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Research Report

UNCONSCIOUS FACIAL REACTIONS TO EMOTIONAL FACIAL EXPRESSIONS

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Abstract—*Studies reveal that when people are exposed to emotional facial expressions, they spontaneously react with distinct facial electromyographic (EMG) reactions in emotion-relevant facial muscles. These reactions reflect, in part, a tendency to mimic the facial stimuli. We investigated whether corresponding facial reactions can be elicited when people are unconsciously exposed to happy and angry facial expressions. Through use of the backward-masking technique, the subjects were prevented from consciously perceiving 30-ms exposures of happy, neutral, and angry target faces, which immediately were followed and masked by neutral faces. Despite the fact that exposure to happy and angry faces was unconscious, the subjects reacted with distinct facial muscle reactions that corresponded to the happy and angry stimulus faces. Our results show that both positive and negative emotional reactions can be unconsciously evoked, and particularly that important aspects of emotional face-to-face communication can occur on an unconscious level.*

Consistent with Darwin's (1872) proposition that facial expressions of emotion have a biological basis, it has been proposed that they are controlled by particular "facial affect programs" (Tomkins, 1962). It has further been suggested that humans are predisposed to react emotionally to facial stimuli (e.g., Buck, 1984; Dimberg, 1997) and, in particular, to have facial reactions to facial expressions (Dimberg, 1982, 1997). Studies on nonhuman primates indicate that the evocation of emotional reactions to a threat display is controlled by "innate releasing mechanisms" (Sackett, 1966) and is underpinned by specific neurons that selectively respond to facial stimuli (Hasselmo, Rolls, & Baylis, 1989). Recent studies have also found that the neural activity in the human amygdala differs when people are exposed to different facial stimuli (Morris, Öhman, & Dolan, 1998; Whalen et al., 1998) and that damage to the amygdala impairs the recognition of facial expressions (Adolphs, Tranel, Damasio, & Damasio, 1994).

If facial expressions are generated by biologically given affect programs (Tomkins, 1962), one would expect these programs to operate automatically by eliciting facial muscle reactions spontaneously, quickly, and independently of conscious cognitive processes (Dimberg, 1997; Ekman, 1992). We previously reported that when people are exposed to pictures of emotional facial expressions, they spontaneously and rapidly react with distinct facial electromyographic (EMG) reactions in muscles relevant for positive and negative emotional displays (e.g., Dimberg, 1982, 1990). Pictures of happy faces spontaneously evoke increased *zygomatic major* muscle activity, whereas angry faces evoke increased *corrugator supercilii* muscle activity, after only 500 ms of exposure (e.g., Dimberg & Thunberg, 1998). The zygomatic muscle elevates the lips to form a smile, whereas the corrugator muscle knits the eyebrows during a frown

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(Hjortsjö, 1970). It has been consistently reported that these muscles more generally distinguish between positive and negative emotional reactions (e.g., Cacioppo, Petty, Losch, & Kim, 1986; Dimberg, 1990).

A critical characteristic of an automatic reaction, besides being spontaneous and rapid, is that it can occur without attention or conscious awareness (e.g., Schneider & Shiffrin, 1977; see Kihlstrom, 1987, for a review and discussion of the impact of nonconscious mental mechanisms on conscious cognition and action). According to Zajonc (1980), the initial response to affective stimuli can be generated without conscious cognitive processes. Thus, if emotional reactions in a face-to-face situation are automatically controlled by particular affect programs, one could expect these reactions to be elicited even without the involvement of conscious processes. To explore this question, in the present study, we used the backward-masking technique to unconsciously expose subjects to pictures of different facial expressions. This technique was used by Marcel (1983), who successfully detected unconscious semantic priming between words. The technique has also been successful in unconsciously exposing subjects to facial expressions (e.g., Dimberg & Öhman, 1996; Morris et al., 1998; Murphy & Zajonc, 1993; Whalen et al., 1998). Thus, in the present study, three groups of subjects were unconsciously exposed to a happy, neutral, or angry face, respectively, while their facial EMG activity in the *zygomatic major* and the *corrugator supercilii* muscle regions was measured. After 30 ms, these target stimuli were turned off, and the subjects were immediately exposed to a new picture of a neutral face, the masking stimulus, which had a duration of 5 s. This procedure prevented the subjects from consciously perceiving the target stimuli.

We predicted that if distinct facial reactions can be unconsciously elicited, then the masked happy target face would evoke larger *zygomatic major* muscle activity and lower *corrugator supercilii* activity than the masked angry target face. The neutral target face was expected to evoke a facial EMG response pattern with an intensity somewhere between the patterns for the happy and angry faces. Because earlier research (e.g., Dimberg & Thunberg, 1998) very clearly demonstrated that distinct facial reactions to facial stimuli are most clear-cut during the period 500 to 1,000 ms after stimulus onset, the critical effects in the present study were expected to be obtained during this period.

METHOD

Subjects

The subjects were 120 students at Uppsala University. They were randomly assigned to three different groups ($n = 40$), the happy-neutral, the neutral-neutral, and the angry-neutral groups. The groups differed only in respect to the type of stimuli to which they were unconsciously exposed. Thus, the subjects in the happy-neutral group

were unconsciously exposed to happy target stimuli, the subjects in the neutral-neutral group were unconsciously exposed to neutral target stimuli, and the subjects in the angry-neutral group were unconsciously exposed to angry target stimuli.

Apparatus, Stimuli, Procedure, and Data Scoring

The subjects were individually tested in a laboratory room, with pictures projected onto a screen 2 m in front of them. The picture size was 25 × 35 cm. The facial stimuli were selected from Ekman and Friesen's *Pictures of Facial Affect* (1976). Nine angry, 9 happy, and 10 neutral facial stimuli were used. The stimuli were combined in 10 different target-mask complexes for each group. Thus, only 4 subjects in each group were exposed to identical stimulus combinations. The target and masking faces were of the same sex, and there were equal numbers of male and female combinations. Each subject was repeatedly exposed to one target-mask combination. The neutral masking faces, however, were selected so that the three groups were exposed to identical masking faces. That is, the three groups were unconsciously exposed to different conditions, but consciously exposed to similar neutral faces. The target-mask complex was exposed six times, with intertrial intervals varying between 25 and 35 s. To ensure that the subjects looked at the pictures, we preceded each trial with a low-intensity (<42 dBA) warning noise. The exposure durations, 30 ms for the target stimuli and 5 s for the neutral masking stimuli, were determined by shutters controlled by Contact Precision Instruments (CPI) hardware and software.

Even though earlier research very clearly had shown that people are not aware of a backwardly masked 30-ms target face (e.g., Dimberg & Öhman, 1996; Morris et al., 1998; Whalen et al., 1998), a pilot study was conducted in order to further confirm that the experimental parameters were effective in preventing conscious recognition of the target faces. In this pilot study, 20 subjects were exposed to conditions similar to those in the present study, except that the subjects were explicitly told that each neutral face was preceded by a happy face, an angry face, or another neutral face. Despite their explicit knowledge about these preceding faces, none of these subjects could report, for any of the presentations, that they had perceived any facial stimuli except for the neutral masking faces. To further confirm that the subjects in the experiment were not aware of the target stimuli, we interviewed them carefully after the experiment to determine if they had seen any targets. None of the subjects reported that they had seen the target faces. This was true even immediately after they had rated the target-mask stimuli (see the next paragraph) and after they were told about the true purpose of the experiment. Finally, all subjects were asked if they had perceived any light phenomenon or motion in the pictures (which could be the case if the target-mask stimulus faces did not overlap sufficiently). Only 2 subjects reported this, and even though these subjects did not perceive the target faces, their data were excluded and replaced by the data for 2 new subjects. Thus, we conclude that the experimental parameters were effective in preventing conscious recognition of the target faces.

Directly after the experiment, each subject was exposed to one presentation of the target-mask complex that had been presented to him or her during the experiment. Subjects were instructed to rate how angry and happy they experienced the target-mask complexes, on a scale from 0 to 9. These ratings did not differ between the groups for any of the rating scales, $Fs(2, 117) < 1$. The means for the ratings

ranged from 1.9 to 2.5, indicating that the subjects overall experienced the target-mask stimulus complexes as relatively neutral. Thus, contrary to the facial EMG reactions (see Results), the experience of the neutral masking faces was not influenced by the targets.

Facial EMG activity was measured by bipolarly attached miniature electrodes over the respective muscle regions (Fridlund & Cacioppo, 1986) on the left side of the face. The raw EMG signals were measured with CPI amplifiers and were further analyzed with contour-following integrators with a time constant of 20 ms. The integrated signals were digitized by a 12-bit analogue-to-digital converter and were stored on a personal computer with a sampling frequency of 200 Hz.

To conceal the recording of facial muscle activity, we used a cover story, telling the subjects that their sweat gland activity was to be measured. After the experiment, the subjects were asked if they were aware of the fact that their facial muscle activity had been measured. No subjects realized the true purpose of the electrodes, which implies that they were not even aware that their facial muscle activity was of interest. After the interview, they were informed about the true purpose of the study.

Facial reactions were scored and averaged in 100-ms intervals during the first second of exposure and were expressed as change in activity from the prestimulus levels, defined as the activity during the last second before stimulus onset. A separate analysis of variance (ANOVA) was performed for each muscle region. Before the ANOVAs, the data were collapsed over trials.

RESULTS

After 500 ms of exposure, the three groups reacted differently with both the *zygomatic major* and the *corrugator supercilii* muscles, $Fs(2, 117) > 3.14$, $p < .05$. Data for the response of the *zygomatic major* muscle are given in Figure 1. As the figure shows, the happy-neutral group reacted with a larger *zygomatic major* muscle reaction than did the angry-neutral group during the 500- to 1,000-ms period, $t(117) = 3.71$, $p < .001$, whereas the response magnitude for the neutral-neutral group was intermediate.

The *corrugator supercilii* muscle displayed a quite different response pattern (see Fig. 2). Note that all three groups reacted with a sudden increase during the initial 500 ms; during this period, the responses of the three groups did not differ. During the 500- to 1,000-ms period, however, the happy-neutral group reacted with lower *corrugator supercilii* muscle activity than the angry-neutral group, $t(117) = 3.57$, $p < .001$, whereas the response for the neutral-neutral group was again intermediate (Fig. 2).

Furthermore, a priori t tests indicated that the corrugator muscle response was larger to angry-neutral faces than to neutral-neutral faces, $t(117) = 2.03$, $p < .03$, as well as being larger to neutral-neutral than to happy-neutral faces, $t(117) = 1.68$, $p < .05$. Contrary to the corrugator muscle, the zygomatic muscle had a larger response to neutral-neutral than to angry-neutral faces, $t(117) = 1.96$, $p < .05$, and also had a larger response to happy-neutral than to neutral-neutral faces, $t(117) = 1.62$, $p < .06$.

DISCUSSION

Our data show that despite the fact that the three groups were exposed to identical neutral faces, they responded with facial response
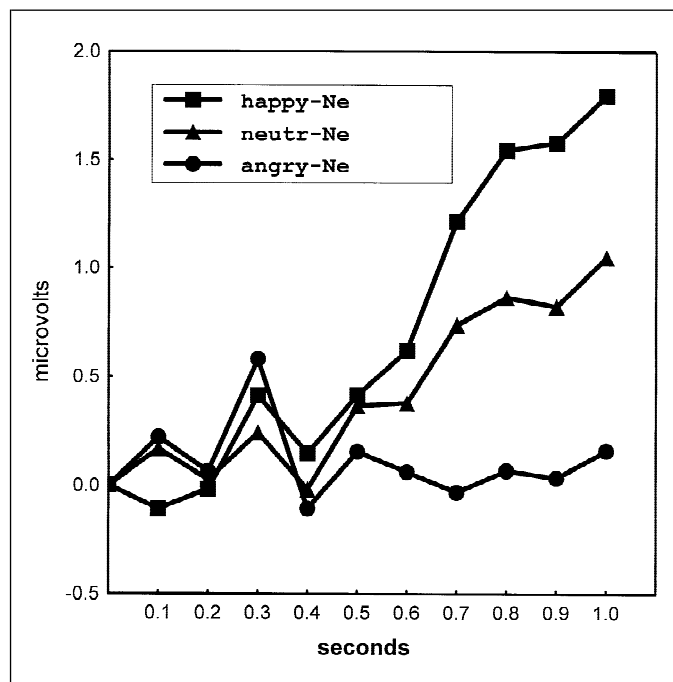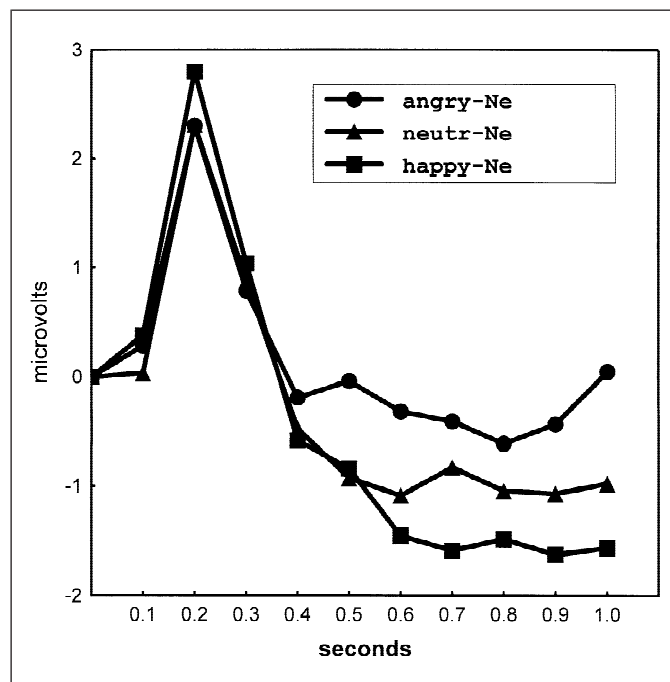
Fig. 1. Mean facial electromyographic response for the *zygomatic major* muscle, plotted in intervals of 100 ms during the first second of exposure. Three different groups of participants were exposed to identical neutral faces ("Ne"), preceded by unconscious exposure of happy, neutral ("neutr"), or angry target faces, respectively.

Fig. 2. Mean facial electromyographic response for the *corrugator supercilii* muscle, plotted in intervals of 100 ms during the first second of exposure. Three different groups of participants were exposed to identical neutral faces ("Ne"), preceded by unconscious exposure of angry, neutral ("neutr"), or happy target faces, respectively.

patterns corresponding to the masked target stimuli. In fact, the different facial reactions were similar, both in shape and in rapidity, to those obtained in earlier studies in which the participants were aware of the first second of exposure to happy and angry faces (e.g., Dimberg & Thunberg, 1998). These results suggest that the initial facial reactions are controlled by rapidly operating affect programs that can be triggered independently of conscious cognitive processes. Thus, the present study shows that it is possible to unconsciously evoke a physiological response that is more than an attention-arousal response (e.g., an aversively conditioned skin conductance response to angry faces, as in Dimberg & Öhman, 1996). That is, the present results demonstrated, in particular, that distinct positive and negative facial emotional response patterns can be spontaneously evoked without awareness of the positive and negative eliciting stimuli. In addition, the present results support the proposition that important aspects of emotional face-to-face communication can occur on an unconscious level.

It is not evident from the present study to what degree the different facial reactions originate in unconscious mimicking behavior, or to what degree the facial reactions initially are readouts of underlying emotional states. In fact, one could argue that the response to a happy target stimulus could well be confounded by mimicry and a reciprocating response, both resulting in increased zygomatic activity. Furthermore, the corrugator response to angry targets could be anger, which also could be confounded by mimicry and a reciprocating response, but the corrugator response could also be a fear response. In earlier research, we found that both mimicry-contagion and emotional reactions occur when people are exposed to facial stimuli (Lundquist & Dimberg, 1995). One way to further elucidate this question would

therefore be to include subjective measures and other facial EMG sites. This procedure would, at least for angry stimuli, reveal to what degree the different facial reactions originate in mimicking behavior or underlying emotional states. Whether the facial reactions originate in mimicry or underlying emotional states, however, it is interesting to relate the present findings to the facial-feedback hypothesis, which states that facial muscle activity is essential for the occurrence of emotional experience (e.g., Buck, 1980). Our findings demonstrate that facial reactions can be elicited both rapidly and without conscious awareness. Thus, according to the facial-feedback hypothesis, the evocation of these facial reactions may constitute an important mechanism and form the basis for affecting emotional experience.

Note that the corrugator muscle activity was certainly higher in response to angry target faces than in response to neutral and happy target faces in the present study. Unlike in some earlier studies (e.g., Dimberg, 1982, 1990), the response was not an absolute increase in comparison to the prestimulus level. However, a similar phenomenon was detected in other studies that, like the present study, used a warning signal before the presentation of the angry and happy stimuli (Dimberg, Hansson, & Thunberg, 1999). Thus, a plausible explanation of this phenomenon is that the corrugator muscle is influenced by preparatory activity, which obscures an increased activity in comparison with the prestimulus levels, but does not obscure the fact that angry faces evoke larger corrugator activity than neutral and happy faces.

Furthermore, note that all three groups reacted with a sudden increased corrugator response during the first 500 ms, with a peak at 200 ms, and this response did not differ between the groups. This initial response component was not apparent for the zygomatic muscle. It is

uncertain what these reactions reflect. The fact that all stimuli evoked this early corrugator response, and that a similar initial response component was detected in earlier studies (e.g., Dimberg & Thunberg, 1998), indicates that this is a general response that does not differentiate between the emotional content of the stimuli, but rather reflects a nonspecific effect of visual stimulation. One plausible interpretation is that it reflects a startle reaction, which typically occurs within 200 ms (e.g., Ekman, Friesen, & Simons, 1985), and which also can be elicited by rather weak stimuli (Blumenthal & Goode, 1991).

Finally, the present results are consistent with neural models proposing that emotional stimuli can be processed both rapidly and automatically (LeDoux, 1996). Furthermore, our data concur with recent studies demonstrating that unconscious presentation of negative facial stimuli (Morris et al., 1998; Whalen et al., 1998) evokes increased neural activity in the human amygdala, which probably plays a crucial role in the evocation of emotional responses (LeDoux, 1996). One question for future research to explore is the degree to which the amygdala is involved in the unconscious control and evocation of facial reactions in face-to-face situations.

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