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Emotion Regulation in High and Low Socially Anxious Individuals: An Experimental Study Investigating Emotional Mimicry, Emotion Recognition, and Self-Reported Emotion Regulation

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Abstract

Emotion recognition and emotional mimicry are both highly important for social interactions. The authors investigated in a subclinical sample if High Socially Anxious (HSA) individuals show an altered pattern of emotional mimicry, and exhibit difficulties in emotion recognition compared to Low Socially Anxious (LSA) individuals. Twenty-one HSA and 20 LSA participants were exposed to 60 dynamic facial expressions that gradually changed from neutral to full-intensity expressions of happiness, anger, sadness, disgust, or fear. Emotional mimicry was assessed using facial electromyography. Emotion recognition was measured after every picture and emotion regulation was measured by self-report. Compared to when participants saw neutral facial expressions, participants demonstrated significantly higher *musculus (m.) corrugator supercilii* activity of anger expressions, *m. frontalis medialis* activity of fear and sad expressions, *m. levator labii* activity of disgust, and *m. zygomaticus* **major** activity of happy expressions. HSA participants had a significantly higher *m. levator labii* activity of disgust expressions than LSA participants. Moreover, HSA participants showed a tendency toward impaired emotion recognition of negative facial expressions (p = 0.07). Results confirm emotion-specific emotional mimicry patterns for all five emotions. No differences for emotional mimicry between the two groups were found, except for subtle alterations in disgust in HSA individuals.

Keywords

Affect, Emotion regulation, Facial mimicry, Social anxiety, Emotion recognition, Emotional mimicry

Introduction

Facial mimicry, the imitation of another person's emotional facial expression [1], and the recognition of others' expressed emotions are highly important for successful interactions with others. It fosters affiliation and liking and serves as "social glue" [2]. The way in which an individual processes and interprets emotional information can be an etiological factor in the development or maintenance of psychopathology [3,4]. Social Anxiety Disorder (SAD), a marked fear or anxiety about one or more social situations in which the individual is exposed to possible scrutiny by others [5], is related to reduce social interactions and impaired social support [6]. So far, treatment for SAD has not been as successful

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as treatments for other anxiety disorders [7]. Therefore, improvement in the treatment of SAD is necessary, by investigating e.g., the relationship between emotional processing and SAD.

Several studies have examined emotion recognition accuracy in individuals with mental disorders and found differences between individuals with a mental disorder and healthy controls [8,9]. Examining differences between patients with depressive and anxiety disorders, Yoon, et al. [9] demonstrated that patients with major depressive disorder showed significant lower emotion recognition accuracy compared to patients with anxiety disorders and healthy controls. No differences between the two clinical groups and the healthy control group were found for the recognition of complex emotions.

Studies with socially anxious adults observed that they interpret ambiguous facial expressions as threatening [10] or angry [11] and identify angry faces at a lower level of emotional intensity [12]. A meta-analysis found a small negative association between emotion recognition and social anxiety, but also increased emotion recognition in socially anxious participants [13]. Whilst some results suggest that there are no significant differences in recognition accuracy between individuals with SAD and healthy controls [12,14-18] and between High Socially Anxious (HSA) and Low Socially Anxious (LSA) individuals [19], others have found a generally enhanced recognition of facial expressions in HSA compared to LSA individuals [20]. Comparably, studies have found an enhanced recognition of negative compared to positive facial expressions in individuals with SAD [21,22] and of negative compared to neutral facial expressions in HSA but not in LSA individuals [23].

Focusing on emotional mimicry and social anxiety, Vrijsen, et al. [24] found that HSA individuals showed less observed mimicry of head movements of a computerized avatar in comparison to LSA individuals. People with high fear of public speaking, a specific aspect of the more generalized concept of social anxiety, showed less mimicry of happy expressions than people with low fear [25-28]. In contrast, the results for the mimicry of angry expressions were inconsistent. Whereas Dimberg and Christmanson [26] found less mimicry, others found higher mimicry in individuals high in fear of public speaking [25,27,28], though small sample sizes in some of the studies might be an explanation for the results. Furthermore, individuals high in fear of public speaking showed more negative facial expressions in reaction to neutral faces [28].

In summary, emotion recognition and emotional mimicry are both important factors for successful social interactions. One possible explanation for impaired social interactions in individuals with social anxiety could be impaired emotion expression recognition because they mimic less compared to healthy individuals. In a review, Levitan and Nardi [29] stated that patients with SAD performed worse in social interactions and were rated as less assertive and friendly, but when specific social skills were measured, there was typically no difference between patients with SAD and healthy controls. An altered facial mimicry pattern could be responsible for the observed difficulties in social interactions and would point to specific interventions, such as emotion recognition and expression training. Group differences for emotional mimicry between individuals high and low in fear of public speaking have been found [24], but it remains unclear if fear of public speaking represents a form of performance-only presentation of SAD or if it is part of a more generalized SAD. Therefore, studies with generally socially anxious individuals are needed to show if the differences apply to a broader definition of social anxiety.

The vast majority of emotional mimicry studies have focused on only two emotions- anger and happiness. Consequently, evidence is available only for these emotions and their corresponding muscles (m.) *m. corrugator supercilii* and *m. zygomaticus major* but not for disgust, fear, and sadness [1]. Therefore, confirmation of emotional mimicry effects for a variety of emotions is still necessary, especially for disgust, fear and sadness, as they have not yet been included in studies on fear of public speaking [25-28]. Additionally, the inclusion of neutral facial expressions could also provide important information [28].

Other methodological issues that might influence emotion recognition and emotional mimicry should also be considered. Most of the mentioned studies investigating emotion recognition used black-and-white static stimuli [12,14,16,17,19,23], which could influence ecological validity. Presentation times of the facial expressions varied from 60 ms [19,23] to 30 s [21] or were self-paced [14], and therefore the results are difficult to compare. The two studies using dynamic facial expressions [12,15] used presentation times longer than 25 s, but these can look unnatural and unrepresentative of daily life, because facial expressions typically change within seconds. Furthermore, previous studies did not control for mood, but mood can influence emotion recognition [30].

The goal of the present study was to extend previous research investigating whether social anxiety is related to altered emotional mimicry and emotion recognition. We extended the quantity of emotional facial expressions to disgust and sadness and included neutral facial expressions. Furthermore, we considered important methodological aspects to increase ecological validity. Participants classified as high or low in social anxiety saw dynamic facial expressions presented in color that changed from neutral to full-intensity expressions of happiness, anger, sadness, disgust, and fear within 7 s (or stayed neutral). For the assessment of emotional mimicry, facial Electromyography (EMG) signals of the *m. zygomaticus* major, *m. corrugator supercilii, m. levator labii* and *m. frontalis medialis* were recorded. Simultaneously, recognition of facial expressions was assessed. Using a neutral mood induction, the influence of mood was controlled for. We hypothesized that HSA individuals would show an altered pattern of emotional mimicry compared to LSA individuals. We expected to find further evidence for the emotional mimicry effect, not only for anger and happiness, but also for the less frequently investigated emotions of fear, sadness, and disgust. Given the results of previous studies, we did not expect to find a substantial group difference in emotion recognition.

Methods

Participants

Forty-one university students from different fields of studies were divided in either the HSA group (n = 21), of those scoring in the top 25%, or the LSA group (n = 20), of those scoring in the bottom 25%, in the Liebowitz Social Phobia Scale LSAS [31]. The LSAS indicates both good sensitivity and sensibility [32], using a cut-off score of 30 as suggested by Rytwinski, et al. [33]. The groups were comparable with respect to sex (LSA: 14 female, 6 male; HSA: 16 female, 5 male), $\chi^2(1) = 0.20$, $p = 0.66$, and age (LSA: M = 25.75 years, SD = 6.31; HSA: M = 25.87 years, SD = 7.53), $t(39) = -0.06$, $p = 0.96$ with an age range from 21- 49 years. To confirm group differences in social anxiety symptoms indicated with the LSAS, $U = 420$, $p < 0.01$, participants completed the Social Interactions Anxiety Scale SIAS [34,35] focusing on difficulties in social interactions, and the Social Phobia Scale SPS [34,35] focusing on the fear of being judged. As shown in (Table 1), HSA participants scored significantly higher on the SIAS, $U = 390$, $p < 0.01$, and the SPS, $U = 392$, $p < 0.01$, than LSA participants. Six HSA participants on the SIAS and eight on the SPS had values above the clinical cut-off, as did all 20 HSA participants on the LSAS [31].

Table 1: Social Phobia Symptoms in Low Socially Anxious (LSA) and High Socially Anxious (HSA) Participants, as well as Mann-Whitney U-Test Results.

Measure	LSA	HSA	*U*
	***M* (*SD*)**	***M* (*SD*)**	
SIAS	11.15 (5.01)	26.67 (10.61)	390**
SPS	3.55 (2.06)	17.71 (9.80)	392**
LSAS	8.00 (2.25)	54.62 (13.18)	420**

Note: SIAS = Social Interactions Anxiety Scale, SPS = Social Phobia Scale, LSAS = Liebowitz Social Phobia Scale. $^{**}p < 0.01$.

Mood induction and emotional state

To ensure that all participants were in a similar, neutral mood before taking part in the experiment, we showed them part of a documentary on stars (3 min 22 sec) that has shown good efficacy in mood induction [36]. After the film and after the mimicry paradigm, participants indicated their current emotional state (arousal, excitement, fear, happiness, tension, sadness) on a 7-point Likert scale (1 = not at all, 7 = very much).

Facial mimicry task

Stimuli: The facial stimuli were taken from the NimStim Face Stimulus Set [37]. Using a morphing technique similar to that in Sato and Yoshikawa [38], 60 facial expressions of 5 male and 5 female actors, changing in 50 steps from a neutral expression to full-intensity emotion [happiness, sadness, anger, fear, disgust, neutral (i.e., no change, as a control condition)] were created using WinMorph 3.01. Each stimulus was presented for 140 ms with the software E-Prime (version 2.0) on a white background to create the impression of an animated clip of the progression of an emotional facial expression lasting 7 s.

Physiological measures: Electromyography (EMG) was performed according to the guidelines of Fridlund and Cacioppo [39]. The activity of the following muscles was recorded on the left side of the face: *m. corrugator supercilii, m. frontalis medialis, m. levator labii* and *m. zygomaticus major*. As mentioned above, sufficient evidence exists only for the emotional mimicry effect of anger and happiness with their corresponding muscles *m. corrugator supercilii* [40] and *m. zygomaticus major* [41], and not for disgust, which is usually indexed by *m. levator labii* activity [42], and fear, which should be related to *m. frontalis medialis* activity [43]. More evidence exists for the imitation of sadness, but this emotion is also indexed by *m. corrugator supercilii* activity and hence it is unclear whether the displayed emotion is anger or sadness. Activation of this muscle can signal a negative mood, concentration, or bewilderment [44]. Therefore, we decided to measure the imitation of sadness with the *m. frontalis medialis*, similar to the procedure followed by Cram and Criswel [45].

The measurement of physiological data was conducted with a separate computer with the software Acknowledge [46]. Ag-Ag/Cl miniature electrodes filled with electrolyte were used for the recordings. The EMG was sampled at 1,000 Hz after anti-aliasing low-pass filtering at 500 Hz. To measure muscle activity magnitude, a 50-Hz notchfilter, a high-passfilter (25 Hz), and, after signal rectification, a moving average filter with a window length of 50 ms were applied offline using ANSLAB software (Autonomic Nervous System Laboratory, version 4.0) [47].

Procedure: The local ethics committee approved the study. All participants were informed of their rights as research participants and gave their written informed consent in accordance with the Declaration of Helsinki. They received either course credit or a cinema voucher for their participation. Participants were seated in front of a computer and all physiological equipment was attached. The neutral mood induction film was shown. Afterward participants indicated their current emotional state. Then six practice trials (including all six emotions) were conducted. Before each morphing sequence of facial expressions (7,000 ms), a fixation cross on a white background appeared for 500 ms. After each morphing sequence a white screen appeared for 2,000 ms. Then participants were presented with a rating screen asking them to identify the emotion as happiness, sadness, anger, disgust, fear, or neutral. Before the start of a new sequence a white screen was shown for 2,000 ms. A total of 60 sequences were shown in randomized order. The task took approximately 40 min. After the task participants indicated their current emotional state again. Electrodes were removed and participants were asked to complete the questionnaires.

Data reduction and statistical analysis: To analyze the EMG data, each continuous file was first visually inspected for noise and artifacts using ANSLAB [47]. During EMG data acquisition, facial movements such as yawning were marked and subsequently excluded. EMG data were used to calculate facial responses to stimuli. The pre stimulus window was 500 ms before the onset of the pictures; post stimulus muscle activity was averaged in 500 ms bins. The pre stimulus value was subtracted from the post stimulus values to calculate facial reactivity as change from baseline. Values were standardized within participants and within muscles in order to allow meaningful comparisons across muscles and participants. Finally, we computed mean levels of activity for each muscle and each type of emotion. For statistical analyses, the first 2 s post stimulus were dropped because in the dynamic facial stimuli, emotional expression was too subtle to be detected and visual data inspection showed only minimal EMG effects. To evaluate mimicry effects, data were analyzed with a 2 (Group: HSA vs. LSA) × 2 (Emotion: target emotion vs. neutral face) × 10 (Time: from Second 2 of the stimuli presentation to the end in 500-ms bins) repeated-measures Analysis of Variance (ANOVA) for each emotion [43]. Furthermore, we calculated all analyses with 1-s bins. To ensure that participants did not react to the neutral stimuli in a specific way, we first calculated a 2 (Group: HSA vs. LSA) × 4 (Muscle: *m. corrugator supercilii, m. frontalis medialis, m. levator labii, m. zygomaticus major*) × 10 (Time: from Second 2 of the stimulus presentations to the end in 500-ms bins) repeated-measures ANOVA only for neutral stimuli. Bonferroni-corrected post hoc comparisons were conducted. Recognition of facial expressions was analyzed in repeated-measures Analysis of Variance (ANOVA) with the percentage of correct responses for the within-subject factor emotion and the between-subjects factor group. If the assumption of sphericity was violated, Greenhouse-Geisser correction was used. The influence of mood was also assessed with a repeated-measures ANOVA and we calculated exploratory Pearson correlations between emotional mimicry and emotional state as well as emotion recognition and emotional state. The statistical significance cut-off has been adjusted for the number of tests applying the Bonferroni-correction for type I error.

Results

Emotional mimicry

As expected, the ANOVA for the reaction to neutral faces (Group × Muscle × Time) yielded no significant interaction effects of Muscle × Time × Group, $F(9.60, 355.31) = 0.63$, $p = 0.78$, $\eta^2 = 0.02$, Muscle × Time, $F(9.60, 355.31) = 0.88$, $p = 0.55$, $\eta^2 = 0.02$, Time × Group, $F(3.92, 144.95) = 1.25$, $p = 0.29$, $\eta^2 = 0.03$, or Muscle × Group, $F(2.04, 75.51) = 2.04$, $p = 0.14$, $\eta^2 = 0.05$, and no significant main effects of Time, $F(3.92, 144.95) = 1.25$, $p = 0.29$, $\eta^2 = 0.03$, or Group, $F(1, 37) = 1.13$, $p = 0.29$, $\eta^2 = 0.03$. However, there was a significant main effect of Muscle, $F(2.04, 75.51) = 3.74$, $p = 0.03$, $\eta^2 = 0.09$. Whereas the *m. corrugator supercilii* and *m. frontalis medialis* indicated a slight activation in response to the neutral stimuli, the *m. zygomaticus major* and *m. labii* showed a slight deactivation. Conducting all analyses with 1 sec-bins did not change the results.

Anger *(m. corrugator supercilii)*: The mean data for the *m. corrugator supercilii* in response to angry expressions are presented in (Figure 1). Angry faces, compared to neutral faces, tended to evoke greater *m. corrugator supercilii* activity over time, indicated by an Emotion × Time interaction effect, $F(3.46, 131.41) = 3.97$, $p < 0.01$, $\eta^2 = 0.10$, and confirming the emotional mimicry effect. However, none of the other effects reached significance: Group × Emotion × Time, $F(3.46, 131.41) = 1.67$, $p = 0.17$, $\eta^2 = 0.04$; Group × Time, $F(2.55, 97.07) = 0.61$, $p = 0.59$, $\eta^2 = 0.02$; Group × Emotion, $F(1, 38) = 0.85$, $p = 0.36$, $\eta^2 = 0.02$; Emotion, $F(1, 38) = 0.20$, $p = 0.66$, $\eta^2 = 0.01$, and Group, $F(1,38) = 0.01$, $p = 0.92$, $\eta^2 = 0.00$.

Fear *(m. frontalis medialis)*: As visible in (Figure 1),

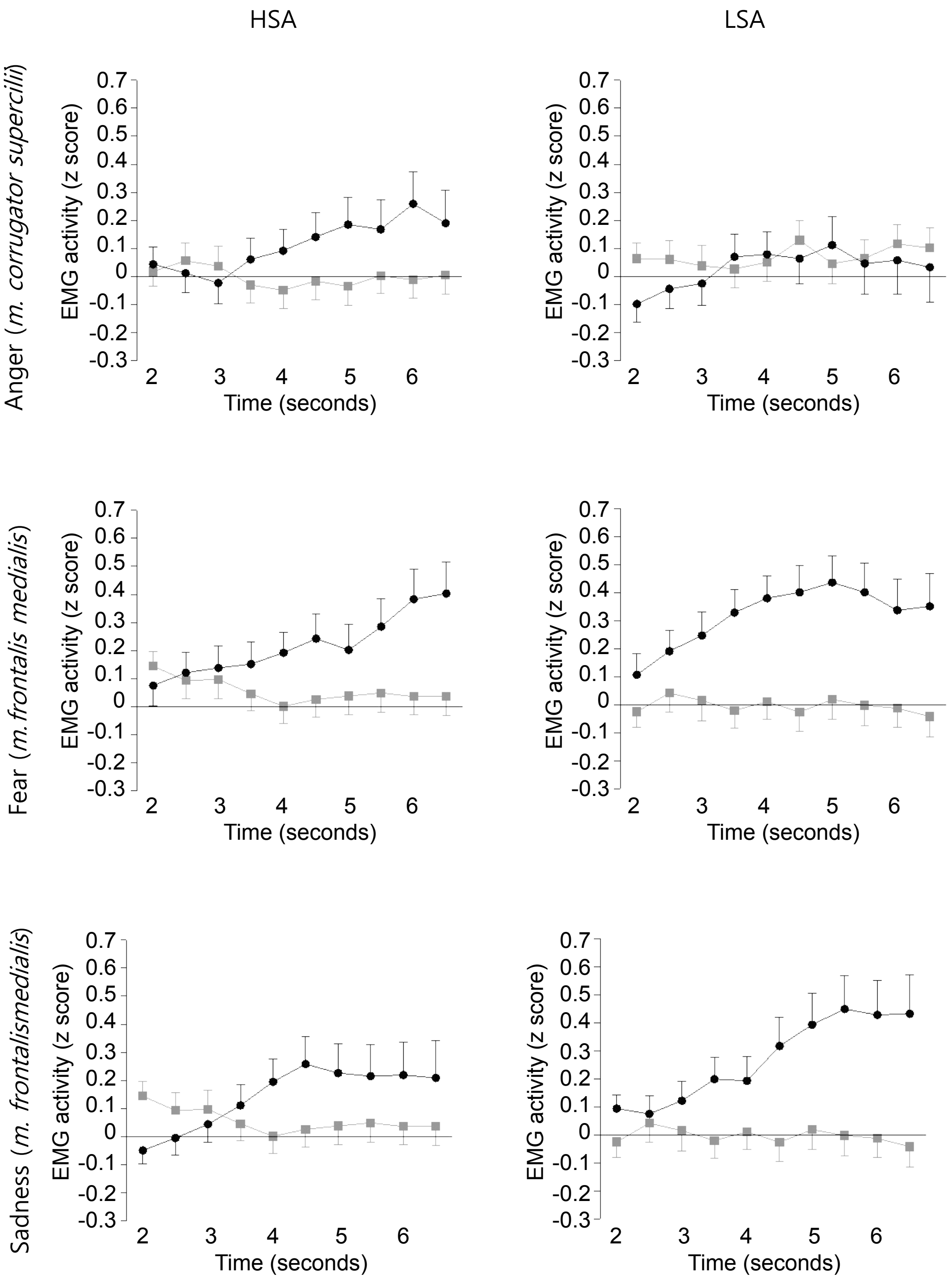

Figure 1: Average facial Electromyography (EMG) activity in emotion-specific channels over 500-ms intervals during Seconds 2-7 for High Socially Anxious (HSA) and Low Socially Anxious (LSA) groups: reactions to dynamic facial expression stimuli depicting anger, fear, and sadness.

Note: Gray line = neutral, black line = target emotion.

fearful faces, compared to neutral faces, evoked greater *m. frontalis medialis* activity over time, indicated by an Emotion × Time interaction effect, $F(3.65, 138.59) = 8.04$, $p < 0.01$, $\eta^2 = 0.18$. The main effect of Emotion, $F(1,38) = 11.45$, $p < 0.01$, $\eta^2 = 0.13$, indicated that *m. frontalis medialis* activity was higher for fear than for neutral stimuli, and the main effect of Time, $F(3, 113.85) = 2.94$, $p = 0.04$, $\eta^2 = 0.07$, indicated an increase over time. However, none of the other effects reached significance: Group × Emotion × Time, $F(3.65, 138.59) = 1.05$, $p = 0.38$, $\eta^2 = 0.03$; Group × Time, $F(3, 113.85) = 2.09$, $p = 0.11$, $\eta^2 = 0.05$; Group × Emotion, $F(1, 38) = 1.24$, $p = 0.27$, $\eta^2 = 0.05$; and Group, $F(1,38) = 0.09$, $p = 0.77$, $\eta^2 = 0.00$.

Sadness *(m. frontalis medialis):* The mimicry effect was shown by a significant Emotion × Time interaction effect, $F(2.55, 96.71) = 9.53$, $p < 0.01$, $\eta^2 = 0.20$, and significant main effects of Emotion, $F(1,38) = 7.12$, $p = 0.01$, $\eta^2 = 0.16$, and Time, $F(2.31, 87.64) = 4.80$, $p = 0.01$, $\eta^2 = 0.11$ (Figure 1). None of the other effects reached significance: Group × Emotion × Time, $F(2.55, 96.71) = 1.16$, $p = 0.33$, $\eta^2 = 0.03$; Group × Time, $F(2.31, 87.64) = 0.71$, $p = 0.51$, $\eta^2 = 0.02$; Emotion × Group, $F(1, 38) = 1.96$, $p = 0.17$, $\eta^2 = 0.05$; and Group, $F(1,38) = 0.23$, $p = 0.63$, $\eta^2 = 0.01$.

Disgust *(m. levator labii)*: There was a significant Emotion × Time interaction effect, $F(2.43, 89.80) = 7.36$, $p < 0.01$, $\eta^2 = 0.17$, indicating a greater increase in *m. levator labii* activity for disgust stimuli than for neutral stimuli (Figure 2). The main effect of time was significant, $F(3.04, 92.92) = 5.69$, $p < 0.01$, $\eta^2 = 0.13$, indicating an overall increase in *m. levator labii* activity over time. The main effect of Emotion was just nonsignificant, $F(1,37) = 3.97$, $p = 0.054$, $\eta^2 = 0.10$, and the *m. levator labii* activation for disgust was higher than for the neutral emotion (Figure 2). Furthermore, there was a significant main effect of Group, $F(1, 37) = 10.46$, $p < 0.01$, $\eta^2 = 0.22$, indicating that HSA participants reacted with a higher *m. levator labii* activation not only to disgust faces, but also to neutral faces. There was no significant effect of Emotion × Group, $F(1, 37) = 0.08$, $p = 0.78$, $\eta^2 = 0.00$; Time × Group, $F(2.51, 92.92) = 1.02$, $p = 0.38$, $\eta^2 = 0.03$; or Emotion × Time × Group, $F(2.43, 89.80) = 0.83$, $p = 0.46$, $\eta^2 = 0.02$.

Happiness *(m. zygomaticus major)*: Happy, compared to neutral faces, tended to evoke overall greater *m. zygomaticus major* activity, indicated by a strong Emotion main effect, $F(1, 37) = 18.29$, $p < 0.01$, $\eta^2 = 0.33$ (Figure 2). There was also an Emotion × Time interaction effect, indicating that the difference in activation between happy faces and neutral faces increased over time, $F(2.27, 83.85) = 3.51$, $p = 0.03$, $\eta^2 = 0.09$. None of the other effects reached significance: Group × Emotion × Time, $F(2.27, 83.85) = 1.35$, $p = 0.27$, $\eta^2 = 0.04$; Group × Time, $F(2.15, 79.50) = 0.54$, $p = 0.60$, $\eta^2 = 0.01$; Group × Emotion, $F(1, 37) = 0.30$, $p = 0.59$, $\eta^2 = 0.01$; Time, $F(2.15, 79.50) = 1.80$, $p = 0.17$, $\eta^2 = 0.05$, and Group, $F(1,37) < 0.01$, $p = 0.97$, $\eta^2 = 0.00$.

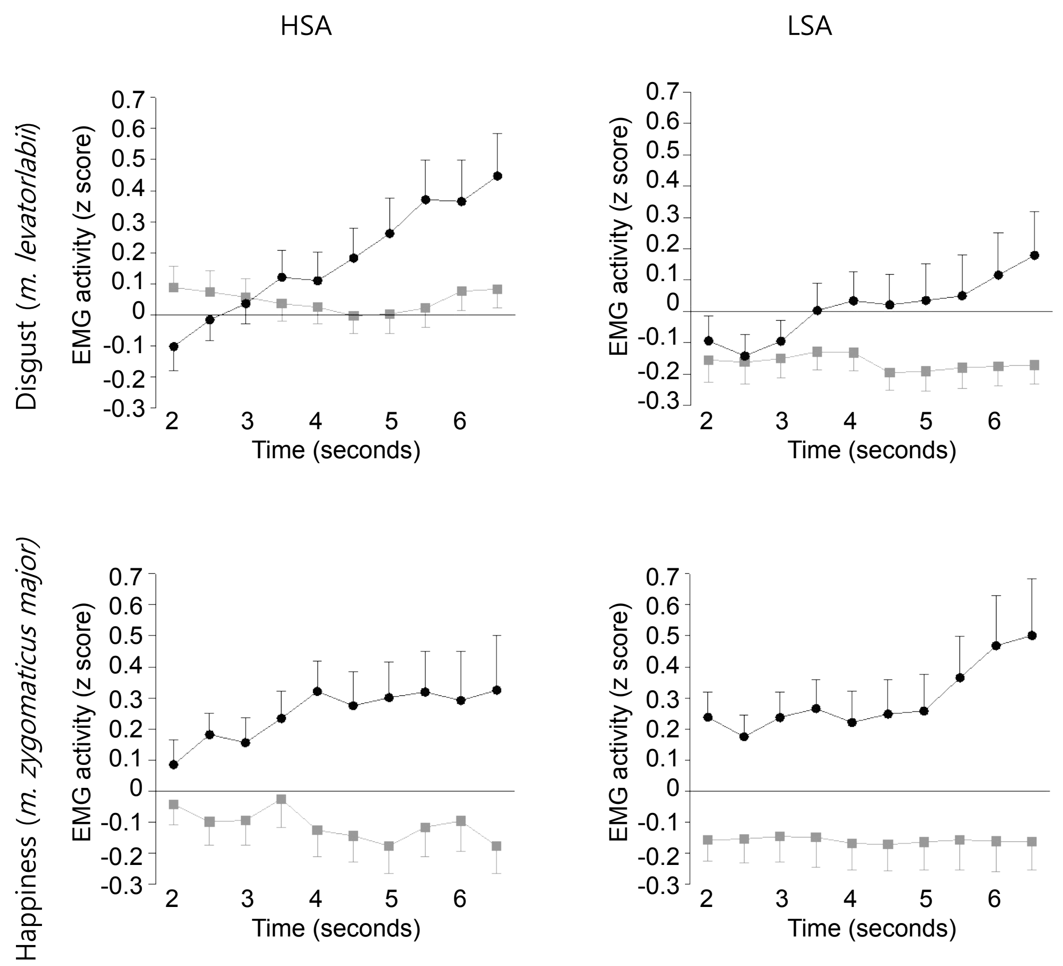

Figure 2: Average facial Electromyography (EMG) activity in emotion-specific channels over 500-ms intervals during Seconds 2-7 for High Socially Anxious (HSA) and Low Socially Anxious (LSA) groups: reactions to dynamic facial expression stimuli depicting disgust and happiness.

Note: Gray line = neutral, black line = target emotion.

Table 2: Mean Percentage (Standard Deviation) of Emotion Recognition Accuracy for Low Socially Anxious (LSA) and High Socially Anxious (HSA) Participants, as well as Exploratory t-Test Results Comparing the Emotion Recognition Performance for each Emotion Separately between HSA and LSA.

Emotion	LSA, *n* = 20	HSA, *n* = 21	*t* (39)
	M (*SD*)	*M* (*SD*)	
Anger	93% (8%)	91% (10%)	0.72
Anxiety	84% (14%)	78% (18%)	1.28
Disgust	81% (11%)	80% (12%)	0.4

Emotion recognition

As reported in (Table 2), participants decoded over 95% of the happy and neutral faces correctly. These two conditions were excluded from the analyses of group differences because of ceiling effects. The ANOVA for the percentage of correct responses for the within-subject factor emotion and the between-subjects factor group showed no significant Emotion × Group interaction effect, $F(3,117) = 0.32$, $p = 0.79$, $\eta^2 = 0.01$. There was a main effect of Emotion, $F(3, 117) = 9.37$, $p < 0.01$, $\eta^2 = 0.19$, indicating that participants made more errors identifying fear and disgust than identifying anger and sadness. The main effect of Group just failed to reach significance, $F(1,39) = 3.51$, $p = 0.07$, $\eta^2 = 0.08$, with HSA participants showing a tendency toward a reduced recognition of facial expressions in general.

Mood

The 2 (Group: HSA vs. LSA) × 2 (Time: before and after mimicry paradigm) × 6 (Emotional state: fear, happiness, sadness, anger, excitement, and arousal) repeated-measures ANOVA revealed no significant interaction effect of Group × Time × Emotional state, $F(3.83, 149.49) = 0.67$, $p = 0.61$, $\eta^2 = 0.02$, Group × Time, $F(1,39) < 0.01$, $p > 0.99$, $\eta^2 < 0.01$, or Time × Emotional state, $F(3.83, 149.49) = 2.28$, $p = 0.07$, $\eta^2 = 0.06$. However, there was a significant interaction effect of Group × Emotional state, $F(3.02, 117.57) = 4.41$, $p < 0.01$, $\eta^2 = 0.10$, with HSA participants experiencing more negative (excitement, arousal, sadness, anger) and fewer positive (happiness) emotions than LSA participants before and after the experiment. There was also a significant main effect of Group, $F(1,39) = 4.04$, $p = 0.05$, $\eta^2 = 0.09$, with HSA participants achieving higher values than LSA participants. Bonferroni-corrected post hoc comparisons indicated Group main effects of excitement (HSA: $M = 2.76$, $SD = 1.07$; LSA 2.00, $SD = 0.73$), $F(1,39) = 7.07$, $p = 0.01$, $\eta^2 = 0.15$, and arousal (HSA: $M = 3.12$, $SD = 1.27$; LSA: $M = 2.03$, $SD = 0.79$), $F(1,39) = 10.82$, $p < 0.01$, $\eta^2 = 0.22$, with HSA participants achieving higher values than LSA participants. Therefore, we calculated correlations of arousal and excitement with all outcome measures. All correlations between emotional mimicry and emotional state were nonsignificant; correlation coefficients ranged between $r = -0.07$ and $r = 0.03$ for excitement and between $r = -0.19$ and $r = 0.02$ for arousal. There was no correlation of emotion recognition with excitement ($r = -0.05$, $p = 0.76$) or with arousal ($r = -0.14$, $p = 0.37$).

Discussion

The aim of the present study was to investigate whether social anxiety is related to emotional mimicry and emotion recognition. To our knowledge, this is the first study examining emotional mimicry with an experimental paradigm in individuals with social anxiety. So far this topic has been investigated only in public speaking anxiety [25-28]. Importantly, the results indicated that the general emotional mimicry effect for each tested emotion was replicated not only for the well-evaluated emotions happiness and anger, with their corresponding muscles *m. zygomaticus major* and *m. corrugator supercilii* [1], but also for the less often investigated emotions of fear [43] and sadness [45], both indexed by *m. frontalis medialis* activity, as well as for disgust with *m. levator labii* activity [42].

The emotional mimicry effect was indicated by either a significant interaction effect (EMG activity increased for the target emotion, whereas there was no change for the neutral emotion) or a significant main effect of emotion (with a higher activity for the target emotion than for the neutral emotion). The successful replication and extension of emotional mimicry effects confirm the validity of the novel set of dynamic color stimuli and support the utility of dynamic images because of their power to elicit particularly large mimicry effects [48]. The emotional mimicry effect for each emotion was generally shown in both groups, providing the basis for successful social interactions by fostering affiliation and liking [2]. Nevertheless, even small differences in emotional mimicry might lead to difficulties in social interactions, therefore examining group comparisons in detail is of special interest. HSA participants reacted to disgusted and neutral faces with higher *m. levator labii* activation. This is comparable to the results from Vrana and Gross [27], which indicated more *m. corrugator supercilii* activity as a reaction to neutral faces in people high in fear of public speaking. Both reactions can be interpreted as a general index of global negative affect [44]. The stronger activation of the *m. levator labii*, and thereby the display of a disgusted emotional state, is of special importance. When compared to the mimicry of negative emotions, the superior influence of positive emotional mimicry on social interactions has already been highlighted [49,50]. Furthermore, disgust can be interpreted as a sign of disapproval [51]. It should be further investigated if the stronger activation of *levator labii* leads to the perception of HSA individuals as less likeable, sympathetic, or talkative [52]. Conversely, there were no group differences for the emotional mimicry of happiness, sadness, anger, or fear. Our results differ from results of studies that compared people with different levels of fear of public speaking. People high in fear of public speaking showed less mimicry of happy expressions [25-28] and either less [26] or more [25,27,28] mimicry of anger. However, these results are based on static facial expressions that might be more limited in ecological validity than the dynamic expressions used in our study.

In the current study, better emotion recognition was associated with more mimicry of fear, but not of other emotions. It remains an open question if emotional mimicry facilitates emotion recognition, as suggested by Niedenthal, et al. [53]. There is evidence suggesting that facial mimicry might play an important role in identifying more subliminal changes in emotional expressions, rather than identifying discreet emotional expressions [1], which might be an explanation for our results. Regarding group differences, only a tendency ($p = 0.07$) toward a decreased emotion recognition rate of negative facial expression in HSA compared to LSA participants emerged in our study. This is in line with previous studies where recognition accuracy did not differ between socially anxious participants and healthy controls [12,14-19]. However, it is in contrast to an enhanced recognition of all facial expressions [20] and of negative expressions [21,22,23] in HSA compared to LSA individuals. In our study, the overall recognition accuracy was high and we had to exclude the conditions happiness and neutral from analyses because of ceiling effects. To avoid ceiling effects, future studies might include more positive emotions and a dynamic presentation of the neutral condition, for example, with opening and closing the mouth. Future studies should also include the reaction time of identifying emotional expressions to analyze differences in the speed of emotion recognition between clinical and nonclinical samples.

We had an equal sex distribution across groups, but in both groups more women participated. This could have influenced the recognition accuracy since women have been shown to be better in emotion recognition than men [54], but only for subtle emotions [55]. Whereas most of the studies carried out so far used black-and-white static stimuli [12,14,16,17,19,23], we used gradually changing dynamic color pictures in order to more closely simulate dynamic facial expressions as they might occur in daily life, to raise ecological validity. The two previous mimicry studies using dynamic facial expressions [12,15] used morphing presentation times longer than 25 s that may have appeared to be too slow and thus unnatural to participants. This may explain some of the divergent findings between their studies and ours.

Previous studies did not control for mood, despite its effect on emotion recognition [30] and emotional mimicry [43]. In our study, a neutral mood was induced with a documentary film. Nevertheless, after mood induction HSA participants still indicated that they experienced a higher amount of excitement and arousal than LSA participants. However, correlational analyses indicated no systematic effect of these emotional states on mimicry and recognition performance. It is well known that participants with high anxiety-related traits react more anxiously to novel laboratory environments with an unknown experimenter. This constitutes a particular challenge in emotion research that might require the use of ambulatory assessment technologies to be circumvented [56].

Several limitations of the current study have to be considered. First, our study has a limited generalizability, since the sample consisted of a subclinical socially anxious group who had not been screened for other mental disorders. However, since eight HSA individuals were above an accepted clinical cut-off score for social anxiety on the SPS [57], it is likely that some of the results generalize to clinical samples. Stopa and Clark [58] indicated that the results from analogue studies are typically similar to those of clinical studies. The LSAS assesses the severity of social anxiety symptoms, the SIAS evaluated difficulties in social interactions and the SPS focuses on the fear of being judged. To discriminate between clinical and nonclinical samples, future studies should include categorical measures. Due to the high comorbidity of SAD, for example with depressive disorders, it would also be important to describe the influence of different comorbid disorders on the capacity to recognize and regulate emotions, as differences between the two disorders in emotion recognition accuracy have been found [9].

Second, in daily life emotional expressions usually occur in social contexts, which could influence mimicry of these expressions and recognition ability. Therefore, more natural laboratory study designs are needed. For example, measuring mimicry during a conversation with a stranger may be a promising approach. Future studies should include naturally changing emotional expressions to increase ecological validity. Another remaining question is the influence of higher arousal in individuals with HSA on mimicry and emotion recognition. There is evidence that arousal levels in pleasant facial expressions enhance facial mimicry [59]. Future studies should therefore systematically vary stimulus arousal and measure perceiver arousal (e.g. skin conductance) given the high somatic arousal in individuals with social anxiety disorder, to examine if there is a link between perceiver arousal and facial mimicry. And third, the relatively small sample size could be responsible for some nonsignificant findings. Therefore, a confirmatory study involving the same stimuli and a larger sample of participants is warranted.

Results of the present study offer new ways to understand the underlying factors and mechanisms of social anxiety. The observed enhanced expression of disgust in HSA participants could be misinterpreted as disapproval and rejection of the conversational partner [51]. Most likely, the conversational partner will react to this rejection by expressing rejection. This could result in a vicious cycle and constitute a self-fulfilling prophecy that contributes to the maintenance of social anxiety. In the improvement of treatment, it remains to be seen if it is helpful to add emotion recognition and expression training to existing treatments of social anxiety.

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Contributors

CR contributed ideas to the paper, drafted and revised the manuscript, and performed psychophysiological and statistical analyses. TI and MS contributed ideas to the paper and drafted and revised the manuscript. SP performed statistical analyses and revised the manuscript. UK performed psychophysiological data analysis, provided support for the collection of psychophysiological data and revised the manuscript. FW provided support for the collection and analyses of psychophysiological data and revised the manuscript. All authors read and approved the final manuscript.

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