Supplementary Materials of "The impact of face masks used for COVID-19 prevention on emotion recognition in facial expressions: an experimental study" by Rizzato et al. (2022)

Section A. Study protocol additional details

A.1 The online database platform

A dedicated online database platform (called "Progetto Udine Parma") was used for this research project. Eligible subjects received an invitation email, and a link to the platform was sent to those who agreed to take part in the study. Participants could remotely access the platform through their smartphones, tablets, or personal computers (this method was adopted because lockdown restrictions in April 2020 did not allow live experimental sessions). Once the homepage was opened, an informed consent and a privacy policy disclaimer had to be read and accepted before registration. The participants' registration was fully anonymous, and only the first letters of names and surnames, as well as age and gender data (Male/Female/Other) were collected. A CAPTCHA test was also administered to ensure that respondents were real humans. Once registered, participants were recommended to find a quiet place without surrounding distractions for completing the test.

A.2 Actors' training

The actors were trained to simulate several emotions through different facial expressions. A protocol with a set of evocative sentences was created to improve the accuracy and verisimilitude of acted emotions. In total, 52 face pictures were selected among the most expressive ones (male and female gender, with and without a face mask on, including six basic emotions, characterized by two intensity levels of expression, plus a neutral expression).

A.3 Preliminary analysis

Table A. Percent rates (%) of correct emotion identification at baseline, with the actors' face uncovered.

Emotion	Actress	Actor
Disgust	86.1 (L)	100 (H)
Happiness	97.2 (L)	98.8 (H)
Anger	88.9 (H)	98.6 (H)
Surprise	97.2 (L)	100 (H)
Sadness	93.1 (L)	83.3 (H)
Neutral expression	90.3	

Legends: L=low emotion intensity; H=high emotion intensity.

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Section B. Study results: secondary outcomes

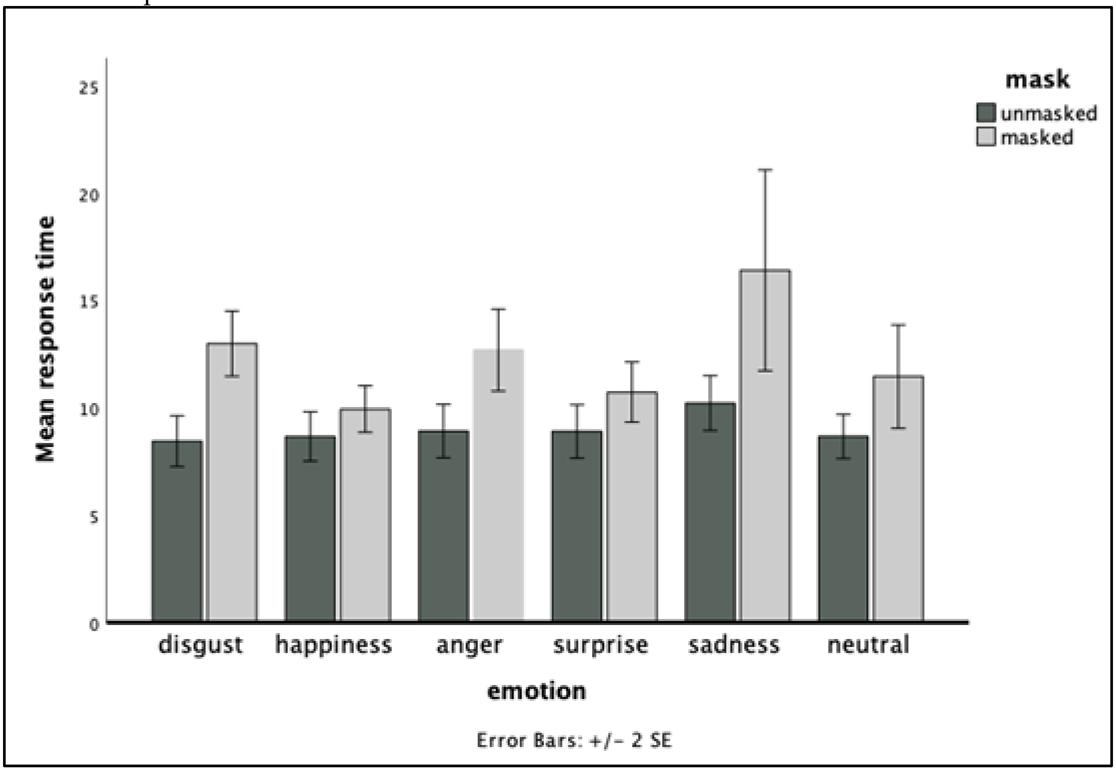
B.1 Accuracy rates of emotion recognition (GLM analysis)

The three-way interaction between emotions, masks and actors indicated that differences in emotion recognition between the with-mask and no-mask conditions were similar between the two actors for disgust, surprise, sadness, and neutrality (P>.05). Happiness recognition was associated with a "ceiling effect" (high accuracy rates), and no significant difference between the two conditions of interest (with and without a face mask) were reported when this emotion was expressed by the male actor, Mdiff=0; SE, 0; P>.05. Likewise, no significant difference between the two study conditions was detected when participants had to recognize the actress' anger, Mdiff=.01; SE, .02; P>.05. This result was reflected by better recognition of happiness when, in the no-mask condition, this emotion was expressed by the actor if compared with the actress, Mdiff=.29; SE, .06; P<.05, and the opposite was observed with regard to anger when displayed by the actress, Mdiff=.31; SE, .06; P<.05. A further difference between actors was found for disgust again in the no-mask condition, for which the actress outscored the actor, Mdiff=.18; SE, .07; P<.05.

B.2 Response time (GLM analysis)

As indicated by the main effect of actors, participants took slightly longer to identify the actress' emotions, Mdiff=1.14; SE, .45, P<.05. This effect was dragged by male participants, who were generally faster in recognizing the actor's emotions compared to the actress's, Mdiff =2.12; SE, .73, P<.01, as highlighted by the interaction between gender and actor. Additionally, the interaction between emotions and actors showed that, in line with with data about accuracy rates reported above, participants struggled more to recognize the actor's anger with respect to happiness, Mdiff=4.21; SE, .92; P<.001, and surprise, Mdiff=4.25; SE, .89; P<.05. Moreover, it took longer for participants to recognize the actress' happiness and surprise, Mdiff happiness=2.28; SE, .71, P<.01, Mdiff surprise=3.36; SE, .93, P<.01. On the contrary, the actress' anger took less time to be recognized if compared with the same emotion expressed by the actor, Mdiff =3.15; SE, .20, P<.01. Mean response times to each emotion are plotted in Figure S1.

Figure S1. Mean response times to each emotion in the two main conditions of interest.



B.3 Response frequency distribution and error analysis

Figure S2 shows the frequency distribution of the participants' responses. For this analysis, fear, which was excluded from the abovementioned GLM analysis, was reintegrated to provide a full picture of the participants' error types. Chi-square tests were significant in all instances ($P<.001$), thus indicating a prevalence of specific responses to each emotion.

Table B, an expanded version of Table 2, reports the main distribution of emotion attribution errors. Most emotions were recognized quite accurately even when the two actors wore a mask. For both actors, the most misinterpreted emotion was disgust, followed by sadness. For disgust, ambivalence tended to fall on happiness, sadness, and fear, whereas for sadness, it mostly fell on disgust and fear.

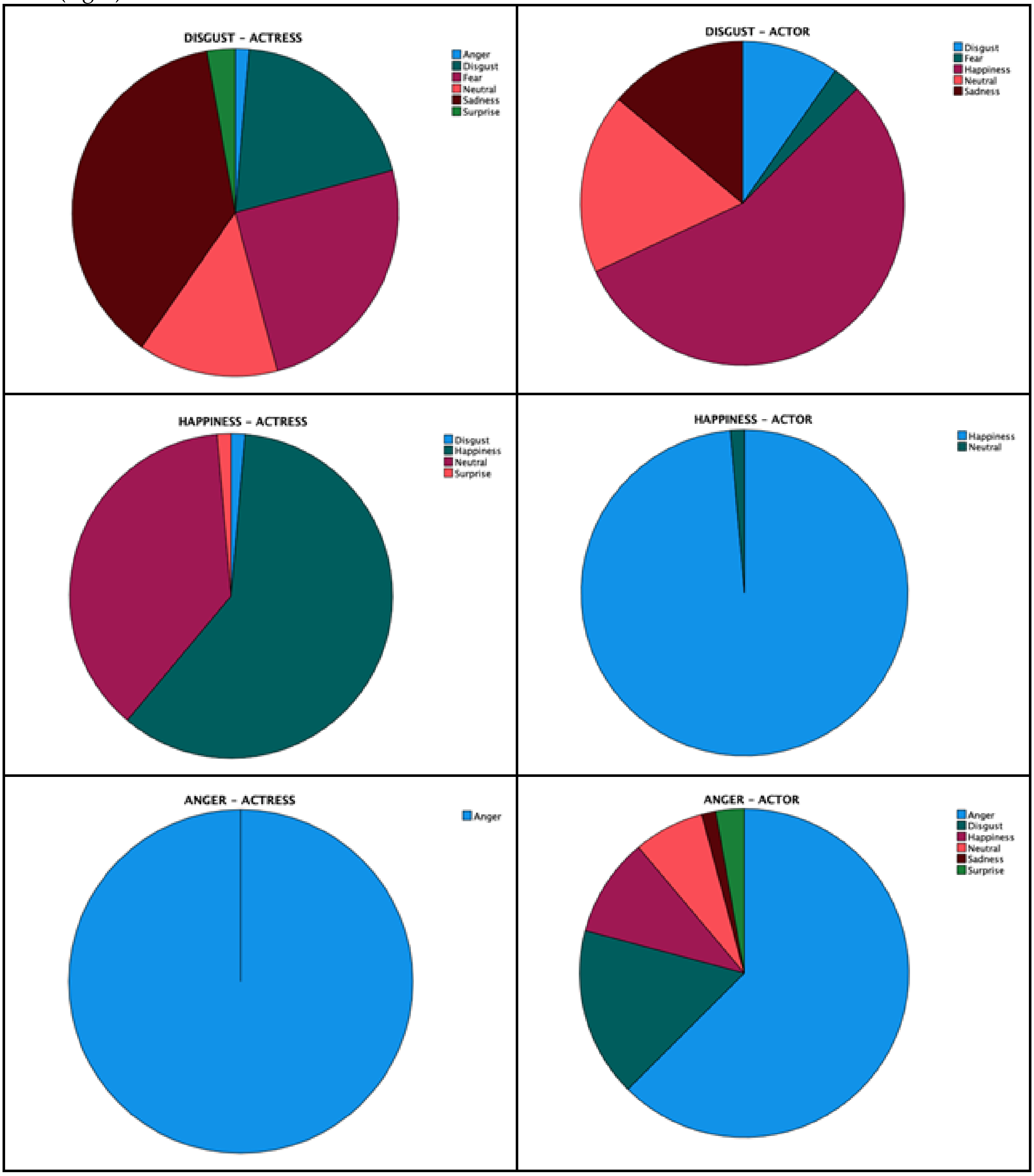
Table B. Distribution of correct hits and main wrong attributions in emotion recognition when the actors had their face mask on.

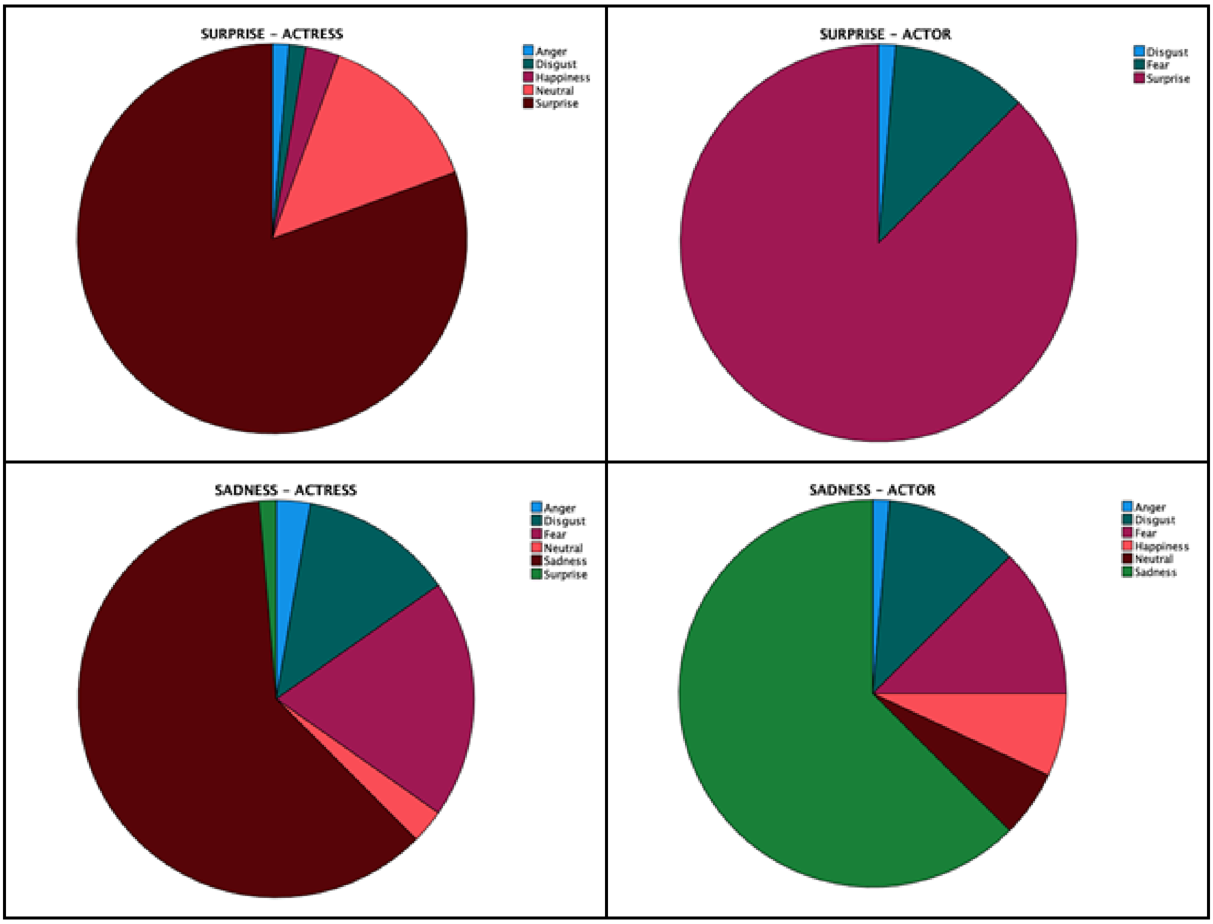
Emotion	Actor's gender	Number of other emotions*	Main wrong attributions (%)	Correct hits (%)
Disgust	F	5	Sadness (38%)	19%
			Fear (25%)	
	M	4	Happiness (56%)	10%
			Neutral (20%)	
Happiness	F	3	Neutral (38%)	60%
	M	1	Neutral (1%)	99%
Anger	F	0	-	100%
	M	5	Disgust (17%)	62%
			Happiness (10%)	
Surprise	F	4	Neutral (14%)	81%
	M	2	Fear (11%)	88%
Sadness	F	5	Disgust (13%)	61%
			Fear (19%)	
	M	5	Disgust (11%)	63%
			Fear (13%)	
Neutral	F	3	-	89%

expression	M	2	-	93%

Legends: F=female; M=male.
*This is the number of emotions other than the correct one provided by study participants when they failed to identify the right emotion in the actors' facial expression.

Figure S2. Distribution (%) of emotion attribution to each facial expression for the actress (left) and the actor (right) with their mask on.





Section C. In-depth analysis and further discussion of our study findings

C.1 Gender Differences

In the scientific literature, it is reported that, compared to men, women are more skilled at reading emotions from faces [1–3]. The reason probably lies in the evolutionary role of females, often involved in caring for offspring and more motivated in building a secure attachment bond with their babies [2,4]. Nevertheless, our data show that men can be almost as fast as women at detecting emotions (or even faster when emotions are expressed by another man): therefore, the size effect of gender differences may be quite small. Even if autonomic emotional experiences seem to be the same regardless of gender [5], several studies have already demonstrated that, when displaying emotions, women tend to be more expressive than men, and their facial expressions are more accurately recognized [2,4]. Specific causes of this difference can be hard to explain, but bio-psychological models of gender differences in emotion expression indicate that developmental and social factors can play an important role, as they can influence biological tendencies in different ways to make individual behaviors more adherent to commonly accepted social customs [4,6].

In general, women learn to display stronger facially-expressed emotions when they show fear, surprise, and happiness, and these emotions are more easily recognizable in women even because of cultural expectations; instead, men tend to express anger more intensively, and they are more likely to be perceived as angry [2,6]. Regarding gender differences in showing disgust and sadness, results of available studies appear to be insufficiently consistent to draw firm conclusions yet [2,6]. However, our study indicates that, with a surgical mask on, a man’s facial expression is harder to read when displaying disgust, sadness, or anger, whereas a woman’s facial expression can be more easily misinterpreted when showing disgust, sadness, or happiness. Further research is advised to clarify these experimental results. In this regard, the actors' performance skills might have been potential sources of bias.

C.2 Intensity levels of emotions

Stronger emotion-related facial expressions, either fully uncovered or partially concealed by face masks, can be recognized in a smaller amount of time if compared with milder emotions. In other words, as empirically expected, the more intense the emotion, the easier and quicker the recognition process can be [2,7], with more limited interference of face masks. However, the majority of human interactions are characterized by a low expressive intensity and, therefore, real-life communication with face masks can be more complicated than in experimental settings. It would be interesting to understand if communication strategies to adapt to this new scenario have already been developed among individuals, for example unintentionally enhancing the intensity of expressed emotions to avoid possible misunderstandings.

C.3 Type of emotions

In our study, when the two actors had a face mask on, some emotions like disgust or sadness were more easily misinterpreted than others. Since different facial muscles are activated for each type of emotion, one can reasonably expect that, for example, the recognition of happiness, mostly conveyed by the mouth, as well as disgust and surprise, expressed to a great degree in the lower part of the face, can be significantly hindered by wearing a surgical mask, as opposed to other basic emotions mainly expressed in the upper part of the face [8,9]. In fact, facial cues have different relevance when attempting to decipher emotions in facial expressions [10,11].

Eye-tracking experiments showed that visual fixation needed to detect ***anger*** is mostly concentrated in the eye region, and looking at the upper part of the face can be sufficient to fully recognize this emotion [10,12,13].

Sadness expression largely depends on the upper part of the face too, and lowering the eyes and eyebrows are characteristic signs of this emotional state, even if the lower part of the face can play a relevant role too [12–14].

Fear is one of the most difficult facial expressions to detect, as its expression involves the entire face, including open eyelids and raised eyebrows, but also a muscle contraction in the nasion area [15,16]. Recognizing fear in facial expressions usually follows specific patterns of visual fixation and, when looking at the upper part of the face, longer fixation duration tends to be reported [17].

Disgust is mostly shown with lowered eyebrows, frowned forehead, and corrugated upper lip, even without exposing teeth [13,14,16]. However, most studies underscore that the lower part of the face can provide more information to quickly recognize disgust if compared with the upper part [10,16,18].

Surprise expression usually involves raised eyebrows, wide open eyes and an empty, open mouth [13,15]. Research has confirmed that being able to watch the mouth plays a key role in surprise recognition [14,18].

Happiness is the only unequivocally positive emotion among basic ones, and this feature is thought to ease its recognition. Even if the eyes can show happiness, the mouth is fundamental in expressing this emotional state: open lips and corners of the mouth pulled up in a vibrant smile with visible teeth are characteristic facial signs of happiness [11,19]. Collecting visual cues from the lower part of the face is considered sufficient – and necessary – to detect this emotion, as demonstrated by some authors [12–15,18].

According to Blais and colleagues, although fear, sadness, and anger are predominantly expressed by the eyes, the mouth is still a major "informative" part of the face irrespective of the emotion type, since it is associated with larger visual signals [20]. In fact, when we look at someone's mouth, only visual information from this part of the face is captured and processed by the brain. Instead, because of a difference in wave frequency, when someone's eyes are observed, visual details from both the eyes and the mouth are analyzed. This occurs because the eyes are smaller than the mouth, and they are associated with higher spatial frequencies, typically processed within the fovea. Instead, the mouth is characterized by lower spatial frequencies, which are processed in the parafoveal area and analyzed even when the gaze is primarily directed towards the upper part of the face. In real life, muscles of the mouth allow for a wide range of movements, resulting in expressions that carry a great amount of information. For being highly informative in emotion deciphering, the mouth and, in general, the lower part of the face seems to play a crucial role even in experimental conditions with static face pictures because, in case of limited information, the study participants' attention tends to focus on the most relevant facial cues [20]. This is probably the reason why our study results show a marked and generalized decline in the accuracy levels of emotional facial expression recognition regardless of the emotion type when the actors had their face masks on. If we only consider face pictures without masks, the lowest scores were recorded when study participants had to recognize fear, and this is in line with available scientific evidence [21–23]. Many environmental explanations can be suggested, including the frequency of different emotions in everyday life – the rarest the emotion, the hardest it is to recognize – and the complexity of facial expressions, each of them characterized by a specific combination of different facial muscle contractions [21].

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