presented face in a forced-choice awareness test. We therefore devised three different instructions, one asking participants to monitor their own internal reactions and two control conditions. This manipulation was inspired by an earlier study which examined different strategies for the perception of briefly presented neutral (non-emotional) words (Snodgras et al., 1993). In that study, an intuitive ‘pop’ strategy, encouraging subjects to “just relax” and say “whatever word pops into your head” improved detection of subliminal words, over a visual look-hard strategy.

A precondition for the use of a physiological response is that such a response actually occurs under the conditions of a forced-choice awareness test. Subliminally presented faces have been shown to induce spontaneous smiling and frowning (e.g., Dimberg et al., 2000; Rotteveel et al., 2001). However, it is not clear whether the same effects occur when people know about the presence of the faces and deliberately try to perceive them. Thus, we have measured the physiological response with facial EMG. Furthermore, we wanted to know how much information about the briefly presented face is mirrored in the physiological signal. This comes down to the question: Using the physiological signal in a computationally optimal way, how precisely can we infer what stimulus has been presented to the subject?

Finally, we varied different parameters of the stimuli and their presentation, such as emotion type, face set, mask, and duration. We did this for several reasons. First, we wanted to identify a condition where the physiological signal induced by the emotional face is strong, but produces low behavioral detection rates. In such a condition, the use of physiological feedback might be particularly beneficial for enhancing recognition. Second, we wanted to learn how the EMG response and identification depend on the parameters of stimulus presentation. This is of theoretical interest, because these parameters bear on different mechanisms involved in emotion processing (we elaborate on this in the discussion). It is also of practical interest to researchers in the field, because individual studies often differ on such parameters, making systematic comparisons across studies difficult.

Thus, first, we varied displayed emotion: happy, angry, and neutral. We chose happiness and anger because these emotions are most commonly used in studies relying on brief presentation. Second, we varied face sets, relying on 3 widely used (details below; Section 2.2). Third, we varied mask type: neutral face or dotted pattern — these represent the two most typical ways of masking. Finally, we varied prime duration: 10 or 20 ms. Although some studies mentioned earlier used presentations as short as 10 ms, others used durations even longer than 20 ms (e.g., Stapel et al., 2002, used 30 ms and 100 ms). We used 10 and 20 ms to explore how the behavioral and physiological parameters depend on the strength of the affective input, while keeping the detection reasonably close to chance.

1.2. Task

A simple forced-choice awareness procedure was used. Participants were flashed with a face that was either emotional or neutral. The face was immediately covered by a mask (either a face or an assembly of dots). After the mask, participants were to indicate whether the briefly presented face was emotional or neutral.

2. Methods

2.1. Participants

Participants were 58 undergraduates from the University of California, San Diego (gender: 14 male, 1 no gender specified; mean age = 19.8 years, sd = 1.39 years). They participated for partial course credit. Ethnicity was predominantly Asian (42 Asian, 6 Caucasian, 6 Hispanic, 1 Indian, 1 Persian, 2 missing), but most had been raised in the USA and spoke perfect English. Because of the need to attach EMG electrodes strong facial hair was an exclusion criterion.

2.2. Materials

Three different face sets were used (Fig. 1), which cover some of the most common sets of stimuli used in emotion research: (1) the

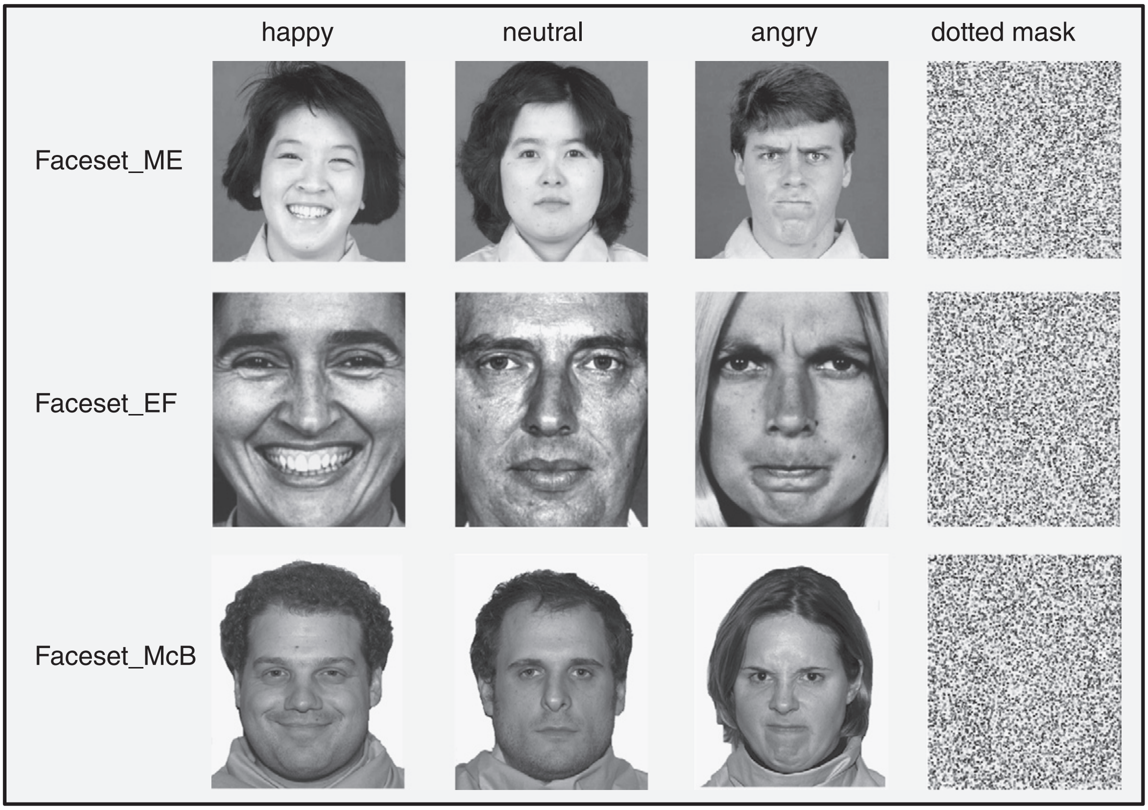

Fig. 1. Examples of the stimuli used as primes (happy/angry/neutral faces) and masks (neutral faces/dotted patterns).

face set by Matsumoto and Ekman (1988); henceforth referred to as faceset_ME; (2) the face set by Ekman and Friesen (1976); henceforth referred to a faceset_EF; and (3) the face set called MacBrain–NimStim,[2] henceforth referred to as faceset_McB (Tottenham et al., 2009, and www.macbrain.org/resources.htm). From the faceset_ME, 8 happy, 8 angry, and 16 neutral faces were used as "primes" (as to-be-detected faces), and another 16 neutral faces were used as masks. The remaining 16 masks were dotted patterns (see next paragraph). From the faceset_EF, 6 happy, 6 angry, and 12 neutral faces were used as primes, and the same 12 neutral faces were used as masks. From the faceset_McB, 17 happy, 17 angry, and 34 neutral faces were used as primes, and the same 34 neutral faces were used as masks. In all face sets, there were 50% males and 50% females, distributed equally across valences. Faces in the faceset_EF were all Caucasian; in the faceset_McB were over 85% Caucasian, and in the faceset_ME were half Asian and half Caucasian. The size of the pictures was 240×290 pixels (about 6×7 cm) for the faceset_EF and the faceset_McB, and 240×245 pixels (about 6×6.25 cm) for the faceset_ME.

The dotted patterns (Fig. 1) were used as masks in half of the trials. They represent a typical monochrome pattern mask used in psychological studies (e.g., Stapel et al., 2002). To create them, pictures of dogs (to avoid any resemblance of faces) were downloaded from the internet, and resized to the width and height of the face-stimuli. They were then converted to black-and-white, scrambled up beyond all recognition, and blurred, using a macro in Adobe Photoshop 7.0.1. None of the dotted pattern masks was used more than once.

[2] In this study, we used pictures from the MacBrain face set where the emotions are displayed with the mouth closed (teeth-showing pictures are available in the set). The set is also referred to as NimStim (Tottenham et al., 2009).

Participants either received no specific instructions on how to approach the task (NONE-condition), instructions to concentrate on visual cues (LOOK-condition), or instructions to concentrate on their own feelings and facial movements (FEEL-condition). The instructions for the LOOK and the FEEL conditions were inspired by those given in the previously mentioned Snodgras et al. (1993) study on the perception of briefly presented words. The instructions for the LOOK-condition were as follows:

> "One strategy for this task is to look hard at where the face is presented, around the fixation cross, for anything you can see. You can sometimes pick up subtle cues that help you identify the face. These cues can be the shape of the mouth or the eyes; things like a smile or a frown or perhaps the look of the area around the eyes."

> The instructions for the FEEL-conditions were as follows:

> "One strategy for this task is to look at the area where the face was presented in a relaxed way and try to sense how you feel about the face. You can sometimes pick up subtle cues that help you identify the face. These cues could be the twitching of your facial muscles; things like a subtle smile on your cheek, or a subtle frown on your forehead. You can also sometimes feel a bit of emotional arousal, or perhaps sense whether the face was positively or negatively inclined towards you."

Six times during the experiment (at the beginning of a new block, see Section 2.3), participants were reminded of the instructed strategy using the following sentences:

> LOOK-strategy: "LOOK hard at the place where the face was presented!"FEEL-strategy: "Try to sense how you FEEL about the face!"NONE-strategy: ""

2.3. Procedure

After participants arrived in the lab, EMG electrodes were placed on the left half of the face. They were positioned according to the guidelines by Fridlund and Cacioppo (1986) and Tassinary et al. (2000) to measure activity over the zygomaticus major (smile) and the corrugator supercilii (frown) (Hjortsjö, 1970). Next, participants were seated in front of a computer monitor with a head-to-screen distance of about 70 cm. The task was explained to the participants via instructions on the screen. They were then assigned to one of the three strategy-conditions using the E-Prime random generator and instructed accordingly, as explained earlier.First, one of the three face sets was selected randomly. It was then selected randomly which stimuli valences are to be discriminated (happy vs. neutral; angry vs. neutral). In each trial, duration (10 ms; 20 ms) and mask type (neutral face; dotted pattern) were selected randomly (drawn from a list without replacement, resulting in an equal number of trials with long and with short durations and with neutral faces and dotted patterns as masks). After all trials of the selected valence discrimination (e.g., happy vs. angry) had been completed, the experiment proceeded with the other valence discrimination (e.g., angry vs. neutral). Before each new valence discrimination task, participants were informed about the task (which two valences may occur) and a reminder of the instructed strategy was displayed (see above).

A trial had the following structure (see Fig. 2): a fixation cross was presented for 2 s to alert participants to the upcoming stimulus (and allow for baseline measurement of facial muscle activity). Then a face was flashed for 10 or 20 ms, immediately followed by a mask, which remained on the screen for 2 s. Participants were then asked: “Which emotion did the briefly presented face display?” Participants indicated whether the face had been emotional (happy or angry, depending on task block) or neutral, using the left and the right CONTROL keys. Assignment of the answers to the response keys was randomized for each subject at the beginning of the experiment and remained constant up from then. When participants had made their decision, a new trial started. There were 120 trials per participant. After the experiment, participants filled out a questionnaire inquiring how they approached the task (open-ended question).

2.4. Apparatus and software

Stimuli were presented on a 17-inch Viewsonic P75f+ CRT Monitor with 100 Hz refresh rate. Experimental software was E-Prime, Version 2.0 (Psychology Software Tools, Pennsylvania, USA). EMG was recorded with a BIOPAC MP150WSW Data Acquisition System (Biopac Systems Inc., California, USA), using the BIOPAC recording software AcqKnowledge, Version 4.0, and BIOPAC EL503 disposable electrodes. Sampling rate was 2000 Hz. Behavioral data were analyzed using the Statistical Software Package for the Social Sciences (SPSS), Version 15 (Lead Technologies, 2006) and Microsoft Excel 2007 (Microsoft Corporation, Washington, USA). The MindWare EMG package, Version 2.52 (MindWare Technologies Ltd., Ohio, USA) was used to extract the EMG signals from the BIOPAC data files, filter (10–1000 Hz filter, see Fridlund and Cacioppo, 1986), and rectify them. They were then analyzed using self-written scripts in MATLAB 2007b (The MathWorks Inc, Massachusetts, USA).

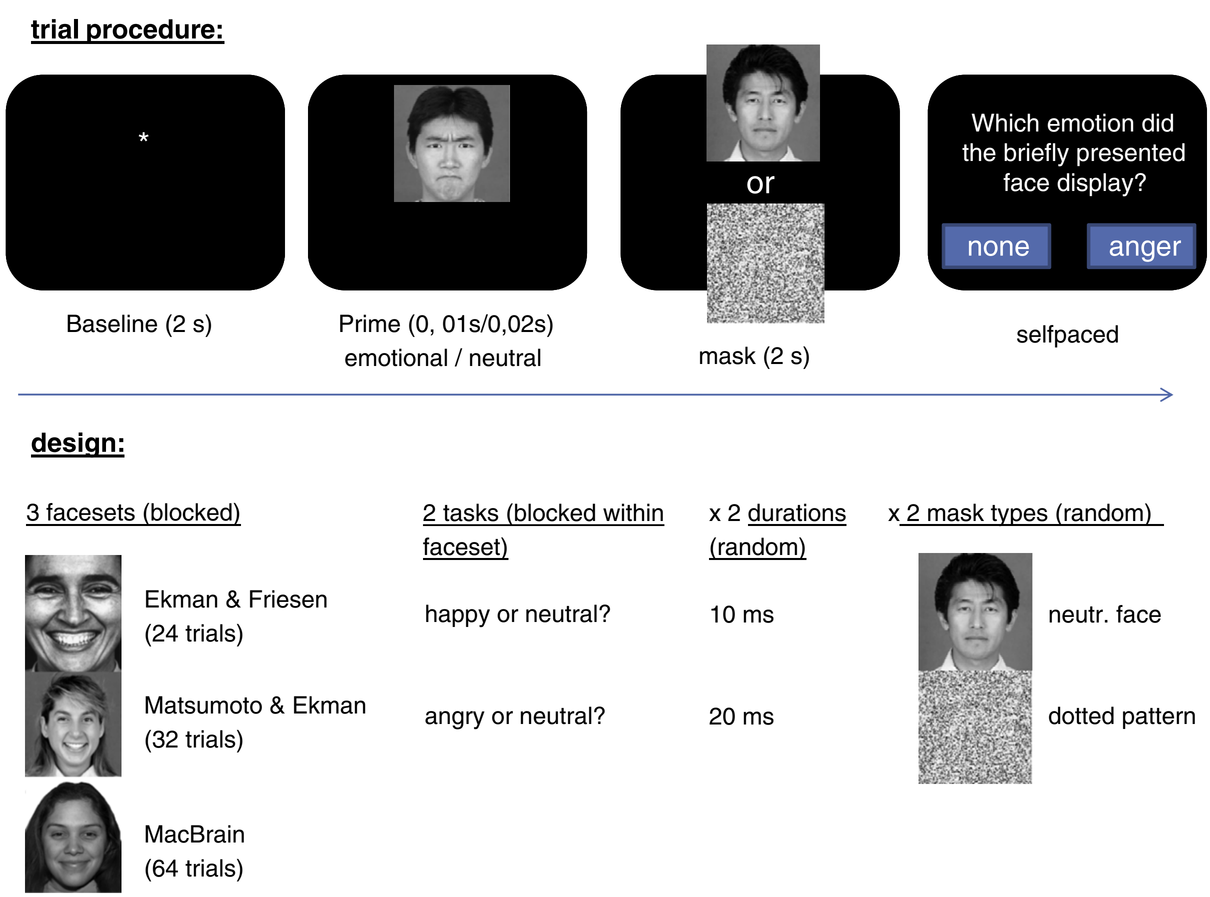

Fig. 2. Procedure of a trial (above) and design of the experiment (below, within-subject).

3. Results

3.1. Data transformations

One subject was removed from the analysis because he always responded with “no emotion”. Response times of the remaining subjects were scanned for outliers. 315 out of 6752 trials (4.67%) were removed because response time was more than two standard deviations away from the individual mean. For the EMG data, outlier/artifact analysis was performed by removing activity that was 2 standard-deviations above or below the individual mean activity of the respective channel. The last 200 ms before the onset of the prime was taken as a baseline and subtracted from the subsequent data points. For statistical tests, muscle activity within the 2 s of mask presentation was averaged. Due to technical problems, physiological data of one subject were lost. Randomization of instructions yielded three groups of roughly identical size ($n_{LOOK} = 18$, $n_{FEEL} = 19$, $n_{NONE} = 20$).

3.2. Behavioral performance and effects of instruction

Mean accuracy across all presentation conditions was 57.2% (SD = 7%), which is significantly better than chance, $t(56) = 7.73$, $p < 0.01$. As discussed later, this performance is driven by the 20 ms condition and the dot mask condition. There were no significant differences between the groups regarding accuracy ($p_{FEEL} = 57.7\%$, $p_{LOOK} = 56.1\%$, $p_{NONE} = 57.1$), $t(35)_{FEEL-LOOK} = 0.4$, $p = 0.35$, $t(37)_{FEEL-NONE} = 0.25$, $p = 0.40$.

Mean response time was 670 ms, SD = 327 ms. There was no overall difference regarding response time ($RT_{FEEL} = 750$ ms, $RT_{LOOK} = 587$ ms, $RT_{NONE} = 667$ ms), $F(2,54) = 1.17$, $p = 0.32$. The difference between FEEL and other conditions (LOOK and NONE) is marginally significant, $t(54) = 1.34$, $p < .1$, suggesting that the instructions had some effect on the subjects' approach to the task.

3.3. Physiological response

Subjects showed a significantly higher corrugator activity (frowning), after angry than happy faces, $t(56) = 4.13$, $p < 0.001$, and neutral faces, $t(56) = 2.83$, $p < 0.01$ (see Fig. 3). After happy faces, participants showed a significantly lower corrugator activity as compared to neutral faces, $t(56) = 2.49$, $p < 0.01$. These effects were independent of instruction (all ps for global or local interactions ≥0.14). Subjects also showed a non-significant tendency towards more smiling (higher zygomaticus activity) after happy than angry faces, $t(56) = 0.98$, $p = 0.16$, or neutral faces, $t(56) = 0.77$, $p = 0.22$. The difference in zygomaticus activity after angry compared to neutral faces was also not significant, $t(56) = 0.49$, $p = 0.31$.

Next, we examined whether the signal from the corrugator can be used to determine what stimulus has been presented using a simple classification rule. To do that, average corrugator activity (arithmetical mean) of each subject over all trials was computed. Trials were then classified according to corrugator activity by applying the following rule: for blocks where subjects had to discriminate between angry and neutral faces, trials with a corrugator activity above the mean were classified as ‘angry’ and trials with a corrugator activity below the mean were classified as ‘neutral’. For blocks where subjects had to discriminate between happy and neutral faces, trials with a corrugator activity (mean of 2 s) below the subject's mean were classified as ‘happy’ and trials with a corrugator activity above the mean were classified as ‘neutral’.[3] Mean accuracy of this classification was M = 51.6%, SD = 0.53%, which is statistically higher than chance, $t(55) = 2.26$; $p = 0.014$.

[3] For this analysis, baseline was computed on the basis of the last 500 ms before stimulus presentation to better correct for stimulus unrelated background muscle activity.

3.4. Effects of different stimulus presentation conditions on behavioral and physiological responses

All variations in stimulus presentation parameters (face set/duration/mask/emotion) had significant effects on behavioral responses (detection accuracy; Fig. 4a). Faces from different sets differed in detection difficulty, $F(55) = 12.24$, $p < 0.01$. Post-hoc mean comparisons (Bonferroni-corrected) showed that expressions from faceset_ME were easier to detect than from faceset_McB, $t(56) = 4.94$, $p < 0.01$. Unsurprisingly, expressions were harder to identify when displayed for 10 ms than 20 ms, $t(56) = 4.95$, $p < 0.01$. Expressions were harder to identify when masked by another face than dotted pattern, $t(56) = 5.93$, $p < 0.01$. Happy vs. neutral faces were easier to discriminate than angry vs. neutral faces, $t(56) = 6.15$, $p < 0.01$ (this difference was not significant in the faceset_McB, $t(56) = .25$, $p = 0.8$). Critically, in none of these conditions did subjects in the FEEL-condition perform significantly better than subjects in the other conditions (all ps > 0.1).

To test the effect of different stimulus presentation conditions on physiological responses, we investigated corrugator activity (Fig. 4b). Reassuringly, in all conditions we found the same ordering of activity, with angry faces producing the strongest corrugator responses, then neutral faces, and then happy faces.

Finally, we analyzed which face sets produced reliable corrugator effects related to different prime valences. The biggest effect was produced by the faceset_ME, $t(55) = 2.35$, $p = 0.01$, see Fig. 4a. The valence effect was also reliable for the faceset_EF, $t(55) = 3.15$, $p < 0.01$. Interestingly, it was not reliable when analyzing only trials from faceset_McB, $t(55) = 0.73$, $p = 0.24$. For the other variations (duration, mask type, emotion), the strength of the physiological reaction paralleled the behavioral performance (see Fig. 4b; and compare Fig. 4a and b).

4. Discussion

The study had several objectives. First, we investigated whether subjects can use changes in their own physiology and subjective feelings to make more accurate judgments about valence of briefly presented emotional faces. This yielded the following main result: simply instructing subjects to pay attention to their own facial muscles and subjective feelings did not suffice to improve detection of emotional stimuli, as compared to subjects who were uninstructed or instructed to look very closely at the screen. The second and related objective was to examine a physiological response while participants are guessing the valence of the briefly presented faces. The main result here was that the EMG activity over the corrugator muscle differentiated between angry, neutral, and happy faces. Classifying the trials according to mean corrugator activity in the 2 s after the briefly presented face worked with above-chance accuracy. The third objective was to examine how behavioral and physiological responses depend on stimulus presentation parameters. All variations in stimulus presentation had significant and parallel impacts on both detection accuracy and physiological response magnitude. In the following sections, we will discuss these results in more detail and give suggestions for future research.

4.1. Effects of instruction

Instructions to base the judgment about outward stimuli on physiological changes and changes in subjective feeling did not improve performance in a forced-choice valence identification task. This is despite the fact that participants were reminded about the instructions 6 times. One interpretation, discussed later below (Section 4.4), is that participants do not have subjective access to fleeting changes in affect and subtle muscle twitches their body generates in response to briefly presented emotional faces. Alternatively, it is possible that, despite

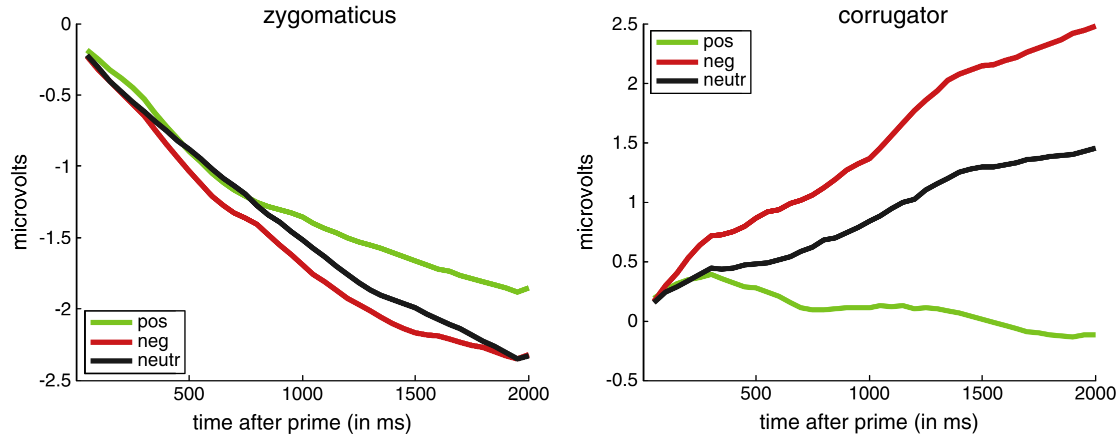

Fig. 3. Activity over the zygomaticus major (left) and corrugator supercilii (right) in the 2 s after presentation of the prime.

reminders, participants did not truly follow the instructed strategy throughout the experiment. This is suggested by the results of the questionnaire in which only a minority of the subjects in the FEEL-condition reported having used a strategy related to emotional or bodily feedback.[4] Ways to increase adherence to the instructions and sensitivity of the subjects to affective changes are discussed below (Section 4.5 Future research directions).

4.2. Physiological response and its predictive validity

On the corrugator supercilii, participants showed the expected response pattern, that is, they showed highest activity after angry faces, medium activity after neutral faces, and lowest activity after happy faces. This pattern has been found in research that used emotional faces as subliminal stimuli (e.g., Rotteveel et al., 2001; Dimberg et al., 2000), that is, without participants being aware of their presence. Our study shows for the first time that this pattern also occurs when subjects deliberately try to discern briefly presented emotional faces in a forced-choice awareness task. It shows us, that the physiological response is robust and largely independent of attentional processes. This is further strengthened by the fact that the direction of attention (inward/outward) does not modulate physiological reactions, as evidenced by similar physiological reactions in the inward-oriented FEEL-condition and the outward-oriented LOOK-condition. This robustness is also in line with findings by Dimberg et al. (2002), demonstrating that the facial reactions are not easily modulated by intentions (see also Lee et al., 2008).

On the zygomaticus major, condition differences followed the expected pattern, but they were not significant. This is surprising, given reports of spontaneous mimicry to subliminal smiles (e.g. Dimberg et al., 2000). This divergence may be due to the fact that our procedures focused participants on detecting the briefly flashed face, rather than "just watching", as in the mimicry studies. This intentional focus on the subliminal face may disturb spontaneous facial reactions to smiles more than facial reactions to anger. We should also acknowledge that in recent experiments in our lab we found some sensitivity issues with the measurement of zygomaticus activity to positive stimuli when using larger, disposable electrodes (BIOPAC EL503) employed in current research.

If trials were classified according to the mean corrugator activity as happy vs. neutral, or angry vs. neutral, an accuracy of 51.6% was reached (statistically above chance). One might argue that this classification is not very precise. But note that this classification is based on a single muscle. If more sources of physiological information were used, accuracy should be improved. It is of course debatable whether untrained subjects are able to monitor a multitude of physiological channels and base inferences about the stimuli on these signals. On the other hand, it is likely that highly trained subjects can perceive the state of their facial muscles with even higher accuracy than that achieved by electromyographic recording. Furthermore, it is notable that a lot of stimulus conditions in the current experiment failed to elicit a significant facial response (e.g., trials with short duration, trials with face-masks, trials from the faceset_McB). A better classification might be achieved in future studies when using only stimuli that elicit a strong facial response. Finally, the classification algorithm that was used was very simple. It is probable that a classification algorithm that regards more parameters of the physiological response than solely the mean (e.g., maximum amplitude, inclination, time-course, non-linear combinations of activity at different muscle sites etc.; see Kim et al., 2004) will lead to higher accuracy. It is, however, doubtful whether such sophisticated computations can be performed by a human interpreter.

4.3. Effects of stimulus presentation on behavioral performance and physiology

Significant effects on detection rate and on physiological response were caused by variations in all four stimulus parameters: (i) face set, (ii) duration (10 ms vs. 20 ms), (iii) mask-type (face vs. dotted pattern), and (iv) valence (happy vs. angry). It is worth highlighting that the strength of the EMG response corresponds well with detection accuracy (compare Fig. 4a and b). Descriptively speaking, behavioral valence detection is good when facial movements are strong. The high parallelism of changes in physiological reaction and behavioral detection to changes in various stimulus dimensions suggests these factors are in close association and are not easily uncoupled by factors (like masking) that sometimes differentially influence motor versus behavioral responses (e.g., Vorberg et al., 2003).

Unfortunately, the causal links behind the observed association between physiology and detection cannot be clarified by the current study. This link could go from physiology to detection or from detection to physiology. Or there could be a common affective process influencing both. For empirical investigations of these links see Hess and Blairy (2001), Niedenthal et al. (2001), Oberman et al. (2007) and Bogart and Matsumoto (2010). For theoretical models, see Goldman and Sripada (2005) and Niedenthal et al. (2005).

[4] Of the 19 subjects who had received the FEEL-instruction, only 4 explicitly mentioned in the questionnaire to have used a strategy of observing their own facial movements or feeling state. However, as mentioned earlier, subjects in the FEEL condition took marginally longer to respond than subjects in the LOOK and NONE conditions (750 ms vs. 627 ms).

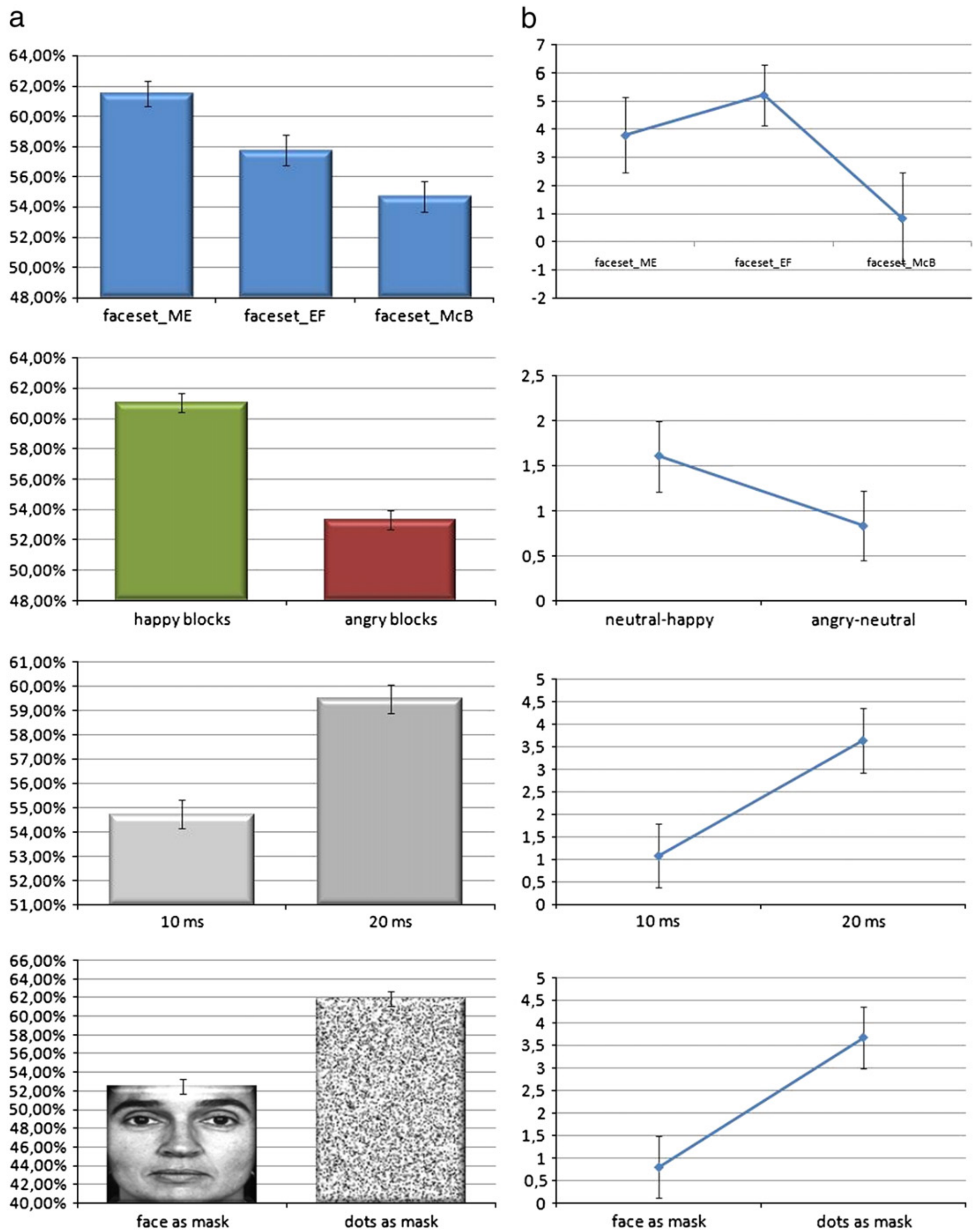

Fig. 4. a) Accuracy (% correct emotion identification) depending on condition. b) Magnitude of emotion-dependent activity differences on corrugator supercilii, computed as act(negative)-act(neutral) + [act(negative)-act(positive)] where act is the muscle activity in microvolts.

For the purposes of our study, the tight link between physiology and detection was somewhat unfortunate, as we aimed to find a condition in which visual strategies fail, but physiological reactions are strong. Such a condition would open opportunities for a FEEL-strategy. However, we found that when detection rates are low, physiological responses are also low. Differences in the face sets pose the only exception to this rule: The face set published by Ekman and Friesen (1976) induced the strongest physiological reactions but had only intermediate detection rates. Thus, a tentative recommendation can be given to use the Ekman and Friesen (1976) face set when such dissociations are demanded by the experimental design. Furthermore, facial reactions to the MacBrain (NimStim) stimulus set were not significant. Thus, researchers may opt to use one of the Ekman sets when strong EMG reactions are required.

EMG and detection responses may vary across face sets for a number of reasons. First, in the MacBrain faces used here happiness was instantiated without the showing of teeth. This might have attenuated the effect of happy faces if the high-contrast of the teeth relative to the surrounding face is an important factor. Second, MacBrain is the only set of the three in which emotion displays were not posed according to a FACS-directed facial action task, but were based on judgments of untrained observers. This may lead to differences in actual emotion intensity (MacBrain angers are less angry) or in emotion purity (MacBrain faces represent emotion blends or different emotions), or both. Third, note the relative size of the relevant features. In the EF set, the size of the mouth, compared to the overall size of the picture, is greater than in other sets. Fourth, the image contrast in the EF set is stronger than the other sets, which could highlight diagnostic features (such as mouth and teeth). Finally, the ME set contains an equal mix of Asian and Caucasian faces, whereas the pictures we used from MacBrain were over 85% Caucasian, and those from Ekman and Friesen were all Caucasian.

It is also worth speculating why a neutral face works better as a mask than dots. First, a neutral face directly competes with relevant features (brow, mouth), diluting the detection and impact of relevant facial action units. An additional level of interference could come from perceptual opponency effects between the neutral face and the priming face (e.g. anger primes may make neutral targets appear happier). This could result from fast, trial-based adaptation processes (Webster et al., 2004) or from slower processes occurring across longer timespans (Arce et al., 2009).

4.4. Subjective feelings, automaticity, and embodiment

In our study, deliberately shifting participants' focus toward their subjective feelings did not improve detection performance. One interpretation is that brief emotional faces fail to induce consciously noticeable affect, as in earlier research which relied on self-report scales of mood (Winkielman et al., 2005b). This interpretation is consistent with evidence that facial expressions are processed largely automatically (Dimberg et al., 2002). The automaticity of facial valence processing is also highlighted by our finding that EMG responses on the corrugator to anger were observed even though participants were fully informed about the presence of the flashing faces, and were focused on a separate task — detection. Of course, the absence of evidence for feelings is not the evidence for absence. Whether the face-induced affect is principally unconscious or only weak and “difficult-to-access” could be revealed by future research with particularly sensitive and trained subjects (see following section).

If affect turned out to be principally unconscious, this would challenge Affect-As-Information explanations of unconscious emotional influences that rely on the assumption that people use their feelings as a guide to judgments (see also Winkielman et al., 1997). Of course, for some brief emotional inducers that are less automatized and perhaps more potent than subliminal faces, the predictions of AAI model may still hold (Schwarz and Clore, 2003).

The implications for theories that postulate the role of facial feedback in emotion detection are more complex. As mentioned, some theories assume that adopting a facial expression generates a change in emotional experience (Laird, 1974; Zajonc et al., 1989). Such theories are challenged by the current findings, which suggest the absence of such conscious feelings. Same is true for older models of embodiment where people explicitly ‘read out’ their muscular twitches. However, more recent embodiment theories propose that motor processes involved in stimulus processing can be unconscious, as they work automatically as an intrinsic part of the perception process (Niedenthal et al., 2005; Oberman et al., 2007). As such, perhaps focusing people on their facial responses will not help and may even disrupt an automatic process.

4.5. Future research directions

As mentioned earlier, one issue with the present study might have been insufficient compliance with the instructions (despite multiple reminders). Thus, future experiments should employ designs in which subjects are more motivated to follow the strategies (e.g., by administering strategies within-subject and giving monetary incentives for the performance in the best block).

Another problem might have been insufficient attention or sensitivity to bodily changes or changes in subjective feeling. One way to increase this sensitivity might be Vipassana-mediation. This ancient and widespread meditation technique is thought to increase sensitivity to changes in the own body and the emotional state (e.g., Hart, 1987; Kabat-Zinn, 2003; Sze et al., 2010). Recent neuropsychological evidence demonstrates the effectiveness of Vipassana-mediation, as evidenced by improved perception (e.g., Cahn and Polich, 2009; Slagter et al., 2007) and increased cortical thickness in the insula and the somatosensory cortex (Hölzel et al., 2008; Lazar et al., 2005). This might make it promising to investigate the perception of brief emotional faces in trained Vipassana-meditators.

A related possibility is that participants are actually conscious of changes in their bodily reaction and subjective feelings, but these reactions do not reach metaconsciousness — or the state of being explicitly articulated as “my own reactions at this moment” (Winkielman and Schooler, 2011). Addressing this possibility would involve giving participants training in on-line monitoring and verbally articulating one's feeling changes.

Yet another way to increase subjects' sensitivity to the state of their facial muscles would be to devise a biofeedback-training before the perception task. In this biofeedback-training, subjects would try to perceive changes in their facial muscle state. By measuring muscle activity via EMG and feeding the actual muscle activity back to the participants, perceptual sensitivity may be increased (e.g., Norris et al., 2007, p.180).

Of course, the aforementioned research strategies (investigating trained meditators; enhancing meta-conscious skills, devising biofeedback-training) would no longer investigate what humans typically do when perceiving brief emotional stimuli, or how this behavior can be changed by simple instruction. Rather, they investigate the borders of human potential. Besides being interesting by itself, such a research endeavor may also lead to interesting theoretical insights about the nature of emotion and cognition in general. If trained subjects were actually able to accurately perceive the emotional valence of subliminal stimulus by observing their physiological signals, this would tell us a lot about the way emotional information is represented in the mind–body-system.

Finally, in the current study, the FEEL instructions were designed to encourage subjects to use all sorts of emotion-related signals in themselves (movements, feelings, etc.). We took this shotgun approach, hoping that this would increase the utility of the internal-focus strategy. If future studies are successful in demonstrating the utility of emotional feedback in the perception of briefly presented stimuli, a next step would be to disentangle the contributions of attention to bodily feedback and attention to subjective feeling.

4.6. Practical implications

If people were able to perceive subconscious stimuli by concentrating on non-visual signals evoked by these stimuli, they might be able to guard against subliminal manipulation. Furthermore, use of feedback from subjective feeling and physiology may help to improve the identification of microexpressions. This may be useful both for everyday empathetic behavior (O'Sullivan and Ekman, 2008; Matsumoto et al., 2000) and to improve the 250-million-dollar security programs currently run at US-Airports (see Ekman, 2006; Cratty, 2010). Finally, emotional influences by non-attended emotional stimuli are ubiquitous (Bargh and Chartrand, 1999). A heightened sense of awareness of these stimuli and their effects may help to improve the understanding and regulation of our emotions throughout the day, as advocated by mindfulness-focused experts of mental health in Eastern and Western psychology (Hart, 1987; Kabat-Zinn, 2003).

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