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Facial reactions to emotional stimuli: Automatically controlled emotional responses

Ulf Dimberg, Monika Thunberg, and Sara Grunedal

Department of Psychology, Uppsala University, Sweden

Based on a model in which the facial muscles can be both automatically/involuntarily controlled and voluntarily controlled by conscious processes, we explore whether spontaneously evoked facial reactions can be evaluated in terms of criteria for what characterises an automatic process. In three experiments subjects were instructed to *not* react with their facial muscles, *or* to react as quickly as possible by wrinkling the eyebrows (frowning) or elevating the cheeks (smiling) when exposed to pictures of negative or positive emotional stimuli, while EMG activity was measured from the corrugator supercilii and zygomatic major muscle regions. Consistent with the proposition that facial reactions are automatically controlled, the results showed that the corrugator muscle reaction was facilitated to negative stimuli and the zygomatic muscle reaction was facilitated to positive stimuli. The results further showed that, despite the fact that subjects were required to not react with their facial muscles at all, they could not avoid producing a facial reaction that corresponded to the negative and positive stimuli.

It has previously been proposed that emotional expressions have a biological basis (Darwin, 1872; Ekman, 1973; Izard, 1977; Tomkins, 1962) and that facial expressions are generated by biologically given *affect programmes* (Tomkins, 1962). It has further been suggested that people are predisposed to react emotionally to different types of emotional stimuli (Buck, 1984; Dimberg, 1983, 1997a) and that the facial muscles function as a read-out system for emotional reactions (e.g., Buck, 1984; 1994; Cacioppo, Petty, Losch, & Kim, 1986; Dimberg, 1990; McHugo, Lanzetta, Sullivan, Masters, & Englis, 1985; Schwartz, Fair, Salt, Mandel, & Klerman, 1976). It has been proposed in particular that people are predisposed to produce distinct facial muscle reactions to different facial expressions (Dimberg, 1982, 1990; 1997a). Consistent with these propositions, studies on nonhuman primates suggest that, for example, the

Correspondence should be addressed to Ulf Dimberg, Department of Psychology, Uppsala University, Box 1225, S-751 42 Uppsala, Sweden; e-mail: Ulf.Dimberg@psyk.uu.se

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evocation of emotional reactions to a threat display is controlled by innate mechanisms (Sackett, 1966), and further, that specific neurons selectively respond to emotional stimuli such as facial expressions (Hasselmo, Rolls, & Baylis, 1989).

Even though it has seriously been questioned whether basic emotions exist at all and are manifested as particular facial expressions of emotion (e.g., see Fridlund, 1994; Ortony & Turner, 1990; Russell, 1994), many researchers agree that there is convincing support for the notion that basic emotions exist that are manifested as both distinct facial expressions (e.g., Ekman, 1992a; Izard, 1994) and different autonomic response patterns (e.g., Levenson, Ekman & Friesen, 1990). The question of whether basic facial expressions exist is intimately related to the proposition that facial reactions/expressions are controlled by particular facial affect programmes (e.g., Ekman, 1973; Izard, 1977; Tomkins, 1962). We might argue that if facial reactions are generated by biologically given affect programmes (Tomkins, 1962), these programmes would be expected to operate quickly and automatically (Dimberg, 1997a; Ekman, 1992b). We have previously reported that when people are exposed to pictures of different negative and positive emotional facial expressions, they spontaneously (e.g., Dimberg, 1982; 1990, 1997b; Lundquist & Dimberg, 1995) and rapidly (Dimberg, 1997b; Dimberg & Thunberg, 1998) produce distinct facial electromyographic (EMG) reactions in muscles relevant to positive and negative emotional displays. For instance, when subjects are exposed to happy faces they react with increased zygomatic major muscle activity (the muscle used when smiling, Hjorstsjö 1970; Fridlund, 1994), whereas angry facial stimuli evoke increased corrugator supercilii muscle activity (the muscle used when frowning). This is also true for other emotional stimuli such as pictures of snakes (Dimberg, 1986; Dimberg, Hansson & Thunberg, 1998). This may be taken as an indication that humans are also predisposed to react emotionally to particular affective stimuli, and the results are further consistent with the proposition that facial reactions are automatically controlled (e.g., Dimberg, 1997a, b).

One way to approach the question of whether facial reactions are automatically controlled could be to apply the concepts from cognitive psychology that differentiate between *automatic* and *consciously controlled* processes (Posner & Snyder, 1975; Schneider & Shiffrin, 1977; for a recent review and discussion see Bargh & Chartrand, 1999). According to Zajonc (1980), the evaluation of affective stimuli can be automatic in the sense that it does not require the involvement of conscious cognitive processes. Consistent with that proposition, research has in fact revealed that unconscious presentation of facial stimuli is sufficient to evoke different aspects of emotional responding (e.g., Esteves, Dimberg, & Öhman, 1994; Murphy & Zajonc, 1993; Whalen et al., 1998). Note, however, that the present study is not focused on the question of whether emotional stimuli are unconsciously processed, but rather on whether distinct facial muscle reactions are automatically controlled.

Traditional markers for what characterises an automatic process are that it occurs spontaneously and effortlessly, without conscious attention and that it occurs rapidly (Schneider & Shiffrin, 1977). One further critical marker of an automatic reaction is that, once evoked, it is difficult to voluntarily interrupt or completely restrain, and it is therefore more or less ‘‘unavoidable” (Schneider & Shiffrin, 1977), and consequently tends to interfere with consciously controlled activities.

If we evaluate our earlier results (e.g., Dimberg, 1982, 1990) in terms of the criteria given above, we might conclude the following. First, the subjects in these experiments reacted spontaneously, effortlessly, and without conscious attention (i.e., in these studies, the only instruction given was to look at the different pictures). Subjects were *not* instructed to move their facial muscles. In fact, they were told a cover story that their sweat gland activity was being measured, which implies that they were *not even aware* that their facial muscle activity was of interest. Furthermore, it is clear that the facial EMG responses were relatively *rapidly* evoked. Distinct facial reactions could be elicited as early as after 300–400 ms of stimulus exposure (Dimberg, 1997b; Dimberg & Thunberg, 1998). Consequently, previous data are consistent with several of the first, above-mentioned criteria characterising an automatic process.

However, support for the last, and perhaps one of the most important of these criteria is not immediately clear. Therefore, the present series of experiments was designed in order to evaluate whether spontaneously evoked facial reactions tend to interfere with consciously controlled facial activities and/or are hard to voluntarily interrupt or completely restrain.

In contrast to earlier studies (e.g., Dimberg, 1990) in which subjects were instructed to sit calmly and only pay attention to the pictures, participants in the present experiments were instead required to be active and *voluntarily* control their facial muscles in two different kinds of conditions. That is, in one type of condition they were instructed to voluntarily react as quickly as possible and in particular ways to particular stimuli (e.g., angry and happy faces), whereas in a second type of condition, they were instructed to *not* react at all with their facial muscles. The main purpose of the first task, ‘‘Instructed to react’’, is to evaluate whether there is any tendency to involuntarily react with a specific, pre-attuned or automatically controlled response pattern, that initially interferes by either *facilitating* or *impairing* the task of consciously controlling the facial muscles. In the second task, ‘‘Instructed to not react’’, we can further evaluate whether there is an early evoked response which is difficult to voluntarily interrupt or completely restrain.

Based on the fact that involuntary and voluntary facial actions are under different neural controls (e.g., Ekman, 1984; Fridlund, 1994; Gellhorn, 1964; Rinn, 1984), a simple model is given in Figure 1, illustrating how facial reactions are automatically/involuntary evoked and voluntary controlled by conscious cognitive processes. This model is not intended to be complete or to

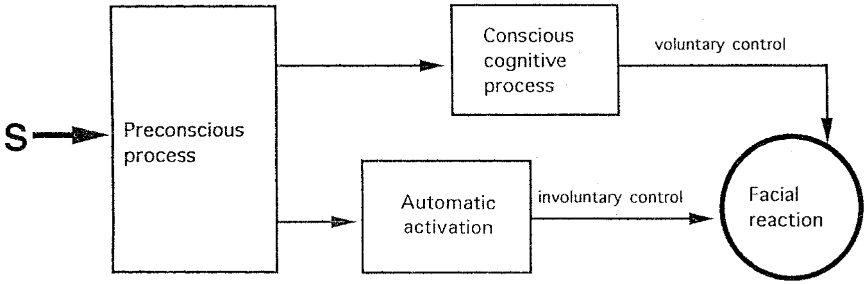

Figure 1. A simple model describing how facial reactions are controlled by voluntary and involuntary processes (see text for an explanation).

describe all processes involved in the elicitation of emotional responses, but rather to illustrate two important factors controlling facial behaviour that are the focus of the present experiments. In the present model, for instance, it is assumed that the first appraisal/evaluation of the emotional significance of the stimuli occurs at a preconscious, automatic level (e.g., Zajonc, 1980), and the model should be easy to incorporate into more complex models of the evocation of emotional reactions (e.g., Öhman, 1993).

EXPERIMENT 1

In Experiment 1, participants were asked, in different conditions, either to frown at angry faces and smile at happy faces *or* the opposite (i.e., to frown at happy faces and smile at angry faces), whereas facial EMG was measured from the corrugator supercilii and zygomatic major muscle regions. The logic behind this manipulation is that if specific facial reactions are initially automatically generated, then these reactions should interfere with ongoing activity to voluntarily control the facial muscles. Because the task of voluntarily frowning at angry faces and smiling at happy faces is assumed to be congruent with a preprogrammed response tendency, the voluntary reaction should be enchanced as compared to the incongruent task (i.e., frowning at happy faces and smiling at angry faces). In other words, it should initially be easier to voluntarily react with the corrugator muscle to angry faces and the zygomatic muscle to happy faces than vice versa, and consequently, it was predicted that the corrugator muscle response should initially be larger to angry than to happy faces, and that the zygomatic muscle response should initially be larger to happy than to angry faces. Because earlier studies have consistently shown that distinct facial reactions to facial stimuli during the first second of exposure are most clear-cut during the period 500–1000 ms after stimulus onset (Dimberg, 1997b; Dimberg & Thunberg, 1998), the critical effects in the present study were expected to be obtained during this interval.

Method

Subjects

A total of 48 subjects, students at Uppsala University, participated in the experiment. The mean age was 24 years, ranging from 20 to 35 years.

Apparatus

The subjects were individually tested in a sound-attenuated room. They were exposed to slides of angry and happy faces projected onto a screen. The slides were selected from Ekman and Friesen's (1976) *Pictures of facial affect*. The distance between subject and screen was 1.5 m and the picture size 30 × 45 cm. The exposure times were controlled by an electronic timer that, together with all other equipment, was situated outside the room. Facial EMG activity was bipolarly measured with Beckman miniature Ag/AgCl electrodes. Before being attached over the corrugator supercilii and the zygomatic major muscle regions (Fridlund & Cacioppo, 1986), the electrodes were filled with Beckman electrode paste. To reduce the electrode site impedance to less than 10 kOhm, the electrode sites were cleaned with alcohol and mildly rubbed with electrode paste prior to application. The muscle activity was detected using Coulbourn Hi Gain Amplifiers, with the high pass filter set to 10 Hz and the low pass filter set to 1000 Hz. The EMG signal was integrated with Coulbourn Contour Following Integrators with a time constant of 20 ms. The signal was transformed by a Coulbourn 12 bit A/D converter to an IBM XT with a sample frequency of 100 Hz. The facial EMG data were collected during one prestimulus second and during the first second after stimulus onset. The response was expressed as the difference in mean activity between the prestimulus level and the mean activity level during each subsequent 100 ms interval.

Procedure

Subjects were first told that the aim of the study was to detect how quickly people are able to voluntarily react with their facial muscles to facial stimuli. Electrodes were then attached over the corrugator supercilii and the zygomatic major muscle regions. The subjects participated in two conditions each, and were given different instructions in a balanced order. In one of the conditions, they were instructed to react as quickly as possible to each stimulus by frowning when shown a picture of an angry face and by smiling when exposed to a happy face; in the other condition they were asked to react by frowning when exposed to a happy face and by smiling when shown an angry face.

The subjects were exposed to 12 different pictures, 6 from each category, presented in a randomised order. The exposure time was 8 s with intertrial intervals of 25–35 s. For each subject, the same picture series was used in both conditions.

Design and analysis

Before analysis, the data were collapsed across the respective six trials. Thus, the basic design was three-factorial, with Emotion (angry vs. happy face), Instruction (frown at angry face/smile at happy face vs. frown at happy face/smile at angry face), and Interval (10×0.1 s) as within-subject factors. Separate ANOVAs were performed for each muscle region, and for those stimuli to which the subjects were instructed to react. Separate analyses were also added for the muscle region with which the subjects were not expected to react in the different conditions. Because repeated-measures F-tests are likely to result in positively biased tests, Geisser and Greenhouse conservative F-tests were used by reducing the degrees of freedom (e.g., Kirk, 1968). Thus, for all comparisons the degrees of freedom for treatments and error terms were 1 and $n-1$, respectively (e.g., Kirk, 1968).

Results

For the corrugator supercilii and the zygomatic major muscles, the facial EMG reactions during the first second of exposure, when the participants were instructed to react with these same facial muscles, are presented in the left and right panels of Figure 2, respectively. As can be seen in the left panel, there was overall increased corrugator supercilii activity as a function of time intervals, $F(1, 47) = 183.36, p < .001$, which was an effect of the fact that the subjects were instructed to react to both stimuli by frowning. Importantly, however, and as can also be seen in the left panel, the response was larger to angry than to happy faces as indicated by both the Emotion factor, $F(1, 47) = 21.49, p < .001$, and the Emotion $\times$ Interval factor, $F(1, 47) = 12.49, p < .001$. As predicted, and shown in Figure 2, this difference was most clear-cut during the 500–1000 ms intervals.

As can be seen in the right panel of Figure 2 and as indicated by the Interval factor, $F(1, 47) = 310.50, p < .001$, the subjects followed the instruction to react to both stimuli with the zygomatic major muscle (to smile). Importantly, however, and contrary to the effect for the corrugator muscle response, the zygomatic major muscle response was larger to happy than to angry stimuli, which was indicated by both the Emotion factor, $F(1, 47) = 239.786, p < .001$, and the Emotion $\times$ Interval factor, $F(1, 47) = 83.25, p < .001$. As predicted and shown in the right panel of Figure 2, this effect was particularly clear-cut during the 500–1000 ms interval.

To explore whether subjects tended to spontaneously respond using the muscle regions with which they were not instructed to react in the different conditions, separate analyses were performed for these conditions. The results of these analyses are given in Figure 3. As can be seen in the left panel, subjects spontaneously tended to react with a larger corrugator supercilii response to angry than to happy faces, $F(1, 47) = 48.50, p < .001$, for the Emotion factor. As can be seen in Figure 3, and also indicated by the Emotion $\times$ Interval inter-

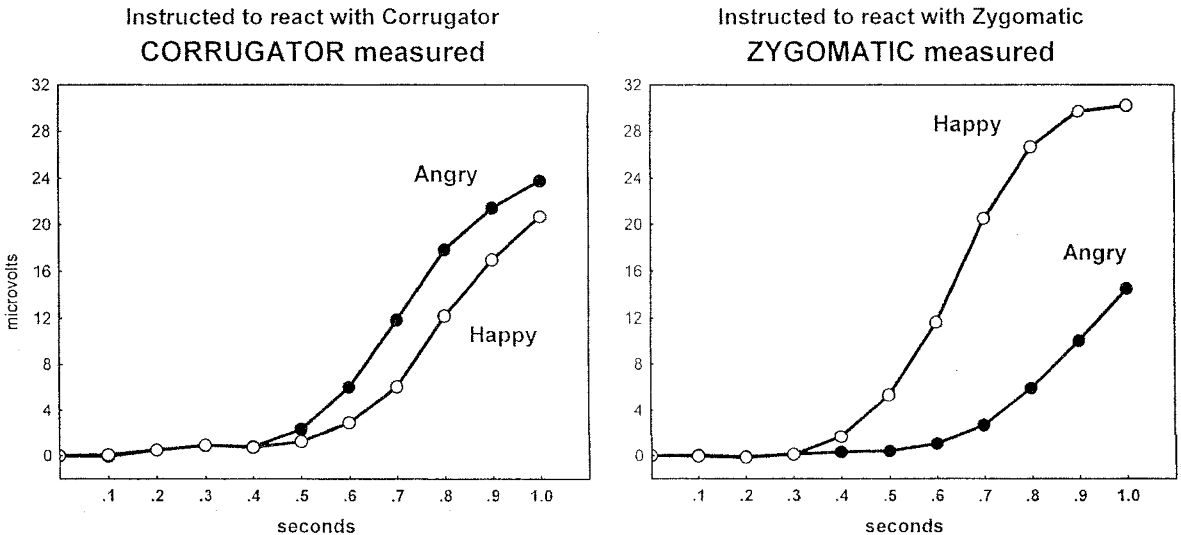

Figure 2. The mean facial EMG response for the corrugator supercilii muscle (left panel) and the zygomatic major muscle (right panel) plotted in intervals of 100 ms during the first second of exposure, when the subjects were instructed to react as quickly as possible to the respective Angry and Happy stimuli in Experiment 1.

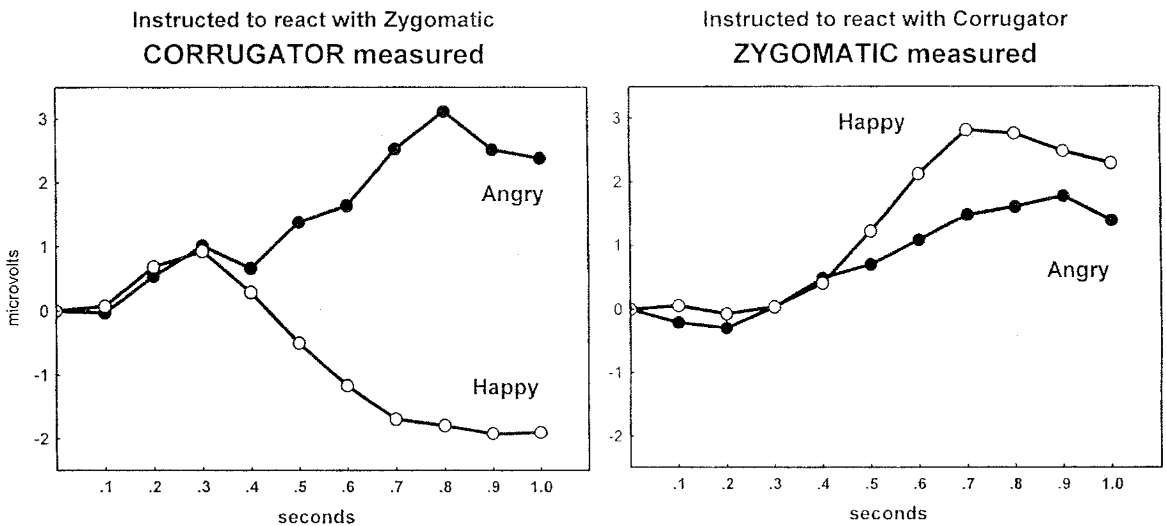

Figure 3. The mean facial EMG response for the corrugator supercilii muscle (left panel) and the zygomatic major muscle (right panel) plotted in intervals of 100 ms during the first second of exposure, when the subjects were instructed to not react with the respective muscles but rather with the alternative facial muscles to the Angry and Happy stimuli in Experiment 1.

action, $F(1,47) = 31.70$, $p < .001$, this effect was most clear-cut after about 500 ms. Furthermore, as can be seen in the right panel of Figure 3, the zygomatic muscle activity increased slightly after onset, $F(1,47) = 21.97$, $p < .001$, but contrary to the Corrugator muscle response, the zygomatic major muscle activity was larger to happy than to angry facial stimuli, $F(1,47) = 6.60$, $p < .02$.

Discussion

The results from Experiment 1 showed that, despite the fact that subjects were instructed to react to both the angry and happy stimuli as quickly as possible using the Corrugator supercilii muscle (to frown), this reaction was larger to angry than to happy faces. Furthermore, and contrary to the corrugator muscle response, the subjects reacted with a more rapid and larger zygomatic major muscle response to happy than to angry facial stimuli, despite the fact that they were instructed to react to both stimuli as quickly as possible (by smiling). Consequently, these data support the proposition that distinct facial reactions were automatically generated which interferes with the task of voluntarily controlling the facial muscles.

It was also found that when subjects were instructed to either frown or smile in response to the different stimuli, they still showed a tendency to spontaneously react in a way that was appropriate to the particular stimulus categories. That is, when subjects were required to react with the zygomatic muscle (smile) to angry faces, they still spontaneously reacted with larger corrugator muscle activity to angry than to happy faces. Furthermore, when subjects were instructed to react with the corrugator muscle (frown) to happy faces, they still reacted with more zygomatic activity to happy than to angry faces. One important question is whether these results can be interpreted as evidence that an early facial muscle response is evoked that is automatically controlled and therefore is hard to voluntarily interrupt and restrain. One main aim of Experiment 2 was to address this question more specifically.

EXPERIMENT 2

The results from Experiment 1 clearly indicated that pictures of angry and happy faces spontaneously evoke a response tendency that interacts with the task of voluntarily controlling the facial muscles, by either facilitating or impairing the performance. The results further showed that subjects tended to spontaneously react to the facial stimuli in a corresponding way with the muscle groups that they were not instructed to use, which may further indicate that there is a spontaneous response tendency that is hard to interrupt and restrain. However, because the subjects in Experiment 1 were instructed to react with the corrugator *or* the zygomatic muscle in certain ways to all presented stimuli, this procedure may obscure our ability to specifically evaluate whether a particular facial reaction is difficult to interrupt and restrain when subjects are explicitly required to not move any of the facial muscles. To solve that problem, subjects in Experiment 2 were required to react with one type of facial reaction to only one of two presented stimuli, within four different conditions (i.e., they were exposed to angry and happy faces in all conditions). However, in one condition they were required to frown at angry faces, but explicitly instructed to not react in any way to the happy stimuli. In a second condition they received the opposite instruction (i.e., to frown at happy faces, but not react to angry faces). In the other two conditions, they were instructed to react with the zygomatic muscle (smile) to one type of stimuli, but with no facial reaction to the other type.

Thus, the prupose of Experiment 2 was twofold: One aim was to replicate the main findings in Experiment 1, demonstrating that it is easier to voluntarily react with the corrugator muscle to angry faces and the zygomatic muscle to happy faces than vice versa. A second specific aim was to explore more directly whether facial stimuli evoke facial muscle reactions that are hard to voluntarily interrupt or completely restrain, even if subjects are explicitly instructed to not move any of their facial muscles.

Method

Subjects

A total of 48 subjects, students at Uppsala University, took part in the experiment. They ranged in age from 19 to 33 years (mean age 24.4).

Apparatus and procedure

The apparatus was identical to that used in Experiment 1. The experiment was divided into four conditions, with four different instructions given to the subjects in a balanced order: (1) to frown when exposed to an angry face but *not* to react in any way when shown a happy face; (2) to frown when exposed to a happy face but *not* to react in any way to an angry face; (3) to smile when exposed to an angry face but *not* to react in any way when shown a happy face; and (4) to smile when exposed to a happy face but *not* to react in any way to an angry face.

The slides used in trial series 1 and 2 consisted of angry and happy faces (Ekman & Friesen, 1976), 12 from each category. Subjects were exposed to two different series of six angry and six happy faces, presented in a randomised order. Due to a limited collection of slides, the pictures in trial series 3 and 4 were the same as those used in trial series 1 and 2, respectively.

Design and analysis

For the two trial series in which subjects were required to react with their corrugator supercilii muscles (to frown), separate analyses were made for: (1) those stimuli subjects were told to react to; and (2) those stimuli they were explicitly told not to react to. Similar analyses were made for the zygomatic major muscle. Before analysis, the data were collapsed over the respective six trials. Thus, each of the four separate ANOVAs was a 2 (Emotion: angry vs. happy faces) $\times$ 10 (Interval) factorial, with both factors manipulated within subjects. Geisser and Greenhouse conservative F-tests were used by reducing the degrees of freedom (e.g., Kirk, 1968).

Results

The facial reactions produced when subjects were instructed to react with the respective muscles are illustrated in Figure 4. As can be seen, the results in Experiment 1 were replicated for both the corrugator and the zygomatic muscles. That is, the corrugator muscle response (left panel in Figure 4) increased as a function of time intervals, $F(1, 47) = 245.37, p < .001$), indicating that subjects followed the instruction to react to the stimuli and, importantly, the response was larger to angry than to happy faces, as indicated by both the Emotion factor, $F(1, 47) = 28.99, p < .001$, and the Interval $\times$ Emotion factor, $F(1, 47) = 11.37, p < .002$.

As can also be seen in Figure 4 (right panel), the zygomatic muscle response also increased over time intervals, $F(1, 47) = 252.46, p < .001$, indicating that subjects followed the instruction to react to the stimuli. Importantly, and similar to the results in Experiment 1, the zygomatic muscle reaction was larger to happy than to angry faces indicated by both the Emotion factor, $F(1, 47) = 48.72, p < .001$, and the Interval $\times$ Emotion interaction, $F(1, 47) = 21.32, p < .001$.

The results for the conditions in which subjects were explicitly instructed to not move their facial muscles are given in Figure 5. As can be seen in the left panel, and as indicated by the Interval factor, $F(1, 47) = 10.26, p < .003$, subjects produced an overall increased corrugator muscle response. This response, however, differed between the stimuli, $F(1, 47) = 25.11, p < .001$. As illustrated in the left panel of Figure 5, and as also indicated by the Emotion $\times$ Interval interaction, $F(1, 47) = 11.76, p < .002$, subjects produced a larger corrugator muscle reaction to angry than to happy faces.

As can be seen in the right panel, zygomatic muscle activity increased as a function of time interval, $F(1, 47) = 7.27, p < .01$. Importantly, however, and contrary to the corrugator muscle response, the zygomatic muscle reaction was larger to happy than to angry faces, $F(1, 47) = 4.56, p < .05$.

Discussion

The results obtained in Experiment 2 replicated the findings from Experiment 1. That is, the results from Experiment 2 showed that angry and happy facial stimuli spontaneously induce a response tendency that facilitates the task of voluntarily reacting with the corrugator muscle to angry faces and with the

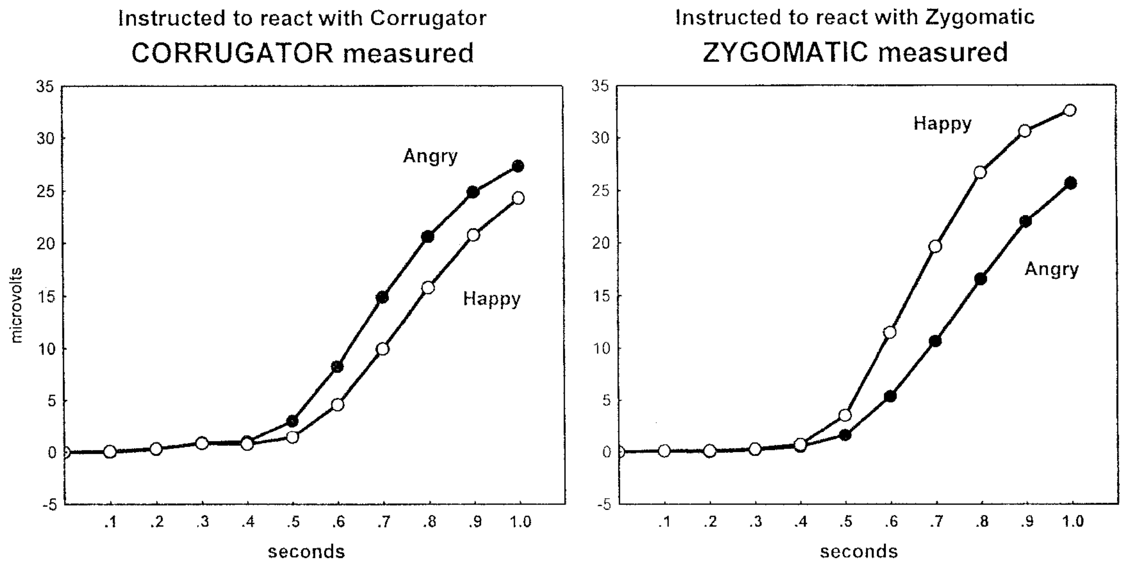

Figure 4. The mean facial EMG response for the corrugator supercilii muscle (left panel) and the zygomatic major muscle (right panel) plotted in intervals of 100 ms during the first second of exposure, when the subjects were instructed to react as quickly as possible to the respective Angry and Happy stimuli in Experiment 2.

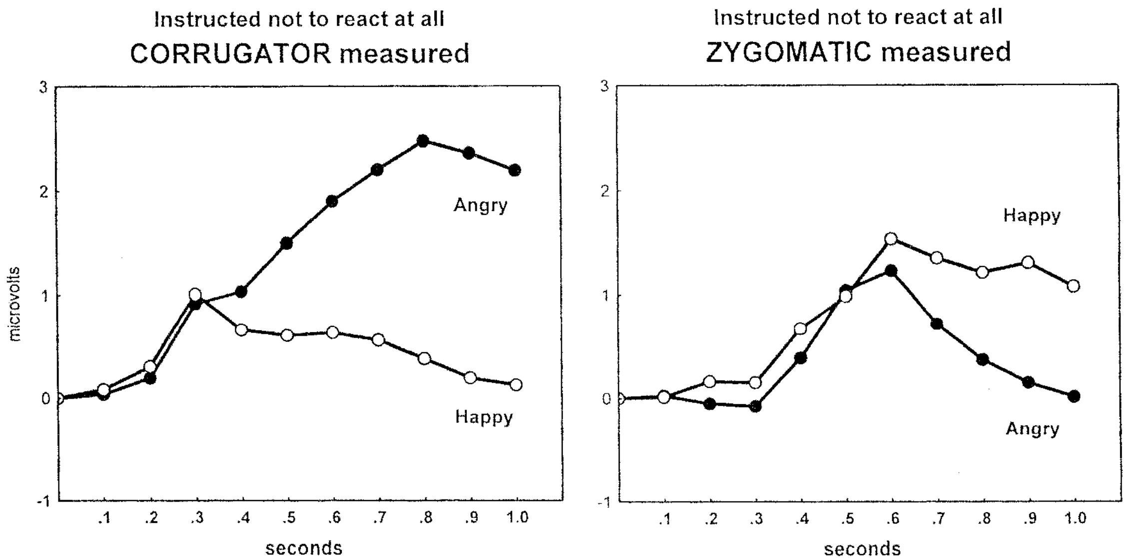

Figure 5. The mean facial EMG response for the corrugator supercilii muscle (left panel) and the zygomatic major muscle (right panel) plotted in intervals of 100 ms during the first second of exposure, when the subjects were explicitly instructed to not react at all in Experiment 2.

zygomatic muscle to happy faces. The second important aim of Experiment 2 was to explore whether facial stimuli spontaneously and involuntarily evoke a response pattern that corresponds to the facial stimuli even if subjects are explicitly instructed to not react in any way with their facial muscles. These results showed very clearly that subjects still reacted with their facial muscles in a way that corresponds to the angry and happy stimuli. These data strongly support the hypothesis that facial emotional stimuli spontaneously and involuntarily evoke an automatic facial reaction that is hard to consciously interrupt and restrain.

EXPERIMENT 3

The results from Experiments 1 and 2 support the proposition that facial reactions are automatically controlled by mechanisms that evoke a ‘‘negative’’ reaction (increased corrugator activity) to angry faces and a ‘‘positive’’ reaction (increased zygomatic activity) to happy faces. One important question is whether the manifestation of these reactions is limited to facial stimuli, in which case we could interpret this as an outcome of mimicking behaviour (e.g., Dimberg, 1982; Lundquist & Dimberg, 1995), or whether automatic facial reactions are also evoked when people are exposed to other types of negative and positive emotional stimuli, that is, whether the facial muscles function more generally as a readout system for emotional reactions (e.g., Buck, 1994; Dimberg, 1986). As mentioned in the introduction, earlier studies have shown that, similar to angry and happy faces, pictures of snakes and flowers also spontaneously evoke specific facial EMG reactions (e.g., Dimberg, 1986) and, in particular, that pictures of snakes (Dimberg, 1997b; Dimberg et al., 1998) very rapidly evoke increased corrugator activity. Thus, if facial reactions are automatically controlled, we might expect these mechanisms to operate not only in an emotional face-to-face situation, but also when people are exposed to other negative and positive affective stimuli such as pictures of snakes and flowers. The aim of Experiment 3 was to explore this question.

Similar to Experiment 1, subjects were asked, in different conditions, to either frown at the negative stimuli (snake pictures) and smile at the positive stimuli (flower pictures) *or* the opposite (i.e., to frown at flowers and smile at snakes), while facial EMG was measured from the corrugator supercilii and zygomatic major muscle regions. As in earlier experiments, the logic behind this manipulation is that if specific facial emotional reactions are automatically generated, then these reactions should interfere with the activity of voluntarily controlling the facial muscles. In other words, it should initially be easier to voluntarily react with the corrugator muscle to snakes and the zygomatic muscle to flowers than vice versa.

Method

Subjects

A total of 48 subjects, students at Uppsala University, participated in the experiment. They were between 20 and 39 years of age (M = 24 years).

Apparatus and procedure

The apparatus and procedure were identical to those used in Experiment 1, except that slides of angry and happy faces were replaced with slides of snakes and flowers. In earlier experiments (e.g., Dimberg, 1986; Dimberg & Karlson, 1997; Dimberg & Thell, 1988), these and similar stimuli had been rated as unpleasant and pleasant, respectively.

Results

The corrugator supercilii and zygomatic major muscle reactions produced when participants were instructed to react with their facial muscles are presented in the left and right panels of Figure 6, respectively. As can be seen in the left panel, corrugator supercilii muscle activity increased as a function of time intervals, $F(1,47) = 240.49$, $p < .001$, which of course was an effect of the fact that subjects were instructed to react to both types of stimuli. This response, however, was larger to snakes than to flowers as indicated by both the Stimulus factor, $F(1,47) = 6.66$, $p < .02$, and the Stimulus × Interval factor, $F(1,47) = 4.30$, $p < .05$.

As can be seen in the right panel of Figure 6, subjects followed the instruction to react to both stimuli with the zygomatic major muscle, $F(1,47) = 190.25$, $p < .001$, for the Interval factor. Contrary to the effect for the corrugator muscle response, however, the zygomatic major muscle response was larger to flowers than to snakes, which was indicated by both the Stimulus factor, $F(1,47) = 18.03$, $p < .001$, and the Stimulus × Interval factor, $F(1,47) = 16.78$, $p < .001$.

As in Experiment 1, separate analyses were also performed for those conditions in which the subjects were not instructed to react with the respective muscles. The results of these analyses are given in Figure 7. As can be seen in the left panel, subjects spontaneously tended to react with a larger corrugator supercilii response to snakes than to flowers, which was indicated by both the Stimulus factor, $F(1,47) = 12.80$, $p < .001$, and the Stimulus × Interval factor, $F(1,47) = 11.56$, $p < .001$.

As can be seen in the right panel, zygomatic muscle activity tended to increase over time intervals, $F(1,47) = 24.84$, $p < .001$, but did not differ between the two stimuli, $F < 1$.

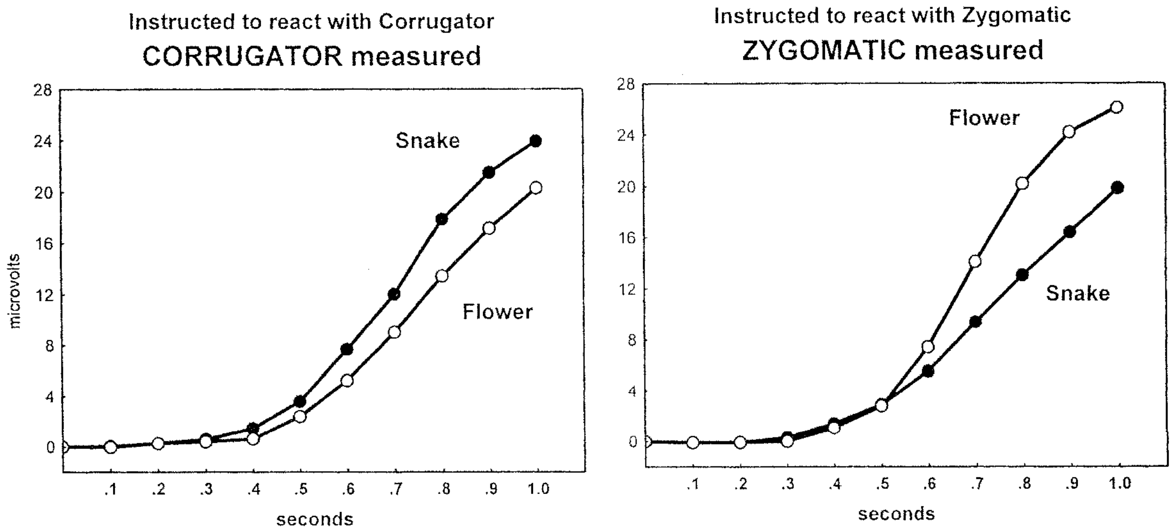

Figure 6. The mean facial EMG response for the corrugator supercilii muscle (left panel) and the zygomatic major muscle (right panel) plotted in intervals of 100 ms during the first second of exposure, when the subjects were instructed to react as quickly as possible to the pictures of snakes and flowers in Experiment 3.

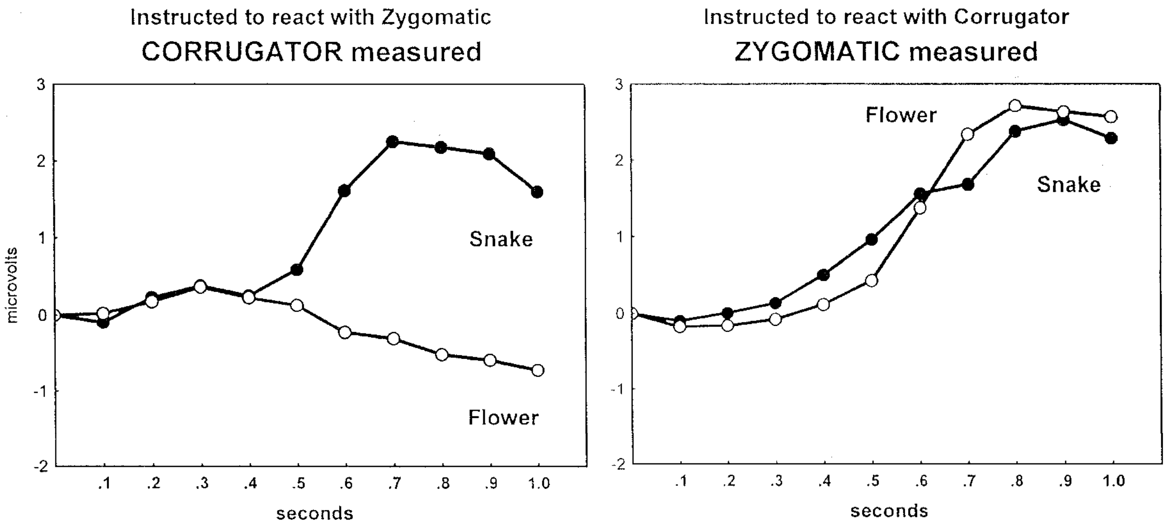

Figure 7. The mean facial EMG response for the corrugator supercilii muscle (left panel) and the zygomatic major muscle (right panel) plotted in intervals of 100 ms during the first second of exposure, when the subjects were explicitly instructed not to react with the respective muscles but rather with the alternative muscles to the pictures of snakes and flowers in Experiment 3.

Discussion

As predicted, the data from Experiment 3 demonstrate that when people are instructed to react with their facial muscles in certain ways, it seems to be easier to voluntarily react with the Corrugator muscle to pictures of snakes and with the zygomatic muscle to pictures of flowers than vice versa. It was further found that, at least for the corrugator muscle, subjects spontaneously reacted with larger activity to pictures of snakes than to flowers, even when they were not instructed to react with the corrugator muscle (to frown), but rather with the zygomatic muscle (to smile). Consequently, these data support the proposition that emotional stimuli automatically generate a response tendency that interferes with the task of voluntarily controlling the facial muscles. Importantly, these results demonstrate that the automatic generation of facial reactions is not confined to facial stimuli, but rather seems to be a more general phenomenon.

CONCLUDING DISCUSSION

Starting from a simple model (Figure 1) illustrating how facial reactions can be both involuntarily and voluntarily controlled, the aim of the present experiments was to explore whether distinct facial reactions to emotional stimuli can be automatically evoked. Based on traditional criteria for what characterises an automatic process (e.g., Schneider & Shiffrin, 1977), we tested whether spontaneously evoked facial reactions are difficult to interrupt and restrain, thus whether they tend to interfere with consciously controlled facial actions. In two separate experiments, it was found that when people were instructed to voluntarily react as quickly as possible with the corrugator muscle (to frown) or the zygomatic muscle (to smile) to angry and happy facial stimuli, they produced a more rapid and larger corrugator response to angry faces and a more rapid and larger zygomatic response to happy faces. It was further found that, despite the fact that subjects were instructed to not react at all with their facial muscles, they still spontaneously and involuntarily produced a facial muscle response pattern that corresponded to the angry and happy facial stimuli. Importantly, in a third experiment, similar effects were also obtained when using other types of negative and positive affective stimuli such as pictures of snakes and flowers. Consistent with previous research (e.g., Dimberg, 1990), these results show that the facial muscles function as a read-out system for emotional reactions (e.g., Buck, 1994). Consequently, the present results can be interpreted as support for the notion that particular facial muscle reactions are automatically activated which interfere with the task of voluntarily moving the facial muscles in particular ways (see Figure 1). The results further support the proposition that facial reactions, once evoked, are difficult to consciously and voluntarily interrupt and restrain, and consistent with traditional criteria for automatic processes, they seem to be more or less ‘‘unavoidable’’. Thus, together with earlier studies demonstrating that facial reactions can be spontaneously, effortlessly, and rapidly evoked (e.g., Dimberg, 1997b), the present results support the proposition that facial reactions are involuntary controlled, mediated by automatically operating mechanisms.

It is important to note that the difference in responding to (e.g., the angry and happy faces) cannot be explained as an effect of the fact that angry and happy faces have different detection and recognition thresholds. For instance, there is evidence that people may have a heightened readiness to react to angry faces, because angry faces have an ability to ''pop-out'' among other visually presented facial stimuli (Hansen & Hansen, 1988). However, in terms of facial muscle reactions, there is no evidence from the present study to suggest that recognition speeds for angry and happy faces are different. On the contrary, the different effects of angry and happy faces seemed to depend on which particular facial muscle subjects were instructed to use. Thus, the effect from the present experiment can instead be explained as a ''stimulus-specific facial muscle'' effect, which supports the proposition that particular negative and positive emotional stimuli tend to spontaneously and automatically evoke increased activity in particular emotion-specific facial muscles.

Two further questions remain that also may be interrelated. First, whether the present effects could be an outcome of mimicking behaviour and, second, whether the effects should be characterised as an outcome of automatic behaviour that is mediated by well-learned reactions or by hard-wired affect programmes. To answer the first question, a simple mimicking behaviour hypothesis can be ruled out, because the subjects reacted in a similar way to pictures of snakes and flowers as they did to pictures of faces. Note that this does not completely rule out the possibility that mimicking behaviour can have been an important mechanism in the present experiments, but it clearly demonstrates that facial reactions can more generally reflect emotional reactions that are not an outcome of mimicking behaviour.

As to the second question, it has been proposed that automatic processes are not all-or-none phenomena, but may be continuous and can emerge with practice (see Cohen, Dunbar, & McClelland, 1990). One classic example of this phenomenon, found in most textbooks, is the Stroop colour-naming task (Stroop, 1935), in which people are required to identify as quickly as possible the colours of ink used to write the names of various other colours. In this situation, people tend to read the written name instead of reporting the colour of the ink. This phenomenon has traditionally been taken as support for the notion that people's ability to read is an automatic process that interferes with the task of voluntarily reporting the ink colour. It is possible to argue that the automatic facial behaviour observed in the present study is an effect of the fact that people have previous experience with mimicking each other in face-to-face situations. Given this interpretation, the effects are an outcome of a well-learned automatic response rather than biologically/hard-wired affect programmes. Again, an argument against this proposition is the fact that the present effects were also obtained in response to snakes and flowers, and it is difficult to imagine that people have well-learned *facial* responses to these stimuli. One alternative interpretation could then be that the different stimuli spontaneously evoke an emotional reaction which is automatically mediated by biologically given affect programmes, and thereby the results may be interpreted as support for the proposition that facial reactions are controlled by particular affect programmes (Tomkins, 1962). Note, however, that in the present experiments, facial muscle activity was measured from only two muscle regions, the corrugator supercilii, which is important for the display of negative emotions, and the zygomatic major, which is important for the display of positive emotions. It follows, therefore, that the results could only be interpreted in terms of the effect of negative and positive affect programmes. To be able to more extensively study automatic activation of different basic facial emotions in a paradigm similar to the present one, one could include the registration of several other relevant facial muscles during presentation of different types of emotional stimuli while people are instructed to move these muscles. One example of such stimuli might be pictures of different basic facial expressions (Ekman & Friesen, 1976), which have been shown to evoke both negative and positive emotional reactions as well as specific emotional reactions that mirror the particular facial display (Lundquist & Dimberg, 1995).

The present results are also consistent with the view that the function of an automatic evaluative process is to predispose the individual to interact appropriately with positive and negative objects (e.g., Bargh & Chartrand, 1999; Dimberg, 1997b). Consistent with that view, it has been found that, when subjects are required to behave as quickly as possible, behaviours that could be classified as approaching behaviours tend to be faster to positive stimuli, whereas avoidance behaviours are faster to negative stimuli (Cacioppo, Priester, & Berntson, 1993; Chen & Bargh, 1999).

Finally, we can conclude that the present results are consistent with the fact that voluntary and involuntary facial actions are controlled by different neural pathways (e.g., Fridlund, 1994; Figure 1). In particular, both the present data and earlier results (e.g., Dimberg, 1997b) are consistent with neural models suggesting that emotional stimuli can be processed both rapidly and automatically (LeDoux, 1989, 1995); this is, of course, the basis for the ability to rapidly produce automatically controlled facial muscle reactions. Thus, these results are also consistent with an evolutionary/biological perspective on emotion, in which one primary adaptive function of rapid emotional reactions is to mobilise the individual for rapid management of different emotionally significant stimuli (e.g., Dimberg, 1997a; Ekman, 1992b; Öhman, 1986). Note that the present model (Figure 1) was based on the assumption that the first step in the evaluation of emotional stimuli is both rapid and preconscious. Although it is not, logically speaking, an absolute necessity that this first process is preconscious, it is most likely that the rapid evocation of facial reactions is initially controlled by a rapid and preconscious evaluation of the stimuli. This proposition is supported by earlier research demonstrating very clearly that unconscious/subliminal presentation of emotional stimuli is sufficient for different aspects of emotional responding to occur (e.g., Dimberg & Öhman, 1996; Morris, Öhman, & Dolan, 1998; Murphy & Zajonc, 1993; Whalen et al., 1998). In particular, this proposition is supported by a recent study (Dimberg, Thunberg, & Elmehed, 2000) in which the subjects, with the help of a priming paradigm (Marcel, 1983), were unconsciously exposed to facial stimuli. This study explicitly demonstrated that unconsciously presented facial stimuli are sufficiently effective to trigger different facial reactions, and perhaps these results may be taken as support for the proposition that facial reactions are automatically mediated by positive and negative affect programmes (Dimberg et al., 2000).

In summary, the present study reveals that a negative and a positive facial reaction is involuntarily evoked when people are exposed to different negative and positive emotional stimuli. This facial reaction interferes with voluntary attempts to control the facial muscles, and it is difficult to voluntarily completely suppress. Thus, the present data can be interpreted as support for the notion that these facial reactions are automatically controlled.

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