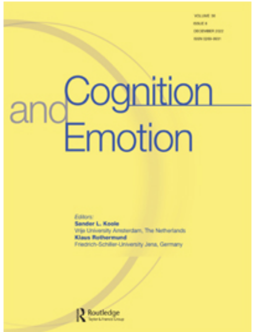


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# Mimicry of partially occluded emotional faces: do we mimic what we see or what we know?

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**ABSTRACT**

Facial electromyography (EMG) was used to investigate patterns of facial mimicry in response to partial facial expressions in two contexts that differ in how naturalistic and socially significant the faces are. Experiment 1 presented participants with either the upper- or lower-half of facial expressions and used a forced-choice emotion categorisation task. This task emphasises cognition at the expense of ecological and social validity. Experiment 2 presented whole heads and expressions were occluded by clothing. Additionally, the emotion recognition task is more open-ended. This context has greater social validity. We found mimicry in both experiments, however mimicry differed in terms of which emotions were mimicked and the extent to which the mimicry involved muscle sites that were not observed. In the more cognitive context, there was relatively more motor matching (i.e. mimicking only what was seen). In the more socially valid context, participants were less likely to mimic only what they saw – and instead mimicked what they knew. Additionally, participants mimicked anger in the cognitive context but not the social context. These findings suggest that mimicry involves multiple mechanisms and that the more social the context, the more likely it is to reflect a mechanism of social regulation.

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facial mimicry; emotion; motor matching; emotional understanding

Emotional facial expressions are an essential source of information about feelings and behavioural intentions, as such it is theoretically and practically important to understand how perceivers recognise them and react to them under challenging conditions, including partial visibility. The COVID-19 pandemic has led to an increased interest in the processing of facial expressions occluded by surgical masks (e.g. Carbon, 2020; Grundmann et al., 2021; Kastendieck et al., 2022; Ramachandra & Longacre, 2022). Here we examine the impact of facial occlusion on emotion recognition and on the related process of facial mimicry. Spontaneous facial mimicry is the tendency to automatically imitate the facial expressions of others (Dimburg, 1982), and plays an important role in face-to-face social interaction. Mimicry increases feelings of rapport (Chartrand & Bargh, 1999; Hatfield et al., 1993; Lakin et al., 2003; Likowski et al., 2008), promotes prosocial behaviour (Van Baaren et al., 2004), and provides at least one mechanism for empathy via emotional contagion and/or the partial simulation of another person's physiological state (Chartrand & Bargh, 1999; Hatfield et al., 2014; Iacoboni, 2009). Facial mimicry is known to promote interaction quality (Yabar & Hess, 2007) and to facilitate the recognition of

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emotional expressions under certain circumstances (Davis et al., 2017; Korb et al., 2015; Maringer et al., 2011; Oberman et al., 2007; Olszanowski et al., 2020; Ponari et al., 2012).

Although emotion recognition and facial mimicry are both important for face-to-face social interaction, the relationship between them is less clear as these two processes present a version of the chicken and egg problem. Disputes regarding the automaticity of facial mimicry raise the issue of whether mimicry contributes to the process of recognising an interlocutor's emotional state, or rather results from it as part of a larger, on-going process of social regulation (Bourgeois & Hess, 2008; Davis et al., 2017, 2021; Hess et al., 1999; Hess & Fischer, 2013; Hess, 2021; Niedenthal, 2007; Niedenthal et al., 2001, 2005, 2010; Oberman et al., 2007; Ponari et al., 2012). We suggest that providing a detailed characterisation of the effect of facial occlusion on mimicry will both support a more nuanced understanding of how face masks and other face coverings impact social interaction and help to resolve longstanding disputes regarding the importance of conceptualisation in facial mimicry. The latter concerns whether facial mimicry is best understood as a bottom-up process that is a reflexive response to social stimuli (Chartrand & Bargh, 1999; Dimberg et al., 2000; Hatfield et al., 1993; 2014), or whether it is driven by top-down factors that influence how people understand and respond flexibly to their social environment (Davis et al., 2021; Hess & Fischer, 2013, 2022).

According to bottom-up models of spontaneous facial mimicry, the process is automatic, grounded in links between perception and action, and represents a subtype of general behavioural mimicry (Chartrand & Bargh, 1999; Hatfield et al., 2014; Lakin et al., 2003). Early studies of the phenomenon provided ample support for its automaticity. First, mimicry is fast, beginning less than a second after the onset of an emotional expression (Dimberg & Thunberg, 1998). Second, individuals are unable to voluntarily suppress their mimicry reaction, suggesting it is an obligatory process unaffected by motivated attempts at suppression (Dimberg et al., 2002). Perhaps most impressively, individuals spontaneously mimic facial expressions presented subliminally (Dimberg et al., 2000) and rapidly, i.e. 17-40ms, (Bornemann et al., 2012; Sonnby–Borgström, 2002), suggesting top-down processes are not required for its elicitation. Fast, obligatory, and operating (largely) below conscious awareness, mimicry would seem to present a paradigmatic example of an automatic process.

However, there is also considerable support for a model of emotional mimicry as a form of social regulation in which mimicry serves social goals and is influenced by situational knowledge (Hess & Fischer, 2013). Support for this more "top-down" model has been found in studies that show the extent of facial mimicry depends on social and contextual factors (for reviews see Arnold & Winkielman, 2019; Hess, 2021; Seibt et al., 2015). For example, observers are more likely to mimic affiliative emotions like happiness than those, such as anger, that do not typically signal affiliation (Bourgeois & Hess, 2008; Seibt et al., 2013; Van der Schalk et al., 2011). Likewise, facial mimicry is more common among social actors in cooperative situations than competitive ones (Lanzetta & Englis, 1989). Similarly, the default pattern of facial mimicry changes when the observer is concerned about their relative social status (Carr et al., 2014) or when the observer watches the expression for its informative value (Hofree et al., 2018). According to the mimicry as social regulation model, mimicry is not a reflexive response to an emotional expression, but rather a reflection of what the emotional expression means to the observer in the social context (Hess & Fischer, 2013). As such, mimicry is an implicit, spontaneous but goal-dependent process, which can be modified by top-down processes that influence the posited affiliation goal of mimicry.

Facial occlusion is particularly germane to this issue because disputes between bottom-up and top-down accounts of facial mimicry can be framed in terms of the relationship between mimicry and visual information from the face. That is, our understanding of the role of facial mimicry in social interaction hinges on whether mimicry is driven by what observers see in another person's facial expression, or what they understand about another's emotional state. Different models of facial mimicry thus make different empirical predictions regarding the mimicry of occluded faces. If facial mimicry is a reflexive response to visual information in the face, mimicry will be confined to the actions of muscles the observer can see. Specifically, even though facial expressions involve patterned responses of muscle activity, the muscles in the face can respond independently, with greater voluntary control over the muscles on the lower half of the face (Matsumoto & Ekman, 2008). Smiles, for example, can be expressed with and without activity in the Orbicularis Oculi muscle (Krumhuber & Manstead, 2009). Given that the muscles that produce emotional expressions can operate independently, a reflexive mimicry response should only be present at the muscles evident in the visual input. On the other hand, if facial mimicry involves a pattern of muscle activity bound together via meaning, it will depend on what observers can infer about the other person's emotional state. Top-down approaches to facial mimicry thus suggest observers might sometimes mimic unseen muscles in the face.

### 1.1 The present study

The present study aims to test the automaticity of mimicry by exploring whether partially occluded emotional faces elicit a mimicry response, and whether that response includes mimicry of unseen muscles. Experiment 1 presented emotional expressions in which participants saw only the top or the bottom half of the face, and then made an alternative forced choice about what emotion was being expressed. The occlusion was purely visual – without any social meaning. Mimicry was measured via facial electromyography (EMG) at two muscle sites – one which was visible in the half-faces and one which was not. Our primary research question was whether these half-face stimuli might elicit mimicry from the unseen muscle site. If mimicry is primarily driven by bottom-up factors, it should only be evident at the muscle site that can be seen by the participant. If mimicry is subject to influence from top-down factors, it should be possible to detect mimicry at both the seen and the unseen muscle sites.

Experiment 2 also presented partially occluded emotional expressions but did so in a more socially meaningful and ecologically valid manner – using clothing. In this study, participants' EMG was recorded as they viewed images of women wearing either western winter wear or Muslim niqabs so that all but their eyes were occluded. Moreover, to encourage social processing of the images, participants were asked to rate the intensity of anger, disgust, fear, happiness, sadness, and surprise expressed by each face. Allowing for the interpretation of mixed emotions is more ecologically valid than a three-alternative forced-choice task, since expressions in the real world can be complex and nuanced and so can observers' interpretations (see Hess & Kafetsios, 2022). Additionally, because Experiment 2 employed a ratings task, participants were not forced to choose one emotion over another. These sorts of open-ended tasks have been shown to be more sensitive measures of emotion recognition than alternative forced choice tasks (Cassels & Birch, 2014). In short, the task in Experiment 2 was intended to promote perspective taking. As in Experiment 1, in Experiment 2 we asked whether occluded faces ever elicit mimicry from the unseen muscle site. Mimicry of the unseen Zygomaticus Major muscle would support top-down models of facial mimicry that posit an important role for the observer's interest in and knowledge about the experiencer's emotional state.

## 2. Facial mimicry during emotion classification (EXPERIMENT 1)

Experiment 1 used electromyography (EMG) to index facial mimicry as participants viewed videos of dynamic emotional expressions that displayed either the top- or the bottom- half of a face. The faces in these videos expressed either anger, happiness, or sadness and participants were asked to classify the emotion on a three-alternative forced choice task. Mimicry was assessed with sensors placed on the cheek (Zygomaticus Major) and on the brow (Corrugator Supercilii). The Zygomaticus Major raises the corners of the lips. It contracts during smiling and relaxes during facial expressions of anger. The Corrugator Supercilii pulls the eyebrows together as during the brow wrinkling component of expressions of anger and sadness. Corrugator Supercilii contraction is thus consistent with the expression of anger and sadness, while its relaxation is consistent with the expression of happiness.

As our use of the forced choice methodology allows participants to approach emotion recognition as a cognitive rather than a social task, our first question was whether these half-face stimuli would elicit any facial mimicry at all. To answer this question, we utilised the mimicry index as our dependent variable, a holistic measure of mimicry that treats it as a patterned response involving the contraction of some muscles and the relaxation of others (Drimalla et al., 2019; Hess et al., 2017; Olszanowski et al., 2020). Moreover, we examined the activity at individual muscle sites to see if participants ever mimic the unseen muscle site in an emotion-appropriate manner. Given the muscle sites measured here, mimicry of happiness is associated with the activation of the Zygomaticus Major and the relaxation of the Corrugator Supercilii, whereas mimicry of anger and sadness are associated with the reverse pattern (Hess & Fischer, 2013; Seibt et al., 2015).

Because our experimental manipulation reduces the potential information conveyed by the face, both top-down and bottom-up accounts of facial mimicry predict half-face stimuli will elicit a muted mimicry response. However, the accounts differ regarding the relationship between facial mimicry and visual information conveyed by the face. Bottom-up accounts suggest mimicry will be present for the visible muscle and absent from the unseen one. By contrast, top-down accounts suggest mimicry will depend on what the observer can infer about the relevant emotion, and thus may be evident at the unseen muscle site.

Moreover, because top-down accounts suggest mimicry depends on the observer's understanding, the impact of the half-face manipulation will be related to the information content in the part of the face the observer actually sees. Whereas bottom-up accounts suggest mimicry is a function of the visual evidence for muscular responses, top-down accounts suggest mimicry will be absent when visual evidence is insufficient to infer which emotion is being expressed. Top-down approaches thus suggest that mimicry of the unseen muscle site will depend on the information provided by the seen portion of the face regarding the relevant emotion. Because participants tend to draw on information from the mouth when recognising happiness, and information from the eyes when recognising sadness (Bassili, 1979; Calder et al., 2000; Eisenbarth & Alpers, 2011), the unseen muscle site involved in happiness mimicry may differ from that in sadness mimicry.

## 2.1 Methods

### 2.1.1 Participants

Forty University of California, San Diego undergraduates (mean age = 20.6 years old, sd = 5.97 years, 32 female) were recruited from the UCSD research participation pool for the EMG study. Sample size was chosen based on prior studies of facial mimicry utilising dynamic stimuli (Rymarczyk et al., 2011; Wróbel & Olszanowski, 2019). All participants provided written informed consent prior to the experiment and received course credit for their time. Three participants whose mean accuracy on the categorisation task was less than 70% correct were removed from the analysis. Results presented were based on the remaining 37 participants.

### 2.1.2 Construction of the materials

Previous research using emotion classification tasks in "dry" cognitive settings has shown that while static images of faces can elicit weak mimicry, dynamic facial stimuli are more effective (Rymarczyk et al., 2011). Consequently, we used morphing software to create short videos in which a neutral face changes gradually into an emotional display over the course of a few seconds. A similar approach has been utilised by previous investigators and is known to elicit mimicry (Olszanowski et al., 2020; Wróbel & Olszanowski, 2019). Moreover, because participants in the main EMG study would be viewing only the upper or the lower portion of the face, we constructed an initial stimulus set using expressions of varying intensities for use in a norming study conducted to ensure that our final stimulus set included emotional expressions that could be recognised reasonably well from either portion of the face (that is, the top or the bottom half).

As in Olszanowski et al. (2020), videos were created using Abrasoft FantaMorph Pro Software to combine two high-resolution full-face photographs from the Warsaw Set of Emotional Facial Expression Pictures (WSEFEP) (Olszanowski et al., 2015). Each video began with a photograph of a neutral expression and morphed into another of the same actor expressing either anger, happiness, or sadness. Stimuli were exported as six-second videos at 14 frames per second and a resolution of 720×540 pixels. These full-view faces were then edited by placing a black rectangle on the top or bottom half of the face and placing them on a black background to become half faces.

An initial stimulus set included both high and low intensity versions of each of the three emotional expressions (anger, happiness, and sadness) conveyed by 8 different actors (4 male and 4 female) each divided into the top and the bottom half of the faces. This initial stimulus set of 96 videos was shown in a separate norming study to 12 participants who were drawn from the same participant pool we later used for the EMG study. The norming task was intended to create a stimulus set that was neither so easy as to promote ceiling effects, nor so difficult that participants could not recognise the target emotions. As in the EMG study, participants in the norming study were asked to categorise each video as expressing happiness, sadness, or anger on a three-alternative forced choice task.

Results of the norming task were then used to select either the high or the low intensity version of

**Table 1.** Average accuracy rates and standard deviations on the three alternative forced choice emotion categorisation task in the norming study described in section 2.1.2 of the text.

| | Anger | Happiness | Sadness |
|---|---|---|---|
| Top Half | 88.6% (11.7%) | 77.1% (21.6%) | 92.8% (12.1%) |
| Bottom Half | 73.8% (15.6%) | 95% (4.1%) | 70.8% (14.6%) |

each emotional expression for each actor. Thus, we first removed any expression for which mean accuracy was less than 50% for either half of the face. This resulted in the exclusion of 63% of the low-intensity expressions of anger and happiness, and 38% of the low-intensity expressions of sadness. In these cases, we selected the high-intensity counterpart for inclusion in the experiment. For the remaining items, we selected the intensity level (either high or low) that elicited accuracy levels closest to 85%.

Results from the norming study for the 48 stimuli chosen for inclusion in the EMG study are shown in Table 1. Average accuracy scores are all greater than 70% and below 100%. Moreover, differences between participants' performance on the bottom and top half of each category of emotional face are consistent with known asymmetries in the information content of each half of the face (Calder et al., 2000; Calvo et al., 2014; Ekman & Friesen, 1971; Ponari et al., 2012; Smith et al., 2005). The top half of the face is more diagnostic of anger (Bassili, 1979; Calder et al., 2000; Ponari et al., 2012;) and sadness (Bassili, 1979; Calder et al., 2000) than the bottom half, and accuracy rates were higher for anger and sadness when our participants saw the top of the face than the bottom. Likewise, performance was better for the bottom half of happy faces than the top, consistent with the presence of information from the Zygomaticus major on the bottom half of the face.

### *2.1.3 Materials*

Stimuli for the EMG experiment were thus a subset of those tested in the norming study described above. Stimuli included 48 different 6-second videos of emotional morphs: 3 emotional expression morphs (anger, happiness, sadness) × 2 face-half shown (top, bottom) × 8 actors (4 male, 4 female). Figure 1 shows an example of the initial (neutral) frame from one actor's top and bottom half videos, as well as the final frame from each of her happiness, sadness, and anger videos.

### *2.1.4 Procedure*

Zygomaticus Major and Corrugator Supercilii muscle sites on the left side of the participant's face were cleaned with rubbing alcohol and prepped with NuPrep gel, then affixed with bipolar derivations of Biopac Systems EL504 disposable Ag/AgCl electrodes according to facial EMG guidelines (Fridlund & Cacioppo, 1986). A reference electrode was placed on the participant's cleaned and prepped left mastoid, and a wireless transmitter was secured to the participant's left shoulder. Conductivity was tested by having participants move parts of their face (without mention of emotions or emotional expressions) as the experimenter visually inspected the EMG signals in real-time. Data collection did not begin until the experimenter was sure that facial actions induced appropriate, clear signals.

After participants were affixed with EMG electrodes, they entered their age and sex into the computer and began the experiment. Written instructions, presented on the monitor, directed participants to watch each video and to categorise the emotion that was expressed. Participants were given the


**Figure 1.** An example from the first frame of the clip presenting the upper (top left) and lower (bottom left) half of an actor's face. In each video the neutral expression morphed slowly into happiness (second column), sadness (third column), or anger (far right column). Images to the right of the ellipses show the final frame of clips showing the upper half (top row) and the lower half (bottom row) of the same actor's face expressing the emotions indicated. Details about materials for Experiment 1 are described in sections 2.1.2 and 2.1.3 of the text.

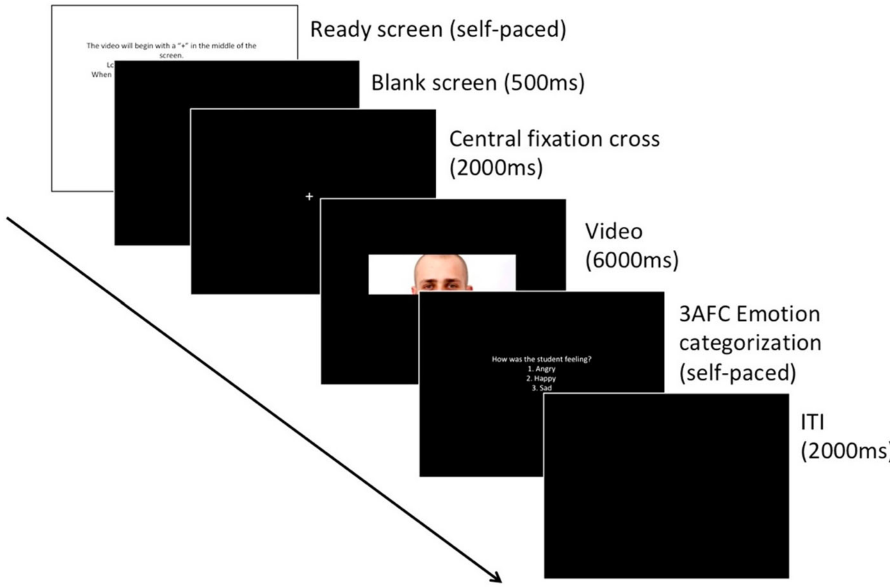


**Figure 2.** A sample trial in Experiment 1.

opportunity to ask questions about the task before the stimulus presentation phase of the study began.

Each trial began with a Ready screen reminding participants of task instructions that disappeared when they pressed the spacebar. The Ready screen was followed by 500ms of blank screen, a 2000ms fixation cross, a 6000ms video, 500ms of blank screen, and a self-paced categorisation screen (see Figure 2 for a trial schematic). The categorisation screen presented the following text, "How was this person feeling? 1. Angry 2. Happy 3. Sad" and participants responded via a keyboard button press. After each button press, a 2000ms blank screen was presented, followed by the Ready screen that signalled the onset of the next trial.

The 48 stimuli (3 emotions x 2 halves of the face x 8 actors) were each presented once for a total of 48 trials. Trials were presented in a random order. Following the study, electrodes were removed, and participants were debriefed.

#### *2.1.5 EMG recording and processing*

EMG signals were recorded at 2000Hz using BioPac Systems Inc. (California, USA) BioNomadix two-channel wireless amplifier, MP 150 acquisition platform, and AcqKnowledge 4.11 recording software. Signals were amplified by 2000×, filtered online with a band pass filter pass of 250–500 Hz, and sampled at 2000 Hz. EMG data were rectified and integrated in 500 ms bins using MindWare EMG software package 2.52 (MindWare Technologies Ltd. Ohio, USA) and exported for further processing in R (R Core Team, 2021). Voltage was z-scored within each participant and muscle site beginning 2 s before the onset of each stimulus and ending at the conclusion of each 6-second video. Bins that were more than 3 standard deviations above or below the mean were removed from the analysis, resulting in the omission of 1.2% of the data points. The remaining data were again normalised within each participant and muscle site, averaged into 1000 ms bins, and baseline activity was subtracted out on a trial-by-trial basis. Trials with participant response times greater than 5500 ms were dropped, resulting in the removal of 3.1% of the trials. Of the remaining trials, only those with accurate responses on the categorisation task were included in the EMG analyses.

### *2.2 Results*

#### *2.2.1 Could participants categorise the half-faces?*

Average accuracy rates on the emotion classification task are shown in Figure 3. As noted in the Methods section, materials were chosen to elicit a range of performance between 70% and 99%. Ranging from 61%

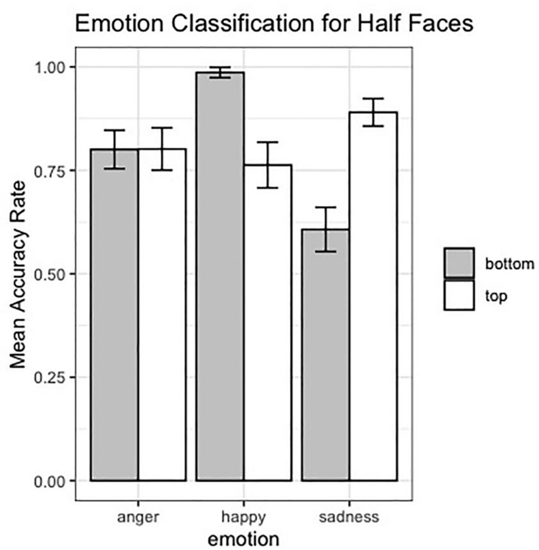


**Figure 3.** Mean accuracy rates on the emotion classification task for half face stimuli in experiment one. Error bars represent 95% confidence intervals.

correct (sadness: bottom half) to 98% correct (happy: bottom half), participants' average accuracy rates were largely in line with these goals.

Analysis of performance on the emotion classification task involved a mixed effects model predicting average accuracy rates in each participant. Fixed effects included one categorical predictor for emotion (anger, happy, sad) and another for Face Half (bottom, top); random effects included an intercept term for each subject. This analysis revealed the following results.

Anger was correctly classified at a rate of 80.05% correct and did not vary as a function of the half of the face ($\beta = 0.001$, $t = 0.035$, $p = 0.97$). Classification performance was significantly better than this for happy faces ($\beta = 0.186$, $t = 5.78$, $p<0.001$) and significantly worse than this for sad faces ($\beta = -0.193$, $t = -6.00$, $p<0.001$). Moreover, classification of both happy and sad faces differed as a function of which half of the face participants viewed. Participants performed significantly better on the top half of sad faces than the bottom ($\beta = 0.282$, $t = 6.19$, $p < 0.001$), and significantly worse on the top half of happy faces than the bottom ($\beta = -0.225$, $t = -4.937$, $p < 0.001$).

### *2.2.2 Did participants mimic the half-faces?*

As mentioned, some scholars suggest the best way to measure facial mimicry is to treat it as a pattern and derive a composite index from EMG recordings of separate muscles (Hess et al., 2017; Olszanowski et al., 2020). Following this idea, and the specific method from Olszanowski et al. (2020), we calculated the mimicry index for happiness by subtracting the standardised activation recorded from the Corrugator Supercilii from that recorded from the Zygomaticus Major. The mimicry index for anger and for sadness each utilised the inverse (that is, by subtracting the standardised activation recorded from the Zygomaticus Major from that recorded at the Corrugator Supercilii). Figure 4 shows the mean mimicry index in each condition as a function of time and which half of the face was visible to participants. Mimicry scores from each trial were analysed for each emotion separately using mixed effects models with fixed effects of Face Half and Time, a random slope for time for each subject, and a random intercept for each item. Model fits from these analyses are depicted in Figure 5.

Analysis of the anger mimicry data failed to reveal any significant effects (Intercept: $\beta = 0.11$, CI [−0.18–0.09]; Face Half [top]: $\beta = -0.07$, CI [−0.48–0.34]; Time $\beta = 0.02$, CI [−0.10 – 0.13]), though the interaction Face Half [top] × Time approached significance (beta = 0.14, CI [−0.01–0.29], $p = 0.069$). The trend towards mimicry for the top half of the face is apparent in both Figures 4 and 5 (left-most panel).

Analysis of the happiness mimicry data indicated that the fixed effect of time was significant, as was its interaction with the half of the face shown. When participants viewed the bottom half of the face, mimicry effects manifested as a significant effect of Time ($\beta = 0.22$, CI [0.12 – 0.32], $p<0.001$) as mimicry increased over the course of the trial. The significant interaction between Face Half [top] and Time ($\beta = -0.24$, CI [−0.38 −0.09], $p < 0.01$) reflects the absence of mimicry when participants viewed the top half of the happy faces (see the middle panel in Figures 4 and 5).

Analysis of the sadness mimicry data suggested the interaction between Face Half [top] and Time was null ($\beta = -0.06$, CI [−0.21– 0.09]), so it was removed from the model. Sadness mimicry manifested as a main effect of Face Half [top] ($\beta = 0.18$, CI [0.03 – 0.33], $p<0.05$), revealing significant mimicry when participants viewed the top half of the face, but not the bottom ($\beta = 0.01$, CI [−0.18 – 0.19], $p = 0.78$). Mimicry for the top half of sad faces is evident in both Figures 4 and 5 (rightmost panels).

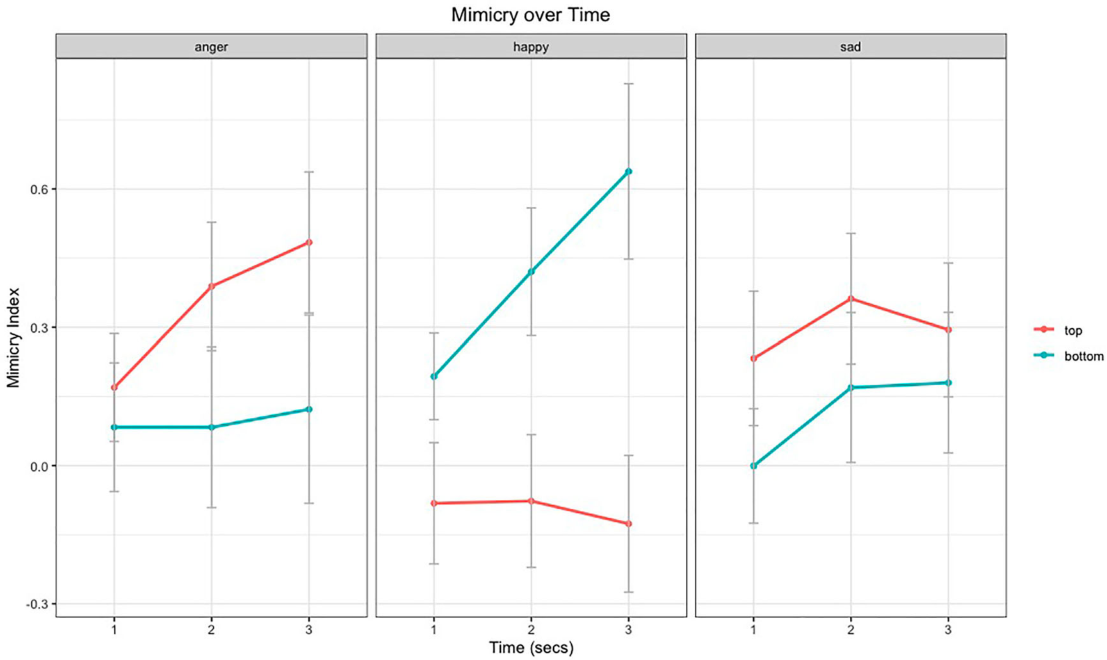


**Figure 4.** Mean mimicry index in each condition as a function of time and which half of the face was shown to participants. Error bars represent 95% confidence intervals.

Overall, these analyses suggest happiness mimicry was elicited by the bottom half of happy faces and sadness mimicry was elicited by the top half of sad faces. However, confidence intervals on these models indicate substantial levels of variability across participants.

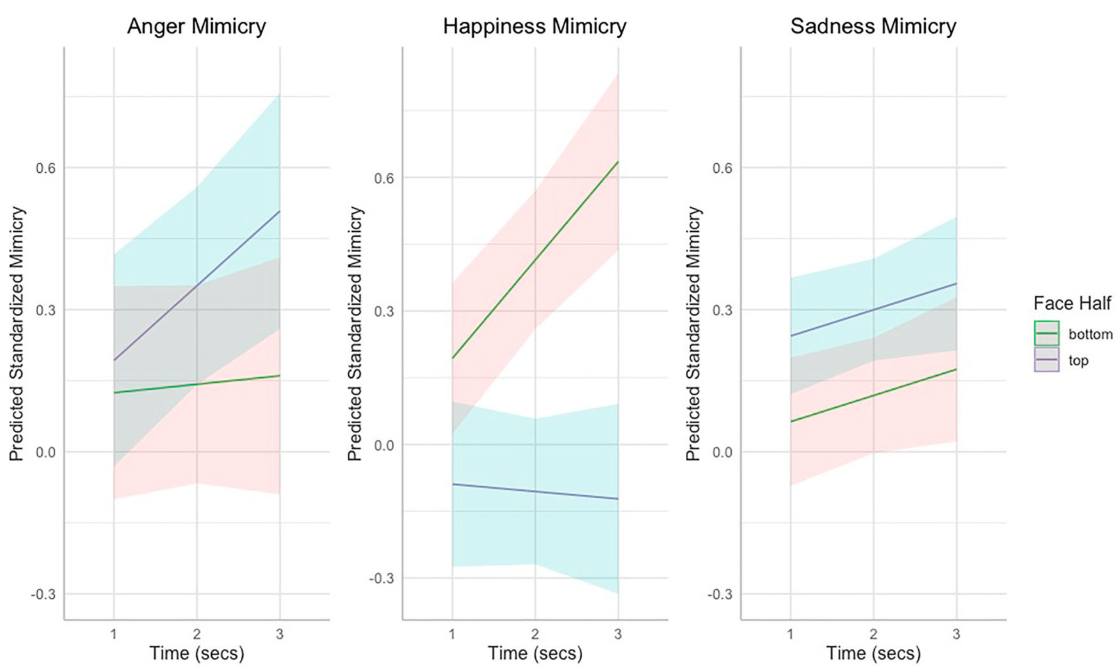


**Figure 5.** Predicted mimicry scores for Anger, Happiness, and Sadness based on the mixed effects models described in section 2.2.2 of the text.

### 2.2.3 Did participants ever mimic what they could not see?

Mimicry analyses suggested mimicry was most robust for the more visually informative half of the face. Specifically, mimicry for happiness was elicited by the bottom half of the face, whereas mimicry for sadness was elicited by the top. However, the mimicry index is (by design) a composite response. In the present study, the question of interest is whether mimicry is a purely imitative response to visual information, or a more nuanced response predicted by the emotional mimicry as social regulation model. A more targeted test of this question thus requires us to assess whether observed muscle activity in our participants always reflected the muscle activity visible in the actor's face, or whether it was ever driven by unseen (inferred) information about emotional state. The motor matching hypothesis predicts Zygomaticus Major activity will be responsive to images of the bottom half of the face while Corrugator Supercilii activity will be responsive to images of the top. By contrast, top-down accounts of facial mimicry would be supported if Zygomaticus Major activity was responsive to emotional information from the top of the face or if Corrugator Supercilii activity was responsive to emotional information from the bottom.

*Zygomaticus major activity.* Mean activation in Zygomaticus Major during Angry, Happy, and Sad faces is shown in the left-hand panel of Figure 6. Zygomaticus Major activity was analysed using linear mixed effects regression with fixed effects of Emotion, Face Half, and Time, and random intercept terms for subject and item. This revealed only an interaction between Emotion and Time ($\beta = 0.13$, CI [0.02-0.24], $p < 0.05$). Follow-up analyses revealed no evidence of significant effects on Zygomaticus Major activity in response to either anger or sadness. Analysis of happy faces revealed a main effect of Time ($\beta = 0.11$, CI [0.03–0.18], $p < 0.01$), and an interaction between Face Half[top] and Time ($\beta = -0.13$, CI [−0.25–0.02], $p < 0.05$). Zygomaticus Major contraction during happy faces was driven by information in the seen portion of the face (Figure 6).

*Corrugator Supercilii activity.* Standardised activation in the Corrugator Supercilii is shown for each of the emotions in the right-hand panel of Figure 6. As for Zygomaticus Major activity, activity in the Corrugator Supercilii was analysed with linear mixed effects regression with fixed effects of Emotion, Face Half, and Time, and random intercept terms for

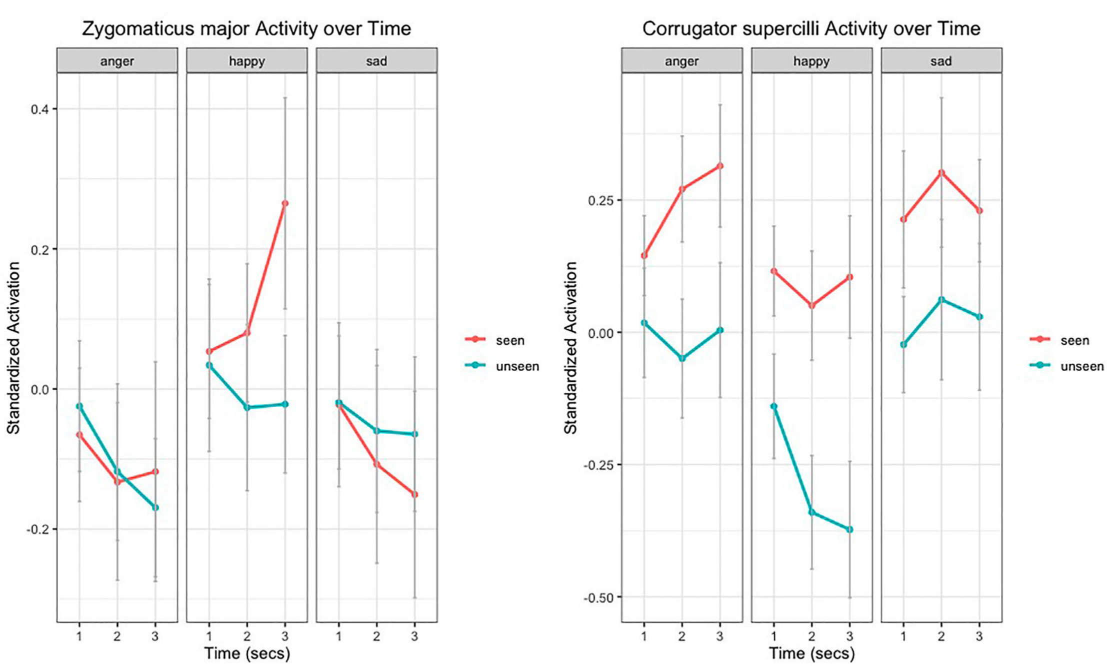


**Figure 6.** Mean standardised activation values in the *Zygomaticus Major* (left hand panel) and *Corrugator Supercilii* (right hand panel) over time as a function of emotion and the visibility of each muscle in the video.

subjects and items respectively. Analysis revealed only an interaction between Emotion [happiness] and Time ($\beta = -0.11$, CI [−0.22, 0], $p < 0.05$). Follow-up analysis of data elicited by happy faces revealed a main effect of Time ($\beta = -0.12$, CI [−0.19 – −0.05], $p < 0.001$) and an interaction between Face Half [top] and Time ($\beta = 0.11$, CI [0 – 0.22], $p < 0.05$). As can be seen in Figure 6, Corrugator Supercilii relaxation was triggered by the bottom half of happy faces – the images in which the relevant emotion was most apparent, but those for which the Corrugator Supercilii muscle itself was not visible.

### 2.3 Discussion

As noted above, Experiment 1 was intended to answer three questions. First, could participants accurately categorise the emotions in these half face stimuli? Second, was emotional mimicry observed for these half face stimuli? Third, did participants ever mimic unseen muscle activity relevant for the expression of the target emotion? We address each in turn below.

#### 2.3.1 Participants were able to accurately categorise the emotions in the half face stimuli

Participants were presented with either the top or the bottom half of dynamic emotional faces and asked to do a three-alternative classification task. Our analysis of accuracy rates was intended to verify that emotion recognition was possible when viewing only half the face. Given that chance on this three-alternative forced choice is 33%, the accuracy rates observed in the present study indicate participants were indeed able to distinguish between the three types of emotional faces. Moreover, we anticipated differences in categorisation accuracy as a function of both the emotional expression and the half of the face that was shown. Happy faces elicited the highest accuracy rates in the present study, consistent with previous studies (Bassili, 1979; Calder et al., 2000; Ponari et al., 2012). Moreover, our results were also in line with previous studies that show diagnostic asymmetries in the expression of emotions (Gagnon et al., 2014; Smith et al., 2005). As in prior studies, our data suggest happiness is easiest to recognise when the bottom half of the expression is shown, whereas sadness and anger are easier to recognise when the top half is shown (Bassili, 1979; Calder et al., 2000; Ponari et al., 2012). In sum, our findings are consistent with the literature and demonstrate that participants were able to categorise the emotional expressions in these half faces.

#### 2.3.2 Mimicry was observed only for some of the half-face stimuli

Because the recognition of emotional faces has been argued to elicit a complex pattern of muscular activity that includes the contraction of some muscles and the relaxation of others, some scholars have argued that the best way to measure the presence or absence of facial mimicry is to derive a composite mimicry index from EMG recordings (Hess et al., 2017; Olszanowski et al., 2020). Our analyses of these mimicry scores suggest that – like accuracy on the emotion classification task – the presence or absence of facial mimicry was related to the visual information presented in each half of the face. Happy faces elicited robust mimicry only when participants viewed the more visually diagnostic information in the bottom half of the face. Likewise, sad faces elicited significant mimicry only when participants viewed the more visually diagnostic and easier to categorise information in the top half of the face. Although there was no clear statistical support for mimicry of angry faces, visual inspection of the data suggests a trend for greater mimicry of the more informative top half of angry faces.

Overall, data suggests that emotion recognition and mimicry are both sensitive to visual information present in the half face images.

#### 2.3.3 Mimicry of happiness was observed at both the seen and the unseen muscle sites

Our analyses of the activity at particular muscle sites on the face showed that the holistic mimicry response elicited by happy faces was driven both by the contraction of the Zygomaticus Major and the relaxation of the Corrugator Supercilii. Moreover, while Zygomaticus Major activity was fairly reflexive, present only when the Zygomaticus Major muscle was visible, the relaxation of the Corrugator Supercilii was evident even when the Corrugator Supercilii muscle itself was not visible. Changes in activity of Corrugator Supercilii elicited by happy faces thus occur not because participants mimic what they see in the actor's face, but because they mimic what they know about the actor's emotional state.

#### 2.3.4 Limitations of the present study

One limitation of Experiment 1 was our use of a relatively small sample, which was mainly comprised of women (8 men and 29 women). The gender imbalance reflects our use of a convenience sample from the UCSD participant pool. Although the sample size was comparable to that used in previous studies with dynamic stimuli (Rymarczyk et al., 2011; Wróbel & Olszanowski, 2019), conceptual replication using a larger, more balanced group of participants would be beneficial. Moreover, another limitation of Experiment 1 was that we only recorded from two muscles on the face. The use of multiple facial muscle measures affords greater resolution regarding the specific emotion being mimicked (see Wingenbach et al., 2020 for a review). Finally, the facial occlusion of materials in Experiment 1 was obviously artificial, raising the question of whether similar patterns of mimicry would be evident in a more ecologically valid paradigm.

## 3. Mimicry while rating the emotions expressed by people with partially occluded faces (EXPERIMENT 2)

Experiment 1 revealed mimicry for the top half of sad faces and the bottom half of happy faces. Moreover, for happy faces, there was evidence for mimicry at both the seen and the unseen muscle sites, consistent with the predictions of top-down accounts of mimicry. However, the stimuli in Experiment 1 were rather artificial, and the emotion classification task we used was not designed to promote naturalistic processing of social stimuli. In Experiment 2, we seek to replicate and extend our findings via the use of a more ecologically valid experimental paradigm in which participants' EMG was recorded as they viewed emotional faces occluded by clothing (either by a scarf or by a niqab) and rated the faces for how intensely each expressed a variety of emotions. Because this rating task has been shown to be more effective in promoting social processing strategies than classification tasks (Hess & Kafetsios, 2022), we expected the stimuli in Experiment 2 to elicit more robust mimicry than Experiment 1.

As in Experiment 1, emotion-appropriate activity at the unseen (Zygomaticus Major) muscle site would support the influence of top-down processing on facial mimicry, while activity confined to the seen muscle sites would support an exclusively bottom-up account. In addition to the primary EMG measure, we also measured explicit and implicit attitudes towards our socially realistic stimuli to test for any potential differences due to different types of face covering.

### 3.1 Methods

#### 3.1.1 Participants

A total of 80 participants (61 women) with a mean age of 27 years ($SD = 6.7$) participated individually in the main experiment. All participants were Germans who reported that they had no affiliation with Islam. They received € 8 for their participation.

#### 3.1.2 Materials

The stimuli were facial expressions of happiness, anger, sadness and fear as well as a neutral expression from the four Caucasian female models of the MSFDE (Montreal Set of Facial Displays of Emotion, Beaupré & Hess, 2005). For the covered faces, a professional design artist added either a winter hat and scarf or a Niqab, such that the identical eye region was visible in both versions of the stimuli (see Figure 7 for an example).

#### 3.1.3 Attitude towards the faces

We assessed the explicit and implicit attitude toward both kinds of covered faces. Explicit attitude was


**Figure 7.** Examples of emotional faces in Experiment 2. A full description of materials can be found in section 3.1.2 of the text.

assessed by showing the neutral face photos of each model with niqab cover or winter hat and scarf cover and asking participants how much they liked this person on a continuous scale ranging from −50 (not at all) to +50 (very much). The average out-group liking score was subtracted from the in-group liking score to derive a single estimate of relative liking, such that a positive score reflected explicit preference for Mid-eastern covered faces vs. Western covered faces.

A version of the IAT (Greenwald, McGhee, & Schwartz, 1998) was created to assess implicit attitude. The two attribute categories were positive ("good", "pleasant", "positive" and "valuable") and negative ("bad", "unpleasant", "negative" and "vile") and the two target categories were neutral faces covered with niqab/hijab (four exemplars, see stimuli section) and neutral faces covered with hat and scarf/hat only (four exemplars). An IAT-D score, which is comparable to Cohen's d, was computed (Greenwald, Nosek, & Banaji, 2003) so that a positive score reflected implicit preference for niqab covered faces ($\alpha = 0.78$).

#### 3.1.4 Procedure

Each participant was greeted by the experimenter and seated in front of a computer. Participants were informed that their task would be to rate a series of facial expressions regarding the emotional expression displayed. Those who gave informed consent then received detailed instructions regarding the task, and the experimenter attached the electrodes.

Activity over the Zygomaticus Major and Orbicularis Oculi (happiness), Corrugator Supercilii (anger and sadness), and Frontalis Medialis (fear) regions was recorded with facial electromyography (EMG) on the left side of the face using bipolar placements of 13/7 mm Ag/AgCl surface-electrodes according to the guidelines established by Fridlund and Cacioppo (1986). The EMG raw signal was sampled at 1000Hz using a MindWare Technologies BioNex Bio-Potential Amplifier. Raw data were filtered with a 30Hz–300Hz bandpass and a 50Hz notch filter, and subsequently rectified and smoothed with a 5Hz low-pass filter. The data were checked for artefacts and averaged into four one second bins. For data analysis, baseline to trial difference scores were calculated and within-subject z-transformed.

Each trial began with a fixation cross for 500 ms, then an emotional face for 6000 ms. The presentation of the stimuli was randomised with the restriction that the same emotion and the same actor never appeared twice in a row. Following each presentation of the stimulus, participants completed the emotional profile. All participants were asked to rate each facial display regarding the emotion expressed on an emotion profile that included scales for happiness, anger, fear, sadness, disgust, and surprise on a seven-point Likert-type scale ranging from 0 (not at all) to 6 (very intensely).

Participants initiated the next trial by clicking a thumbnail with the mouse. At the end of the experiment, they completed the explicit and implicit attitude measure in counterbalanced order.

### 3.2 Results

#### 3.2.1 Did participants have different attitudes toward faces in Niqab versus western winter wear?

No significant difference emerged for participants' self-reported explicit attitude as a function of clothing ($M_{Niqab} = 8.71$, $SD = 14.3$; $M_{Winter} = 9.57$, $SD = 14.5$; $t(79) = 0.88$, $p = .383$, $d = .10$). The IAT score was significantly different from 0, $t(79) = 2.34$, $p = .022$, $d = .26$, and positive ($M = 0.11$, $SD = 0.43$) indicating a somewhat more positive implicit attitude towards the women wearing a niqab.

#### 3.2.2 Could participants categorise the partially occluded faces?

Since all faces were rated for their intensity of expressing surprise, sadness, happiness, disgust, fear, and anger, the highest rated emotion for each face was used to determine how that face had been categorised. For Niqab faces, categorisation of Anger (100%), Happiness (95%), and Sadness (72%) was very good. However, Fear faces were correctly categorised only 8.8% of the time (categorised instead as Surprise the remaining 91.2% of the time). Likewise, for Winter Wear faces, categorisation of Anger (97.5%) and Happiness (97.5%) was very good, and the categorisation of Sad faces was somewhat lower (58.8%), but still above the chance level of 16.7%. Fear faces were correctly categorised only 8.8% of the time, miscategorised as Surprise 90% of the time and Disgust the remaining 1.2% of the time.

Emotion recognition was evaluated statistically via linear mixed effects regression models of ratings for Happiness, Anger, Sadness, and Fear, respectively. Each of these models included fixed effects of Cover (Winter Wear, Niqab) and Facial Emotion (Neutral, Happy, Angry, Sad, Fear), as well as a random intercept term for the subject.

*Happiness*. Regression models of happiness ratings indicated that Happy faces were rated as showing significantly more happiness than neutral ones ($\beta = 2.32$, $t = 21.1$, $p < 0.001$), while angry, sad, and fear faces showed significantly less happiness (Anger $\beta = -0.55$, $t = -5.04$, $p < 0.001$; Sad $\beta = -0.64$, $t = -5.85$, $p < 0.001$; Fear $\beta = -0.36$, $t = -3.30$, $p < 0.001$). Although clothing did not impact happiness ratings overall ($\beta = 0.06$, $t = 0.58$, $p = 0.56$), Happy faces in niqab were rated as slightly happier than those in winter wear ($\beta = 0.61$, $t = 3.95$, $p < 0.001$).

*Anger*. Angry faces were rated as significantly more angry than neutral ones ($\beta = 3.66$, $t = 34.6$, $p < 0.001$), and Fear faces were rated as significantly less angry ($\beta = -0.35$, $t = -3.38$, $p < 0.001$). clothing did not significantly impact anger ratings ($\beta = -0.02$, $t = -0.18$, $p = 0.86$).

*Sadness*. Sad faces were rated as showing significantly more sadness than neutral ones ($\beta = 1.64$, $t = 15.1$, $p < 0.001$), whereas Happy ($\beta = -0.69$, $t = -6.38$, $p < 0.001$), Angry ($\beta = -0.62$, $t = -5.77$, $p < 0.001$), and Fear ($\beta = -0.57$, $t = -5.32$, $p < 0.001$) faces were rated as showing significantly less sadness. Clothing significantly impacted sadness ratings, as faces in niqab were rated as showing slightly more sadness than those in winter wear ($\beta = 0.28$, $t = 2.54$, $p < 0.05$), especially when those faces were actually sad ($\beta = 0.54$, $t = 3.54$, $p < 0.001$).

*Fear*. Fear faces were rated as showing significantly more fear than neutral ones ($\beta = 1.08$, $t = 9.19$, $p < 0.001$), as were sad faces ($\beta = 1.35$, $t = 11.46$, $p < 0.001$). Happy faces were rated as showing significantly less fear than neutral ones ($\beta = -0.26$, $t = -2.24$, $p < 0.05$). Although clothing did not impact fear ratings overall ($\beta = 0.04$, $t = 0.38$, $p = 0.70$), the interaction between clothing and facial emotion [fear] was significant ($\beta = -0.53$, $t = -3.19$, $p < 0.01$), indicating participants rated fear faces in niqab as expressing less fear than those in winter wear.

In sum, assessed categorically, emotion recognition was high for happiness and anger, lower for sadness, and below chance for fear. However, ratings of all four categories of emotional faces were higher for the target emotion than they were for the neutral faces. Rather than eliminating trials in which participants "miscategorised" the target emotion – which would have dramatically reduced the dataset for sad and fear faces – it was decided to include all (artifact-free) trials in the EMG analyses.

### 3.2.3 Did participants mimic the partially covered faces?

As can be seen in the top panel of Figure 8, the Happiness Mimicry Index increased significantly over time for Happy faces but not for the Neutral ones. Likewise, the bottom panel of Figure 8 shows that the Sadness Mimicry Index increased over time for the Sad faces but not the Neutral ones. No mimicry was observed in Angry faces or Fear faces.

*Happy faces*. The happiness mimicry index was calculated by subtracting the standardised activation recorded at the Corrugator Supercilii from the average of the (standardised) activations recorded from the Orbicularis Oculi and Zygomaticus Major. That is: (Orbicularis Oculi + Zygomaticus Major)/2 – Corrugator Supercilii. Data were analysed using a linear mixed effects model with fixed factors, clothing style (Western/Mideastern), emotion (Neutral/Happy), and time (4 s) along with a random intercept term for the subject. This model revealed a significant interaction between Clothing Style[Mideastern] and Emotion[Happy] ($\beta = 0.30$, CI [0.13 – 0.48], $p < 0.001$), suggesting greater mimicry to the niqab faces. Further, the significant interaction between Emotion [Happy] and Time ($\beta = 0.16$, CI [ 0.08 – 0.24], $p < 0.001$) reflect increasing happiness mimicry over time.

*Anger Faces*. The mimicry index for anger was calculated by subtracting the average of standardised activity at the Orbicularis Oculi and Zygomaticus Major from the Corrugator Supercilii, that is: Corrugator Supercilii – (Orbicularis Oculi + Zygomaticus Major)/2. Data were analysed using a linear mixed effects model with fixed factors including clothing

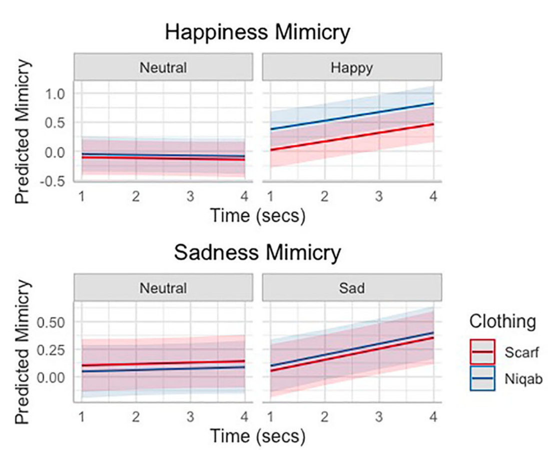


**Figure 8.** Model fits for Happiness Mimicry (top) in Neutral versus Happy Faces and Sadness Mimicry (bottom) in Neutral versus Sad Faces.

style (Western/Mideastern), emotion (Neutral/Anger), and time (4 s) along with a random intercept term for the subject. No mimicry effects were evident.

*Sad faces.* The mimicry index for sadness was calculated by subtracting the average of standardised activity at the Orbicularis Oculi and Zygomaticus Major from the Corrugator Supercilii, that is: Corrugator Supercilii − (Orbicularis Oculi + Zygomaticus Major)/2. Data were analysed using a linear mixed effects model with fixed factors including clothing style (Western/Mideastern), emotion (Neutral/Anger), and time (4 s) along with a random intercept term for the subject. Mimicry effects were evident in the significant interaction between Emotion[Sad] and Time ($\beta = 0.09$, CI [0.02 – 0.16], $p < 0.05$), reflecting increasing sadness mimicry over time.

*Fear faces.* The mimicry index for fear was calculated by subtracting the average of the standardised activity at the Zygomaticus Major from the Frontalis Medialis. Data were analysed using a linear mixed effects model with fixed factors including clothing style (Western/Mideastern), emotion (Neutral/Fear), and time (4 s) along with a random intercept term for the subject. No mimicry effects were evident.

### 3.2.4 Did participants ever mimic what they could not see?

Analyses in the previous section revealed mimicry to covered faces expressing both happiness and sadness. As noted previously, however, the mimicry index is a composite response that reflects activity in all three of the muscles relevant for expressing these emotions. To establish whether participants ever mimic unseen (inferred) information about the actor's emotional state, here we analyse activity in the Zygomaticus Major. Both naturalistic face coverings used here covered the mouth so that activity in the Zygomaticus Major was never visible. Either Zygomaticus Major contraction to happy faces or Zygomaticus Major relaxation to angry or sad faces would support the influence of top-down factors on facial mimicry.

Zygomaticus Major activity elicited by happy faces was analysed via a linear mixed effects regression model with fixed effects for Emotion (Neutral, Happy), Clothing (Winter Wear, Niqab), and Time (4 s), as well as fixed intercept terms for the subjects and the images. Analysis revealed a main effect of Clothing due to greater activation to faces in Niqab ($\beta = 0.09$, CI [0.03 – 0.16], $p < 0.005$), and an interaction between Emotion [Happy] and Time ($\beta = 0.19$, CI [0.04 – 0.15], $p < 0.001$) reflecting an increase in Zygomaticus Major activity over time (see the leftmost panel of Figure 9).

Zygomaticus Major activity to angry faces was analysed via a linear mixed effects regression model with fixed effects for Emotion (Neutral, Angry), Clothing (Winter Wear, Niqab), and Time (4 s), as well as fixed intercept terms for the subjects and the images. Analysis revealed an interaction between Emotion [Angry] and Clothing[Niqab] ($\beta = -0.35$, CI [−0.65 – −0.05 ], $p < 0.05$), reflecting less overall activation to the angry faces in niqab. The rightmost panel of Figure 9 suggests neither the faces clad in winter wear nor those in Niqab elicited the pattern of Zygomaticus Major activity expected for angry faces (viz. a gradual decrease across the trial) as there was a non-significant trend for a three-way interaction between Emotion[Angry], Cover[Niqab], and Time ($\beta = 0.09$, CI [−0.01 - 0.20], $p = 0.088$).

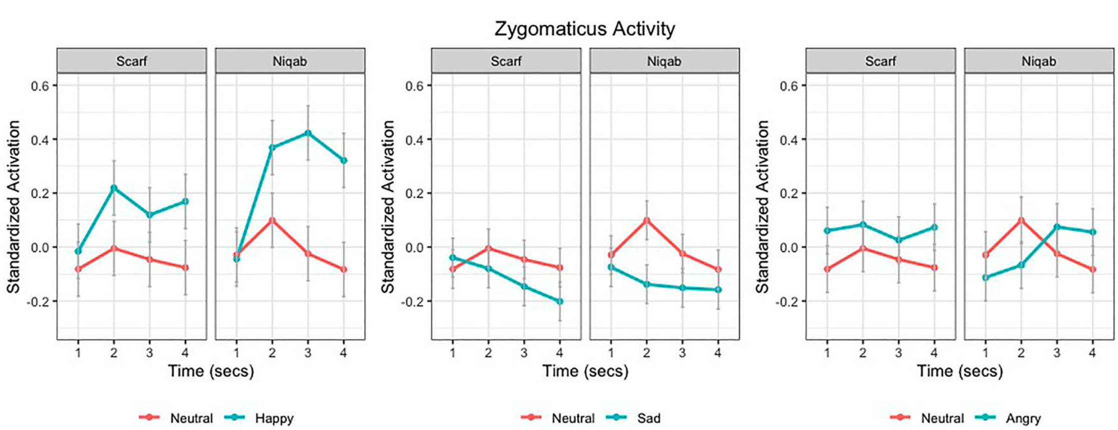


**Figure 9.** Zygomaticus major Activity to Covered Faces in Experiment 2.

As for the other two emotions, Zygomaticus major activity to sad faces was analysed via a linear mixed effects regression model with fixed effects for Emotion (Neutral, Sad), Clothing (Winter Wear, Niqab), and Time (4 s), as well as fixed intercept terms for the subjects and the images. Analysis revealed only main effects of Emotion[Sad] ($\beta = -0.10$, CI [−0.15 – −0.04], $p < 0.001$) due to relaxation of the Zygomaticus major and Time ($\beta = -0.03$, CI [−0.05 – −0.01], $p < 0.05$), suggesting a gradual reduction in activity across the course of the trial (see the middle panel of Figure 9).

### 3.3 Discussion

Experiment 2 employed pictures of emotional faces in which information from the face was occluded by the actor's clothing, either by winter wear (e.g. hats and scarves) commonly worn in the participants' community (an urban and diverse German university) or by a niqab more commonly worn by members of the immigrant community. Although it was hypothesised that this manipulation of clothing might affect participants' propensity to identify with the actor – and thus impact mimicry – we found no differences in participants' explicit attitudes toward faces clothed in Western versus Middle Eastern garb. Moreover, implicit attitudes toward both groups were positive, with slightly more positive implicit attitudes toward the group wearing niqab.

Positive attitudes observed towards faces in niqab may be a function of the demographic characteristics of our sample – predominantly female students at a German university in the multicultural city of Berlin. Recent research suggests anti-Muslim feelings are less common among women than men, are less likely as the level of education increases, and less likely among those who espouse multi-cultural values (Yendell & Pickel, 2020). As our participants apparently identified with faces wearing both sorts of face coverings, we believe the inclusion of the clothing served primarily to increase the ecological validity and social nature of the stimuli.

As in Experiment 1, our research questions concerned first whether participants could adequately recognise emotion in these occluded faces, whether these occluded faces would elicit a holistic mimicry response, and whether a mimicry response would ever be present at the Zygomaticus major muscle that was occluded by the clothing. We consider each of these questions in our discussion below, followed by a brief account of the impact of the clothing manipulation on emotion recognition and mimicry.

#### 3.3.1 Recognition of emotion in occluded faces

Happiness and anger were recognised well, and even though the recognition of sadness was somewhat lower (72% correct), participants readily perceived sadness in the sad faces. Participants' performance on faces expressing happiness, anger, and sadness is thus consistent with reports in the literature that these emotions are recognised fairly well from information conveyed exclusively by the area around the eyes (Calder et al., 2000). Relative to happy and angry faces, the lower accuracy rates for sad faces may be attributable to the absence of visual information from the mouth. Sadness has been shown to be correctly recognised 28% more frequently in images of uncovered faces versus the same actor wearing a surgical mask (Grahlow et al., 2022).

The detrimental impact of facial occlusion was most evident for the expression of fear. Fear was barely recognised at all by our participants and was confused with surprise. This is not entirely unexpected as even under normal viewing conditions, fear is miscategorised more often than other expressions (Biehl et al., 1997; Calvo & Lundqvist, 2008; Jack et al., 2012; Matsumoto & Hwang, 2011; Tracy & Robins, 2008; Wingenbach et al., 2016), and is frequently confused with surprise (Gagnon et al., 2014; Gosselin & Larocque, 2000; Jack et al., 2012; Matsumoto & Hwang, 2011; Roy-Charland et al., 2014). Both fear and surprise involve wide open eyes and the action units on the upper half of the face have considerable overlap (Gagnon et al., 2014). Confusion between the two emotions likely occurred in the present study because of their visual similarity, especially because critical information from the bottom half of the face was not visible to participants.

Future work on occluded faces would likely benefit from the replacement of fear faces with those expressing surprise. Surprise is readily recognised from the top half of the face (Calder et al., 2000), and tends to elicit robust patterns of facial mimicry (Wingenbach et al., 2020).

#### 3.3.2 Mimicry of occluded faces

Holistic estimates of mimicry in Experiment 2 indicate that participants mimicked occluded faces that were happy and sad, but not angry ones or fear faces. We return to these findings in the next section where we suggest they are consistent with social regulation models of mimicry. Further, Experiment 2 supports the claim that participants do sometimes mimic unseen facial activity. Although the Zygomaticus Major muscle was not visible in any of the faces presented in this study, participants' muscle activity was appropriate for both happy (Zygomaticus Major activation) and sad faces (Zygomaticus major relaxation). Data are also consistent with Zygomaticus major relaxation to angry faces clad in Niqab, though here the results are more equivocal.

### 3.3.3 Did the clothing manipulation impact emotion recognition or mimicry?

The effect of the clothing manipulation on emotion recognition was quite subtle. Happy faces in niqab were rated as slightly happier than those same faces in winter wear; likewise, sad faces in niqab were rated as slightly sadder than those in winter wear. Fear faces in winter wear were rated as expressing more fear than those in niqab, and clothing had no impact on participants' ratings of anger. We suggest that these minor differences may stem from the slight differences in the positive implicit attitudes toward the groups.

As for emotion recognition, there was a small but significant impact of clothing on mimicry. Prior research suggests that increasing the implicit attitude towards faces via conditioning results in more mimicry of happy expressions (Sims et al., 2012). Similarly, we observed greater mimicry for happy faces in niqab, which may be a product of the slightly more positive implicit attitudes toward the niqab group. Overall, the impact of clothing on emotion recognition and mimicry was relatively small.

## 4. General discussion

We investigated the mechanisms of mimicry by testing whether partial emotional faces elicit a spontaneous mimicry response, and whether that response includes an emotion-appropriate response in facial muscles that are not visible to observers. Bottom-up accounts of mimicry suggest observers automatically mirror the facial expressions of others, and thus predict facial mimicry only in muscle sites that can be seen. Top-down accounts of mimicry suggest that facial mimicry is subject to influence by conceptual and other social contextual factors. Facial mimicry on these accounts is more flexible, and thus top-down accounts allow for the possibility of facial mimicry both in muscle sites that are visible to observers as well as muscle sites that are not. That is, whereas bottom-up accounts suggest observers will mimic only what they see, top-down accounts suggest observers may mimic what they know about the actor's emotional state. Results of the present study suggest that while much of facial mimicry is driven by what observers see, mimicry responses are more flexible than allowed for by pure motor matching accounts, being more consistent with top-down accounts such as the Social Context Model of Mimicry (Hess, 2021; Hess & Fischer, 2022).

In Experiment 1, we recorded EMG as participants viewed dynamic videos of emotional expressions in order to classify the emotion as either anger, happiness, or sadness. We manipulated which half of the face was visible to participants – either the top or the bottom – to test its impact on the mimicry response in the seen versus the unseen muscle site. In Experiment 2, EMG was recorded as participants viewed images of emotional faces in which the mouth was occluded by socially relevant clothing. Rather than asking participants to classify the emotions, the task in Experiment 2 encouraged more naturalistic social processing strategies by asking participants to rate how intensely each face expressed a range of different emotions. Again, we tested whether an appropriate mimicry response was present in the unseen muscle site.

Consistent with the predictions of top-down models of facial mimicry, both experiments revealed the presence of mimicry at unseen muscle sites. This finding was most robust for mimicry of happy faces as Experiment 1 revealed relaxation of the Corrugator Supercilii when participants saw the bottom half of happy faces and Experiment 2 showed contraction of the Zygomaticus Major when participants viewed the information in the eyes from happy faces whose bottom half was occluded by clothing. Moreover, Experiment 2 also revealed relaxation of the Zygomaticus Major for sad faces in which the mouth region was covered. Although participants' mimicry response was sometimes present only in the muscles that were visible in the images – for example, in Experiment 1 the Corrugator Supercilii was activated when that muscle was visible in the top half of angry faces but not for the bottom half of those faces – mimicry of the unseen muscle sites in happiness and sadness argues against an exclusively bottom-up account of facial mimicry.

### 4.1 Emotion recognition

Overall, our data are consistent with prior claims in the literature that emotion recognition is often possible from partial information from the face. Note, however, that Experiment 1 was not designed to test the impact of occlusion on emotion recognition, per se, as stimuli were chosen in such a way as to promote good task performance. However, Experiment 1 does afford comparison of participants' performance based on which portion of the face they viewed – the top or the bottom. Here our findings were in line with those in the literature, happiness is more readily perceived from the bottom portion of the face, sadness from the top (Bassili, 1979; Calder et al., 2000), and performance was similar for both the bottom and the top half of angry faces.

As predicted, the impact of facial occlusion on emotion recognition differed as a function of expression. Happiness was recognised quite well in both experiments. Although anger was not recognised as well as happiness, it was nonetheless also recognised well in both experiments. Sadness was readily perceived when participants viewed the top portion of the face (Experiment 1 and Experiment 2), but performance dropped when they viewed only the bottom half (Experiment 1). Fear was the emotion that elicited the lowest levels of recognition as Experiment 2 showed that occluding the lower half of the face made it nearly impossible for our participants to recognise fear.

### 4.2 Holistic estimates of facial mimicry

Results of the present study suggest emotion recognition is necessary for the elicitation of mimicry but not sufficient. In Experiment 1, mimicry was present in the conditions that elicited better performance on the classification task. That is, mimicry was present for happiness when participants viewed the bottom of the face, and absent when they viewed the top. Similarly, mimicry was present when participants viewed the more informative top half of sad faces, and absent when they viewed the bottom. Only for anger did mimicry patterns diverge from accuracy on the emotion classification task. Again, mimicry was present when participants viewed the more informative top half of the face, but absent when they viewed the bottom. Thus, the relatively high accuracy rate on the bottom portion of angry faces was not associated with anger mimicry. In Experiment 2, mimicry was present for expressions that were well recognised by participants (happiness and sadness) but was entirely absent for fear – the expression that was almost never recognised.

The mimicry in context model suggests that observers do not mimic what they do not explicitly recognise and thus participants in the present study did not mimic fear. Moreover, prior research on mimicry of occluded faces suggests mimicry is mediated by the perceived intensity of the emotion (Kastendieck et al., 2021). We suggest that the differences in participants' mimicry for the top and the bottom half of emotional faces in Experiment 1 may reflect a similar phenomenon. That is, the perceived intensity of happiness may have been greater when participants saw the bottom portion of the face, whereas the perceived intensity of sadness and anger may have been greater when participants saw the top. Accuracy on the forced choice categorisation task is only a rough proxy for perceived intensity, and thus is only weakly associated with the presence or absence of mimicry. Indeed, when observers perceive anger in their target, the mimicry response may be attenuated.

As in Experiment 1, mimicry in Experiment 2 diverged from emotion recognition in the case of anger. Despite their excellent performance recognising anger, participants in Experiment 2 did not mimic angry expressions. We suggest that participants' relative propensity to mimic happiness and sadness over anger fits with a key tenet of the Social Context Model of Mimicry, viz., that mimicry is a social signal rather than a reflexive response to visual stimuli (Hess, 2021). Mimicry of happiness signals affiliation (Hess & Bourgeois, 2010); mimicry of sadness suggests the observer has adopted the actor's perspective and is empathising with them (Seibt et al., 2015). By contrast, the expression of anger is a warning signal rather than an affiliative one (Hess, Blairy, & Kleck, 2000; Knutson, 1996).

Because the mimicry of anger can amplify conflict, observers may not mimic anger when it is inappropriate for the social situation (Seibt et al., 2015). Some evidence even suggests that mimicry of anger results in the reduction of anger quality (Mauersberger & Hess, 2019). In a similar vein, anger mimicry is less likely when the sender is a romantic partner than it is when the sender is a stranger (Häfner & Ijzerman, 2011). Moreover, an angry expression is less likely to be mimicked when the target's gaze is directed toward the observer than away from them

(Bourgeois & Hess, 2008). In fact, the discrepancy between the mimicry of anger in the two experiments in the present study is in line with the finding that the more social the situation, the less likely observers are to mimic anger (Seibt et al., 2015). Thus, the social processing encouraged by the paradigm in Experiment 2 led participants to a suppression of anger mimicry.

Although multiple studies have investigated the recognition of emotional expressions in which the upper- (or lower-) half is partially occluded (Bassili, 1979; Carbon, 2020; Grundmann et al., 2021; Kastendieck et al., 2021) or a composite of neutral-expressive halves (Calder et al., 2000; Ponari et al., 2012), relatively little research has addressed how this manipulation influences mimicry. Consistent with the one prior study of how limiting information from the face influences mimicry, we also find that observers mimic happy and sad faces despite occlusion (Kastendieck et al., 2021). However, prior work by Kastendiek and colleagues utilised a holistic measure of mimicry that – by design – does not discriminate between the individual muscles in the mimicry response. The present study is thus the first to show that the observer's mimicry response goes beyond the visual input and extends to the unseen, inferred portion of the sender's emotional response. These data argue against a purely bottom-up account of facial mimicry and support a role for contextual factors in mimicry.

### 4.3 Implications

The current research found support for both bottom-up and top-down models of mimicry. In Experiment 1, mimicry often assumed a bottom-up character. Sadness and anger mimicry were both confined to the Corrugator Supercilii muscle site which was visible to participants. However, when happiness was clearly expressed, mimicry was observed at both the seen and the unseen muscle sites. Further, Experiment 2, the more socially valid experiment, found even more support for top-down accounts of mimicry. For example, there was mimicry of happiness and sadness, but not anger, as predicted by social regulation models (Hess & Fischer, 2013). Additionally, the mimicry occurred both at muscle sites that were observed, and at the Zygomaticus Major site that was obscured by clothing. This pattern is in line with an account of facial mimicry as a social signal rather than a reflexive response to visual input. That is, just because the sender's expression is partially concealed, there is no reason that the receiver's expression should be partial as well.

This suggests that mimicry involves a combination of a relatively automatic motor-matching mechanism that promotes synchrony, affiliation, and emotional contagion (Chartrand & Bargh, 1999; Dimberg & Thunberg, 1998; Dimberg et al., 2000, 2002; Hatfield et al., 1993, 2014; Lakin et al., 2003), and a social regulation mechanism that can flexibly modulate the motor response in a situationally appropriate manner (Hess, 2021; Hess et al., 1999; Hess & Fischer, 2013, 2017; Hess & Fischer, 2013; Kastendieck et al., 2022; Likowski et al., 2008, 2011; Seibt et al., 2013, 2015; Sims et al., 2012; Van der Schalk et al., 2011; Yabar & Hess, 2007). If we assume that mimicry is a dynamic process that unfolds over time with both bottom-up motor-matching and top-down social regulation mechanisms, the bottom-up signal may play a functional role in emotion recognition. Reflexive motor matching might serve as memory cues that supplement visual information from the face and thus facilitate cognitive aspects of emotion recognition via a dynamic process of multimodal pattern completion. Indeed, there is growing support that sensorimotor neural activity involved in mimicry, and perhaps even mimicry itself, can influence conceptual processing and emotion recognition in some contexts (Davis et al., 2017, 2021; Niedenthal, 2007; Niedenthal et al., 2001, 2005, p. 2010; Oberman et al., 2007; Ponari et al., 2012; Winkielman et al., 2018; Wood, Rychlowska, Korb, & Niedenthal, 2016).

The top-down portion of facial mimicry is aimed at social regulation. It serves to enhance the mimicry response for affiliative emotions such as happiness and sadness, and to inhibit it for anger. Note that the relative impact of bottom-up visual cues to emotion is expected to be most evident when contextual information provides no other cues. Perhaps this is why we observed more reflexive mimicry responses in Experiment 1 – utilising as it did a decontextualised and socially impoverished stimulus and the explicit demand to categorise the emotion expressed. In more naturalistic paradigms that encourage social processing, participants are less likely to utilise automatic mimicry. Thus, in Experiment 2 of the present study we saw mimicry of happiness and sadness that involved the recruitment of the unseen muscle site, and the apparent suppression of mimicry for anger. Moreover, when the situational context provides normative cues regarding the appropriate expression of emotion, mimicry functions more strategically, being absent when the actor's expression is contextually inappropriate (e.g. smiling at a funeral), and present when it is appropriate, as if to support the situationally appropriate expression of emotion (Kastendieck et al., 2021). In showing the importance of top-down factors in the elicitation of facial mimicry in general (and for occluded faces in particular), our data suggest that the detrimental effects of occlusion on social interaction might be either mitigated or accentuated by a variety of contextual factors.

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