Behind the mask: The impact of face masks and mask mandates on facial emotion recognition

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I. Personal Section

After going to school in face masks during COVID-19, I began to contemplate their impact on human connection and how well people could recognize each other's emotions behind the mask. My curiosity led me to investigate. In an online search, I discovered Dr. Felicity Bigelow's study on facial emotion recognition in the scientific journal, *Developmental Cognitive Neuroscience*, and I was immediately captivated. Her research aligned perfectly with my own interests, so I decided to reach out to her with my idea for an independent research project. I asked if she'd consider being my mentor, and I was ecstatic when she agreed, despite living across the globe in Australia. For nine months, I'd log onto Zoom at 8:30 PM every Monday in New York, while Dr. Bigelow did the same at 10:30 AM every Tuesday in Melbourne.

Our research aimed to pinpoint how face masks and mask mandates impact facial emotion recognition accuracy. Using data from fifteen previous studies from Asia, Europe, and North America, we discovered that happiness, sadness, and disgust are significantly more difficult to recognize with a face mask. Conversely, we found that face masks have no significant effect on an individual's ability to perceive fear or anger, which we suggest could be tied to evolution, as detecting fear and anger is necessary for survival. Additionally, results revealed that individuals residing in countries with less strict mask mandates had more difficulty accurately identifying emotions in the presence of a face mask, when compared to individuals residing in countries with stricter mask mandates.

To complete this project, I had to learn how to manipulate data from previous studies to create my own database and perform statistical analyses such as t-tests. I initially thought the mathematics of the project would be daunting because I never pictured myself as much of a "math person." However, I was surprised to find how much I enjoyed compiling an extensive spreadsheet of facial emotion recognition accuracies and using creative methods to obtain data such as plot digitizer and a color eyedropper. While conducting this research, math became much more tangible and exciting to me.

My advice for high school students looking to undertake a research project is to not limit yourself and to ask questions. Even though you may not have a lot of research experience, people are extremely willing to help you if you just ask. Before this project, I was someone who was good at giving help, but never great at asking for it. After collaborating with Dr. Bigelow, it became second nature to ask both her and others in the scientific community for support. I hope to keep this spirit of helpfulness and generosity alive by being a "Dr. Bigelow" to another aspiring researcher someday. She has not only inspired me to pursue a career in research, but she has also shown me what meaningful collaboration looks like.

II. Research Section

Abstract

Socio-cognitive abilities, such as the recognition of facial emotions, are essential in the everyday interactions between humans. These skills help people communicate and form relationships with each other. However, the implementation of face masks due to COVID-19 compromised an individual's ability to perceive another's emotions, resulting in problems in understanding, empathy, and communication. While recent studies have begun to analyze the effects of face masks on facial emotion recognition, there remains a gap in the literature when exploring how these effects may differ across countries in light of mask mandates and wider communities. Therefore, this study examined the effects of face masks on facial emotion recognition from a global perspective and explored how different levels in mask mandates may impact the ability to recognize facial emotions. Data from 3,357 adult participants across fifteen studies conducted in Asia, Europe, and North America were used to analyze masked and unmasked emotions of happiness, sadness, disgust, anger, and fear. Additionally, mask mandates in different countries were assigned ratings based on varying levels of mandate stringency. A series of paired sample t-tests and independent samples t-tests were used to analyze data. Across emotions, there was a significant difference in facial emotion recognition accuracy between the masked and unmasked conditions. Specifically, recognition accuracy of happiness, sadness, and disgust was significantly lower for masked faces, when compared to unmasked faces. Conversely, anger and fear were not found to have significant differences in facial emotion recognition accuracy when comparing masked and unmasked emotion recognition. Finally, participants who resided in a region where masks were required in some public spaces had significantly lower accuracy compared to those living in a more stringent mandate region, where masks were required in all public spaces. Broadly, findings suggest that facial emotion recognition has been significantly impacted by the presence of face masks during COVID-19. Utilizing these results, schools and workplaces can have a better understanding of which emotions were most affected by face masks and develop strategies to improve communication skills impacted during the pandemic. Additionally, by highlighting the difference in facial emotion recognition between mask mandates, policymakers can effectively evaluate the long-term implications of public policy. Overall, this study provides insight into the current and potential long-term impacts of face masks and mask mandates on facial emotion recognition accuracy.

Introduction

Social communication leads to mutual understanding and the building of interpersonal relationships, making it vital in the everyday lives of humans. These skills begin to develop during infancy and continue to become more sophisticated with age (Gooden & Kearns, 2013). Together, the continual refining of social communication skills allows for individuals to socially interact with their peers using verbal and non-verbal cues (Luong et al., 2011).

While social communication can be verbal or visual, the majority of communication is non-verbal (Mohammadi, 2020; Pavlova, & Sokolov, 2021). Facial expressions constitute a large part of non-verbal communication by displaying an individual's thoughts and feelings (Smelser, 2001). Therefore, social interactions rely heavily on the ability to read an individual's emotions to understand what they are trying to convey, which is defined as facial emotion recognition (Tian et al., 2011). However, due to the COVID-19 pandemic, face mask mandates have been implemented around the world at different levels of stringency to minimize the transmission of the disease (Centers for Disease Control and Prevention, 2021). With these facial masks, the middle and lower sections of an individual's face are occluded. This heightens the importance of using the section of the face that is visible, namely the upper half of the face, to recognize and interpret emotions. As a result, this study aims to explore the impact of face masks on facial emotion recognition accuracy. This study investigates how facial emotion recognition accuracy differs across emotions and countries with various mask mandates.

Literature Review

Importance of Facial Emotions

Facial emotions provide important information about the feelings, thoughts, and beliefs of others, and therefore, assist in social interaction (Adolphs, 2006; Keltner et al., 2019; Xu et al., 2017). Accurately recognizing and differentiating between facial emotions is a skill that provides insight necessary for survival (Marshall, 2017). For example, the ability to differentiate between a happy face, indicating warmth and safety, and a scared face, indicating an impending threat, can either assure someone in a social situation or can induce apprehension, respectively (Bublatzky et al., 2019; Buckley, 2016). Proficiency in facial emotion recognition skills allow individuals to predict events and situations more accurately and effectively prepare responses accordingly (Isaacowitz et al., 2007).

The ability to accurately identify emotions is socio-cognitively important for building interpersonal relationships and conveying emotions to others (Drigas & Papoutsi, 2018; Lewis et al., 2016). This importance is reflected from a neural perspective, with the development of specific brain regions specializing in recognizing and processing particular emotions. For example, research has shown that the amygdala plays a crucial role in modulating the human fear response (Ressler, 2010). Additionally, previous research (see Blair, 2013; Richard et al., 2022) has identified the amygdala, hypothalamus, and periaqueductal gray as key regions involved in anger responses in humans.

Dangers of Inaccurate Facial Emotion Recognition

The positive impacts of accurately identifying facial emotions are emphasized by the negative impacts of interpreting facial emotions incorrectly. While recognizing emotions correctly allows an individual to empathize and form interpersonal connections, the inability to understand another's emotional state can prevent individuals from forming meaningful social connections, leading to social exclusion (Juckel et al., 2018; Mheidly et al., 2020). Moreover, if an individual fails to recognize threatening emotions that signal danger, such as anger or fear, they have a diminished chance at survival, when compared with individuals who can better predict events (Folz et al., 2022).

Main Indicators of Emotions

Recognizing specific facial emotions draws on several key facial elements or collective movements, as illustrated below in Figure 1. The main indicators of a happy face are the narrowing and wrinkling of eyes, the raising of cheeks, and the raising and drawing back of the lips to expose teeth (Campiche et al., 2020; Wegrzyn et al., 2017). A sad face is typically recognized by the raising of inner eyebrows, downward looking eyes, and downward facing lips (Fox et al., 2000; Semyonov et al., 2021; Tipples et al., 2002). Key factors of a disgusted face include the narrowing of eyes, the wrinkling of the nose, the depressing of lip corners, and a gaped jaw (Osgood-Cornell, 2014; Sato et al., 2019; Rozin et al, 1994). Main indicators of an angry face include the lowering of eyebrows, the narrowing of eyes, and the firm closing of lips (Horstmann et al., 2012; Kohler et al., 2004; Marshall, 2017). Finally, fearful faces can be recognized by the lifting of eyebrows and upper eyelids, the gaping of the jaw, and the drawing back of lips in the horizontal direction (Kohler et al., 2004; Wegrzyn et al., 2017). Overall, these

indicators highlight that subtle differences in the collection of facial movements can convey a wide range of emotional states.

Figure 1
Facial Expressions Demonstrating Main Indicators of Emotion

Source: Ebner et al. (2018)

Previous research has established that face components (such as the upper, middle, and lower sections of a face) aid in interpreting facial emotions (Minaee et al., 2021; Wegrzyn et al., 2017). A study by Baron-Cohen et al. (2001) found that individuals are capable of discerning emotion using only the upper section of a face (such as the eyes). However, it is important to acknowledge the role of the middle and lower sections in emotion recognition. For example, the middle face is responsible for scrunching the nose, creating wrinkles in the nose that often expresses disgust (Ekman et al., 2002). Additionally, the lower face is responsible for stretching and separating lips which expresses fear, tightening lips and raising the chin which express anger, and the dropping the jaw which expresses surprise (Gagnon et al., 2014). Collectively, these main indicators of emotion highlight that different facial emotions utilize various combinations of facial components across face sections.

Facial Emotions & COVID-19

The COVID-19 pandemic has led to new safety measures being implemented around the world to mitigate the spread of this infectious disease (Martinelli et al., 2021). One of the most notable measures has been the introduction of face masks, designed to cover the mouth and nose

(Liao et al., 2021). While necessary in preventing contamination, face masks have impacted how one recognizes facial emotions, thus affecting social communication (Carragher & Hancock, 2020).

Given that the middle and lower sections of faces are occluded due to masks, people may miss vital emotional cues necessary for communication. This suggests that facial expressions with greater emphasis on middle and lower sections (as opposed to upper sections) may be more susceptible to emotion recognition errors following the implementation of mask mandates (Magherini et al., 2022). Additionally, due to the limited available emotional cues gained from the middle and lower face, people must rely more heavily on the upper portion of the face and adapt their emotional face processing (Barrick et al., 2021). While there is no general consensus as to what features encompass the middle face, for the purposes of this study, the middle face will collectively be grouped with the lower face, as both sections are occluded by a face mask.

Lower Face Dependent Emotions & COVID-19

Based on the components of each facial expression, the following facial emotions are suggested to be mainly dependent on the lower portion of the face: happiness, sadness, and disgust. As these emotions primarily rely on face components that are occluded by a face mask, it is possible that an individual will have more difficulty in accurately recognizing these three emotions in the presence of a mask versus in the absence of a face mask.

Upper Face Dependent Emotions & COVID-19

Based on the components of each facial expression, the following facial emotions are suggested to be mainly dependent on the upper portion of the face: anger and fear. As these emotions primarily rely on the upper portion of the face, it is possible that an individual's ability to accurately recognize these two emotions will not significantly differ in the presence of a face mask.

Facial Emotion Recognition & Mask Mandates

Despite the universality of COVID-19, the stringency of masks mandates was dependent on each nation or region's respective government officials. Therefore, nations had different experiences during COVID-19 and had various mask mandate terms. Additionally, past exposure to facial masks and previous epidemics has differed across countries. For example, the 2002 SARS outbreak largely affected East Asian countries, and thus resulted in heightened recommendation for face masks (Lau et al., 2004). Conversely, certain regions within Europe

and North America were less affected by the epidemic, and as a result had more lenient mask recommendations.

Although there is a lack of previous literature on the effects of mask mandates on facial emotion recognition, it is possible that individuals who are more acclimated to viewing masked faces are more likely to accurately identify facial emotions.

Research Purpose

With masked faces, some emotions may be harder to recognize, and therefore, it may be more difficult to respond within a social situation. In light of the pandemic, it is important to understand how face masks affect facial emotion recognition accuracy, from both local and global perspectives. Moreover, it is crucial to understand how the exposure to face masks, as illustrated through mask mandates and prior experience, may influence emotion recognition. Together, this research will assist in understanding how face masks and mask mandates currently impact facial emotion recognition for happiness, sadness, disgust, anger, and fear.

Hypotheses

For the purposes of this study, facial emotions of happy, sad, disgusted, angry, and fearful were explored. In line with previous research, the following hypotheses were established.

1. The presence of a face mask will decrease the ability to accurately recognize facial expressions.
2. The ability to accurately recognize happy facial expressions will be significantly weaker for faces presented wearing a mask, when compared to no mask.
3. The ability to accurately recognize sad facial expressions will be significantly weaker for faces presented wearing a mask, when compared to no mask.
4. The ability to accurately recognize disgusted facial expressions will be significantly weaker for faces presented wearing a mask, when compared to no mask.
5. The ability to accurately recognize angry facial expressions will not significantly differ for faces presented wearing a mask, when compared to no mask.
6. The ability to accurately recognize fearful facial expressions will not significantly differ for faces presented wearing a mask, when compared to no mask.
7. Countries with stricter mask mandates will have higher facial emotion recognition accuracies than countries with more lenient mandates.

Methodology

Participants

This research was conducted using data from participants of recent studies across Asia (Israel, South Korea), Europe (Germany, Italy, the Netherlands, and the United Kingdom,), and North America (Canada and the United States). Participants ranged in age from 18 to 89 years and were from neuro-typical populations. See Table 1 for further demographic information.

Table 1

Participant Demographic Information by Study

Study	Country	Age Range (years)	N	Gender (F/M)
Carbon, 2020	Germany	18-87	41	30/11
Fitousi et al., 2021	Israel	N.R.	30	25/5
Grahlow et al., 2022	Germany	18-89	790	636/154
Grenville & Dwyer, 2022	United Kingdom	18-38	100	91/9
Grundmann et al., 2021	Netherlands	19-80	191	101/90
Gori et al., 2021	Italy	18-30	39	N.R.
Kang et al., 2021*	South Korea	N.R.	240	120/120
	United States	N.R.	273	129/144
Kim et al., 2022	South Korea	N.R.	39	20/19
Maiorana et al., 2022	Italy	21-58	31	15/16
Marini et al., 2021	Italy	N.R.	122	47/75
McCrackin et al., 2022	Canada	N.R.	120	103/17
Pazhoohi et al., 2021*	Canada	18-36	420	287/133
	United States	18-73	199	69/130
Ramachandra & Longacre, 2021	United States	18-40	403	185/218
Shepherd & Rippon, 2022	United Kingdom	18-73	199	121/78
Tsantani et al., 2022	United Kingdom	18-60	120	82/38

Note: N.R. = Not Reported.

** = study consisted of two distinct sample groups from different countries.*

Data Collection

Emotion recognition accuracy data was collected for stimuli with a face mask and without a face mask. Data was collected from a total of fifteen studies. Due to the variations in data availability for each study, data was collected using one of three techniques. The first method of data collection was to utilize recorded data, which was done for six studies (Fitousi et al., 2021; Grundmann et al., 2021; Kang et al., 2021; McCrackin et al., 2022; Ramachandra & Longacre, 2022; Shepherd & Rippon, 2022). Data for two studies (Pazhoohi et al., 2021; Tsantani et al., 2022) was provided by authors upon request. Lastly, when necessary, values were estimated using the plot digitizer program, WebPlotDigitizer, for six studies (Carbon, 2020; Grahlow et al., 2022; Grenville, & Dwyer, 2022; Kim et al., 2022; Maiorana et al., 2022; Marini et al., 2021) or a color eyedropper for one study (Gori et al., 2021).

The second phase of data collection was to determine the degrees of mask mandates within each country. To accomplish this, an online database used to track worldwide mask mandates was utilized (see Hale et al., 2021). This database used ratings that, for the purposes of this study, were numbered one to five, with higher ratings reflecting more stringent mandates. See Table 2 for additional information.

Table 2

Mask Mandate Rating Categorization

Rating	Mask Mandate
1	No mask policy
2	Masks recommended
3	Masks required in some spaces
4	Masks required in all public spaces
5	Masks required outside the home at all times

Source: Hale et al. (2021)

Given the lack of available data, limited variation of mask mandates within the sample size, and the fact that not all studies looked at the same emotions, the average for all emotions in each mandate rating group was analyzed rather than each individual emotion.

Data Analysis

To determine the relationship between facial emotion recognition accuracy and face masks as well as facial emotion recognition accuracy and face mask mandates in each country, data was analyzed using IBM SPSS Statistics for Windows, Version 26.0. Data was screened for any assumption violations (outliers did not exceed the critical value of +/- 3.29 standard

deviations and the distribution was normal), with results suggesting that assumptions were met. Therefore, where necessary, cases were excluded on a pair-wise basis for analyses.

This study utilized paired sample t-tests to compare the masked condition with the unmasked condition in terms of accurately recognizing each emotion (happiness, sadness, disgust, anger, and fear). Additionally, to compare the masked condition with the unmasked condition for each facial emotion separated by mask mandate rating, paired sample t-tests were utilized.

Finally, an independent samples t-test was used to compare the average accuracy across each facial emotion in countries with face mask mandates rated three (masks required in some public spaces) with mandates rated four (masks required in all public spaces). To be statistically significant, the p-values had to be less than .05.

Results

H1: Data analysis supported the hypothesis that the ability to recognize facial expressions would significantly differ for faces presented wearing a mask, when compared to no mask ($t(16) = 8.53$, $p < .001$). Findings demonstrated that face masks reduced the ability to accurately recognize another's facial expressions, as masked faces ($M = 0.67$, $SD = 0.13$) were, on average, significantly more difficult to recognize than unmasked faces ($M = 0.80$, $SD = 0.11$).

For Hypotheses 2-6, see Figure 2.

H2: Results supported the hypothesis that the ability to accurately recognize happy facial expressions would significantly differ for faces presented wearing a mask, when compared to no mask ($t(15) = 5.83$, $p < .001$). Specifically, results demonstrated that the ability to recognize happy faces was significantly lower for happy faces with a mask ($M = 0.80$, $SD = 0.14$) when compared to happy faces with no mask ($M = 0.93$, $SD = 0.10$).

H3: Findings supported the hypothesis that the ability to accurately recognize sad facial expressions would significantly differ for faces presented wearing a mask, when compared to no mask ($t(15) = 2.71$, $p < .001$). These results revealed that the ability to recognize sad faces was significantly lower for sad faces with a mask ($M = 0.57$, $SD = 0.15$) when compared to sad faces with no mask ($M = 0.78$, $SD = 0.12$).

H4: Analysis of data supported the hypothesis that the ability to accurately recognize disgusted facial expressions would significantly differ for faces presented wearing a mask, when

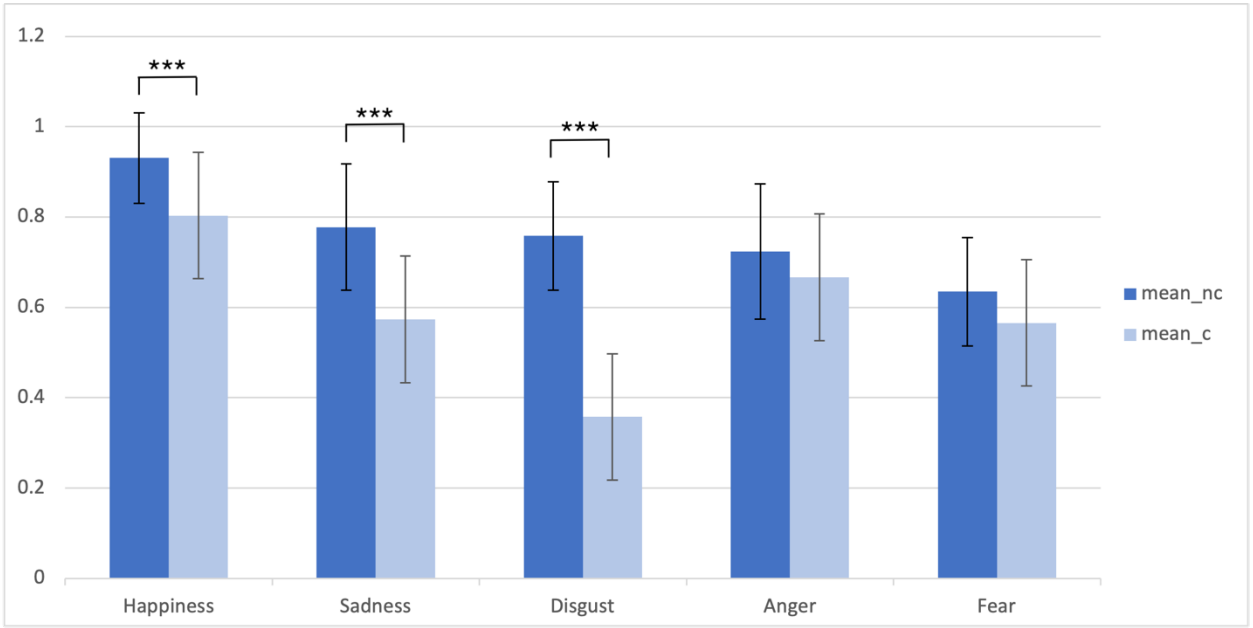
compared to no mask ($t(12) = 10.43$, $p < .001$). Results indicated that, on average, the ability to recognize disgusted faces was significantly lower for disgusted faces with a mask ($M = 0.36$, $SD = 0.10$) when compared to disgusted faces with no mask ($M = 0.76$, $SD = 0.11$).

H5: Results supported the hypothesis that the ability to accurately recognize angry facial expressions would not significantly differ for faces presented wearing a mask, when compared to no mask ($t(15) = 2.06$, $p = .057$). Masked angry faces ($M = 0.67$, $SD = 0.14$) were not significantly different in accuracy when compared to unmasked angry faces ($M = 0.72$, $SD = 0.12$).

H6: Statistical analysis was in support of the hypothesis that the ability to accurately recognize fearful facial expressions would not significantly differ for faces presented wearing a mask, when compared to no mask ($t(14) = 1.97$, $p = .069$). Masked fearful faces ($M = 0.57$, $SD = 0.30$) did not significantly differ in accuracy when compared to unmasked fearful faces ($M = 0.63$, $SD = 0.25$).

Figure 2

Means of Facial Emotion Recognition Accuracy +/- 1 SD With Significant Differences Illustrated



Note: nc = no facial covering, c = facial covering

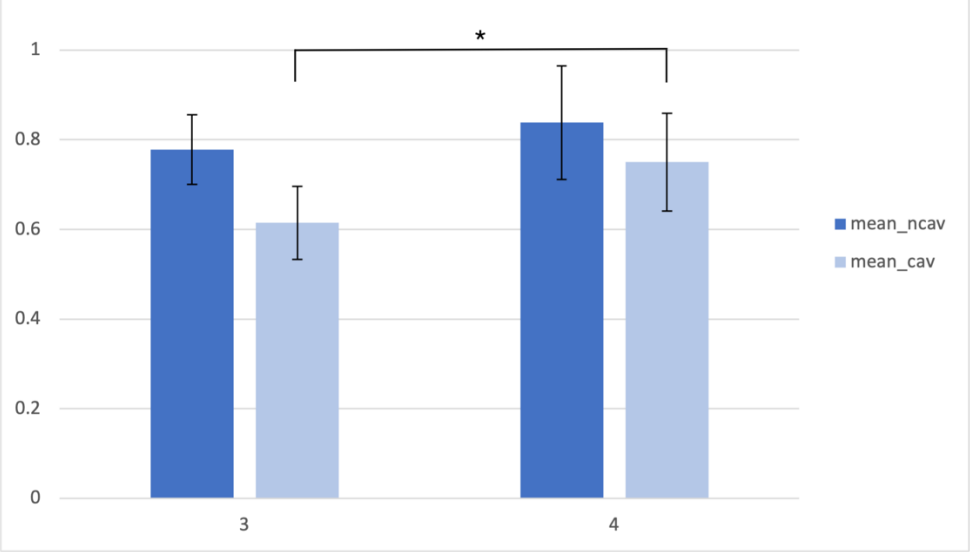
****= p < .001*

H7: Results supported the hypothesis that facial emotion recognition accuracy would significantly differ when comparing harsher mask mandates with more lenient mask mandates ($t(11) = -2.57$, $p = .026$). Findings demonstrated that participants in regions with a mask mandate

rating of 3 (M = 0.61. SD = 0.08) were significantly less accurate in identifying emotions than those exposed to harsher ratings of 4 (M = 0.75, SD = 0.11). Results also revealed that in the unmasked condition, there was no significant difference between accuracies when comparing mask mandate ratings of 3 versus 4 ($t(11) = -1.08$, $p = .304$). See Figure 3 for further information.

Figure 3

Average Facial Emotion Recognition Accuracy by Mask Mandate +/- 1 SD With Significant Differences Illustrated



Note: ncav = no covering average, cav = covering average
**= p < .05*

Discussion

The purpose of this study was to explore the effects of face masks and mask mandates on facial emotion recognition accuracy in happiness, sadness, disgust, anger, and fear. Overall, results suggested that facial emotion recognition accuracy was impacted by the presence of a face mask, as the accuracy of each separate emotion tended to be lower for the masked condition. Specifically, emotions of happiness, sadness, and disgust were significantly more difficult to recognize in the presence of a mask, with disgust having the most pronounced difference between masked and unmasked conditions. Conversely, anger and fear were not significantly different when comparing masked and unmasked conditions. Results also found that facial emotion recognition accuracy for masked faces was significantly lower for a more lenient mask

mandate, where masks were required in some public spaces, when compared to a stricter mandate, where masks were required in all public spaces.

Facial Emotions & Face Segment Reliance

As hypothesized, emotions dependent on the lower face for recognition (i.e., happiness, sadness, and disgust), were identified significantly less accurately in the presence of a mask. Results suggested that the emotions most heavily reliant on the lower face were most impacted by masks covering the lower segment of the face. As for happiness and disgust, results confirmed that the main indicators of these emotions are in the mouth region, namely the smile in happiness, and the depressed lip corners and gaped jaw in a disgusted face. This was in line with previous research (Rozin et al, 1994; Wegrzyn et al., 2017) that found happiness and disgust relied primarily on the mouth. Results demonstrated that sadness was significantly more difficult to recognize in the masked condition. While past literature indicated that sadness relies on both the lower and upper regions of the face (Pavlova, & Sokolov, 2021), results from this study suggest that accurately identifying this emotion may primarily be reliant upon the lower face.

As hypothesized, there was no significant difference for emotions dependent on the upper face (anger and fear) when comparing masked and unmasked conditions. This finding is reflective of previous research, which maintained that these emotions rely primarily on the upper face (Horstmann et al., 2012; Kohler et al., 2004; Marshall, 2017; Pavlova, & Sokolov, 2021). This suggests that the presence of a mask does not hinder the recognition of anger, fear, threats, or danger. While the results demonstrated that it is more difficult to recognize anger and fear, it was not a significant difference, meaning that these emotions are still detectable.

Face Masks & Face Segment Reliance

The juxtaposition of facial emotion recognition accuracy between masked and unmasked faces demonstrates that on average, happiness, sadness, and disgust rely on the lower face, while fear and anger rely on the upper face. Further, since this study included the middle face as part of the lower face, it is suggested that anger and fear do not require any middle features for accurate emotion recognition. Specifically, this means that parts of the face covered by a mask (mouth, cheeks, and nose) are not vital for the recognition of anger and fear. Rather, these emotions can be identified by the eyes, eyebrows, and forehead (Horstmann et al., 2012; Kohler et al., 2004; Marshall, 2017; Wegrzyn et al., 2017). Contrastingly, happiness, sadness, and disgust are dependent on the lower segment of the face for emotion recognition, and these emotions are

significantly more difficult to identify when cues from only the upper segment of the face are available.

Facial Emotion Recognition & Mask Mandates

Results indicated that on average, emotions were significantly more difficult to recognize in the masked condition than the unmasked condition across any mask mandate region. Further, it was found that emotions in a more lenient mask mandate region of 3 (masks required in some public spaces) were significantly more challenging to identify than emotions in a stricter mask mandate region of 4 (masks required in all public spaces). While speculative, this finding suggests that greater exposure to face masks may lead to stronger facial emotion recognition skills for covered faces.

This finding highlights the meaningful impact of subtle mask mandate differences. The only difference between ratings of 3 and 4 was that in the former, masks were required in some public spaces, while the latter required masks in all public spaces (Hale et al., 2021). In other words, there was only a slight shift in mask mandates in public spaces. This difference could be due to heightened facial emotion recognition abilities with increased exposure to masks. Alternatively, this may be due to the fact that the term "some public spaces" is subjective. This unclear mandate category could have led to inconsistent mask usage, which, in turn, led to decreased exposure to masks and decreased communication skills while wearing masks. With this information, it is evident how greatly mask mandates can affect people. Moreover, slight differences in policy, such as limiting masks to some public spaces versus all public spaces, can have great impacts in facial emotion recognition.

Face Masks & Social Communication

COVID-19 has impacted the world in many ways– the way we socialize, the way we communicate, and the way we interpret each other's emotions. As evidenced by the results, the ability to accurately identify an individual's emotions overall is significantly impacted by the presence of face masks. In the long-term, this could have detrimental effects on the way we socialize with one another, as facial emotions are vital in conveying an individual's thoughts, feelings, and intentions; it can lead to confusion, a lack of insight into the feelings of others, and a lack of connection between people. Each emotion provides unique insight necessary for social communication. Therefore, each emotion must be evaluated in terms of their impact on forming and protecting relationships within the wider community.

Emotions Important in Forming and Maintaining Relationships

Happiness was found to be significantly more difficult to identify in the presence of a face mask, which could have implications on mental health. Happiness is a positive social cue, and it is necessary for social interaction (Fredrickson, 1998). If an individual fails to understand if someone else is happy, this individual may doubt themselves and be insecure about how he or she is received. For example, if two people are wearing masks and one of them tells the other exciting news, the second person's emotion may be hard to identify, leaving the first person confused as to whether or not they're socially accepted by the other. Developmentally, not having the ability to discern what a happy face is could be detrimental to forming and maintaining relationships, and its effects should be examined in the future.

Sadness was also significantly harder to recognize when the stimulus was wearing a face mask. Sadness is an especially important emotion to recognize because it signals vulnerability (Wignall, 2020). Therefore, this result could translate to major impacts on empathy and social connectivity. When one cannot understand that another is upset, it makes it much more difficult for them to show empathy. This lack of understanding can lead to a lack of support between peers, ultimately resulting in diminished social skills. Without this social cue, connections are harder to make, and this can hurt the development of emotional acuity.

Overall, the ability to recognize happiness and sadness in the masked condition was significantly lower than in the unmasked condition for adults from ages 18 to 89. While this study investigated neuro-typical adults, it is important to consider how findings may be reflected across neuro-diverse, developmental, and clinical populations. Because of the aforementioned detrimental impacts on mental health, social connection, and empathy, schools and workplaces should work to reverse the negative effects of COVID-19. These institutions can target these emotions by implementing exercises and activities to improve socio-cognitive skills that were perhaps lost during the pandemic.

Emotions Important in Pathogen-Related Communication

Disgust had the most pronounced difference between masked and unmasked faces, meaning that it was the most difficult to understand behind a face mask of all the emotions studied. This finding, in particular, is interesting, as both COVID-19 and disgust are associated with contamination, and the presence of a mask to protect against COVID-19 impedes the perception of disgust, another protection from pathogens. This result can be damaging, as disgust

is vital in protecting from contamination (including bad food, poison, etc.) and expressing repulsion (Carragher & Hancock, 2020). If one person is not able to communicate about a pathogen or contaminant to another, that second person could be in serious danger. Mask mandates were in place to make sure people did not get infected, yet these very measures are responsible for the worsened recognition of disgust and the presence of pathogens, like COVID-19, itself. This finding is especially interesting given the context of COVID-19. Because of the diminished recognition of disgust, it is important to consider other ways to communicate this emotion, such as gesticulations. Further, schools can pay special attention to identifying disgust to strengthen skills affected by the implementation of masks.

The Application of Facial Emotion Recognition to Survival

Facial emotions of anger and fear were found to not be significantly more difficult to recognize in the presence of a mask. This could be due to upper face dependency in these emotions, as supported by previous research (Horstmann et al., 2012; Kohler et al., 2004; Marshall, 2017; Wegrzyn et al., 2017). Alternatively, this may reflect survival mechanisms. Throughout human history, humans have had to learn how to adapt and survive. Therefore, it has been essential to know when someone else is angry or afraid, as this indicates potential threats and dangers.

Evolutionary adaptations to recognize anger are demonstrated by specialized neural development of the amygdala, hypothalamus, and periaqueductal gray regions (Blair, 2013). The mere fact that the brain has regions dedicated to understanding and processing anger signals how important it is and has been in human evolution. As a result, humans have adapted to be better at facial emotion recognition for improved social skills and, in turn, survival.

Similarly, the amygdala is the primary indicator of fear in the brain, which has also been essential in human evolution (Ressler, 2010). Again, evidence that fear is detected in this brain region highlights the importance of this emotion. Fear is extremely crucial to detect today with terrorism, natural disasters, and wars in our global climate. The fact that there was no significant difference between the masked and unmasked condition could indicate the prevalence and importance of fear in our society. Also, if someone feels threatened by another person, a bystander will be able to help if they can tell that the individual is fearful; if not, it can become a dangerous situation.

Facial emotion recognition plays a major role in human survival, and it is important that anger and fear are not significantly impacted by face masks. Further, it is interesting that emotions linked to specialized brain regions displayed non-significant differences. This suggests that neural mechanisms to identify emotions are essential in facial emotion recognition.

Limitations and Future Research

The current study has several limitations. A fundamental limitation is that there are methodological differences between the fifteen studies used, including task design and emotions studied. This may have increased the variance and impacted the results. As a result, future research should study the impacts of face masks on facial emotion recognition using the same methodology across sample groups. Another limitation to this research was that there was a small sample size in terms of mask mandate analysis. Many studies were conducted in countries with the same mask mandate rating, so there were not enough studies in each rating category to draw any significant conclusions. In order to generalize results to the greater population, this sample size would have needed to be larger. Therefore, future research should examine the effect of face masks on facial emotion recognition with a larger and more diverse sample size. Lastly, because the COVID-19 pandemic was still recent during the time the current study was conducted, there was not enough data available to evaluate children, those who are hard-of-hearing or deaf, and those with attentional issues or learning disabilities. Children were forced to develop social skills and learn how to interact with peers behind masks, hard-of-hearing and deaf people could not read lips, and those with learning and attentional problems suffered from the limited engagement of online school and work. Future research should consider these groups, as they were likely greatly impacted by the effects of the pandemic.

Beyond the aforementioned directions of future research, there are additional ways this study can be extended. As reported by this study, fear is not significantly more difficult to recognize in the masked condition than the unmasked condition, and this may be because of evolution. Future research should examine communities with heightened exposure to fear in everyday interactions, such as marginalized groups and groups of people surrounded by external threats such as war or famine. Due to the elevated levels of societal threats in these groups, it is possible that their increased exposure to threat will lead to differences in fear recognition. This was supported by results relating to mask mandates and may be applied to varying levels of threats. Additionally, future research could study differences in facial emotion recognition

between urban and rural communities in masked and unmasked conditions. These two groups may differ in exposure to masks during the pandemic and may give further insight to the impacts on facial emotion recognition during COVID-19.

Conclusion

Overall, the COVID-19 pandemic has impacted the world in terms of how we communicate and interact while wearing face masks. Therefore, this study aimed to understand the impact of face masks and mask mandates on the ability to recognize facial emotions. Results indicated statistically significant differences across happiness, sadness, and disgust. Interestingly, angry and fearful facial emotions were not found to be statistically significant. This may be due to the evolutionary development of threat recognition to enhance survival. Lastly, it was found that a more lenient mask mandate made it significantly more difficult for participants to recognize emotions than a stricter mask mandate. Collectively, this suggests that increased exposure to face masks may improve emotion recognition skills in the presence of face masks. In the wake of COVID-19, this study provides crucial insight into the present and future impacts of face masks and mask mandates on social communication skills.

Bibliography

Adolphs, R. (2006). Perception and Emotion: How We Recognize Facial Expressions. *Current Directions in Psychological Science*, *15*(5), 222-226. https://doi.org/10.1111/j.1467-8721.2006.00440

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., and Plumb, I. (2001). The "Reading the Mind in the Eyes" Test revised version: a study with normal adults, and adults with Asperger syndrome or high-functioning autism. *Journal of child psychology and psychiatry, and allied disciplines*, *42*(2), 241-51

Barrick, E. M., Thornton, M. A., & Tamir, D. I. (2021, October 12). *Mask exposure during COVID-19 changes emotional face processing*. PLOS ONE. https://doi.org/10.1371/journal.pone.0258470

Blair, R.J.R. (2013, January 1). *Considering anger from a cognitive neuroscience perspective*. Wiley Interdisciplinary Reviews Cognitive Science. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3260787/

Bublatzky, F., Riemer, M., & Guerra, P. (2019, September 13). *Reversing threat to safety: Incongruence of facial emotions and instructed threat modulates conscious perception but not physiological responding*. Frontiers in psychology. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6753879/#:~:text=Thus%2C%20regarding%20threat%20ratings%2C%20happy,when%20instructed%20to%20signal%20safety

Buckley, R. C. (2016, August 10). *Qualitative analysis of emotions: Fear and Thrill*. Frontiers. https://www.frontiersin.org/articles/10.3389/fpsyg.2016.01187/full

Campiche, R., Pascucci, F., Jiang, L., Vergne, T., Cherel, M., Gougeon, S., Préstat-Marquis, E., François, G., Laurent, G., & Gempeler, M. (2020, November 29). *Facial expression wrinkles and their relaxation by a synthetic peptide - International Journal of Peptide Research and therapeutics*. SpringerLink. https://link.springer.com/article/10.1007/s10989-020-10146-z

Carbon, Claus-Christian. (2020). "Wearing Face Masks Strongly Confuses Counterparts in Reading Emotions." *Frontiers*. https://www.frontiersin.org/articles/10.3389/fpsyg.2020.566886/full

Carragher, D. J., & Hancock, P. J. (2020). Surgical face masks impair human face matching performance for familiar and unfamiliar faces. *Cognitive research: principles and implications*, *5*(1), 1-15

Centers for Disease Control and Prevention. (2021, December 6). *Science brief: Community use of masks to control the spread of SARS-COV-2*. Centers for Disease Control and Prevention. https://www.cdc.gov/coronavirus/2019-ncov/science/science-briefs/masking-science-sars-cov2.html

Drigas, A. S., & Papoutsi, C. (2018). "A New Layered Model on Emotional Intelligence." *Behavioral sciences (Basel, Switzerland)*, *8*(5) 45. https://doi.org/10.3390/bs8050045

Ebner, N. C., Riediger, M., & Lindenberger, U. (2018). FACES: A database of facial expressions in young, middle-aged, and older women and men (publicly available datasets). Max Planck Society. https://faces.mpdl.mpg.de/imeji/collection/IXTdg721TwZwyZ8e

Ekman, P., Friesen, W. V., & Hager, J. C. (2002). *Facial action coding system*. Research Nexus

Fitousi, D., Rotschild, N., Pnini, C., & Azizi, O. (2021, November 3). *Understanding the impact of face masks on the processing of facial identity, emotion, age, and gender*. Frontiers. https://www.frontiersin.org/articles/10.3389/fpsyg.2021.743793/full#:~:text=The%20results%20revealed%20that%20masks,speed%20and%20accuracy%20of%20categorization

Folz, J., Fiacchino, D., Nikolić, M., van Steenbergen, H., & Kret, M. E. (2022, March 8). *Reading your emotions in my physiology? reliable emotion interpretations in absence of a robust physiological resonance - affective science*. SpringerLink. https://link.springer.com/article/10.1007/s42761-021-00083-5

Fox, E., Lester, V., Russo, R., Bowles, R. J., Pichler, A., & Dutton, K. (2000, January 1). *Facial expressions of emotion: Are angry faces detected more efficiently?* Cognition & emotion. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1839771/

Fredrickson B. L. (1998). What Good Are Positive Emotions?. *Review of general psychology : journal of Division 1, of the American Psychological Association*, *2*(3), 300–319. https://doi.org/10.1037/1089-2680.2.3.300

Gagnon, M., Gosselin, P., & Maassarani, R. (2014, February 12). *Children's ability to recognize emotions from partial and complete facial expressions*. Taylor & Francis. https://www.tandfonline.com/doi/full/10.1080/00221325.2014.941322

Gao, X., & Maurer, D. (2010, June 12). *A happy story: Developmental changes in children's sensitivity to facial expressions of varying intensities*. Journal of Experimental Child Psychology. https://www.sciencedirect.com/science/article/pii/S0022096510000810

Gooden, C., & Kearns, J. (2013). “The Importance of Communication Skills in Young Children." Research Brief. Summer 2013. Human Development Institute

Gori, M., Schiatti, L., & Amadeo, M. B. (2021, May 25). *Masking emotions: Face masks impair how we read emotions*. Frontiers. https://www.frontiersin.org/articles/10.3389/fpsyg.2021.669432/full

Grahlow, M., Rupp, C. I., & Derntl, B. (2022, February 11). *The impact of face masks on emotion recognition performance and perception of threat*. PLOS ONE. https://doi.org/10.1371/journal.pone.0262840

Grenville, E., & Dwyer, D. M. (2022, February 14). *Face masks have emotion-dependent dissociable effects on accuracy and confidence in identifying facial expressions of emotion - cognitive research: Principles and implications*. SpringerOpen. https://doi.org/10.1186/s41235-022-00366-w

Grundmann, F., Epstude, K., & Scheibe, S. (2021, April 23). *Face masks reduce emotion-recognition accuracy and perceived closeness*. PLOS ONE. https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0249792

Hale, T., Angrist, N., Goldszmidt, R., Kira, B., Petherick, A., Phillips, T., Webster, S., Cameron-Blake, E., Hallas, L., Majumdar, S., & Tatlow, H. (2021). "A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker)." Nature Human Behaviour. https://doi.org/10.1038/s41562-021-01079-8

Horstmann, G., Lipp, O. V., & Becker, S. I. (2012, May 1). *Of toothy grins and angry snarls-open mouth displays contribute to efficiency gains in search for emotional faces*. Journal of Vision. https://jov.arvojournals.org/article.aspx?articleid=2192034

Isaacowitz, D., Löckenhoff, C.E., Lane, R.D., Wright, R., Sechrest, L., Riedel, R., & Costa, P. (2007, April). *Age differences in recognition of emotion in lexical stimuli and facial expressions*. Psychology and Aging. https://www.researchgate.net/publication/6421582_Age_Differences_in_recognition_of_emotion_in_lexical_stimuli_and_facial_expressions

Jennings, R. (2020, March 11). *Not just coronavirus: Asians have worn face masks for decades*. VOA. https://www.voanews.com/a/science-health_coronavirus-outbreak_not-just-coronavirus-asians-have-worn-face-masks-decades/6185597.html

Juckel, G., Heinisch, C., Welpinghus, A., & Brüne, M. (2018, September 6). *Understanding another person's emotions-an interdisciplinary research approach*. Frontiers in psychiatry. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6135884/

Kang, J., Kang, S., Jeong, E., & Kim, E. H. (2021). Age and Cultural Differences in Recognitions of Emotions from Masked Faces among Koreans and Americans. *International journal of environmental research and public health*, *18*(19), 10555. https://doi.org/10.3390/ijerph181910555

Keltner, D., Sauter, D., Tracy, J., & Cowen, A. (2019). Emotional Expression: Advances in Basic Emotion Theory. *Journal of nonverbal behavior*, *43*(2), 133–160. https://doi.org/10.1007/s10919-019-00293-3

Kim, G., Seong, S. H., Hong, S.-S., & Choi, E. (2022, February 3). *Impact of face masks and sunglasses on emotion recognition in South Koreans*. PLOS ONE. https://doi.org/10.1371/journal.pone.0263466

Kohler, C. G., Turner, T., Stolar, N. M., Bilker, W. B., Brensinger, C. M., Gur, R. E., & Gur, R. C. (2004). *Differences in facial expressions of four universal emotions*. Psychiatry Research. https://doi.org/10.1016/j.psychres.2004.07.003

Lau, J. T., Yang, X., Tsui, H. Y., & Pang, E. (2004). SARS related preventive and risk behaviours practised by Hong Kong-mainland China cross border travellers during the outbreak of the SARS epidemic in Hong Kong. *Journal of epidemiology & community health*, *58*(12), 988-996.

Lewis, G. J., Lefevre, C. E., & Young, A. W. (2016). Functional architecture of visual emotion recognition ability: A latent variable approach. *Journal of experimental psychology. General*, *145*(5), 589–602. https://doi.org/10.1037/xge0000160

Liao, M., Liu, H., Wang, X., Hu, X., Huang, Y., Liu, X., ... & Lu, J. R. (2021). A technical review of face mask wearing in preventing respiratory COVID-19 transmission. *Current Opinion in Colloid & Interface Science*, *52*, 101417.

Luong, G., Charles, S. T., & Fingerman, K. L. (2011, February 1). *Better with age: Social relationships across adulthood*. Journal of social and personal relationships. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3291125/

Magherini, R., Mussi, E., Servi, M., & Volpe, Y. (2022). Emotion recognition in the times of COVID19: Coping with face masks. *Intelligent Systems with Applications*, *15*, 200094.

Maiorana, N., Dini, M., Poletti, B., Tagini, S., Rita Reitano, M., Pravettoni, G., Priori, A., & Ferrucci, R. (2022, February 19). *The effect of surgical masks on the featural and configural processing of emotions*. MDPI. https://doi.org/10.3390/ijerph19042420

Marini, M., Ansani, A., Paglieri, F., Caruana, F., & Viola, M. (2021). The impact of facemasks on emotion recognition, trust attribution and re-identification. *Scientific reports*, *11*(1), 5577. https://doi.org/10.1038/s41598-021-84806-5

Marshall, L. (2017, June 8). *Stink-eye, other expressions likely originated as survival mechanisms*. CU Boulder Today. https://www.colorado.edu/today/2017/06/08/stink-eye-other-expressions-likely-originated-survival-mechanisms#:~:text=Eye%2Dnarrowing%20was%20associated%20with,like%20awe%2C%20cowardice%20and%20interest

Martinelli, L., Kopilaš, V., Vidmar, M., Heavin, C., Machado, H., Todorović, Z., Buzas, N., Pot, M., Prainsack, B., & Gajović, S. (2021). Face Masks During the COVID-19 Pandemic: A Simple Protection Tool With Many Meanings. *Frontiers in public health*, *8*, 606635. https://doi.org/10.3389/fpubh.2020.606635

McCrackin, S. D., Capozzi, F., Ristic, J., & Mayrand, F. (2022, February 21). *Face masks impair basic emotion recognition*. Social Psychology. https://econtent.hogrefe.com/doi/full/10.1027/1864-9335/a000470

Mheidly, N., Fares, M. Y., Zalzale, H., & Fares, J. (2020, December 9). *Effect of face masks on interpersonal communication during the COVID-19 pandemic*. Frontiers. https://www.frontiersin.org/articles/10.3389/fpubh.2020.582191/full

Minaee, S., Minaei, M., & Abdolrashidi, A. (2021, April 27). *Deep-emotion: Facial expression recognition using attentional convolutional network*. MDPI. https://doi.org/10.3390/s21093046

Mohammadi, K. (2020, May 30). *The eyes have it: Communication and face masks*. The Guardian. https://www.theguardian.com/lifeandstyle/2020/may/30/face-mask-eye-contact-commuication-coronavirus

Osgood-Cornell, M. (2014, March 21). *Faces show fear and disgust to help eyes see*. Futurity. https://www.futurity.org/eye-evolution-shape-facial-expressions/

Pavlova, M. A., & Sokolov, A. A. (2021, September 14). *Reading covered faces*. OUP Academic. https://academic.oup.com/cercor/article/32/2/249/6370295

Pazhoohi, F., Forby, L., & Kingstone, A. (2021, September 30). *Facial masks affect emotion recognition in the general population and individuals with autistic traits*. PLOS ONE. https://doi.org/10.1371/journal.pone.0257740

Ramachandra, V., & Longacre, H. (2022). *Unmasking the psychology of recognizing emotions of people wearing masks: The role of empathizing, systemizing, and autistic traits*. Personality and Individual Differences, *185*, 111249. https://doi.org/10.1016/j.paid.2021.111249

Ressler, K. J. (2010, June 15). *Amygdala activity, fear, and anxiety: Modulation by stress*. Biological psychiatry. https://www.ncbi.nlm.nih.gov/sites/ppmc/articles/PMC2882379/

Richard, Y., Tazi, N., Frydecka, D., Hamid, M. S., & Moustafa, A. A. (2022). A systematic review of neural, cognitive, and clinical studies of anger and aggression. *Current Psychology*, 1-13.

Rozin, P., Lowery, L., & Ebert, R. (1994). Varieties of disgust faces and the structure of disgust. *Journal of personality and social psychology*, *66*(5), 870–881. https://doi.org/10.1037//0022-3514.66.5.870

Sato, W., Hyniewska, S., Minemoto, K., & Yoshikawa, S. (2019, February 12). *Facial expressions of basic emotions in Japanese laypeople*. Frontiers. https://doi.org/10.3389/fpsyg.2019.00259

Semyonov, O., Ziv-El, A., Krumhuber, E. G., Karasik, S., & Aviezer, H. (2021). *Beyond shared signals: The role of downward gaze in the stereotypical representation of sad facial expressions.* Emotion*, 21*(2), 247–259. https://doi.org/10.1037/emo0000706

Shepherd, J. L., & Rippon, D. (2022, April 27). *The impact of briefly observing faces in opaque facial masks on emotion ...* Quarterly Journal of Experimental Psychology. https://journals.sagepub.com/doi/10.1177/17470218221092590

Smelser, N. J. (2001). In *International Encyclopedia of the Social & Behavioral Sciences* (pp. 5230–5234). Elsevier, Pergamon

Tian, Y., Kanade, T., & Cohn, J. F. (2011). Facial expression recognition. In *Handbook of face recognition* (pp. 487-519). Springer, London.

Tipples, J., Atkinson, A. P., & Young, A. W. (2002, October). *The eyebrow frown: A salient social signal*. Emotion (Washington, D.C.). https://pubmed.ncbi.nlm.nih.gov/12899361/

Tsantani, M., Podgajecka, V., Gray, K. L. H., & Cook, R. (2022, January 13). *How does the presence of a surgical face mask impair the perceived intensity of facial emotions?* PLOS ONE. https://doi.org/10.1371/journal.pone.0262344

Wegrzyn, M., Vogt, M., Kireclioglu, B., Schneider, J., & Kissler, J. (2017, May 11). *Mapping the emotional face. how individual face parts contribute to successful emotion recognition*. PLOS ONE. https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0177239

Wignall, N. (2020, June 14). *Emotional vulnerability: What it is and why it matters*. Nick Wignall. https://nickwignall.com/emotional-vulnerability/

Xu, Q., Yang, Y., Tan, Q., & Zhang, L. (2017, December 12). *Facial expressions in context: Electrophysiological correlates of the emotional congruency of facial expressions and background scenes*. Frontiers. http://www.frontiersin.org/articles/10.3389/fpsyg.2017.02175/full