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Rapid Facial Reactions to Emotionally Relevant Stimuli

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Abstract
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The present thesis investigated the relationship between rapid facial muscle reactions and emotionally relevant stimuli. In Study I, it was demonstrated that angry faces elicit increased *Corrugator supercilii* activity, whereas happy faces elicit increased *Zygomaticus major* activity, as early as within the first second after stimulus onset. In Study II, during the first second of exposure, pictures of snakes elicited more corrugator activity than pictures of flowers. However, this effect was apparent only for female participants. Study III showed that participants high as opposed to low in fear of snakes respond with increased corrugator activity, as well as increased autonomic activity, when exposed to pictures of snakes. In Study IV, participants high as opposed to low in speech anxiety responded with a larger difference in corrugator responding between angry and happy faces, and also with a larger difference in zygomatic responding between happy and angry faces, indicating that people high in speech anxiety have an exaggerated facial responsiveness to social stimuli. In summary, the present results show that the facial EMG technique is sensitive to detecting rapid emotional reactions to different emotionally relevant stimuli (human faces and snakes). Additionally, they demonstrate the existence of differences in rapid facial reactions among groups for which the emotional relevance of the stimuli can be considered to differ.

Keywords: Emotion, facial EMG, facial reactions, facial expressions, rapid responses, automatic responses, phobia, social fear, speech anxiety

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The present thesis is based on the following studies, which will be referred to in the text by their Roman numerals:

I Dimberg, U., & Thunberg, M. (1998). Rapid facial reactions to emotional facial expressions. *Scandinavian Journal of Psychology, 39,* 39–45.

II Thunberg, M., & Dimberg, U. (2000). Gender differences in facial reactions to fear-relevant stimuli. *Journal of Nonverbal Behavior, 24,* 45–51.

III Dimberg, U., Hansson, G., & Thunberg, M. (1998). Fear of snakes and facial reactions: A case of rapid emotional responding. *Scandinavian Journal of psychology, 39,* 75–80.

IV Dimberg, U., & Thunberg, M. (2007). Speech anxiety and rapid emotional reactions to angry and happy facial expressions. *Scandinavian Journal of psychology, 48,* 321–328.

Contents

Introduction

I. Introduction and general background

There is an age-old popular belief that facial expressions signal the emotional state of their bearer. This notion, which has been termed the *expression-feeling link* (Izard, 1992), is probably as old as the human species, if not older. However, Charles Darwin was the first to turn this belief into a scientific hypothesis. In *The expression of the emotions in man and animals* (1872) Darwin proposed that the emotional expressions of humans are innate and have an evolutionary origin. He based his idea on his own and his collaborators' observations of animals, human infants, and people from different cultures. Darwin's conclusion was that some of the expressions of other animals resembled those of humans, and from this he inferred that some human emotions were also present in animals.

A number of modern theories influenced by Darwin (1872), contemporary ethology, and neuroscience, (Ekman, 1992; 1994; Izard, 1977; 1992; 1994) propose that there are a number of basic emotions such as anger, fear, sadness, disgust, surprise, and happiness, which are accompanied by distinct facial expressions and bodily reactions. Different theories postulate different numbers of basic emotions but agree with Darwin's idea that emotions are innate and have evolved because they serve adaptive functions, such as preparing organisms for fight and flight responses.

According to Ekman (1992) and Izard (1992), the term "basic" in connection with emotions has two separate meanings: Firstly, emotions differ from each other in important ways (Ekman 1992) in that each emotion has innate neural substrates, a unique and universally recognised facial expression, and a unique feeling state (Izard, 1977). Secondly, they are the basis for coping strategies and adaptation (Izard, 1992), that is, they are shaped by evolution to serve the adaptive value in dealing with fundamental life-tasks such as inter-organismic encounters with people and other animals (Ekman, 1992). The basic emotions approach is *modular* in the sense that distinct emotions are presumed to have evolved to deal with distinct types of situations (Cosmides & Tooby, 2000; Ekman, 1992; Izard, 1992).

Definition of emotion

Before embarking on a discussion of the nature of emotions, it would be convenient to have an agreed-upon definition of emotion. Unfortunately, such a definition does not exist.

It has even been argued that emotions have no biological or psychological reality. The behaviourists, for example, held that the concept emotion had no explanatory value because emotions could not be directly observed. In addition, some anthropologists have claimed that certain cultures lack words for emotions and hence that emotion is merely a concept invented by western culture to explain certain aspects of behaviour (Ekman, 1998). What unites the majority of historically influential and contemporary theories of emotion is the shared assumption that emotions involve interpretation of a stimulus, physiological arousal, expressive behaviours such as facial expressions, impulses to instrumental behaviours, and subjective feeling (Ellsworth, 1994).

A common and useful model of emotion is the three-component model of emotion (Dimberg, 1997*b*; Lang, 1968; Öhman, 1986). According to this model, the emotional system consists of three distinguishable components: the physiological/autonomic, the cognitive/experiential, and the behavioural/expressive. Hence, there are three possible ways of measuring an emotional response: physiological responses, verbal reports, and overt behaviour (Öhman, 1986).

Discrete emotions or dimensions

Another much-debated issue is whether there is a number of distinct emotions or whether emotional states are better conceived of as distributed along various dimensions. Arnold (1960*a*; reported in Plutchik, 1991) observed that most emotions involve an intuitive appraisal of a stimulus as good (beneficial) or bad (harmful) and numerous attempts have been made to account for all emotions in terms of a small number (typically two or three) of general dimensions, one of which pertains to the emotional valence (pain–pleasure; pleasantness–unpleasantness). Additional dimensions usually include some description of level of arousal (active–passive; relaxation–tension; excitement–quiet) and/or approach–withdrawal tendencies (Duffy, 1962; Schlosberg, 1941; Spencer, 1890; Wundt, 1896; for a review see Plutchik, 1991). Examples of contemporary theory of emotion dimensions are the ones proposed by Russell (1980; 1983) emphasising the dimension of pleasantness–unpleasantness, and those by appraisal theorists arguing for six or more dimensions of perceptual appraisal such as novelty, pleasantness, certainty, control, and agency (Ellsworth, 1994).

In contrast to this dimensional view, Darwin held that emotions were basic distinct patterns of arousal which were innate and observable in all organisms. Similarly, Plutchik (1991) suggested eight prototype patterns of behavioural reactions identifiable at all evolutionary levels. Contemporary basic emotion theorists (Ekman, 1992; Izard, 1994; Tomkins, 1962), on the basis of findings from infant and cross-cultural research, also argue that emotions are served by neural affect programmes which are distinct for each emotion.

As support for the discrete emotions approach, Izard (1992) has claimed that, during human evolution, effective communication in situations where adaptive responses were essential, i.e., when survival was threatened, would have required emotion-specific communication, as merely expressive behaviour contingent with broad dimensions of experience such as valence or arousal would not have been sufficiently effective.

Fixed or infinite number of emotions

Although researchers differ in their opinion on how many basic emotions there are and which emotions should be called basic, there is some agreement about anger, fear, sadness, enjoyment (or happiness), disgust and surprise, whereas possible candidates include contempt, shame, guilt, embarrassment, awe (Ekman, 1992), interest and love (Izard, 1991). In addition, there is controversy about whether all emotions are basic (e.g., Ekman, 1992) or whether there exist other, non-basic emotions. For instance, Plutchik (1991) has proposed that emotions can mix to form new emotions in an analogy to colours.

Relations among components

One of the most obvious differences between competing theories of emotions is how they conceive of the relations between the various components. For instance, one topic that has been the subject of much discussion is the time sequence involving the different components in an emotional reaction; what has been termed the *order of events* debate (Ellsworth, 1994). The order of events debate was started by James (1884) who challenged the then prevailing common sense theory that an emotional reaction started with the interpretation of stimulus followed by an affective reaction, which was in turn followed by bodily response (Ellsworth 1994). James' claim was that the subjective feeling state was caused by a psychophysiological response and thus he was in effect interchanging the positions of affect and bodily response. Central to James' theory was the point that different physiological states were correspondent to different subjective experiences. However, he did not think of these feelings as discrete but rather as continuous and infinite in number (Ellsworth, 1994).

Cannon (1928) countered James' theory by insisting that physiological reactions were far too slow to cause subjective experience. Instead he suggested that feelings and physiology were simultaneously evoked as a consequence of distinct patterns of brain activity. Cannon identified the thalamus as a central brain region in connection with emotions.

Various historically important as well as contemporary cognitive theories of emotion hold that emotional reactions are the consequences of certain perceptive-cognitive processes and thus it might seem as if we have gone the full circle and are back with the common sense theory of old. Arnold (1960*a*, 1960*b*) viewed emotion as resulting from the cognitive processes of perception and appraisal. Another important cognitive theory is the one presented by Schachter (Schachter & Singer, 1962) who held that emotions have their origins in a non-specific enhanced arousal state which is interpreted as a specific emotion dependent upon the situation. Similar views have been brought up by Mandler (1975) and Lazarus (1982).

Zajonc (1980) made a major objection to cognitive theories by claiming that the first responses to a stimulus are affective. In other words, liking or disliking a stimulus precedes any objective knowledge about it. Thus, in direct opposition to Arnold (1960*b*), Zajonc insisted that affect precedes interpretation. Similarly, a central point of basic emotions theories is that emotions are pre-cognitive in origin and nature (Izard, 1991).

Before leaving the subject of the relations among components, some mention should be made of the facial feedback hypothesis (Tomkins, 1962) which claims that facial muscle activity can cause or reinforce the experience of emotion. The hypothesis is highly controversial, particularly so in its most extreme form stating that facial muscle activity is necessary for the experience of emotion (e. g., Buck, 1980). The major objection is that people with paralysis to the facial muscles are still able to experience emotions, and Buck (1980) has concluded that facial activity cannot be considered either necessary or sufficient for emotional experience. Obviously, a prerequisite for the hypothesis to be true would be that facial muscle reactions can be very quickly elicited (at least, they would need to be faster than autonomic responses, which typically have a response latency of 1–4 s, as for example skin conductance responses).

Contrary to cognitive theories, theories sharing the basic emotions approach agree with James that different emotions are accompanied by distinct physiological states (Ekman, 1992; Tomkins, 1962). There are also assumed to be specific emotion expressions which are innately linked with corresponding subjective feelings (Ekman, 1992; Izard & Malatesta, 1987; Izard, 1990). The answer to the question whether there is coherence among expressive behaviours and physiological patterns (Ekman, 1992) is still obscure. There are indications of distinctive autonomic nervous system (ANS) patterns for the negative emotions anger and fear (Ekman, Levenson & Friesen 1983; Levenson, Ekman & Friesen, 1990) and possibly for sadness (Levenson, Carstensen, Friesen & Ekman, 1991). However, distinctive ANS patterns have not been found for positive emotions, such as interest and enjoyment. Ekman (1992) suggests this may be due to the fact that there is no need for urgent motor activity, such as fight or flight responses, in situations involving positive emotions.

Function of emotions

A central point of basic emotions theories is that emotions have evolved because they serve adaptive functions (e. g., Ekman, 1992; Izard, 1991). Although the adaptive function of emotions has been questioned, particularly within the field of clinical psychology where emotions have often been considered sources of problems and conflict (Izard, 1991), most modern theories of emotion share the common assumption that emotions have evolved to serve essential biological and social functions (Izard, 1992), and that they are central to the motivation and organisation of behaviour (Ekman, 1992; Izard, 1991). In other words, emotions have evolved to enable organisms to deal effectively with inter-organismic encounters, both within and between species. This capacity is genetically transmitted and based on adaptive behaviour in the past history of the species (Ekman, 1992; Cosmides & Tooby, 2000).

One function of emotions which should be important from an evolutionary perspective is the avoidance of potentially dangerous, or fear-relevant stimuli. Much of the research on fear or defence reactions has employed an aversive conditioning paradigm based on the prepared learning theory. Prepared learning theory (e. g., Dimberg, 1983; Seligman, 1971; Seligman & Hager, 1972; Öhman, 1986) proposes that those individuals who during biological evolution had the capacity to easily and rapidly learn to avoid dangerous situations had an adaptive advantage and consequently made a larger contribution to the gene pool. According to prepared learning theory, humans are predisposed to associate certain stimuli but not others. Stimuli easily associated with fear include predators, snakes, and spiders, heights, open spaces (as evidenced by people suffering from agoraphobia), and confined spaces. All these are also objects for which people are known to develop phobic reactions. Empirical data support the proposition that certain stimuli are more effective as conditioned stimuli in aversive conditioning, being more resistant to extinction (e. g., Dimberg, 1983; Öhman, 1986).

II. Facial expressions of emotion

Basic emotion theories follow Darwin by assuming that human facial expressions are linked with certain subjective feelings. This was not an original idea of Darwin's but is a popular belief too old to be traced historically (Izard, 1994). However, Darwin was the first to turn this idea into a scientific hypothesis and back it up with systematic observations. From his observations of animals, human infants, and people from primitive cultures, Darwin concluded that facial expressions are universal and that many human expressions are present in other animals as well. From this he inferred that facial expressions have an evolutionary origin and have developed to serve adaptive functions, similarly to physiological characteristics.

Universality and innateness of facial expressions

Although it has been questioned whether there are distinct facial expressions associated with specific emotions (Ellsworth, 1991; Ortony & Turner, 1990; Russell, 1994) and even whether facial expressions are related to emotions at all (Fridlund, 1994) many contemporary researchers agree that there is ample evidence that emotion-specific facial expressions do exist which are innate and subsumed in neural programmes. The group of emotions for which there is evidence of universality in expressions are *sadness*, *anger*, *enjoyment/happiness*, *disgust*, *surprise* and *fear* (most agreed upon) and possibly contempt, guilt, embarrassment and shame (e. g., Ekman, 1992). These emotions are presumed to be distinctly manifested in different facial expressions. Evidence supporting this view includes the fact that humans possess a complex pattern of facial muscles. Although some of these muscles are involved in other types of behaviour such as chewing, most facial muscles seem to be predominantly involved in the display of a variety of emotional expressions (Dimberg, 1990*a*). For instance, the *Corrugator Supercilii* is the muscle used in a frowning expression, whereas the *Zygomaticus major* is used to elevate the cheeks to form a smile. Furthermore, the *Levator labii superioris* raises the upper lip and widens the nostrils in disgust expressions, whereas the *Frontal lateralis* raises the brow when showing surprise (Hjortsjö, 1970).

Additional evidence is found in cross-cultural studies demonstrating that emotional expressions are universally understood (e. g., Ekman, 1973), as well as in studies of human infants demonstrating that facial expressions of emotion are displayed by young infants and that some of these expressions are even present at birth (Izard, 1977). Further support for the evolutionary origin of facial expressions is provided by the fact that facial expressions of emotion similar to those of humans are displayed by non-human primates (Andrew, 1963; Sackett, 1966).

Function of facial expressions

As mentioned above, theories of basic emotions assume that one important characteristic of a discrete emotion is a distinct facial expression. Obviously, what distinguishes the expressive component of emotion from the others is its communicative value. From an evolutionary perspective, it makes sense to presume that primate facial expressions have evolved as social signals for the expression and communication of emotions in face-to-face situations (e.g., Andrew, 1963). Thus, Tomkins (1962) proposes that the evocation of expressive emotional reactions is generated by emotion-specific, biologically given "affect programs".

It is obvious that there are two necessary conditions for an overt expression to have a communicative value. Firstly, facial expressions must reflect emotional activity. Secondly, other individuals must be able to identify and respond appropriately to the display. Therefore, it seems reasonable to expect that humans are biologically predisposed not only to display different facial expressions and act as *senders*, but also to act as *receivers*, that is to recognise and respond adaptively to the facial display of others (Dimberg, 1997*b*). Individuals who were able to respond adaptively to the facial display of others had an adaptive advantage during biological evolution. However, it is obvious that in some situations it can be to the advantage of an individual not to advertise his or her emotional state, and the fact that adult humans and other primates are able to, at least to some extent, control their facial displays (Ekman, 1994; Izard, 1994) does not detract from the general idea of innateness.

Apart from functioning as social signals (Izard, 1977; Dimberg, 1983), another possible function of facial expressions is the one mentioned above in connection with the facial feedback hypothesis; that facial muscles serve as a sensory feedback system for the intra-individual experience of emotion (Buck, 1980; Izard, 1981; Tomkins 1962). Although some support has been found for the hypothesis (Laird, 1974; 1984; Strack, Martin, & Stepper, 1988) the hypothesis remains controversial, especially so the strong claim that facial feedback is necessary for an emotion to occur (Adelmann & Zajonc, 1989; Buck, 1980; Dimberg, 1990*a*; Tomkins, 1981).

III. Facial reactions and EMG

One way to investigate whether facial muscle activity is related to emotions is to take advantage of the facial electromyography (EMG) technique, which makes it possible to objectively detect changes in activity in individual facial muscle groups. Muscle activity is detected by help of electrodes, which are attached to the skin above the facial muscles. Advantages of the facial EMG technique, as compared to visual observation techniques, are that it is sensitive enough to detect activity too small to be visible as an overt expression and that it is easy to quantify and objectively compare different intensities of the facial muscle reaction, as the amplitude of the EMG signal is proportional to the contraction of the muscle.

Emotional imagery and facial EMG

Early research on facial EMG and emotions was mainly concerned with responses to cognitively induced emotions. In a number of empirical studies, different facial EMG responses were found to be related to different self-induced emotions and cognitive manipulations (e.g., Cacioppo & Petty, 1981; Schwartz, Fair, Salt, Mandel, & Klerman, 1976; Schwartz, Brown, & Ahern, 1980). For example, Schwartz and co-workers demonstrated that pleasant thoughts, expected to induce feelings of happiness, evoked increased activity in the *Zygomaticus major* muscle, whereas unpleasant thoughts, expected to induce feelings of anger or sadness, evoked increased activity in the *Corrugator supercilii* muscle. As mentioned above, the zygomatic is the muscle used to elevate the cheeks to form a smile, thus indicating a positive emotional reaction, whereas the corrugator muscle is used to knit the brow as when frowning, indicating a negative emotional reaction. Thus, these studies demonstrate that the facial muscle response system is sensitive enough to indicate different emotional responses, at least for cognitively induced emotions.

External stimuli and facial EMG

If emotions have evolved for their adaptive value, one important feature of the evocation of emotional reactions should be that these are typically caused by exposure to external emotional stimuli (Dimberg, 1990*a*; Ekman, 1992). It has further been proposed that it is not only adaptive for emotions to be capable of mobilising the organism very quickly, but also for the response changes not to last very long (Ekman, 1992). Consequently, external stimuli probably evoke short-term phasic emotional responses. Therefore, to conclude that facial muscle activity is a general component of the emotional response and that facial EMG activity reflects emotional activity, it was also important to demonstrate that involuntary facial EMG reactions are spontaneously elicited when subjects are exposed to various external stimuli (Dimberg, 1990*a*).

Social stimuli

From an evolutionary perspective it seems reasonable to expect that some objects and situations are more likely to elicit emotional reactions than others, with stimuli critical to survival being the most emotionally relevant (e. g. Seligman, 1971). From this perspective, one class of stimuli which should be highly emotionally relevant, especially for highly social species, is communicative stimuli such as facial expressions (Dimberg, 1983; Öhman, 1986).

It has been proposed that humans are biologically prepared to recognise and respond to different facial expressions (Buck, 1984; Dimberg, 1983; 1997*b*). For instance, Ekman (1992) believes that the most important function of emotions is to prepare individuals to respond adaptively in situations involving interpersonal encounters. Such encounters typically involve communicative stimuli such as facial expressions. As mentioned above, it is important for individuals to recognise and correctly interpret the facial expression of conspecifics. One important function for facial displays is to serve as dominance and submission signals in a social hierarchy. In species in which strong dominance hierarchies exist, there is considerable value for future reproductive success in being able to recognise one's relative position in the hierarchy and in being able to choose the best time for challenging and overthrowing an ageing dominant animal (Plutchik, 1991). As mentioned above, individuals who were able to respond adaptively to the facial display of others had an adaptive advantage. Consequently, facial stimuli could be expected to function as particularly emotionally salient visual stimuli. Consistent with the proposition that emotional reactions are typically caused by external stimuli (e.g., Dimberg, 1990; Ekman, 1992), and further confirming that facial activity is involved in emotional reactions, it has been shown that positive and negative emotional visual stimuli such as pictures of facial expressions (e.g., Dimberg, 1982; 1988; 1990*a*; 1991; Dimberg & Christmanson, 1991; Dimberg & Lundquist, 1990; Dimberg & Pettersson, 2000; Dimberg, Thunberg, & Elmehed, 2000; Dimberg, Thunberg, & Grunedal, 2002) evoke different facial EMG reactions, manifested as phasic EMG responses, in muscles relevant for emotional displays (for a review see Dimberg, 1997*b*). Happy faces, as compared to angry faces, evoke larger activity in the *Zygomatic major* muscle, whereas angry faces, as compared to happy faces, evoke larger activity in the *Corrugator supercilii* muscle. Consequently, these studies demonstrate that a sensitive and probably an optimal measure to detect a negative emotional response is to compare the corrugator response to angry faces with the response to a happy control face, that is, to express the response as the differential corrugator responding to angry vs. happy faces. Similarly, a sensible measure to detect positive emotional responses is to compare the zygomatic response to happy faces and the response to an angry control face, that is, to express the response as the differential zygomatic responding to happy vs. angry faces.

Fear-relevant stimuli

If facial EMG responses were unique to facial stimuli, they could be explained away as reflecting only mimicking behaviour. Thus, to demonstrate that facial activity is related to emotional activity in general, it has been important to demonstrate that also emotionally salient stimuli other than facial stimuli can evoke responses in facial muscles involved in emotional responding. Another class of stimuli which, from an evolutionary perspective (Öhman, 1986), should be highly emotionally relevant is potentially dangerous stimuli, such as snakes and spiders, as rapid and adequate reactions to these stimuli would have increased individuals' possibility of survival. Consistent with this perspective, it has been demonstrated that pictures of snakes, as compared to pictures of control stimuli, evoke increased corrugator activity (Dimberg, 1986; Dimberg & Thell, 1988). These results can be taken as support for the proposition that facial muscle activity is a general component in emotional reactions.

Additional findings

Furthermore, it has been demonstrated that differential facial muscle activity can be elicited by a large variety of external positive and negative emotional stimuli, including videotaped dynamic facial expressions (McHugo, Lanzetta, Sullivan, Masters, & Englis, 1985), sexual stimuli (Sullivan & Brender, 1986), landscape scenes (Dimberg & Ulrich, 1990; reported in Dimberg, 1990*a*), as well as auditory stimuli such as tones (Dimberg, 1990*c*; 1990*d*), noise (Kjellberg, Sköldström, Tesarz, & Dallner, 1994) and emotional vocalisations (Hietanen, Surakka, & Linnankoski, 1998). These findings lend further support to the hypothesis that the facial reaction is a general component of the emotional response. These results may also be interpreted as consistent with the theory (Tomkins, 1962) that specific "affect programs" elicit biologically prepared facial expressions.

IV. Consistency among emotion components?

Findings obtained using the facial EMG technique can also throw some light upon the question whether different emotions are characterised by different activity in all three aspects of the emotional response, as proposed by James (1884) and basic emotion theorists (e.g. Ekman, 1992; Izard, 1991), or whether emotional experience is caused by undifferentiated arousal and interpretation of the situation, as proposed by cognitive theorists (Lazarus, 1982; Mandler, 1975; Schachter & Singer, 1962). So far, the data are somewhat ambiguous.

As concerning facial activity and emotional experience, happy faces are rated as positive and angry faces as negative, which is consistent with the EMG reaction (Cacioppo, Petty, Losch, & Kim, 1986; Dimberg, 1997*a*). Furthermore, and again congruent with the facial response, snakes are rated as negative and flowers as positive (Dimberg, 1986; Dimberg & Thell, 1988). Additionally, when subjects were required to rate their own perceived emotion when exposed to facial stimuli (Dimberg, 1988; Lundquist & Dimberg, 1995), this was consistent with their facial activity. However, the findings of Dimberg & Karlsson (1997) imply that, although facial activity is related to emotional experience, there does not exist a one-to-one correspondence between facial expressions and experience. Interestingly, happy faces evoked more zygomatic activity than either flowers or highly rated landscape scenes, in spite of the fact that the latter were rated as more pleasant to look at. Thus, it seems that facial reactions are more pronounced to biologically relevant stimuli.

There is as yet no definitive answer to the question whether there is coherence among expressive behaviours and physiological patterns (Ekman, 1992). Whereas autonomic activity measured as heart rate and skin conductance responses differed between snakes and flowers (Dimberg, 1986), no difference was found between angry and happy facial stimuli (Dimberg, 1982). As mentioned above, there are indications of distinctive ANS patterns for the negative emotions anger and fear (Ekman, Levenson & Friesen 1983; Levenson, Ekman & Friesen, 1990) and possibly for sadness (Levenson, Carstensen, Friesen & Ekman, 1991). However, distinctive ANS patterns have not been found for positive emotions, such as happiness and interest. From an evolutionary perspective, Ekman (1992) suggests this may be due to the fact that there is no need for urgent motor activity, such as fight or flight responses, in situations involving positive emotions.

In summary, facial EMG research demonstrates that different visual emotional stimuli spontaneously evoke different and consistent facial EMG reactions which are further consistent with, at least for biologically relevant stimuli, how the subjects experience the stimuli, as well as with their own perceived emotion when exposed to stimuli. The EMG response is, at least for fear-relevant stimuli, congruent with ANS responses.

V. Background to the present studies

Is the facial muscle response a rapid response?

Taken together, the above findings may be considered to provide overwhelming evidence that the facial response is an integrated part of an emotional reaction. However, it has been proposed that an important feature of emotional reactions is that they can be very quickly and sometimes automatically evoked, resulting in the experience of emotions as something happening to rather than chosen by the individual (Ekman, 1992). If humans have a pre-programmed capacity to react to emotional expressions and if facial reactions are automatically evoked and controlled by genetically given affect programs, as proposed by proponents of basic emotions, then the reactions should not only be spontaneously evoked but also be detectable after only a short duration of exposure. Thus, as the above data on facial EMG were based on averaging the reactions over a number of seconds (typically eight), it still remains to be demonstrated that facial responses are detectable with a relatively short latency. The fact that the EMG signal is instantaneously detectable makes the technique suitable for investigating rapid facial reactions.

There are some indications that facial muscle reactions can be rapidly evoked, at least when compared to autonomic responses, which typically have a response latency of 1–4 s (Dimberg, 1990*a*). In earlier research on facial EMG it was observed that distinct facial reactions can be evoked as early as after only one second of exposure to facial stimuli. Furthermore, Haggard & Isaacs (1966) observed that distinct changes in facial muscle activity can occur within as little as 125–200 ms (Hatfield, Cacioppo, & Rapson, 1994). Therefore, it would be interesting to study the early component of the facial response, that is, whether emotionally relevant reactions can be evoked as early as during the first second of exposure to pictures of different emotional stimuli.

Research on the early component of the facial response could also shed some light on the related questions whether facial activity is a necessary condition for emotion, as proposed by the facial feedback hypothesis, and whether cognitive appraisal or physiological responding (in the form of facial muscle activity) is primary in the evocation of emotional reactions. Although a quick onset of facial reactions would not conclusively prove that emotional reactions are automatically evoked, or that facial activity is necessary for emotion, a prerequisite for any of these two hypotheses to be true would be that facial reactions should be detectable after only a short duration of exposure.

Neural models (LeDoux, 1995) support the proposition that emotional stimuli can be processed rapidly and automatically. Studies of the neural basis of emotion have a long history within neuroscience. Although it is not yet known whether there is a general purpose system of emotion in the brain, there has been a great deal of systematic and productive research on the neural basis of specific emotions, e.g., fear. Apparently, there are two parallel and partly separate systems for emotional activation in the brain, including a pathway leading directly from thalamus to the amygdala, allowing for emotional reactions to be elicited pre-cognitively and unconsciously. As rapid responses to danger have obvious survival value, this cognition-independent pathway could serve the adaptive function of allowing a shorter latency in important avoidance reactions (LeDoux, 1995).

Within cognitive psychology, a distinction is made between automatic and consciously controlled processes (e.g., Schneider & Shiffrin, 1977). According to Zajonc (1980), evaluation of affective stimuli can be automatic in the sense that it does not require the involvement of conscious cognitive processes. Traditional markers for what characterises an automatic process are that it occurs rapidly, spontaneously and effortlessly, and without conscious attention. What seems clear from the neural systems perspective (LeDoux, 1995) is that there are both involuntary and voluntary responses. Involuntary emotional responses include behavioural (e.g., freezing and flight reactions, facial responses) as well as visceral (e.g., autonomic and endocrine) responses.

With regard to the issue whether facial reactions are voluntarily controlled or automatic, it should be noted that, in our EMG research, the subjects are not aware of the fact that their facial muscle reactions are being measured. To achieve this end, we employ a cover story telling them that their sweat gland activity is measured, and the data from any subjects who afterwards report being aware of the true purpose of the experiment are excluded.

Social fear

Social phobia, defined as "marked and persistent fear of one or more social or performance situations in which the person is exposed to unfamiliar people or possible scrutiny by others" (DSM-IV, American Psychiatric Association, 1994) is now considered the most common anxiety disorder (Jefferys, 1997; in Tillfors, 2001).

It has been proposed that an exaggerated sensitivity to social stimuli (perceptual as well as physiological and experiential) including facial expressions is an important characteristic of people suffering from social fear (Öhman, Dimberg, & Öst, 1985). Consistent with this proposition, a number of studies indicate that social phobics have an exaggerated perceptual sensitivity to social stimuli, including facial expressions (e. g., Birbaumer, Grodd, Diedrich, Klose, Erb, Lotze, Schneider, Weiss, & Flor, 1998; Lundh & Öst, 1996). For instance, in a study using the "face-in-the-crowd paradigm" (Gilboa-Schechtman, Foa, & Amir, 1999), social phobics, as compared to non-anxious controls, exhibited greater attentional biases for angry than for happy faces in a neutral crowd. Social phobics were further more slowed down in their performance by both angry and happy vs. neutral distracters, whereas the performance of controls were not influenced by distracter type.

However, it is not self-evident that a greater sensitivity on a *perceptual* level should be accompanied by a greater *responsiveness.* Although Dimberg, Fredrikson & Lundquist (1986) found that people high in public speaking fear displayed exaggerated autonomic responses when exposed to social stimuli (pictures of human faces), a recent study (Vrana & Gross, 2004), found some support for the opposite, whereas most other studies (e.g., Edelmann & Baker, 2002; Grossman, Wilhelm, Kawachi, & Sparrow, 2001; Merckelbach, van Hout, van Hout, & Mersch, 1989) have not found any differences between subjects high and low in social fear. Thus, with some exceptions, it has been found that subjects high in social fear do not overreact with autonomic responses when exposed to social stimuli.

Furthermore, it may not be self-evident that a fear reaction to a social stimulus should be accompanied by an enhanced autonomic reaction. When the threatening stimulus is a snake, the relevant response is flight, an action which is facilitated by physiological arousal. As mentioned above, earlier studies have demonstrated that increased autonomic activity is one component of the phobic reaction in animal phobias, such as snake fear (e.g. Dimberg et al., 1998). On the other hand, when the threatening stimulus is an angry face, the most adaptive response may not be physical action at all, but rather communicative, such as display of facial expressions (Öhman, Dimberg, & Öst, 1985). Thus, any enhanced reaction to social stimuli could not self-evidently be expected to occur at the physiological/autonomic, but rather at the expressive level of the emotional response system.

It has been proposed that people suffering from social fear could be expected to experience facial stimuli, particularly angry faces, in a negative way (Dimberg & Christmanson (1991). Consistent with this proposition, when subjects were required to rate facial stimuli on different dimensions, it was found that subjects high in public speaking fear, as compared to low fear subjects, perceived angry faces as more negative, whereas low fear subjects perceived angry faces as more positive (Dimberg & Christmanson (1991). Likewise, Dimberg (1997*a*) found that high fear subjects rated happy faces as being less friendly and less happy than did a low fear group.

If facial activity is an integrated part of emotional activity, as suggested by the basic emotions approach, then people high and low in social fear could be expected to differ with respect to their facial reactions. Consistent with this proposition, in a study with a small number of subjects, people relatively high in social fear tended to display stronger facial EMG reactions, at least when exposed to angry faces (Dimberg, 1997*a*).

Animal fears

Further demonstrating that facial EMG reflects emotional activity, it has been possible to detect different facial reactivity in subjects high and low in animal fear when they are exposed to their feared objects. Thus, people with fear of snakes and spiders show enhanced electrodermal responses (e.g., Dimberg et al., 1986; Öhman & Soares, 1994), elevated heart rate (Fredrikson, 1981; Hare & Blevings, 1975, forehead vasoconstriction (Hare, 1973), as well as a negative emotional facial reaction (Dimberg, 1990*b*; 1997*b*) when they are exposed to pictures of their fear-relevant stimulus.

Phobic reactions have been described as irrational and difficult to control or suppress, indicating that they may be analysed independently of conscious cognitive processes (Öhman & Soares, 1994), resulting in a relatively automatic and rapidly evoked emotional response. The capacity to quickly learn to avoid certain stimuli must have been adaptive during biological evolution. Therefore it could be expected that fear reactions, in particular, should be very rapidly elicited. Thus, subjects high and low in fear of snakes could be expected to differ with respect to the early component of their facial EMG reactions, i.e., the response during the first second after stimulus onset.

Gender differences in facial activity

Previous research on non-verbal communication has demonstrated that females are more facially expressive than males in an emotion-provoking situation (e.g., Buck, Savin, Miller & Caul, 1972; see Buck, 1984). Females also score higher than males in non-verbal receiving ability (Brody & Hall, 1993, Hall, 1978).

Consistent with previous research on non-verbal communication, studies on facial EMG and emotional imagery (e.g., Schwartz, Brown, & Ahern, 1980) have presented evidence that females generate larger facial muscle activity than males. Analogous results were obtained when subjects were exposed to auditory stimuli (Dimberg, 1990*b*) and females also tended to be more reactive when exposed to pictures of different facial expressions (Dimberg, 1990*a*; Dimberg & Lundquist, 1990).

It is important to point out that this does not mean that males do not react at all with their facial muscles, but only that the magnitude of the facial reactions is larger for females. Thus, earlier findings clearly indicate that the difference in responding between males and females is quantitative rather than qualitative. This quantitative difference should not necessarily be interpreted as reflecting genetic neural mechanisms, but might equally well be due to simple peripheral anatomical factors (e.g., the smoother skin of most females resulting in EMG responses being easier to detect in female subjects). As the present series of studies was the first on rapid facial reactions to emotional stimuli, it was important to optimise the possibility of detecting differences between stimuli. On the basis of previous findings, there was no reason to expect that males and females should respond in qualitatively different ways. Therefore, with the exception of Study II, which involved a comparison of facial reactions of males and females exposed to fear-relevant (snake) stimuli, only female subjects were selected to take part in the present studies.

VI. Aim of the present thesis

The overall aim of the present thesis was to investigate the relation between rapid facial muscle reactions and emotionally relevant stimuli. In four separate studies, it was explored 1) whether rapid emotional facial muscle reactions can be evoked to different emotionally relevant stimuli (human faces, snakes), and 2) whether rapid facial muscle reactions differ between groups for which the emotional relevance of stimuli can be considered to differ (people high and low in snake fear and social fear, respectively).

The main aim of Study I was to determine how rapidly emotion relevant facial muscle reactions are evoked when people are exposed to pictures of facial expressions. Particularly, it was explored whether reactions can be evoked during the first second of exposure. A second aim was to explore whether rapid facial reactions can also be evoked to stimuli with a short duration (0.5–1 s of exposure).

The main aim of Study II was to investigate whether fear-relevant stimuli, such as pictures of snakes, evoke rapid differentiated facial reactions in the corrugator muscle, a muscle relevant for negative emotional displays. A second aim was to explore whether females are specifically more facially reactive than males, but not more reactive in other respects, as evidenced not only by facial reactions but also by autonomic responding and emotional experience.

The aim of Study III was to explore whether people with explicit fear of snakes, as compared to non-fearful people, react with a more pronounced rapid negative facial emotional reaction when exposed to pictures of snakes, manifested as increased corrugator activity during the first second of exposure.

The main aim of Study IV was to investigate possible group differences in rapid facial reactions between subjects high and low in social fear (specifically speech anxiety). A second aim was to explore possible differences between subjects high and low in speech anxiety with respect to their autonomic responses and emotional experience when exposed to facial stimuli.

Empirical studies

General method

The subjects were mostly university students with an age range of about 20–40 years. With the exception of Study II, which involved an equal number of males and females, all subjects were females. Individually tested in a sound-attenuated room, they were exposed to slides projected onto a screen. The distance between subject and screen was 2 m and the picture size 40x50 cm. Depending on the different experiments, stimulus duration varied between 0.5, 1 and 8 s and the inter-trial intervals varied between 25 and 45 s. The exposure times were controlled by an electronic timer which together with all other equipment was situated outside the room.

Following a standardised instruction procedure, the subjects were told that their physiological activity was going to be measured while they were exposed to slides of different emotional stimuli. In order to conceal the fact that their facial muscle activity was measured, a cover story was used. The subjects were told that sweat gland activity was measured in their faces (e.g., Dimberg, 1988; 1990*a*). When interviewed after the experiment, the small number of subjects who reported having been aware of the fact that their facial muscle activity had been measured had their data excluded and were substituted with new subjects. After the interview, the subjects were told the true purpose of the experiment.

Facial EMG activity was bipolarly measured with Beckman miniature Ag/AgCl electrodes. Before attached over the *Zygomaticus major* and/or the *Corrugator supercilii* muscle regions (Fridlund & Cacioppo, 1986) the electrodes were filled with Beckman electrode paste. To reduce the electrode site impedance to less than 10 kΩ the electrode sites were first cleaned with alcohol and mildly rubbed with electrode paste. The muscle activity was detected with 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 connected to an IBM PC which collected data with a sample frequency of 100 Hz. Facial EMG data were recorded during the first second after stimulus onset. Phasic responses were scored as change in activity from the pre-stimulus levels which were defined as the activity during the last second before stimulus onset. The data were expressed in microvolts.

In Studies II–IV, autonomic activity (skin conductance responses and heart rate responses) was also measured. Skin conductance responses (SCRs) were measured with two Beckman Ag/AgCl electrodes (8 mm diameter) attached to the second phalanxes of the first and second fingers of the left hand. The electrodes were filled with Unibase 0.05 M NaCl electrode paste and were connected to a Coulbourn Skin Conductance Coupler. The electro-cardiogram was measured with Beckman Ag/AgCl electrodes filled with Beckman electrode paste. The electrodes were attached to the subjects' chest and were connected to a Coulbourn Hi Gain Amplifier. SCRs were expressed as the largest phasic responses within the 1–4 second interval after stimulus onset. Heart rate (HR) responses were scored in beats per minute (bpm) and were expressed as mean activity during exposure and/or as phasic responses (change in activity from the pre-stimulus levels defined as mean activity during the last 3 seconds before stimulus onset).

After exposure to the different stimuli, the participants were, in Studies II–IV, required to rate how unpleasant and sometimes also how pleasant they experienced the stimuli on a scale from 0 to 9, where 0 was "not at all" and 9 was "very much".

Study I

Study I was performed to determine how rapidly emotion relevant facial muscle reactions are elicited and manifested when subjects are exposed to pictures of facial expressions. In three different experiments, involving two sets of stimulus pictures, facial EMG activity was measured from the *Zygomaticus major* and the *Corrugator supercilii* muscles during the first second after stimulus onset while subjects were exposed to happy and angry facial stimuli. As mentioned in the introduction, earlier studies have found females to be more facially expressive than males. Therefore, to optimise the possibilities of finding differences in responding between stimuli, only female subjects were selected to take part in the present study. Earlier observations have indicated that distinct changes in facial muscle activity can occur within as little as 125–200 ms (Haggard & Isaacs, 1966; reported in Hatfield, Cacioppo & Rapson, 1994) and consequently the facial muscle activity in the present study was measured during intervals of 100 ms. It was predicted that happy faces should evoke more zygomatic muscle activity than angry faces, while angry faces should evoke more corrugator muscle activity than happy faces.

In Experiment 1, the stimuli were black and white slides of 8 angry and 8 happy faces selected from Ekman and Friesen's (1976) "Pictures of facial affect". All subjects (N=24) were exposed to six presentations each of one slide of a happy and one of an angry face with an exposure time of 8 s. The order of the stimulus categories was counterbalanced across subjects, and different subjects saw different combinations of the slides. Consistent with earlier studies (e.g., Dimberg, 1982), the results in Experiment 1 showed that happy faces evoked more *Zygomaticus major* activity than angry faces, whereas angry faces evoked more *Corrugator supercilii* activity than happy faces. Interestingly, these reaction patterns were significant as early as 400–500 ms after stimulus onset. Thus, data in Experiment 1 demonstrate that it is possible to detect differential responding to angry and happy faces during the first second after stimulus onset. These results consequently support the hypothesis that the evocation and manifestation of facial reactions to facial expressions can be a very rapid process.

The main goal of Experiment 2 was to replicate the findings in Experiment 1 using a larger sample of subjects (N=80). A second aim was to test the generality of the findings by using another set of stimulus pictures. In Experiment 2, the angry and happy stimuli were selected from a standardised set of colour slides of facial expressions developed by Matsumoto and Ekman (1989). The results are illustrated in Figure 1. The responses were basically similar to those in Experiment 1. Thus, as can be seen in the figure, differentiated rapid facial muscle reactions to angry and happy faces occurred as early as 300–400 ms after stimulus onset, with happy faces evoking more *Zygomaticus major* activity than angry faces, whereas angry faces evoked more *Corrugator supercilii* activity. The fact that different collections of angry and happy stimulus pictures were used within the different experiments further indicates that rapid facial reactions to facial expressions is a general phenomenon.

As in earlier studies in which rapid facial reactions have been studied (e.g., Dimberg, 1991; 1994; 1997*b*) the *Corrugator supercilii* muscle reaction was an initial increase during the first 300–400 ms. Note that this early response component was released both by pictures of angry and happy faces. It is uncertain what this response component reflects, but the fact that a similar initial response was released by the different stimuli is consistent with the results obtained in earlier studies (e.g., Dimberg, 1991; 1994; 1997*b*). Thus, these data indicate that this response component does not reflect the emotional content of the stimuli but is rather a general effect of visual stimulation. For a more elaborate discussion of this early response component, see General discussion.

Although the stimulus duration was 8 s, the results from Experiments 1 and 2 showed that the facial responses differed between the stimuli as early as during the first second of exposure. Therefore, a further interesting question to investigate was whether rapid facial reactions can also be elicited when people are exposed to stimuli with a much shorter duration. Particularly, as the responses differentiated just before half a second after stimulus onset, the reactions during the first two half-seconds after stimulus onset were of interest. Thus, a third experiment was designed in which subjects (N=96) were exposed to black and white slides of angry and happy faces with 0.5 s and 1.0 s duration. In order to keep one condition similar to the first two experiments, the subjects were also exposed to faces with 8 s duration.

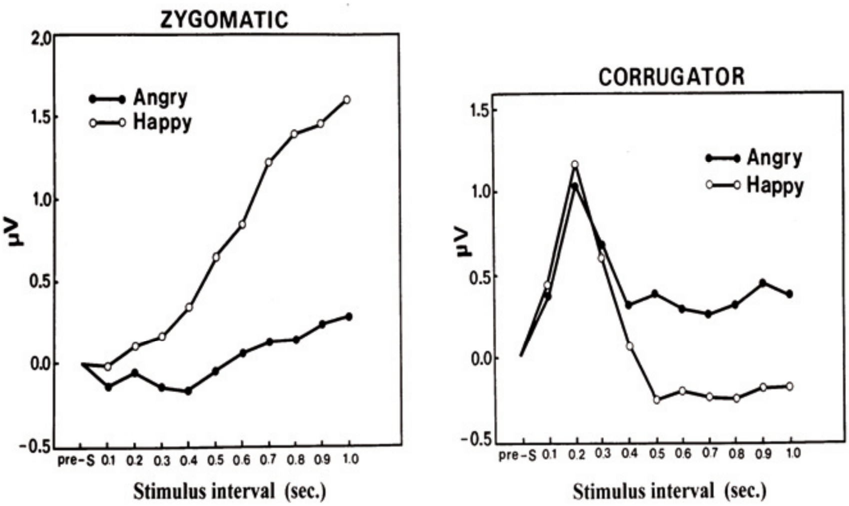

Figure 1. The mean facial electromyographic response to happy and angry facial stimuli for the *Zygomaticus major* and the *Corrugator supercilii* muscle regions, plotted in intervals of 100 ms during the first second of exposure. (Adapted from "Rapid facial reactions to emotional facial expressions" by U. Dimberg & M. Thunberg, 1998, *Scandinavian Journal of Psychology, 39,* p.41. Copyright 1998 by Blackwell Publishing. Reprinted with permission).

Similarly to previous experiments, the zygomatic responses were larger to happy than to angry faces. The activity overall increased as a function of intervals, and this effect was mainly dependent of an overall increased activity to happy faces. Separate analysis for the respective intervals showed that the tendency to larger reactions to happy faces was statistically significant at 400 ms and during all the following intervals. Further, the responses to 1.0 s and 8.0 s exposures tended to be larger than those to 0.5 s exposures. This effect, however, was not statistically significant.

The response to angry faces was larger than to happy faces after 400 ms, and during all the following intervals. Finally, although the means indicated that the responses to 0.5 s exposures were smaller than those to 1.0 and 8.0 s exposures, there were no statistically significant differences in responding to the different stimulus durations.

Consistent with earlier research (e.g., Dimberg, 1982; 1988; 1990*a*), the results from all three experiments indicated that happy faces spontaneously evoked a facial reaction in emotion relevant muscles indicating a positive emotional reaction, i.e., increased *Zygomaticus major* muscle activity. Angry faces evoked a facial response reflecting a negative emotional reaction, i.e., increased activity in the *Corrugator supercilii* muscle. Most importantly, the results demonstrated that the differences in responding to happy and angry faces occurred as early as 300–400 ms after stimulus onset. These findings are consistent with the hypothesis that facial reactions can be very quickly evoked and manifested and that facial reactions are generated by biologically controlled fast operating “affect programs”.

Similar results were obtained in three independent experiments. Thus, the results proved to be possible to replicate, and in addition, with different sets of stimulus pictures (Ekman & Friesen, 1976; Matsumoto & Ekman, 1989), and also with different short stimulus durations. In fact 0.5 s of duration was sufficient to spontaneously evoke differential responses to angry and happy stimuli. These findings indicate that rapid facial reaction is a general phenomenon when people are exposed to angry and happy facial expressions.

Study II

One important question is whether the short latency of the facial response is limited to a face-to-face situation or if it reflects emotional reactions *in general*. In other words, do the rapid facial reactions rely on neural mechanisms which are specific to the evocation of facial reactions to facial stimuli only, or do the reactions rely on more general mechanisms which evoke rapid facial emotional reactions not only to facial stimuli but to other types of emotional stimuli as well?

In previous research it was found that facial EMG reflects emotional activity in general (e.g., Cacioppo & Petty, 1981; Dimberg 1990*a*). For instance, negative visual emotional stimuli such as pictures of snakes, when compared to control stimuli, also evoke increased corrugator activity (e.g., Dimberg, 1986; 1990*a*). One question to investigate would then be whether negative stimuli, such as snakes, also tend to evoke *rapid* facial reactions in emotion relevant facial muscles.

The main aim of Study II was to investigate whether fear-relevant stimuli, such as snakes, evoke *rapid* differentiated negative facial reactions (i.e., during the first second of exposure) manifested as increased corrugator activity. The subjects were exposed to slides of snakes and flowers. Flowers were chosen as control stimuli because they have in earlier studies been accompanied by a neutral or a mildly positive reaction (e.g., Dimberg, 1990*b*). Therefore, it was predicted that snakes would evoke larger corrugator activity than pictures of flowers and that this effect would be apparent during the first second of exposure.

As further mentioned in the introduction, studies on facial EMG and emotional imagery (e.g., Schwartz, Brown, & Ahern, 1980), auditory stimuli (Dimberg, 1990*b*), and pictures of different facial expressions (Dimberg, 1990*a*; Dimberg & Lundquist, 1990) have presented evidence that females tend to generate larger facial muscle activity than males. Therefore, a second aim in the present study was to explore whether females are specifically more facially reactive than males, but not more reactive in other respects, or whether females are more emotionally reactive in general, as reflected not only by facial reactions but also by autonomic responding and emotional experience. In order to test the two hypotheses given above, males (n=48) and females (n=48) were exposed to pictures of snakes while their corrugator activity and SCRs were measured, and afterwards the subjects were asked to rate how unpleasant they experienced the stimuli. According to the first hypothesis, females should generate larger facial reactions than males, while there should be no difference between the groups regarding SCRs or ratings. According to the second hypothesis, females should generate not only larger EMG responses but also larger SCRs and should rate the negative stimuli as more unpleasant. The control stimuli also made it possible to evaluate whether differences in responding between males and females might be due to a general difference in reactivity unrelated to the emotional quality of the stimuli. The stimuli were presented in blocks of six trials. Facial EMG was scored and analysed as mean activity during the first second after stimulus onset.

The results are shown in Table 1. Snakes evoked a larger corrugator response than flowers, but only for females. Thus, snakes did not evoke overall significantly higher corrugator muscle activity than the control stimuli. Snakes further elicited larger SCRs and higher ratings of unpleasantness, and these measures were almost identical for females and males. These results, then, seem to indicate that females are more facially reactive than males, at least as regards corrugator activity elicited by negative stimuli, but not more reactive in other respects.

	Females		Males	
	Fear-relevant	Fear-irrelevant	Fear-relevant	Fear-irrelevant
Corrugator response (μV)	0.305	0.130	0.155	0.185
SCR (μS)	0.146	0.071	0.146	0.080
Unpleasantness (1-9)	4.458	0.562	4.360	0.880

Table 1. The mean *Corrugator supercilii* muscle responses, skin conductance responses and unpleasantness ratings of fear-relevant and fear-irrelevant stimuli for females and males. (Adapted from "Gender differences in facial reactions to fear-relevant stimuli" by M. Thunberg & U. Dimberg, 2000, *Journal of Nonverbal Behavior, 24,* p. 46. Copyright 2000 by Springer Science and Business Media. Reprinted with permission).

Study III

The aim of Study III was to explore whether people with explicit fear of snakes, as compared to nonfearful people, react with a more pronounced negative facial emotional reaction when exposed to pictures of snakes and, in particular, whether these facial reactions are manifested during the first second of exposure.

It has been proposed that the evocation of rapid responses to dangerous stimuli has been adaptive during biological evolution (e.g., Dimberg, 1997*b*; LeDoux, 1995; Öhman, 1986). Since the ability to react rapidly to fear relevant stimuli probably is one important feature of a fear reaction, it follows that it is important to explore whether the fear response can be rapidly initiated and manifested as a distinct bodily reaction. The present study examined whether fear reactions can be rapidly manifested as distinct facial emotional reactions.

Two groups of subjects, High (n=28) or Low (n=28) in fear of snakes, were exposed to pictures of snakes and flowers. Because the results from Study II indicated the possibility that females may be more facially expressive than males when exposed to snakes, only female subjects were chosen for the present study. It was predicted that, because a snake constitutes a particularly salient emotional/fear relevant stimulus for people suffering from fear of snakes, those people should react with a larger and more rapid "negative" facial response to snakes than people low in fear of snakes. More specifically, subjects with fear of snakes were expected to react with larger *Corrugator supercilii* muscle activity to pictures of snakes than to pictures of flowers as early as within the first second of exposure. Pictures of flowers, on the other hand, were not expected to induce different responding between the two groups, but were rather expected to induce a mildly positive reaction (e. g., Dimberg, 1997), manifested as an overall larger *Zygomaticus major* muscle response to flowers than to snakes. Because the results from Study I had shown that the difference in reaction between angry and happy faces is typically beginning to be apparent towards the end of the first half-second of exposure, the first second after onset was separately analysed in two periods (0–500 and 500–1000 ms) each with five 100 ms intervals, and the most clear-cut differences between stimuli and groups were expected to appear during the second period.

As noted above, earlier studies have demonstrated that increased autonomic activity is one important component of the phobic reaction. Consequently, autonomic activity indexed by skin conductance responses (SCRs) and heart rate (HR) activity was also recorded in the present study. It was predicted that people with fear of snakes should react with larger SCRs and HR activity when exposed to snakes. In order to further confirm that people high in fear of snakes experience pictures of snakes as negative stimuli, the subjects were asked to rate how unpleasant and pleasant they experienced the pictures.

The EMG results are illustrated in Figure 2 and Figure 3. As can be seen in the figures, the *Corrugator supercilii* response was larger to pictures of snakes than to flowers as early as within 500–1000 ms after stimulus onset. This effect, however, was evident only in the High fear group. Thus, consistent with the prediction, people high as compared to people low in fear of snakes responded with a more pronounced and, particularly, with a rapidly evoked negative emotional facial reaction to pictures of their fear relevant stimulus. Pictures of flowers, on the other hand, tended to evoke an overall increased *Zygomaticus major* muscle response which did not differ between the High and Low fear subjects. These results further demonstrate that the facial muscles constitute a rapid emotional response system and the results are consistent with earlier studies which have shown that fear relevant stimuli tend to evoke distinguished facial reactions after only 500 ms of exposure (Dimberg, 1991; 1994; 1997*b*). The interpretation that the snake stimuli evoked a negative emotional response was also supported by the autonomic data as well as the rating data. Thus, the High fear group reacted with larger autonomic responses to snakes, and also experienced pictures of snakes as highly unpleasant. Furthermore, whereas the Low fear group rated snakes as relatively pleasant to look at, the High fear group did not.

Similarly to Study I, the initial *Corrugator supercilii* muscle reaction was an increase during the first 300–400 ms, released both by pictures of snakes and of flowers within both groups. As mentioned above, a more elaborate discussion of this early response component will follow in the General discussion.

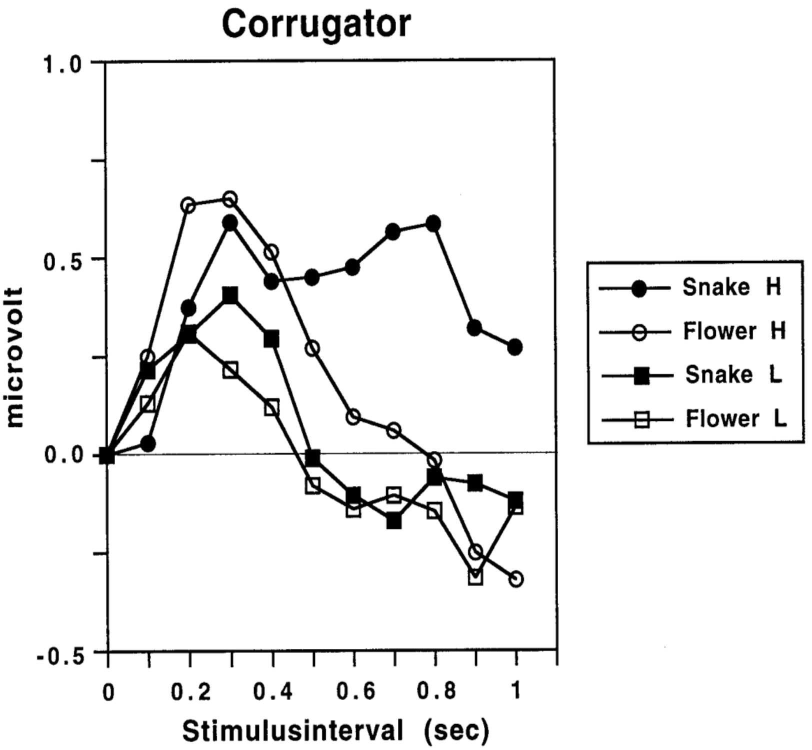

Figure 2. The *Corrugator supercilii* muscle response to pictures of snakes and flowers for the High and the Low fear groups plotted as a function of 100 ms intervals during the first second after stimulus onset. (From "Fear of snakes and facial reactions: A case of rapid emotional responding" by U. Dimberg, G. Hansson & M. Thunberg , 1998, *Scandinavian Journal of Psychology, 39,* p 77. Copyright 1998 by Blackwell Publishing. Reprinted with permission).

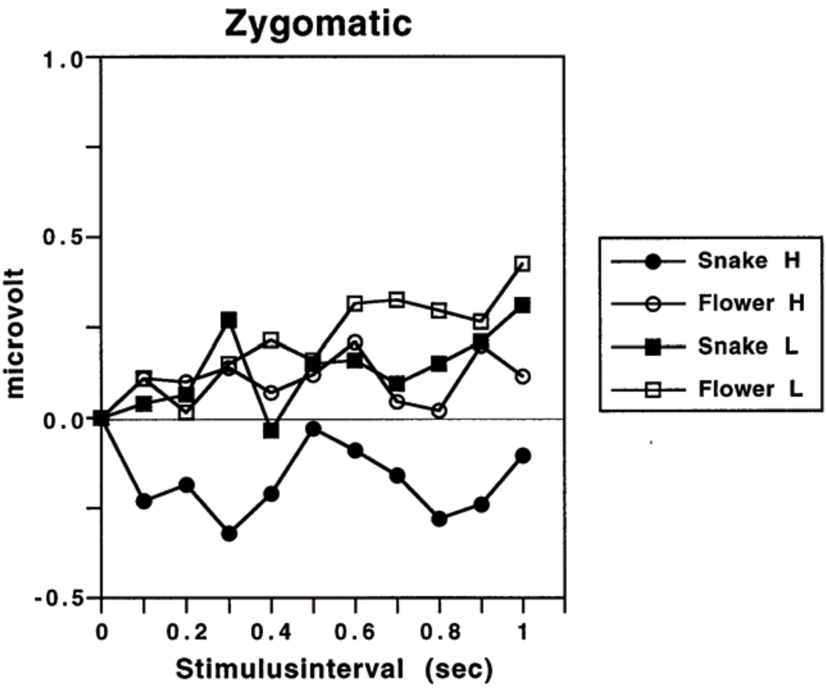

Figure 3. The *Zygomaticus major* muscle response to pictures of snakes and flowers for the High and the Low fear groups plotted as a function of 100 ms intervals during the first second after stimulus onset. (From "Fear of snakes and facial reactions: A case of rapid emotional responding" by U. Dimberg, G. Hansson & M. Thunberg, 1998, *Scandinavian Journal of Psychology, 39,* p.78. Copyright 1998 by Blackwell Publishing. Reprinted with permission).

Study IV

The results from Study I indicated that happy faces spontaneously evoked a rapid facial reaction in emotion relevant muscles indicating a positive emotional reaction, i.e., increased *Zygomaticus major* muscle activity, whereas angry faces evoked a facial response reflecting a negative emotional reaction, i.e., increased activity in the *Corrugator supercilii* muscle. These findings indicate that a rapid facial reaction is a general phenomenon when people are exposed to angry and happy facial expressions.

One could expect that the sensitivity to social signals may differ between individuals, with certain persons having a higher ability to recognize, and possibly also to respond more forcefully to, facial expressions. One such group of persons with a high degree of sensitivity to social signals might be people with social phobias, such as speech anxiety. Similarly to a snake phobic's reaction to a snake, a person with social fear could be expected to be especially vigilant for an angry face as a threat signal and thus, as compared to a non-fearful person, possibly also respond with a more pronounced negative reaction to the angry face. On the other hand, it is possible that a socially sensitive person also would be especially vigilant for a happy face, because of its explicit signal value as a contra-indication of threat. In other words, the happy face might function as an important "safety signal" for the socially sensitive person, who might then respond with an exaggerated emotional reaction consistent with the positive signal of the happy face.

According to DSM-IV (American Psychiatric Association, 1994) social fear is defined as a "marked and persistent fear of one or more social or performance situations in which the person is exposed to unfamiliar people or possible scrutiny by others". Although there is as yet no final agreement on whether social phobia consists of distinctive subtypes, empirical evidence suggest that it might be better to consider social fear as being distributed on a continuum of severity (Furmark, 2000; Tillfors, 2001). However, the most prevalent form of social fear in the general population is fear of public speaking (Furmark, 2000). Thus, the specific aim of the present experiment was to investigate whether people high as compared to low in social fear display larger facial reactions when exposed to facial expressions. Participants were selected on the basis of their self-rating scores on a Swedish standardised translation (Fredrikson, 1983) of Paul's (1966) Personal Report of Confidence as a Speaker questionnaire (PRCS). Because earlier studies have indicated that females are more facially reactive than males when exposed to facial stimuli, only female subjects were chosen to take part in the present study.

In the present study, it was predicted that if speech anxiety is related to a capacity to react emotionally in a face-to-face situation, then people with high PRCS scores could be expected to show an exaggerated responsiveness to negative stimuli. According to earlier studies, this would be manifested as a larger differential corrugator muscle reaction between the angry and happy stimuli, for the High as compared to the Low scoring group.

Based on the hypothesis that people with high social fear are more sensitive to emotional facial expressions, one could also predict that the High fear group should respond with a larger positive reaction to happy stimuli. According to earlier studies (e.g., the present Study I) this would be manifested as a larger differential zygomatic muscle responding between happy and angry stimuli for the High as compared to the Low fear group. Because earlier studies (e.g., Dimberg, 1996) have demonstrated that different reaction patterns can be detected as early as 500–1000 ms after stimulus onset, clear-cut differences in response to the stimuli were expected to appear during this stimulus period.

High and Low fear participants were exposed to black and white slides of angry and happy faces selected from Ekman and Friesen's (1976) "Pictures of facial affect". The participants were also asked to rate, on different emotional scales, how they experienced the stimuli. In accordance with the prediction made for the facial EMG responses, it was predicted that people with high PRCS scores would experience angry faces as more negative. Based on the assumption above, it was further predicted that the High fear group, as compared to the Low fear group, should experience happy faces as more positive.

Finally, as mentioned in the general introduction, conflicting results have been obtained with regard to how people with social fear react with autonomic responses when exposed to social stimuli. Consequently, in order to further explore possible differences between people high and low in speech anxiety with respect to their autonomic responses when exposed to social stimuli, autonomic activity, indexed by skin conductance responses (SCRs) and heart rate (HR) activity, was also recorded in the present study.

The EMG results are illustrated in Figures 4 and 5. Similarly to studies I and III, the initial *Corrugator supercilii* muscle reaction was a sudden increase during the first 300–400 ms, released by pictures of both angry and happy faces within both groups. However, as can be seen in the figure, during the remainder of the stimulus period people with high as opposed to low PRCS scores reacted with a larger difference in corrugator responding between angry and happy faces. The High fear subjects also reacted with a larger difference in zygomatic responding between happy and angry faces, indicating that High fear subjects have an exaggerated sensitivity to react emotionally not only to angry, but also to happy facial stimuli. In both experiments, this effect was particularly evident during the 500–1000 ms period after stimulus onset. On the other hand, and in contrast to the snake fear study, there were no differences in SCR or HR responding between High and Low speech anxiety groups.

Angry faces were rated higher on the dimensions of anger, fear, sadness, disgust, and unpleasantness, whereas happy faces were rated higher on happiness, pleasantness, and directedness. More interesting to the present study, however, was the fact that the difference in unpleasantness and disgust ratings between angry and happy faces was larger for the High fear than for the Low fear group. Interestingly, in parallel with the unpleasantness ratings, the difference in pleasantness ratings between happy and angry faces tended to be larger for the High fear group than for the Low fear group.

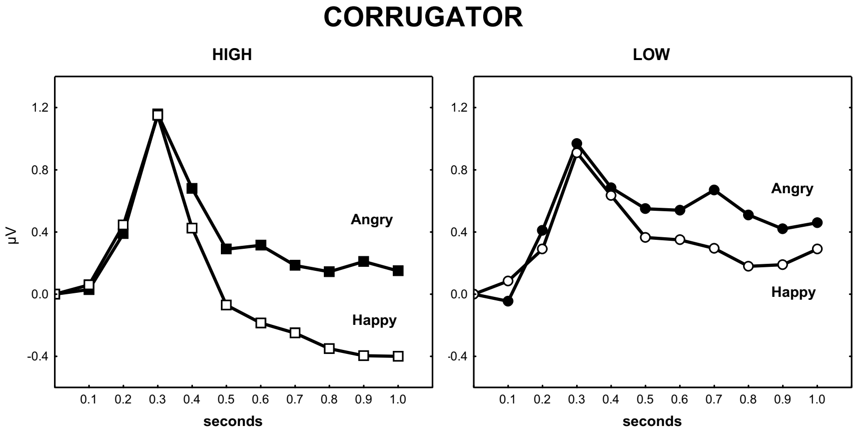

Figure 4. The *Corrugator supercilii* muscle response to pictures of angry and happy faces for the High and Low fear groups, plotted as a function of 100 ms intervals during the first second of exposure. (From "Speech anxiety and rapid emotional reactions to angry and happy facial expressions" by U. Dimberg & M. Thunberg 2007, *Scandinavian Journal of Psychology, 48,* p. 324. Copyright 2007 by Blackwell Publishing. Reprinted with permission).

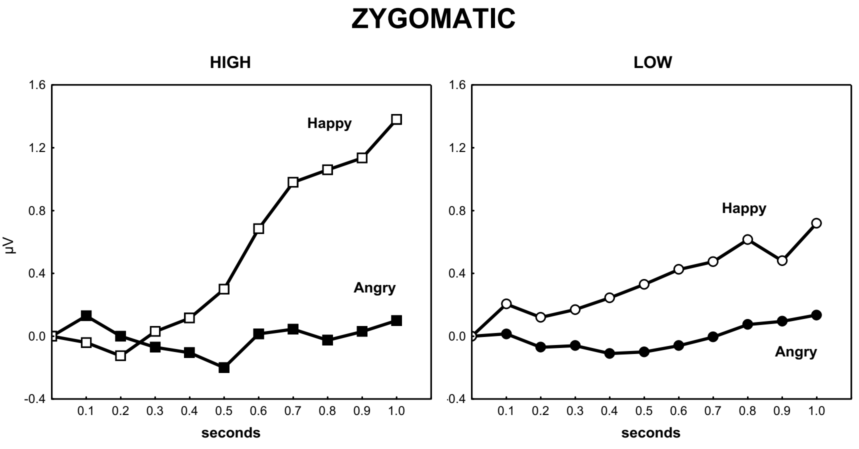

Figure 5. The *Zygomaticus major* muscle response to pictures of happy and angry faces for the High and Low fear groups, plotted as a function of 100 ms intervals during the first second of exposure. (From “Speech anxiety and rapid emotional reactions to angry and happy facial expressions” by U. Dimberg & M. Thunberg 2007, *Scandinavian Journal of Psychology, 48,* p.325. Copyright 2007 by Blackwell Publishing. Reprinted with permission).

Discussion of the individual studies

Study I

The results from Study I demonstrate that pictures of angry and happy faces spontaneously evoked facial reactions in emotion relevant muscles as early as 300–500 ms after stimulus onset. This means that the facial muscle response is faster than that of the autonomic response system, which typically has a response latency of 1–4 s, as for example SCRs.

Replicable results were obtained in three independent experiments using different sets of facial stimuli and different lengths of stimulus duration. The results in experiment 3 show that 0.5 s of exposure is sufficient to evoke differential facial muscle responding between angry and happy stimuli. These results demonstrate that stimuli with a relatively short duration evoke rapid facial reactions. Taken together, this indicates that the elicitation of rapid facial reactions is a general phenomenon elicited by exposure to angry and happy faces. The results demonstrate that facial reactions are quickly evoked and manifested and are thus consistent with the hypothesis that facial reactions may be quickly and automatically evoked (Dimberg, 1997*c*; Ekman, 1992) and that these reactions are possibly generated by biologically controlled fast operating "affect programs" (Tomkins, 1962).

All subjects in the present study were females. However, in the light of previous findings, there is no reason to expect that males should not respond in a similar way. As mentioned in the introduction, both males and females have in a number of earlier studies been shown to respond with facial muscle activity to emotionally relevant stimuli. However, females tend to generate larger facial muscle activity than males, possibly because of peripheral anatomical factors (e. g., smoother skin). Therefore, in an attempt to optimise the possibility of detecting differences between stimuli, only female subjects were chosen to take part in the present study.

The present data showed an initial increase in activity for the *Corrugator supercilii* muscle during the first 300 ms after stimulus onset in response to both happy and angry facial stimuli. It is uncertain what these reactions reflect, but the fact that this early response component is similar in response to both angry and happy facial stimuli and was seen in all experiments, indicates that this response is a general phenomenon, independent of the emotional quality of the stimuli.

Another question is whether the response latency is different for different facial muscles. The present results showed that the differentiated rapid facial muscle reactions to angry and happy faces occurred at 300–500 ms after stimulus onset, with in some cases corrugator and in some cases zygomatic reactions being slightly faster. Consequently, there seems to be no basis for considering either muscle to be consistently faster to react than the other. A related question is whether the facial response latency differs depending on whether subjects are exposed to angry or happy facial stimuli. However, as the present data are based on the difference between stimuli, the present study does not answer the question whether angry or happy facial stimuli are faster at eliciting a facial response.

The present study demonstrated that 0.5 s of duration was sufficient to spontaneously evoke differential responses to angry and happy stimuli. Although the responses to 0.5 s exposures tended to be smaller than those to 1.0 and 8.0 s exposures, there were no statistically significant differences in responding to the different stimulus durations. Furthermore, the facial reactions did not differ as a function of the number of presentations. Thus, the responses in the present study did not habituate, nor could they be explained as an effect of sensitisation or priming, i.e., that the subjects were "warmed-up" by the first presentations and then successively started to react during the later trials. These findings indicate that rapid facial reaction is a general phenomenon, at least when people are exposed to angry and happy facial expressions.

Study II

The present study did not fully replicate the results from some earlier studies (e.g., Dimberg, 1986; Dimberg et al., 1998), as there was no significant overall difference in corrugator muscle responding between snakes and the control stimuli. Only females responded with a larger corrugator muscle reaction to the snake stimuli. However, the highly significant difference between the stimuli in SCRs and unpleasantness ratings for both males and females indicate that snakes evoked a negative emotional reaction in both groups.

The present results demonstrated that females, as compared to males, produced a larger corrugator muscle reaction to snakes. However, there were no differences in responding between males and females in SCRs or ratings of unpleasantness. These results are consistent with the hypothesis that females are more facially reactive than males, but not more reactive in other respects. Consequently, the results did not support the hypothesis that females are more emotionally reactive in general.

It is obvious that males and females differed in facial reactivity in the present study. However, how this difference should be interpreted is not obvious. For instance, there could be genetic dissimilarities such as different mediation by the central nervous system or peripheral dissimilarities resulting in different facial reactivity (for a discussion see Schwartz et al., 1980). Another possible explanation could be that males and females are differently facially reactive because they are trained to express emotions differently. Several studies (e.g., Fuchs & Thelen, 1988; Gleason, 1989) suggest that girls are encouraged to learn to express feelings through words and facial expression, whereas boys are discouraged from learning to express feelings in these ways (for a review see Brody & Hall, 1993). A third factor may be that females possess a more sensitive perceiving ability (Buck, 1984; Hall, 1978), and therefore react more intensely. However, there were no differences between males and females in perceiving ability as indicated by unpleasantness ratings in the present study. Additionally, an earlier study using facial stimuli (Dimberg & Lundquist, 1990) found no difference in how males and females perceived the stimuli.

An obvious limitation of the present study is that no subjective snake fear ratings were performed. Earlier research has found snake fear to be more prevalent among females (Fredrikson, 1983). Consequently, it is possible that the females, as a group, were more fearful of snakes. Even though this interpretation is not supported by the autonomic data or the ratings of unpleasantness, in future research on gender differences with respect to fear-relevant stimuli the groups should be matched with respect to subjective fear.

Even if not consistently found, some studies have indicated a negative relationship between expressivity and autonomic activity such as SCRs (for a review see Buck, 1984). The so-called "internaliser–externaliser" dimension is a term used to describe this relation between spontaneous facial signs of affect on the one hand and internal physiological arousal on the other. The *externalising* mode of response involves high overt expression but low electrodermal responding, while the *internalising* response involves the opposite pattern (e.g., Buck et al., 1972). From this perspective, males – being less facially reactive than females – would have been expected to react with larger SCRs in the present study, but no such effects were found. On the contrary, the SCR reactions of males and females were nearly identical.

When discussing the three aspects of the emotional response system, it is important to point out that, in the present study, subjects were required to rate the unpleasantness of the stimuli, not their own emotional experience. However, in earlier studies using facial stimuli (e.g., Lundquist & Dimberg, 1995), no difference in self-perceived emotion was found between males and females.

In summary, the present results indicated that, when exposed to snake stimuli, females generated more pronounced corrugator muscle reactions than males, but similar SCRs and unpleasantness ratings. These results are consistent with earlier research on facial EMG and emotion as well as research on non-verbal communication indicating that females are more facially expressive than males. A comparison of the present results with the two hypotheses outlined in the introduction favours the hypothesis that females are more facially reactive than males, but not more reactive in other respects.

Study III

The present results demonstrate that, in the High snake fear group, the *Corrugator supercilii* response was larger to pictures of snakes than to pictures of flowers as early as within 500–1000 ms after stimulus onset. On the other hand, the corrugator response of the Low snake fear group did not differentiate between stimuli. Consequently, the present results support the proposition that people high as compared to people low in fear of snakes are disposed to respond with a more pronounced and, particularly, with a very rapidly evoked negative emotional facial reaction to pictures of their fear relevant stimulus. These results further demonstrate that the facial muscles constitute a rapid emotional response system which is not limited to the exposure to facial stimuli. The results are further consistent with earlier studies which have shown that fear relevant stimuli tend to evoke distinguished facial reactions after only 500 ms of exposure (Dimberg, 1991; 1994; 1997*b*). The interpretation that the snake stimuli evoked a negative emotional response is also supported by the autonomic data as well as the rating data. Thus, together the present results show that when people high in fear of snakes are exposed to pictures of snakes, they consistently react with a genuine negative emotional response pattern indicated by all three (the expressive, the autonomic and the experiential/verbal) components of the emotional response system (e.g., Izard, Kagan & Zajonc, 1984).

It is important to note that the response pattern displayed by the High fear subjects is specifically associated to snakes. In the present study, pictures of flowers tended to evoke an overall increased *Zygomaticus major* muscle response which, consistent with earlier findings, indicates a positive emotional reaction (e.g., Dimberg, 1990*b*). This response, however, did not differ between the High and Low fear subjects. Thus, the present findings cannot be explained as an effect of a general difference in reactivity between fearful and non-fearful subjects but rather as an effect of a specific tendency in the High fear group to react with a negatively toned emotional reaction to the fear relevant stimuli.

Even though the present study was not designed to specifically explore whether a phobic/fear reaction can be automatically elicited independent of conscious cognitive processes, one could speculate whether the present results may be interpreted as consistent with that proposition. That is, the results in earlier studies (Öhman & Soares, 1994) have shown that the phobic response, indicated by SCRs, can be elicited without conscious awareness of the exposure to pictures of snakes among snake phobics. Thus, the present results, which showed that the emotional reaction can be very rapidly manifested as a facial reaction, may be interpreted as consistent with the proposition that phobic reactions can be pre-attentively evoked without conscious cognitive appraisal processing (Öhman & Soares, 1994; Zajonc, 1980).

In summary, the present study demonstrates that people high in fear of snakes react with a complex pattern of a negative emotional response indicated by all three aspects of the emotional response system. Particularly, the results show that people with explicit fear of snakes react with a "negative" facial EMG response after only 500 ms of exposure to pictures of snakes. This supports the hypothesis that people High as compared to Low in fear of snakes are disposed to react very rapidly to their fear relevant stimuli.

Study IV

As predicted, people with high as opposed to low PRCS scores reacted with a larger differential corrugator responding between angry and happy faces. Consistent with earlier studies, (e.g. Dimberg, 1982) this effect could be interpreted as reflecting a larger negative emotional reaction to angry faces for the High social fear group.

The High fear participants also reacted with a larger difference in zygomatic responding between happy and angry faces. Consistent with earlier studies, this result may reflect a larger positive emotional reaction to happy faces for the High fear group. Furthermore, this latter result is consistent with our hypothesis, indicating that High fear participants have an exaggerated sensitivity to emotional facial expressions in general, and thus respond not only with larger negative facial reactions to angry, but also with larger positive facial reactions to happy facial stimuli. Consequently, the present study did not replicate the findings of Dimberg (1997*a*) and Vrana & Gross (2004) that people with social fear respond with lower intensity of positive reactions to happy facial stimuli. For a possible explanation of this inconsistency, see below.

As is evident in Fig. 5, the level of corrugator responding to both angry and happy faces tended to be higher for the Low fear group. It would be possible to interpret this effect as a larger negative reaction to both angry and happy stimuli. However, as stated in the introduction, earlier findings within the present paradigm (e.g., Dimberg, 1982; 1997*b*; the present Study I) have shown that the critical effect to be evaluated is the differential responding between angry and happy faces. Thus, in parallel to these studies, the present findings of a larger differential corrugator reaction between angry and happy faces should be interpreted as a larger negative reaction to angry faces for the High fear group.

As expected, and consistent with earlier studies, the High fear group rated the angry faces as being more negative (disgust; unpleasant) than did the Low fear group. Furthermore, the High fear group also tended to experience happy faces as more positive (pleasant). Interestingly, these data seem to be consistent with the facial reaction patterns. That is, the larger negative experience of angry vs. happy faces for the High fear group paralleled the larger negative facial response to angry faces, whereas the larger positive experience of happy vs. angry faces for the High fear group paralleled their larger positive facial response to happy faces.

The present results for the corrugator response to angry faces are consistent with our earlier research, demonstrating that people with fear of snakes react with a larger corrugator response to snakes, as compared to flowers, than do non-fearful people. On the other hand, and in contrast to the snake study (Study III), there were no differences in SCR or HR responding between High and Low social fear groups. These findings are consistent with most earlier studies on social fear and autonomic responses (e.g., Edelmann & Baker, 2002; Grossman et al., 2001; Merckelbach, et al., 1989). Thus, it seems to be the fact that the facial EMG technique is sensitive to detect different response patterns among people high and low in social fear, whereas autonomic reactions are not. The present data indicate that the physiological response pattern in social fear is different from that of animal phobias, such as snake fear. One possible explanation, briefly mentioned in the introduction, was suggested by Öhman et al. (1985). From an evolutionary perspective, it could be expected that agonistic inter-species encounters, such as an encounter with a snake, should elicit emotional reactions accompanied by physical activity such as fight or flight, whereas intra-species encounters, such as exposure to an angry face, should result in emotional reactions more likely to be associated with decreased activity such as crouching and relative immobility. However, it is obvious that the reaction to angry faces in the present study is not the “submissive smile” or “fear grin” described by Öhman et al. (1985), as this would seem to call for increased zygomatic activity, but rather the more generalised “negative” emotional response described in the present introduction.

Another explanation could be that autonomic responses to social fear in social phobics, as opposed to such responses to snake fear in snake phobics, show habituation over time (Grossman et al., 2001), possibly because of more frequent exposure to social interactions among social phobics than to snakes among snake phobics. Edelmann & Baker (2002) suggest that the failure to find group differences between social phobics and non-phobics could stem from the fact that social phobics are not a homogenous group in terms of their autonomic reactivity.

The aim of the present study was to explore whether the facial reactions of people with social fear differ from those of non-fearful people. However, it could be questioned whether the present assignment of people into High and Low fear groups is optimal in order to distinguish the reactions of people with social fear from those of the average person. If sensitivity to social stimuli is distributed on a continuum, it may be that the Low fear group in the present study is not representative of the population at large, but rather composed of people with a below average social sensitivity. To clarify this issue, further research should include a Medium fear group consisting of participants with ratings in the middle range of the PRCS scale.

It should also be noted that all participants in the present study were female university students selected solely on the basis of their PRCS ratings. To further clarify the relation between social fear levels and facial reactions, and possible gender differences, further research should investigate social fear in both male and female participants, including people selected on the basis of a clinical diagnosis of social phobia.

Because of the rapidity of the facial muscle response, one might speculate that the initial response may be elicited unconsciously. This might explain the difference between the results of the Study IV and those from earlier studies using a longer stimulus period (e. g. Dimberg, 1997; Vrana & Gross, 2004). One might further speculate that the initial mimicking response is related to a facial feedback system with the function of aiding the individual's own interpretation of the situation (Buck, 1980; Hatfield, Cacioppo, & Rapson, 1994), whereas the following period is influenced by social context (Vrana & Gross, 2004). For instance, in parallel with their well-established tendency to avoid eye contact (Bögels & Mansell, 2004), social phobics may choose to avoid answering a smile in the fear that such an action might lead to an unwanted social contact. To test this hypothesis, in a future study High and Low fear participants should be exposed to angry and happy faces for a longer (e.g. 8 s) stimulus duration, and separate analyses should be made and compared for the first second and for the subsequent stimulus seconds.

In summary, the present study demonstrates that people high as opposed to low in social fear tend to react with a more negative facial response to angry as compared to happy faces, as well as a more positive response to happy as compared to angry faces. Furthermore, these responses were consistent with the respective group's experience of the stimuli. Thus, the present results support the hypothesis that people high as opposed to low in social fear are disposed to show an exaggerated sensitivity and facial responsiveness to both positive and negative social stimuli.

General Discussion

Taken together, the present studies demonstrate that facial EMG is sensitive to detecting rapid emotional responses to social (facial) stimuli as well as to fear-relevant stimuli (snakes). Additionally, it can detect differences in responding between subjects high and low in fear of snakes as well as social fear. According to the basic emotions approach, quick onset is an important characteristic of emotional reactions (e.g., Ekman, 1992), and thus the present findings indicate that the facial reaction is an integrated part of the emotional response system.

One question is how fast an emotional reaction should be, to be considered as a rapid response. Earlier studies have indicated that facial stimuli evoke early components in the evoked rapid potentials (ERP) response (Carretie & Iglesias, 1995). It is, however, self-evident that activity in the brain must anticipate the bodily response. It is therefore more interesting to note that the facial response system is more rapid than the autonomic response system, which typically has a response latency of 1–4 seconds, as for instance SCRs. On the other hand, a spontaneously evoked response such as a startle reaction can be more rapidly evoked. The initial corrugator response in the present experiments can in fact be interpreted as reflecting a startle response. However, it is important to note that the startle response was nonspecific in the sense that it did not differentiate between the stimuli. Thus, the important finding in the present study is not that muscle responses, as such, can be rapidly evoked, but rather that distinguished facial muscle reactions are spontaneously and rapidly evoked in emotion relevant facial muscles when people are exposed to negative and positive emotional stimuli. Obviously, this is what should be expected, from the theoretical point of view that an important feature of emotional reactions is that they can be very quickly and automatically evoked (e.g. Ekman, 1992). In accordance with this view, the present data rather uniquely demonstrate that different emotional reactions are relatively rapidly manifested as distinguished bodily responses as early as towards the end of the first half-second of exposure.

The present results further demonstrate that the short facial response latency is not limited to a face-to-face interaction, or in other words, that facial reactions do not play a role exclusively in communicative situations as proposed by e.g. Fridlund (1994). Rather, the results favour the theory that the facial reaction is a general component of the emotional response. However, one alternative interpretation could be that, rather than being sensitive in general, the facial muscle response system may be particularly sensitive to biologically/evolutionary relevant stimuli (e.g., Dimberg, 1983; Öhman, 1986; Seligman, 1971). This interpretation is supported by the results from two studies comparing facial reactions when people were exposed to pictures of pleasantly experienced happy faces, flowers, and different types of nature scenes, as well as to unpleasantly experienced angry faces and snakes. Dimberg (1997*c*) found that facial responses can be evoked after half a second of exposure to facial stimuli and snakes, but not to flowers and nature scenes. A similar stimulus sensitivity was further found in a study by Dimberg & Karlsson (1997), in which facial activity was measured as mean activity during 8 s of exposure. In support of the hypothesis that the facial muscle system is more sensitive to particular evolutionary relevant stimuli rather than to a simple positive–negative quality dimension of the stimuli, their data indicated that the facial muscle reactions were not proportional to the experience of the stimuli. For instance, happy faces evoked the largest *Zygomatic Major* responses, in spite of the fact that flowers and nature scenes were experienced as more pleasant.

In all the present studies, the C*orrugator supercilii* muscle reaction was a sudden initial increase which peaked at 300 ms. Note that this early response component was released by both angry and happy facial stimuli, as well as by snakes and flowers. Thus, these data indicate that this response component does not reflect the emotional content of the stimuli but is rather a general effect of visual stimulation. One way to interpret these reactions may be that they reflect a movement artefact and/or that they are an effect of "cross-talk" from muscles controlling eye movements. A second interpretation would be that the response reflect an orienting response, OR (e.g., Graham, 1979; Turpin, 1986). However, one traditional criterion for what characterises an orienting response is that it habituates as a function of repeated stimulation (Sokolov, 1963, reported in Turpin, 1986). This question was specifically evaluated by Dimberg (Dimberg, unpublished) who found that this early response component did not habituate after repeated stimulation. Thus, this finding did not favour the OR interpretation. Rather, a more plausible interpretation is that the early component of the corrugator response in the present studies is a startle reaction which occurs within 200 ms after stimulus onset (e.g. Ekman, 1984; Ekman, Friesen & Simons, 1985; Turpin, 1986; Dimberg, 1997*c*) and which has also been shown to be elicitable even by rather weak stimuli (Blumenthal & Goode, 1991).

All the significant results in the present studies were obtained from female subjects. However, in the light of previous findings, there is no reason to expect that males should respond in a qualitatively different way to emotional stimuli. However, it still remains to be explained why male subjects did not respond with increased corrugator activity to snakes in Study II. The fact that they did not makes it possible to question whether males do in fact react at all with rapid facial responses to emotional stimuli. However, in a further unpublished study by Dimberg, the responses of males and females were explicitly compared during the first second of exposure when they were exposed to angry and happy facial stimuli. In this study, males and females responded similarly to each other with a rapidly evoked facial muscle response congruent with the emotional relevance of the facial stimuli, i.e., with increased corrugator activity to angry faces and with increased zygomatic activity to happy faces. These findings clearly demonstrate that males, as well as females, can react with rapid responses to emotionally relevant stimuli. In view of the results from Study IV, in which only subjects high in snake fear responded with increased corrugator activity to snakes, and considering the fact that explicit snake fear was not measured in Study II, one possible reason why males did not respond with increased corrugator activity to snakes could be that male and female subjects differed with respect to their fear of snakes. As mentioned above, snake fear has previously been shown to be more prevalent among females (Fredrikson, 1983). However, this interpretation is not supported by the rating data, which show that males and females rated snakes as equally unpleasant. In future studies, care should be taken to match male and female subjects on snake fear, as measured by a snake fear questionnaire.

The data from Studies III and IV indicate that the physiological response pattern, in terms of autonomic reactions, is different for social fear compared to that of snake fear. A possible explanation was suggested by Öhman, Dimberg, & Öst (1985). From an evolutionary perspective, it could be expected that agonistic inter-species encounters, e.g., an encounter with a snake, should elicit emotional reactions accompanied by physical activity such as fight or flight, whereas agonistic intra-species encounters, e.g., a face-to-face interaction, should result in emotional reactions more likely to be associated with decreased activity such as submissive behaviour. Another explanation could be that autonomic responses to social fear show habituation over time (Grossman et al., 2001), possibly because of more frequent exposure to social interactions among social phobics than to snakes among snake phobics. Edelmann & Baker (2002) suggest that the failure to find group differences between social phobics and non-phobics could stem from the fact that social phobics are not a homogenous group in terms of their autonomic reactivity.

When discussing the relationship among different aspects of the emotional response system, it is important to point out that, in the present studies, subjects were required to rate the unpleasantness of the *stimuli*, not their own emotional experience. An obvious alternative would be to ask subjects to rate their own self-experienced emotion. For instance, the subjects could be required to rate their experience of fear when exposed to snakes and angry faces. Furthermore, when exposed to facial stimuli, the ratings could be performed on scales corresponding to the emotions expressed by the facial stimuli. In this way, it would be possible to determine whether emotions are better conceived of as distinct from each other, as proposed by the basic emotions approach, rather than distributed on a positive–negative dimension. In a study by Lundquist & Dimberg (1995) who used an 8 s based response measure, subjects were required to rate their own self-experienced emotions when exposed to facial stimuli, and these results indicated that a corresponding subjective feeling was indeed evoked by the facial stimuli.

Another related question is whether the present findings are relevant to the *facial feedback hypothesis* (Buck, 1980) stating that facial muscle activity is essential for emotional experience to occur. Earlier data indicate that there exists a relationship between emotional experience and facial responses. For instance, Lundquist & Dimberg (1995) demonstrated that facial reactions occur together with a self-experienced emotion which could be interpreted as consistent with the subject's own facial expression. Because the facial feedback hypothesis predicts the existence of a close relationship between facial muscle activity and the experience of emotion, it would be interesting to explore whether both angry faces and snake stimuli evoke a "negative" facial reaction which is related to the experience of fear.

A remaining problem for the facial feedback hypothesis is to demonstrate that facial reactions occur prior to the experience of emotion. Although it is difficult or perhaps impossible to detect exactly when the experience of emotion occurs, the short latency of the facial response indicates that facial reactions may be rapid enough to precede the experience of emotion.

A related question is whether emotionally relevant facial reactions can be evoked *independently of conscious cognitive processes* (Zajonc, 1980). The fact that distinguished facial EMG activity can be detected to emotionally relevant stimuli as early as 400 ms after stimulus onset makes it interesting to speculate about this possibility. As briefly mentioned in the introduction, there is an on-going debate within psychology whether or not emotions are dependent on cognitive processes. Whereas cognitive theories of emotion claim that emotion experience includes various cognitive components such as activating appraisals, subsequent desires, and intentions, the basic emotions approach emphasises the point that emotions can occur as the direct result of neurochemical and affective processes independently of cognition (Izard, 1991). In support of this view, it has been demonstrated that emotions can be induced by unanticipated pain (Izard & Malatesta 1987), manipulation of facial expressions (Duclos et al., 1989), and by changing the temperature of cerebral blood flow (Zajonc et al., 1989; reported in Izard, 1992). Additionally, conceiving the emotions as a separate system that does not require cognitive mediating or include cognition as a component has support from neuroscience. Emotion can be activated by a thalamoamygdala (subcortical) pathway that can operate independently of neocortex and therefore independently of any type of cognition requiring cortical processing or integration (Izard 1992, LeDoux, 1995).

The results from a recent study (Dimberg et al., 2000) could be seen as further support for the possibility that emotional reactions can be evoked independently of conscious cognitive processes. In this study, it was demonstrated that subjects' awareness of stimuli is not necessary for eliciting a facial reaction. That is, with the use of the backward masking technique (Dimberg et al., 2000), subjects were unconsciously exposed to angry and happy faces masked by a neutral face. In spite of the fact that they were only aware of having seen the neutral face, subjects responded with distinct facial muscle reactions that corresponded to the angry and happy stimulus faces, i.e., corrugator activity to angry faces and zygomatic activity to happy faces. In this latter study, as in earlier studies (Dimberg, 1996; Dimberg & Thunberg, 1998) the facial responses were very similar in size and shape to those in the present experiments. This makes it interesting to speculate that the responses detected during the first second in the present study could have been elicited unconsciously. Interestingly, an earlier study (Öhman & Soares, 1994) has shown that the phobic response, indicated by SCRs, can be elicited without conscious awareness of the exposure to pictures of snakes among snake phobics. In order to further study possibly unconscious mechanisms behind the evocation of facial reactions to snakes, one could apply the backward masking technique by exposing subjects to masked presentations of pictures of snakes. Finally, a similar experimental paradigm could be used to compare people high and low in social fear. If emotional facial reactions are controlled by unconscious, automatic affect-programmes, people high and low in social fear and snake fear should also differ in their responses to their fear-relevant stimuli, even when these stimuli are presented unconsciously.

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