Emotion

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# Behavioral and Neural Evidence for Difficulty Recognizing Masked Emotional Faces

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Facial emotion recognition is vital for human social behavior. During the COVID-19 pandemic, face masks were widely adopted for viral mitigation and remain crucial public health tools. However, questions persist about their impact on emotion recognition and neural processing, especially in children, parents, and young adults. We developed the Masked Affective and Social Cognition task, featuring masked and unmasked faces displaying fear, sadness, and anger. We recruited three racial and ethnically diverse samples: 119 college students, 30 children who entered school age at the beginning of the pandemic, and 31 fathers of the aforementioned children. Of the latter two groups, 41 participants ($n = 23$ fathers, 18 children) did the Masked Affective and Social Cognition task during a neuroimaging scan, while the remaining 20 participants ($n = 8$ fathers, 12 children) who were not eligible for scanning completed the task during their lab visit. Behaviorally, we found that participants recognized emotions less accurately when viewing masked faces and also found an interaction of emotion by condition, such that accuracy was particularly compromised by sad masked faces. Neurally, masked faces elicited greater activation in the posterior cingulate, insula, and fusiform gyrus. Anterior insula and inferior frontal gyrus activation were driven by sad, masked faces. These results were consistent across age groups. Among fathers, activation to sad masked faces was associated with stress and depression. Overall, our findings did not depend on previous mask exposure or timing of participation during the pandemic. These results have implications for understanding face emotion recognition, empathy, and socioemotional neurodevelopment.

*Keywords:* masked faces, emotion recognition, depressive symptoms, perceived stress, brain and behavior

*Supplemental materials:* https://doi.org/10.1037/emo0001444.supp

During the COVID-19 pandemic, face masks were widely adopted as a public health strategy to mitigate viral transmission. Mask requirements were implemented in many parts of the United States, particularly in educational environments such as K–12 schools, colleges, and universities. Although masks were familiar in countries that had previously experienced mass viral outbreaks, such as China and Japan, they represented a novel phenomenon in much of the Western world, prompting public concern about how masks might affect facial emotion recognition in ways that could alter social behavior and affect the socioemotional neurodevelopment of children and emerging adults (Wong et al., 2020). This concern is understandable given that facial emotion recognition is a fundamental component of human social interaction. Humans evolved to rapidly detect others' emotional states and intentions from facial expressions (Schmidt & Cohn, 2001; Susskind et al., 2008). Masks, which obscure key parts of the face, such as the nose and mouth, might compromise the accurate recognition of emotional states (Carbon & Serrano, 2021; Freud et al., 2020;

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Gori et al., 2021; Ruba & Pollak, 2020). For school-aged children, whose ability to read facial expressions is still developing, spending a critical stage of development interacting with masked peers and teachers might have lasting socioemotional effects (Stajduhar et al., 2021). Fathers play an important role in parenting (Cardenas et al., 2022), but they have been understudied relative to mothers, so neural research on emotion processing in fathers is warranted. College students represent another group who might be particularly affected by mask-wearing as their social connections are rapidly evolving in emerging adulthood (Hoffman et al., 2018). However, there has been surprisingly little empirical research exploring how masks affect emotion recognition across age groups, and particularly little research on the neural correlates of emotion recognition when viewing masked faces. The present study introduces the MASC (Masked Affective and Social Cognition) task and describes both behavioral and neural correlates of masked versus unmasked facial emotion recognition across three samples of individuals. These individuals all represent groups with high rates of mask exposure during the pandemic: college students, school-aged children, and their fathers. The MASC task, completed by all participants, featured both masked and unmasked child and adult faces displaying fear, sadness, and anger (i.e., both child and adult participants did the same task with the same mix of child and adult stimuli).

## Universality and Variability in Facial Emotion Recognition

Identifying and responding to emotions is integral to human interaction (Phillips et al., 2003). Although there appears to be cultural variability in facial displays and facial emotion recognition (Chen et al., 2024; Dailey et al., 2010; Elfenbein & Ambady, 2002), research has also pointed to some consistent visual cues that signal emotions, at least in Western countries (Chen et al., 2024; Ekman et al., 1980; Tate et al., 2006; Wegrzyn et al., 2017). From an evolutionary perspective, emotions signaling threat or danger (e.g., fear, anger) are known to be more ecologically relevant than other negative emotions (e.g., sadness; Schmidt & Cohn, 2001; Susskind et al., 2008) and may be more consistently detectable across cultures (Chen et al., 2024). Emotional displays make use of specific parts of the face that may differ across emotions (Beaudry et al., 2014; Chen et al., 2024; F. W. Smith & Schyns, 2009). Some facial features may be sufficient for identifying and responding to fearful or angry stimuli, but relying on isolated facial features may be more challenging when classifying less conserved emotional profiles (e.g., sadness). In understanding the potential impact of masking on facial emotion recognition, emotions that use more of the upper face (e.g., corrugated brows in anger) might be more easily detectable than emotions that use more of the lower face, but research in this area is still emerging.

## Prevalence of Mask-Wearing as a Public Health Intervention

Face masking has been one of the primary public health strategies used to mitigate the spread of COVID-19. Though the Centers for Disease Control and Prevention's original guidance in March 2020 urged civilians to avoid face mask usage to save supplies for medical professionals, by April, the organization had reversed course and urged Americans to wear face masks whenever they were in public. By the end of 2020, state mask mandates impacted 74% of U.S. counties, including in Los Angeles County, where the present study was conducted (Guy et al., 2021). In early April 2020, nearly nine in 10 Americans said that they had used a face mask at least once in the past week (Brenan, 2020b), and in Summer 2020, 72% of Americans said they wore face masks in public "very often" or "always" (Brenan, 2020a). Although rates of mask-wearing decreased after the most acute phase of the pandemic, the use of masks is still much higher than before the pandemic, when face mask use was less than 5% (YouGov, 2020). Public health officials encourage individuals to continue wearing face masks when they are in close contact with someone with COVID-19, in health care settings, and on public transportation (Los Angeles County Department of Public Health, 2023), and mask-wearing rates may increase again during future outbreaks and pandemics.

Mask mandates were particularly widespread in educational settings during the pandemic. The Los Angeles Unified School District, the nation's second-largest school district, and the district from which many of the children in the current sample are drawn maintained an indoor mask mandate until Spring 2022 (Sequeira, 2022). In 2021, one study conducted on 12 university campuses found that 91.7% of university students wore masks indoors (Barrios et al., 2021). By the spring of 2022, most college campuses and K–12 schools had lifted their mask mandates but continued to require masks in health facilities, at testing sites, and on public transportation (Haring, 2022).

## Neural Correlates of Emotion Recognition and Mental Health

Emotional face recognition is often studied using functional magnetic resonance imaging (fMRI) methods. The fusiform gyrus (FG) has been widely implicated in face recognition and processing, including for emotional faces (Kawasaki et al., 2012; McCarthy et al., 1997). Emotional face recognition, however, additionally involves neural pathways beyond those mostly implicated in visual pattern recognition. Concurrent activity and connectivity with traditional affective regions, such as the amygdala and insular cortex, and the default mode network regions are important for recognizing emotional faces (Del Casale et al., 2017; Herrington et al., 2011; Sprengelmeyer et al., 1998; Xu et al., 2021), and various regions may differentially contribute to the recognition of specific emotions (Fusar-Poli et al., 2009). In addition, affective regions such as the anterior insula appear to be crucial for accurate facial emotion recognition, based on stimulation studies (Motomura et al., 2019; Papagno et al., 2016).

Emotion recognition is well-known to be affected by mental health and stress (Daudelin-Peltier et al., 2017; Demenescu et al., 2010). Depression may have complicated interactions with facial emotion recognition due to mood-induced negativity biases (Krause et al., 2021; Penton-Voak et al., 2021). These types of biases have been found to both increase and decrease the accurate recognition of emotional faces depending on context and specific emotions. fMRI research also indicates that individuals facing mental health challenges, such as depression, exhibit increased activation in brain regions including the amygdala, insula, and FG (central to emotional processing) and the cuneus and precentral gyri (are involved in visual processing and the coordination of attention) when recognizing faces, particularly those displaying negative emotions (Quevedo et al., 2018; Stuhrmann et al., 2011).

## What Is Known About the Processing of Masked Faces

Even though mask mandates have been relaxed in the past several years and were less prevalent when data for the present study were collected (between early 2022 and Fall 2023), the long-term implications of cumulative mask exposures on the development of emotion recognition are not yet well understood. Preliminary behavioral studies found that masking the nose and mouth may impede emotion processing accuracy (Carbon & Serrano, 2021; Freud et al., 2020; Gori et al., 2021; Ruba & Pollak, 2020). Specifically, an Italian study of toddlers (age 3–5), school-aged children (age 6–8), and adults (Gori et al., 2021) found that participants' facial expression recognition was significantly less accurate when viewing masked versus unmasked faces. Another study in a U.S. sample of 7- to 13-year-olds (Ruba & Pollak, 2020) found that children showed less accurate emotion recognition when faces were occluded by either sunglasses (covering the eyes) or masks (covering the nose and mouth), compared to faces that were not obscured. More specifically, these participants found it especially challenging to recognize sad faces that were masked. Another U.S. study, this one focusing on 9- to 11-year-olds, found impairments in masked face recognition that were emotion-specific, with strong decrements in the ability to read disgust, fear, and sadness; mild effects on happiness; and improved facial recognition performance for anger and neutral faces (Carbon & Serrano, 2021). Moreover, whereas these three studies found significant but relatively small effects of masks on overall emotion perception, a study of Israeli school-aged children (Freud et al., 2020) found that face perception performance on a standardized task of facial emotional perception was significantly compromised when faces were masked. Adults show similar reductions in emotion recognition in masked faces: A recent study found that though participants were still able to correctly identify expressions above chance with masked faces, they were slower and less accurate in emotion recognition for masked faces versus unmasked faces (Williams et al., 2023).

While various studies have investigated how face masks affect emotion recognition behaviorally, studies on neural processing are limited. One fMRI study of 16 participants found that while accuracy was not affected in their sample, recognition was slower and was associated with activation in FG, frontoparietal regions, and the insular cortex in the lead-up to emotion recognition (Kleiser et al., 2022). A similar finding with electroencephalogram found a slower N170 response to masked faces compared to unmasked, as well as a large anterior P300 amplitude possibly reflecting the greater cognitive effort, with these effects being particularly prominent for sad and disgusted faces (Proverbio et al., 2023). This N170 effect, however, appears to be less prominent in individuals with more exposure to masks, suggesting experience-related adaptation to altered facial cues (Prete et al., 2022). Due to its experience-dependent nature, there have been questions about how masked faces may affect the development of facial emotion recognition (Carnevali et al., 2022), though studies on the neural underpinnings of emotion recognition across different developmental time points have not been performed, to our knowledge.

We deployed the MASC task following the onset of the COVID-19 pandemic and targeted populations undergoing significant life transitions who might be uniquely affected by social distancing and mask exposure, such as school-aged children, their parents, and young college students. This sample composition provides a valuable opportunity to examine emotion recognition differences across various age groups and the extent to which recent mask exposure has impacted emotion recognition more broadly. A subsample of our participants completed the behavioral task while undergoing an fMRI scan, allowing the exploration of differences in brain activation concerning masking and emotional expression. The larger behavioral data set allows us to better assess the validity of the MASC task, while the smaller neuroimaging sample explores a match between brain activity and facial recognition accuracy.

## The Present Study

We investigated emotion recognition of masked versus unmasked faces using the novel MASC task across three samples, including 119 college students, 30 school-aged children, and 31 fathers. Forty-one of these father and child participants completed the MASC task in the MRI scanner so we could examine the neural processing of masked versus unmasked emotional faces. We hypothesized that masked versus unmasked faces would elicit less accurate emotion recognition (Hypothesis 1a) and distinct patterns of neural processing (Hypothesis 1b), such as greater activation in regions associated with facial recognition and emotional processing, notably the FG and insula. We anticipate these behavioral (Hypothesis 2a) and neural effects (Hypothesis 2b) to be more pronounced for the recognition of sadness, since compared to more conserved emotions like anger and fear, masked sadness may be even more challenging to detect. We also hypothesized that these behavioral (Hypothesis 3a) and neural (Hypothesis 3b) effects will be less pronounced in individuals who have spent more time in the company of masked others as facial processing strategies may change as individuals interact more with masked others. In addition, we anticipated that higher levels of depression and perceived stress would be associated with an increased effort or use of neural resources to complete the task, resulting in heightened neural activity in regions associated with facial recognition and emotion processing, particularly when interpreting masked sad faces (Hypothesis 4). Given prior work's mixed findings on the relationship between emotion recognition accuracy and mental health outcomes, we chose not to posit a directional behavioral hypothesis, instead opting to explore this relationship as detailed in the Supplemental Material (Exploratory Question 1).

# Method

## Transparency and Openness

We report how we determined our sample size, and we affirm that there were no data exclusions, and that all manipulations and all measures in the study are disclosed. All data, analysis code, and research materials, including the MASC task, are available upon reasonable request from the first author. Data were analyzed using R (R Core Team, 2023) and FSL (S. M. Smith et al., 2004), utilizing the packages noted above. Finally, this study was not preregistered.

## Participants

The study data were collected from two institutions: the University of Southern California (USC) and California State University, Northridge (CSUN). USC data were collected between January 2022 and September 2023, and CSUN data were collected between April 2022 and May 2022. At USC, a community sample of 100 cohabiting couples expecting their first child were recruited during pregnancy and followed across the transition to parenthood. Data for this article were collected as part of a 7-year follow-up wave of this larger longitudinal study when children were around 7 years old, and children participated along with their fathers. Since we did not want the USC study time frame to extend more than a year and a half past the partner study (CSUN) data collection, of the USC sample, 31 fathers and 30 children participated in the 7-year follow-up lab visit and completed the MASC task. At CSUN, students were recruited from the CSUN undergraduate population using the university's research management system, wherein students received course credit for participating in research studies as part of their introductory psychology course requirement and participated in one visit, conducted via synchronous videoconferencing. All 119 recruited CSUN college students completed the MASC task behaviorally. No participant was excluded from the study. Demographic information for all participants can be found in Table 1.

## Procedure

The larger USC study consisted of one family lab visit and two MRI visits—one for fathers and one for children. During the family lab visits, families participated in video-recorded activities and discussions. Following these discussions, parents each completed a computerized battery of demographic and psychosocial questionnaires, including the Beck Depression Inventory–II (BDI; Beck et al., 1996), the Perceived Stress Scale (PSS; Cohen et al., 1983), and the Mask Exposure Questionnaire (Barrick et al., 2021). The 20 participants ($n = 8$ fathers, 12 children) who were either not eligible or did not consent to MRI scanning completed the MASC task behaviorally during the family lab visit. The original MASC task consisted of 120 trials, 10 per condition, and lasted approximately 18 min (Table 2). The 41 eligible participants ($n = 23$ fathers, 18 children) completed the MRI scan within approximately 1 week ($M = 5.61$ days for fathers, 7.83 days for children) of the lab visit. In the MRI, they completed a series of tasks in the scanner, lasting approximately 1 hr in total. Of those tasks, they completed either the original 120-trial MASC task (Table 2) or a modified 72-trial version (Table 3) of the MASC task. The 72-trial version consisted of six trials per condition and lasted approximately 11 min (Table 3). Lab personnel decided which version of the task to administer based on scanning limitations and challenges in

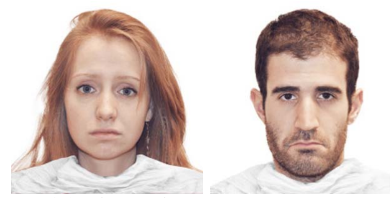
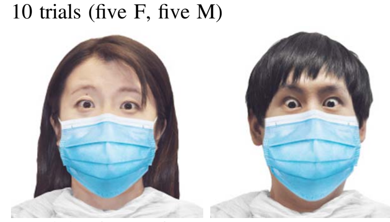
**Table 1**
*Sample Demographics*

| Measure | USC child ($N$ = 30) *M* | *SD* | Range | USC father ($N$ = 31) *M* | *SD* | Range | CSUN college student ($N$ = 119) *M* | *SD* | Range |
|---|---|---|---|---|---|---|---|---|---|
| Age (years) | 7.18 | 0.42 | 6.50–8.02 | 43.76 | 7.79 | 29.35–64.86 | 20.70 | 4.12 | 18.45–50.28 |
| Time between questionnaire and task administrations (days) | 7.83 | 18.13 | 0–97 | 9.61 | 17.96 | 0–97 | | | |
| Perceived Stress Scale | | | | 30.33 | 4.15 | 21–38 | 30.69 | 8.26 | 5–54 |
| Beck Depression Inventory | | | | 7.48 | 7.64 | 0–33 | | | |
| Emotion recognition accuracy for masked trials only | 62 | 12 | 38–82 | 81 | 7 | 62–92 | 79 | 10 | 48–95 |
| Emotion recognition accuracy for unmasked trials only | 72 | 14 | 38–90 | 89 | 9 | 71–98 | 86 | 6 | 52–100 |

| Measure | USC child *N* | % | USC father *N* | % | CSUN college student *N* | % |
|---|---|---|---|---|---|---|
| Gender | | | | | | |
| Female | 14 | 44.67 | 0 | 0 | 34 | 28.57 |
| Male | 16 | 53.33 | 31 | 100 | 83 | 69.75 |
| Gender Queer | 0 | 0 | 0 | 0 | 1 | 0.84 |
| Decline to state | 0 | 0 | 0 | 0 | 1 | 0.84 |
| Race/ethnicity | | | | | | |
| White | 16 | 53.33 | 16 | 51.61 | 14 | 11.76 |
| Black | 1 | 3.33 | 2 | 6.45 | 8 | 6.72 |
| Hispanic or Latino/a | 6 | 20.00 | 6 | 19.35 | 68 | 57.14 |
| AAPI | 4 | 13.33 | 4 | 12.90 | 17 | 14.29 |
| Other | 2 | 6.67 | 2 | 6.45 | 11 | 9.24 |
| Decline to state | 1 | 3.33 | 1 | 3.23 | 1 | 0.84 |
| MASC task location | | | | | | |
| Scanner | 18 | 60 | 23 | 74.19 | 0 | 0 |
| Behaviorally outside of scanner (in lab or via Zoom) | 12 | 40 | 8 | 25.80 | 119 | 100 |
| MASC task length | | | | | | |
| Short | 14 | 46.67 | 9 | 29.03 | 0 | 0 |
| Long | 16 | 53.33 | 22 | 70.97 | 119 | 100 |

*Note*. $n = 180$. USC = University of Southern California; CSUN = California State University, Northridge; AAPI = Asian American and Pacific Islander; MASC = Masked Affective and Social Cognition.

**Table 2**
*MASC Task—Original (Long) Version With 120 Trials*

| Emotion type | Child face stimuli | Adult face stimuli |
|---|---|---|
| Sad masked | 10 trials (five F, five M) | 10 trials (five F, five M)  |
| Sad unmasked | 10 trials (five F, five M) | 10 trials (five F, five M)  |
| Scared masked | 10 trials (five F, five M) | 10 trials (five F, five M)  |
| Scared unmasked | 10 trials (five F, five M) | 10 trials (five F, five M)  |
| Angry masked | 10 trials (five F, five M) | 10 trials (five F, five M)  |
| Angry unmasked | 10 trials (five F, five M) | 10 trials (five F, five M)  |

*Note*. The RADIATE data set is a comprehensive, publicly available collection of facial expressions from adult models. MASC = Masked Affective and Social Cognition; F = female face stimuli; M = male face stimuli. The adult stimuli were selected and adapted from "The Racially Diverse Affective Expression (RADIATE) Face Stimulus Set," by M. I. Conley, D. V. Dellarco, E. Rubien-Thomas, A. O. Cohen, A. Cervera, N. Tottenham, and B. J. Casey, 2018, *Psychiatry Research*, *270*, p. 1062 (https://doi.org/10.1016/j.psychres.2018.04.066) and "The NimStim Set of Facial Expressions: Judgments From Untrained Research Participants," by N. Tottenham, J. W. Tanaka, A. C. Leon, T. McCarry, M. Nurse, T. A. Hare, D. J. Marcus, A. Westerlund, B. J. Casey, and C. Nelson, 2009, *Psychiatry Research*, *168*(3), p. 13 (https://doi.org/10.1016/j.psychres.2008.05.006). In the public domain. See the online article for the color version of this table.

**Table 3**
*MASC Task—Short Version With 72 Trials*

| Emotion type | Child face stimuli | Adult face stimuli |
|---|---|---|
| Sad masked | Six trials (three F, three M) | Six trials (three F, three M) |
| Sad unmasked | Six trials (three F, three M) | Six trials (three F, three M) |
| Scared masked | Six trials (three F, three M) | Six trials (three F, three M) |
| Scared unmasked | Six trials (three F, three M) | Six trials (three F, three M) |
| Angry masked | Six trials (three F, three M) | Six trials (three F, three M) |
| Angry unmasked | Six trials (three F, three M) | Six trials (three F, three M) |

*Note*. Refer to Table 2 for adult stimuli examples. MASC = Masked Affective and Social Cognition; F = female face stimuli; M = male face stimuli.



maintaining child participants' stillness in the scanner for extended periods. See Table 1 for a breakdown of the number of participants that completed each of these task-length versions.

CSUN participants completed the study using synchronous videoconferencing via the Zoom platform. Participants logged on with a research assistant and completed the informed consent, followed by a computerized battery of demographic and psychosocial questionnaires, including the PSS and the Mask Exposure Questionnaire. They were then given instructions to disable their notifications, confirm their internet speeds, and appropriately share their screen with all videos (i.e., images, names) turned off so that the research assistant could monitor their authentic completion of the task without interfering. The research assistant guided them through the practice and trial runs of the MASC task, after which participants were directed to complete the other measures on their own in Qualtrics after the Zoom had concluded. The full study, including questionnaires, took 1 hr.

This study was approved by both USC's and CSUN's Institutional Review Boards.

## Measures

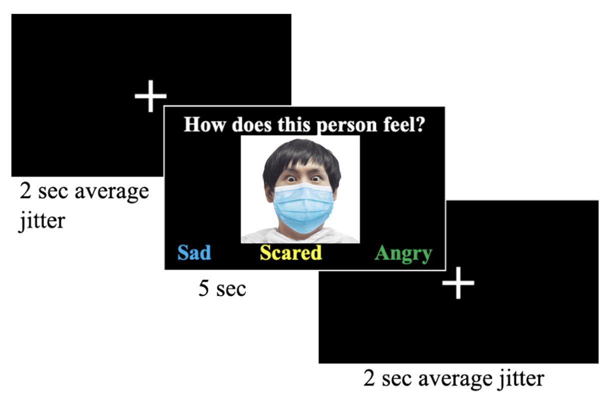
### *MASC Task*

The MASC task comprised of five separate runs. It featured an event-related design, with each run and stimuli presented in a random order. During a trial, participants viewed emotional face stimuli and had 5 s to identify the emotion (sad, scared, or angry) through a button press. Subsequently, they were shown a 2-s averaged jittered fixation (Figure 1). The task had two versions: faces masked in one were unmasked in the other, and vice versa. Each participant completed only one version determined by a counterbalancing order among participants. Before completing the task, participants received thorough training on the appropriate button for each emotion and completed a brief practice run.

In selecting stimuli for the MASC task, we utilized original unmasked facial stimuli from two established databases: the Racially Diverse Affective Expression set (Conley et al., 2018; Tottenham et al., 2009), featuring adult faces, and the Child Affective Facial Expression (CAFE) set (LoBue, 2014; LoBue & Thrasher, 2015), featuring child faces. Each database provided a mean emotion recognition accuracy score for each facial emotion type. To maintain consistency across age group stimuli, we carefully matched each child face stimulus from the CAFE set with an adult face stimulus from the Racially Diverse Affective Expression set, ensuring comparable accuracy scores for each emotion. This matching process ensured that the accuracy scores from these databases were statistically equivalent, both within each emotional category and across the adult and child face stimuli groups. Furthermore, this approach was vital in ensuring that each emotional facial category (sad, scared, or angry) remained statistically comparable based on the original accuracy scores from these databases, even after we digitally added a realistic face mask using Photoshop.

Since the MASC task features minors from a protected database, it is not openly available; however, researchers can request access to the task by contacting the first author for instructions. Upon request, the original CAFE data set will also be accessible via

**Figure 1**
*MASC Task Trial Depiction*




*Note*. This figure illustrates a depiction of each trial of the task, which is identical across all trials of the original long (Table 2) and short versions (Table 3) of the task. The RADIATE data set is a comprehensive, publicly available collection of facial expressions from adult models. MASC = Masked Affective and Social Cognition; RADIATE = Racially Diverse Affective Expression. The adult stimuli were selected and adapted from "The Racially Diverse Affective Expression (RADIATE) Face Stimulus Set," by M. I. Conley, D. V. Dellarco, E. Rubien-Thomas, A. O. Cohen, A. Cervera, N. Tottenham, and B. J. Casey, 2018, *Psychiatry Research, 270*, p. 1062 (https://doi.org/10.1016/j.psychres.2018.04.066) and "The NimStim Set of Facial Expressions: Judgments From Untrained Research Participants," by N. Tottenham, J. W. Tanaka, A. C. Leon, T. McCarry, M. Nurse, T. A. Hare, D. J. Marcus, A. Westerlund, B. J. Casey, and C. Nelson, 2009, *Psychiatry Research, 168*(3), p. 13 (https://doi.org/10.1016/j.psychres.2008.05.006). In the public domain. See the online article for the color version of this figure.

Databrary—a web-based platform dedicated to the storage and dissemination of data within the domains of developmental and learning sciences. This is also why this article only includes examples of adult facial stimuli (Table 2) and not child facial stimuli.

### Mask Exposure Questionnaire

The level of exposure to individuals wearing face masks was assessed using the Mask Exposure Questionnaire that was adapted from Barrick et al. (2021). College students and fathers completed the self-report version of the questionnaire, while fathers completed the parent-report version for their children. The self-report version included five total questions probing responses on mask exposure ("What percentage of the day do you spend in the company of others [coworkers, peers, family members, etc.] wearing face masks?"). These questions were answered as percentages (i.e., 0%, 25%, 50%, 75%, 100%).

### PSS

This 14-item self-report questionnaire measured participants' perceived stress levels over the past month. They rated each item (e.g., "In the last month, how often have you found that you could not cope with all the things that you had to do") on a 5-point Likert scale from 0, indicating *never*, to 4, signifying *very often*. Positively phrased items underwent reverse scoring. An elevated total score on this scale reflected an increased level of perceived stress. Fathers and college students completed the PSS questionnaire during their lab visit. One father and four college students had missing responses in his PSS survey and, therefore, were excluded from analyses that used this measure. No other participant had missing responses for any of the PSS items. The PSS has demonstrated good psychometric validity across a large stratified random U.S. sample (Cohen et al., 1983). Internal consistency was high in our sample of college students (α = .86) and fathers (α = .93).

### BDI-II

This well-validated 21-item self-report survey evaluated participants' depressive symptoms over the prior 2 weeks. Participants were asked to rate each item using a 4-point Likert scale. Symptoms include sadness, pessimism, loss of pleasure, guilty feelings, and agitation (e.g., 0 = *I do not feel sad*; 3 = *I am so sad or unhappy that I cannot stand it*). A higher sum of scores indicated more pronounced symptoms of depression. Fathers completed the BDI questionnaire during their lab visit. None of the fathers had any missing responses for any of the BDI items. The BDI demonstrates good psychometric properties across many studies (Beck et al., 1996), and internal consistency was high in our sample of fathers (α = .89).

## Image Acquisition

Scans were acquired at USC's Dornsife Cognitive Neuroimaging Institute using a 32-channel head coil. Anatomical images were acquired with a T1-weighted magnetization-prepared rapid gradient echo sequence (repetition time/echo time = 2300/2.26, voxel size 1-mm isotropic voxels, flip angle 9°). Functional images were acquired with a T2*-weighted gradient echo sequence (repetition time/echo time = 2000/25 ms, 41 transverse 3-mm slices, flip angle 90°). A T2-weighted volume was acquired for blind review by an independent neuroradiologist, in compliance with the scanning center's policy and USC's Institutional Review Board guidelines.

## Data Analyses

### Behavioral Analyses

Behavioral data analysis was performed using R (R Core Team, 2023). To investigate emotion recognition accuracy among college students, fathers, and their children, we applied a single linear mixed model via R's "lmer()" function, considering emotion type, stimulus age, condition, and participant type as factors. This analysis reflected the complexity of our data, where individual trials (Level 1) were nested within participants (Level 2), allowing for the examination of both fixed and random effects. Specifically, our single model was designed to investigate the roles of emotion type (sad, scared, or angry) and condition (mask vs. unmask) as primary predictors of interest. Stimulus age, which refers to the age of the face presented in each trial (either child face stimuli or adult face stimuli), and participant type (college students, fathers, or children) were included to adjust for potential confounding variables. The effects for Hypothesis 1a and Hypothesis 2a were tested within a single model. For Hypothesis 1a, we focused on the main effect of condition (mask vs. unmask faces) on emotion recognition accuracy, emphasizing the impact of face masks on emotion recognition accuracy. Hypothesis 2a was approached by assessing the main effect of emotion type (specifically, sadness in comparison to anger and fear) on recognition accuracy and investigating the interaction of emotion type with condition to understand how masking influences the recognition of different emotional expressions.

We also ran two additional linear-mixed models to test the effects of emotion, stimulus age, condition, and participant type on correct/incorrect reaction times (RTs). These were set up in the same way as the model described above, only with the outcome variable either being correct/incorrect RTs.

To test the potential impact of mask exposure on emotion recognition (Hypothesis 3a) among college students, fathers, and their children, we conducted separate linear regression analyses using R's "lm()" function for three distinct outcomes: overall accuracy and correct/incorrect RT across all trials. These analyses sought to determine whether the level of mask exposure since the start of the pandemic influenced emotion recognition performance differently across masked versus unmasked conditions. To this end, we included interaction terms between mask exposure and condition in our models, while also controlling for potentially confounding variables such as task length, the interval between questionnaire and task completion, participant type, and the number of days since the start of the study.

### fMRI Preprocessing

fMRI data were processed with Functional Magnetic Resonance Imaging of the Brain (FMRIB) Software Library

(FSL) (S. M. Smith et al., 2004). All functional images were visually inspected for motion artifacts and image quality. fMRI data were processed using the fMRI Expert Analysis Tool v.6.00, part of FMRIB's Software Library (Woolrich et al., 2001). Using FMRIB's Linear Image Registration Tool, T1-weighted images were registered to standard space (Jenkinson et al., 2002). For preprocessing, we employed motion correction using Motion Correction FMRIB's Linear Image Registration Tool (Jenkinson et al., 2002), spatial smoothing using a Gaussian kernel of full width at half maximum 5 mm, grand-mean intensity normalization of the entire 4D data set by a single multiplicative factor, and high-pass temporal filtering (Gaussian-weighted least-squares straight line fitting, with sigma = 50.0 s).

### *fMRI Analyses*

For first-level analyses, we fit two models to each subject's data from each run. In the first model, we included whether each stimulus was a masked or unmasked face as our two variables of interest and set our contrasts for activity related to these: masked>unmasked and unmasked>masked. For the second model, we had six variables in our analysis: one for each emotion masked and each emotion unmasked. For each emotion, we tested whether there was a significant difference in activity between masked and unmasked faces. In each subject, we averaged across all runs for each $z$-stat and then used these $z$-stats for higher level group analysis using FSL's FMRIB's local analysis of mixed effects methods for modeling. More specifically, at the group level, we used FSL's FMRIB's local analysis of mixed effects Stage 1 for mixed-effects modeling. This included both fixed-effects and random-effects components, which allows for the generalization of findings beyond the sample. For thresholding, we applied a voxel-wise threshold of $z > 3.1$ and corrected for multiple comparisons using a cluster-wise correction at $p < .05$ (family-wise error rate).

For region of interest (ROI) analyses, we used anatomical masks from the Harvard-Oxford Cortical Structural Atlas to define the insular cortex and the temporal fusiform cortex. Significant clusters within these ROIs were identified using a voxel-wise threshold of $z > 3.1$ and corrected for multiple comparisons using a cluster-wise correction at $p < .05$ (family-wise error rate).

## Results

The single linear mixed model described in the Behavioral Analyses section, which considered emotion type, stimulus age, condition, and participant type as factors, revealed that stimulus age, participant type, and their interactions with emotion type and condition did not have significant effects in our study. This finding reinforces our focus on emotion type and condition as the critical variables for emotion recognition accuracy. Overall, this single model revealed significant main effects of condition (Hypothesis 1a) and emotion type (Hypothesis 2a), as well as a significant interaction between emotion type and condition (Hypothesis 2a), with no other significant main effects or interactions detected (see detailed results for each of these hypotheses below). Moreover, while the overall accuracy scores for both masked and unmasked trials were slightly lower for child participants compared to fathers and college students (see Table 1), participant type did not elicit a significant main effect or interaction in our model. The main effect of emotion type, condition, and their interaction remained consistent when controlling for task length, version, the number of days between the task administration and questionnaire completion, and the number of days since the start of the study. This re-tested model with covariates also did not elicit significant main effects or interactions with participant type.

The additional linear mixed models tested the effects of emotion type, stimulus age, condition, and participant type on correct/incorrect RTs. We did not pursue follow-up neural analyses for correct/incorrect RTs given that these behavioral models revealed that correct/incorrect RTs were not different for masked and unmasked trials in general or for different facial emotions. These results also remained unchanged when controlling for the task length version, the number of days between the task and questionnaire completion, and the number of days since the start of the study.

### Hypothesis 1a: Accuracy of Overall Masked Versus Unmasked Faces

To test our hypothesis that recognizing masked faces would be more difficult than unmasked faces, we examined the main effect of condition on accuracy from the model described in the Behavioral Analyses section that is also used to answer Hypothesis 2a below. As predicted, this model revealed a significant main effect of condition on accuracy, $\beta = 0.248$, $t = 3.717$, $p < .001$, 95% CI [0.117, 0.380], indicating that participants, including college students, fathers, and children, found masked faces more challenging to recognize than unmasked faces (Figure 2).

### Hypothesis 1b: Neural Differences of Overall Masked Versus Unmasked Faces

To test distinct neural patterns of activation to masked compared to unmasked faces among fathers and their children, we first ran a whole-brain analysis and found one significant cluster of activation in the posterior cingulate gyrus (PCC) for the mask > unmask contrast (Table 4, Figure 3).

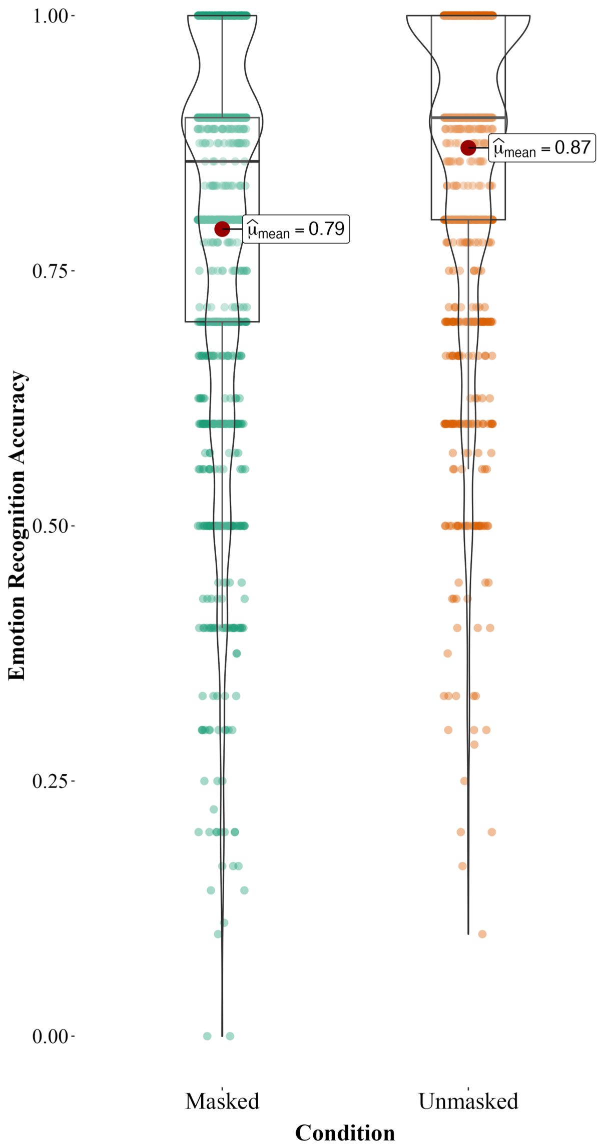
We also ran an ROI analysis with the FG to test whether the neural differences between mask > unmask face emotion recognition are found in regions associated with face processing. This analysis revealed a significant cluster of activation in the FG (Table 5, Figure 4).

We also ran an ROI analysis with the insular cortex to test whether the neural differences between mask > unmask face emotion recognition are found in regions associated with emotion processing. This analysis showed two significant clusters of activation in the insula (Table 6, Figure 5).

Additional exploratory whole-brain and ROI (for the FG and insula) analyses were performed for the mask > unmask contrast when comparing the participant groups (with the father group coded as 1 and the child group coded as 2 in FSL). These analyses revealed no significant group differences, suggesting that the brain activation in the PCC, insular cortex, and FG for mask > unmask faces across these three analyses (whole-brain, insula ROI, and FG ROI) was consistent across our father and child participants.

**Figure 2**

*Emotion Recognition Accuracy for Masked and Unmasked Faces*




*Note*. As hypothesized in Hypothesis 1a, masked faces were significantly more difficult to recognize than unmasked faces ($n = 119$ college students, 30 children, 31 fathers). See the online article for the color version of this figure.

## Hypothesis 2a: Comparing Emotional Accuracy of Masked Versus Unmasked Faces

To test our hypothesis that recognizing sad faces would be the most difficult to recognize in general and even more so when masked, we examined the main effect of emotion type and the interaction between emotion type and condition on accuracy using the single model described in the Behavioral Analyses section and also used in Hypothesis 1a above. Supporting our hypothesis, this analysis using data from college students, fathers, and their children revealed a main effect of emotion on accuracy, $\beta = 0.183$, $t = 3.717$, $p < .001$, 95% CI [0.087, 0.279] (Figure 6). In addition, there was a significant interaction effect between emotion and condition on accuracy, $\beta = -0.095$, $t = -3.049$, $p = .002$, 95% CI [−0.156, −0.034] (Figure 7). This suggests that the difficulty in recognizing emotions on masked faces varies by the type of emotion, with sadness being the most challenging (Figure 7).

To further explore the interaction between emotion type and condition on accuracy for college students, fathers, and their children, post hoc analyses were conducted to examine the simple effects of emotion within each condition. In the masked condition, sad faces were significantly more difficult to recognize compared to scared faces, $\beta = -0.157$, $t(1975) = -14.226$, $p < .001$, and angry faces, $\beta = -0.125$, $t(1975) = -11.346$, $p < .001$, while angry faces were more difficult to recognize compared to scared faces, $\beta = 0.032$, $t(1975) = 2.880$, $p = .011$. In the unmasked condition, sad faces remained more difficult to recognize compared to scared faces, $\beta = -0.055$, $t(1975) = -4.992$, $p < .001$, while no difference was found between sad faces and angry faces, $\beta = -0.009$, $t(1975) = -0.818$, $p = .692$. In addition, unmasked scared faces were recognized significantly more accurately compared to unmasked angry faces, $\beta = 0.046$, $t(1975) = 4.174$, $p < .001$. These findings suggest that the accuracy of recognizing emotions varies depending on both the type of emotion and the condition, where the effect of masking on accuracy was the most pronounced for sad faces.

## Hypothesis 2b: Neural Correlates of Masked Versus Unmasked Emotional Faces

To test distinct neural patterns of activation to masked compared to unmasked faces across the three emotional faces (sad, scared, or angry) among fathers and their children, we ran three separate whole-brain analyses for each emotion and found two significant clusters of activation in the insula and inferior frontal gyrus (IFG) for the sad mask > sad unmasked contrast (Table 7, Figure 8). No significant difference was found in the whole-brain analyses comparing the other two emotions by condition (scared mask > scared unmask and angry mask > angry unmask).

We also ran two ROI analyses with the FG and insular cortex to test whether the neural differences between sad masked > sad unmasked face emotion recognition are found in regions associated with face and emotion processing. Only the analysis with the insular cortex were two significant clusters of activation (Table 8, Figure 9), while no significant clusters were found with the FG.

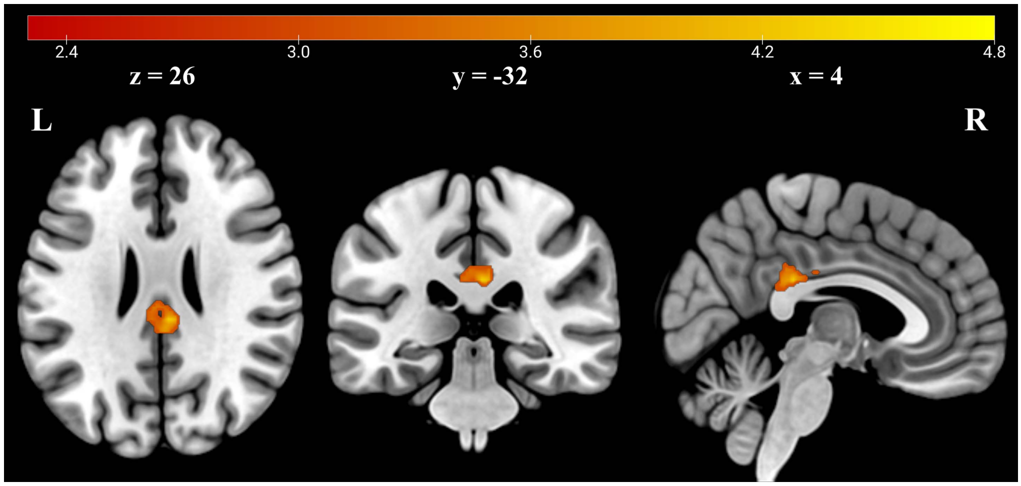
**Table 4**

*Whole-Brain Mask > Unmask: One Significant Activation Cluster in the PCC (Hypothesis 1b)*

| Area | Voxel | MNI coordinate | | | |
|---|---|---|---|---|---|
| | | *Z*-max | *x* | *y* | *z* |
| PCC | 201 | 4.46 | 4 | −32 | 26 |
| PCC | | 3.77 | −4 | 26 | 30 |
| PCC | | 3.61 | 6 | −20 | 30 |

*Note*. All peaks survived a whole-brain search thresholded at a voxel-wise family-wise error rate of 0.05 and a *z*-threshold of 3.1. *x*, *y*, *z* = MNI coordinates in the left–right, anterior–posterior, and inferior–superior dimensions, respectively ($n = 23$ fathers, 18 children). PCC = posterior cingulate gyrus; MNI = Montreal Neurological Institute.

**Figure 3**
*Whole-Brain Mask > Unmask: One Significant Activation Cluster in the Posterior Cingulate Gyrus*




*Note*. This figure displays the sagittal, coronal, and axial views of whole-brain activation for mask > unmask contrast. Analyses are cluster-corrected at $z = 3.1$ ($n = 23$ fathers, 18 children). L = left; R = right. See the online article for the color version of this figure.

Additional exploratory whole-brain and ROI (for the insula) analyses were performed for the sad mask > sad unmask contrast when comparing the participant groups (with the adult group coded as 1 and the child group coded as 2 in FSL). These analyses revealed no significant group differences, suggesting that the brain activation in the insula (from the whole-brain and ROI analyses) and IFG (from the whole-brain analysis) for sad masked > sad unmasked faces was consistent across our father and child participants.

## Hypothesis 3a: Emotion Recognition Accuracy and Mask Exposure

We assessed the impact of mask exposure on emotion recognition through multiple linear regression analyses using R's "lm()" function for three outcomes: accuracy, correct RT, and incorrect RT across all trials, incorporating interaction terms between mask exposure and condition, while controlling for task length, the time between questionnaire and task completion, participant type, and the number of days since the start of the study. Our findings across these models were consistent: There were no significant interactions between mask exposure and condition for any of the outcomes assessed, indicating that mask exposure does not differentially affect emotion recognition accuracy or RTs, irrespective of whether faces are masked or unmasked.

**Table 5**
*FG ROI Mask > Unmask: One Significant Activation Cluster (Hypothesis 1b)*

| Area | Voxel | Z-max | MNI coordinate *x* | *y* | *z* |
|---|---|---|---|---|---|
| Left FG | 13 | 3.49 | −24 | −52 | −16 |
| Left FG | | 3.37 | −24 | −48 | −16 |

*Note.* FG ROI = fusiform gyrus region of interest; MNI = Montreal Neurological Institute.

## Hypothesis 3b: Neural Correlates of Emotion Recognition and Mask Exposure

Using FSL's Featquery tool, we computed the mean percent signal change for each subject ($n = 23$ fathers, 18 children) in the significant activation cluster (Table 4, Figure 3) from the whole-brain mask > unmasked contrast. No significant associations were found between the level of mask exposure a participant had since the start of the pandemic and brain activation for the mask > unmask contrast. We also used FSL's Featquery tool to compute the mean percent signal change for each subject in the significant activation cluster (Table 7, Figure 8) from the whole-brain sad mask > sad unmasked contrast. No significant association was found between the level of mask exposure a participant had since the start of the pandemic and brain activation for the sad mask > sad unmasked contrast. Both of these regression analyses were conducted using R's "lm()" function, and results remained consistent when controlling for the participant type, the task length version, the number of days between the task and questionnaire completion, and the number of days since the start of the study.

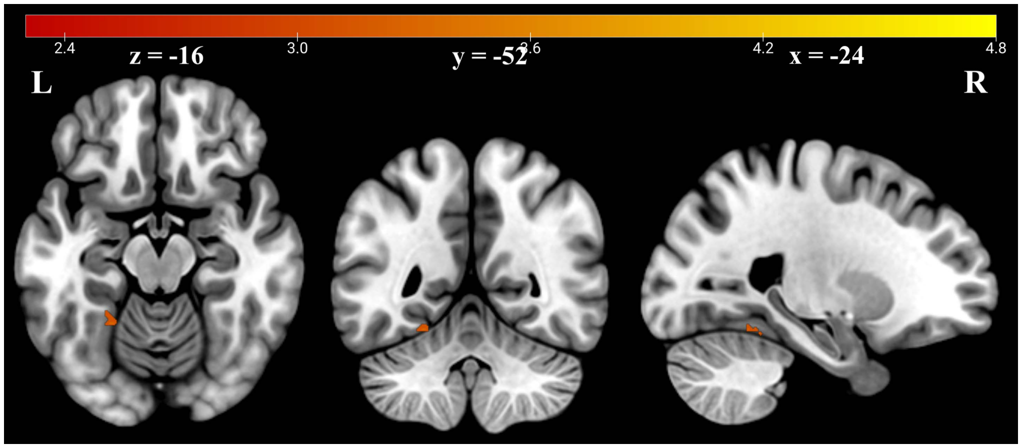
Given the lack of behavioral findings for correct/incorrect RTs across task conditions being linked with mask exposure, we did not pursue follow-up neural analyses for these.

## Hypothesis 4: Neural Correlates of Emotion Recognition of Sad Faces and Links With Depression or Perceived Stress

For fathers, in our analysis of the neural correlates of emotion recognition of sad faces, we used FSL's Featquery tool to compute the mean percent signal change within the significant activation cluster (insula and IFGorb) for sad mask > sad unmasked

**Figure 4**

*Fusiform Gyrus Region of Interest Mask > Unmask: One Significant Activation Cluster*




*Note*. This figure displays the sagittal, coronal, and axial views of fusiform gyrus region of interest analysis for mask > unmask contrast. Analyses are cluster-corrected at $z = 3.1$ ($n = 23$ fathers, 18 children). L = left; R = right. See the online article for the color version of this figure.



contrast, as reported in Table 7 and illustrated in Figure 8. Subsequent linear regression analyses, utilizing R's "lm()" function, revealed that higher levels of depressive symptoms and perceived stress were positively correlated with increased neural activation in the insula and IFGorb during recognition of sad masked > sad unmasked faces ($p < .05$; Figures 10 and 11, respectively). Moreover, when re-running the analysis excluding the father, who appeared to be an outlier with a BDI total score of 33, the results for depressive symptoms predicting neural activation remained consistent. These relationships persisted after adjusting for several variables: task length version, the interval between task and questionnaire completion, and the elapsed time since the start of the study. These findings were only present in our neural analyses, as we did not find significant behavioral links between sad masked accuracy scores and mental health outcomes (depressive symptoms and perceived stress). See Supplemental Material for the behavioral examinations between mental health and emotion recognition among both college students and fathers.

## Discussion

Across three groups of individuals who completed a facial emotion recognition task, we found convergent results suggesting that face masks affect face emotion recognition in ways that appear consistent across age groups and degree of mask exposure. Specifically, at the behavioral level, as expected, facial expression recognition among college students, fathers, and child participants was less accurate when faces were masked, and accuracy was particularly diminished when faces were displaying sad emotions. Our results did not show significant differences in emotion recognition accuracy between children, adolescents, and adults, indicating that emotion recognition capabilities, even under the challenging condition of masked faces, are relatively consistent across these age groups. These results are consistent with earlier research indicating that children can exhibit adultlike emotion recognition skills for certain emotions as early as 6 years old (Lawrence et al., 2015). At the neural level for both fathers and their children, we found activation to masked versus unmasked faces in several regions of the brain linked to social cognition and emotion perception, including whole-brain results for the PCC and ROI results for the FG and the insula. Insular and IFG activation also emerged at the whole-brain level when viewing sad masked versus unmasked faces, whereas no patterns of neural activation differentiated masked versus unmasked fear or anger faces. These results suggest that the attempt to recognize masked faces, particularly sad faces, required more neural activation in parts of the brain associated with mentalizing, empathy, and executive functioning. It is important to note that these results are based on the neural response to viewing masked versus unmasked emotional faces, regardless of whether the emotion was accurately identified. These behavioral and neural findings did not appear to be explained by cohort age or participant group, timing of participation across the pandemic, or mask exposure, suggesting that our findings are not solely reflective of recent experience with masks and can be generalized to understand the implications of face masks when deployed during future public health threats. For fathers, anterior insula and IFG activation when viewing sad masked faces were correlated with symptoms of depression and stress.

**Table 6**

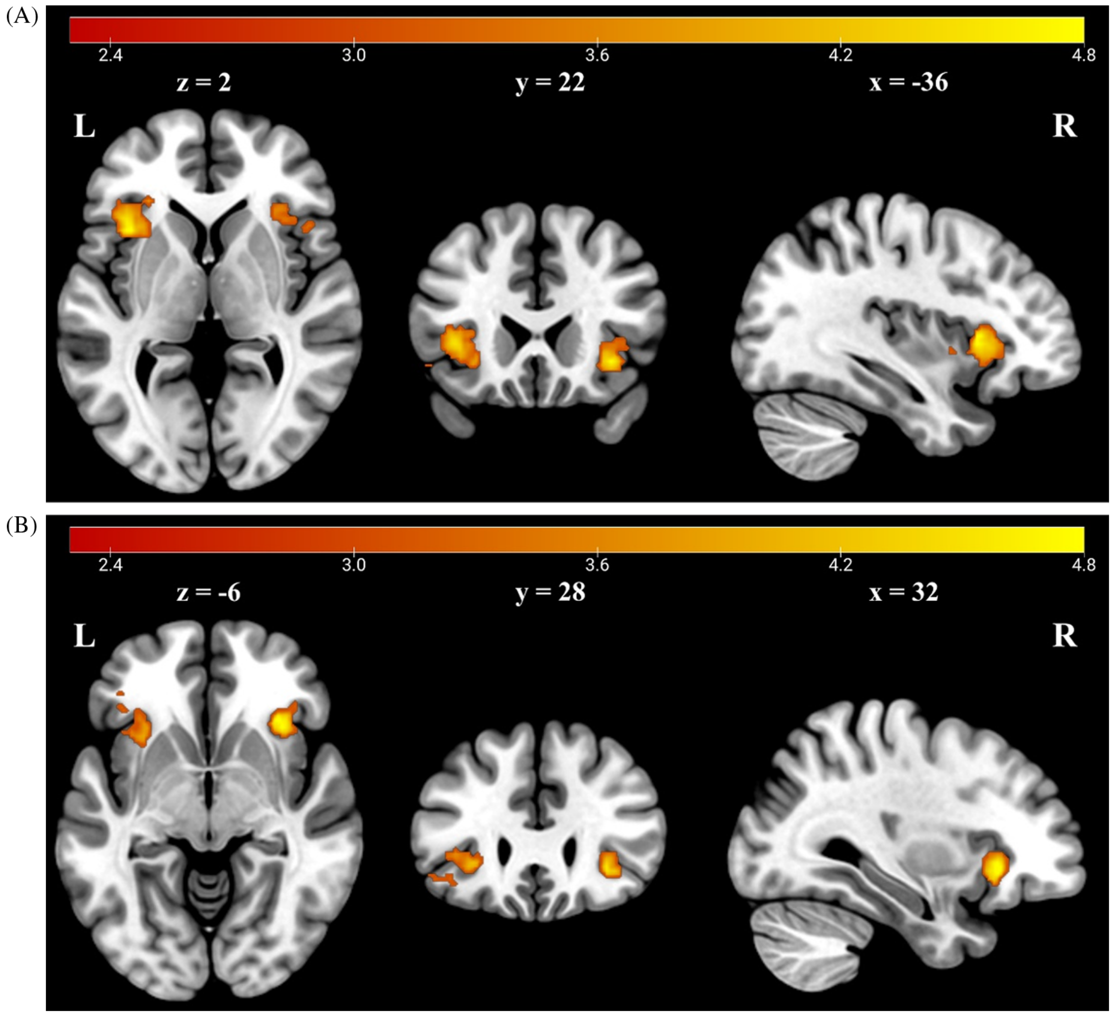
*Insular Cortex ROI Mask > Unmask: Two Significant Activation Cluster (Hypothesis 1b)*

| | | | MNI coordinate | | | |
|---|---|---|---|---|---|---|
| Cluster index | Area | Voxel | *Z*-max | *x* | *y* | *z* |
| A | Left insula | 67 | 4.04 | −36 | 22 | 2 |
| A | Left insula | | 3.73 | −28 | 22 | 4 |
| A | Left insula | | 3.52 | −34 | 16 | 2 |
| B | Right insula | 61 | 4.76 | 32 | 28 | −6 |
| B | Right insula | | 3.77 | 34 | 24 | −2 |

*Note*. ROI = region of interest; MNI = Montreal Neurological Institute.

**Figure 5**

*Insular Cortex Region of Interest Mask > Unmask: Two Significant Activation Cluster*



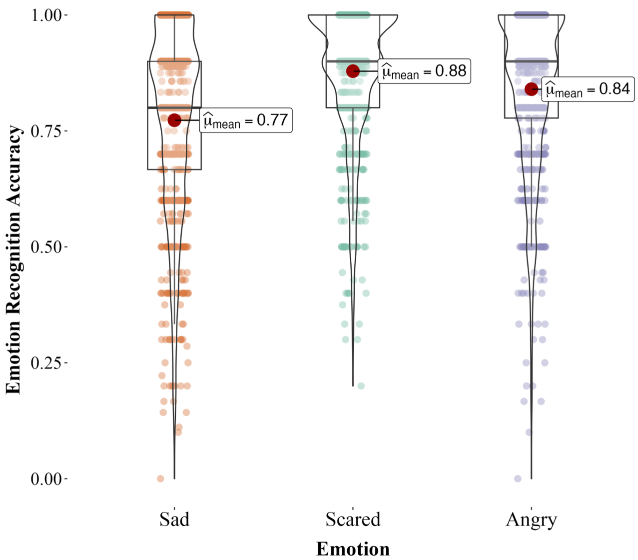

*Note*. This figure displays the sagittal, coronal, and axial views of insular cortex region of interest analysis for mask > unmask contrast. Analyses are cluster-corrected at $z = 3.1$ ($n = 23$ fathers, 18 children). A and B correspond to the significant activation clusters shown in Table 6. L = left; R = right. See the online article for the color version of this figure.



Among college students, fathers, and their children, our findings support our hypothesis that the emotional recognition accuracy of masked faces is lower than unmasked faces. This is consistent with other studies that found reduced emotional accuracy to masked faces in children (Chester et al., 2023; Schneider et al., 2022) and adults (Freud et al., 2020; Rizzato et al., 2022). Since emotion recognition is important to socio-emotional development and to forming and maintaining relationships, it will be important for future studies to examine whether this impaired accuracy is associated with social behavior and children's long-term development. We also found an interaction of emotion and condition such that sad faces were recognized the least accurately when masked. Chester et al. (2023) found mask-wearing to impair emotion recognition in children, with challenges arising in happy, sad, and fearful conditions. Interestingly, they found that children during the pandemic were worse at classifying sadness compared to other emotions irrespective of mask-wearing. In another recent study, Rinck et al. (2022) found mask-wearing to impair the classification of disgust, fear, surprise, sadness, and happiness, but not anger or neutral expressions. Further, they found impairment to be larger in the fearful condition than in the sad condition, which does not track with our findings. Considering the evolutionary salience of threat, it makes sense that anger and fear faces may be particularly rapidly detectable (LeDoux & Daw, 2018; Mobbs et al., 2015; Öhman, 2009; Russell et al., 2003; Tate et al., 2006). On the contrary, less threatening emotions (e.g., sadness) involve less distinctive morphological cues and, thus, may be generally harder to classify (Beaudry et al., 2014; Gantiva et al., 2019). However, it has been theorized that perceptions of others' sadness and distress play a foundational role in empathy (Bandstra et al., 2011) and that exposure to others' sadness might promote more prosocial

**Figure 6**

*Accuracy for Masked and Unmasked Emotional Faces*

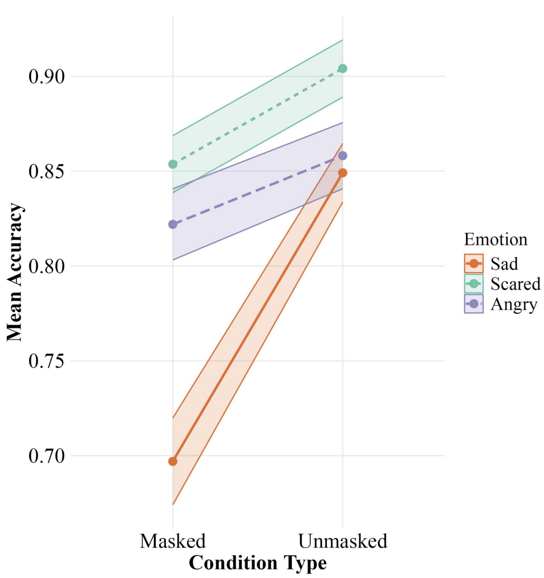



*Note*. As hypothesized in Hypothesis 2a, sad faces were significantly more difficult to recognize, followed by angry and then scared faces ($n$ = 119 college students, 30 children, 31 fathers). See the online article for the color version of this figure.

helping behavior in children (Barnett et al., 1982). Difficulty perceiving sad faces due to masking might affect the development of empathy and the formation of social bonds, but this hypothesis requires greater empirical investigation.

**Figure 7**

*Significant Interaction Between Emotion and Condition on Recognition Accuracy*




*Note*. As hypothesized in Hypothesis 2a, the effect of masking on accuracy was most pronounced for sad faces ($n$ = 119 college students, 30 children, 31 fathers). See the online article for the color version of this figure.

As hypothesized, for fathers and their children, brain analyses revealed greater activation in the PCC (whole-brain analyses), FG (ROI analyses), and insula (ROI analyses) for overall masked faces compared to unmasked faces. This is consistent with prior work showing that the PCC is activated during the recognition of emotional stimuli, including emotional words (Maddock et al., 2003) and emotional facial expressions (Morris et al., 1998; Sprengelmeyer et al., 1998). These results also align with the FG's well-documented role in being sensitive to facial features and their emotional expressions (Kawasaki et al., 2012; McCarthy et al., 1997). Our findings demonstrate that even when facial features are partially obscured by masks, the FG is actively engaged, potentially compensating for the reduced visual information. This suggests a heightened demand for this facial recognition system to extract emotional cues from the available facial features. A recent study revealed that participants showed different approaches to processing masked versus unmasked faces (Freud et al., 2020)—they used more holistic processing of unmasked faces (processing the face as an entire unit) and more localized processing of masked faces (processing the face feature by feature). This might explain the heightened brain activation during the recognition of masked emotional faces.

Additional whole-brain analysis showed insular and IFG activation when children and their fathers viewed sad masked versus sad unmasked faces. Extant work has found the insula is essential in integrating cognitive and affective networks (Gasquoine, 2014; Gu et al., 2013; Kurth et al., 2010; Pavuluri & May, 2015) and has linked insula activity and performance on emotion recognition tasks in various samples (Blom et al., 2015; Klepzig et al., 2023; Motomura et al., 2019). In patients with tumors in the insula, Motomura et al. (2019) found improved classification of angry faces during intraoperative direct electrical stimulation to the anterior insula and better recognition of sad faces postlesioning of the anterior insula. In addition, the IFG has been shown to provoke activity within the insular cortex in response to emotional stimuli, supporting major theories on the integration of multiple systems to generate appraisal and response to emotional stimuli (Jabbi & Keysers, 2008; Krumhuber et al., 2023). The anterior insula has been implicated in empathy and affective congruence, suggesting that this region might be an important target for future research on emotion recognition and empathy in masked conditions.

As expected, we also found that fathers with greater levels of stress and depressive symptoms showed greater activation in the insula and the IFG when recognizing sad masked faces compared to sad unmasked faces, suggesting that they may have needed to recruit more neural resources to achieve accuracy. This aligns with prior work showing that more depressive symptoms are associated with greater activation in the IFG during a cognitively demanding task (Waizman et al., 2023). Previous research has also found increased anterior insula activity and connectivity in response to sad faces in individuals with various mood disorders, including depression (Arnone et al., 2012; Blom et al., 2015; Westlund Schreiner et al., 2022). The anterior insula's role in emotional face recognition may be related to interoceptive processes, as the region is implicated in one's own emotional states. In the case of depression, anterior insula functioning appears to be related to behaviorally observed negativity bias (Guha et al., 2021). Higher anterior insula activity

**Table 7**

*Whole-Brain Sad Mask > Sad Unmask: Two Significant Activation Clusters in Insula and IFGorb (Hypothesis 2b)*

| | | | MNI coordinate | | | |
|---|---|---|---|---|---|---|
| Cluster index | Area | Voxel | *Z*-max | *x* | *y* | *z* |
| A | Left insula | 566 | 5.21 | −38 | 16 | 6 |
| A | Left insula | | 4.26 | −32 | 26 | −4 |
| A | Left insula | | 4.12 | −30 | 14 | 0 |
| A | Left insula | | 4.11 | −30 | 20 | −8 |
| A | Left insula | | 3.91 | −32 | 10 | −2 |
| B | IFGorb | 210 | 3.89 | −50 | 24 | −8 |
| B | Right insula | | 5.22 | 32 | 26 | −6 |
| B | Right insula | | 4.89 | 34 | 22 | −6 |
| B | Right insula | | 3.62 | 44 | 20 | 0 |

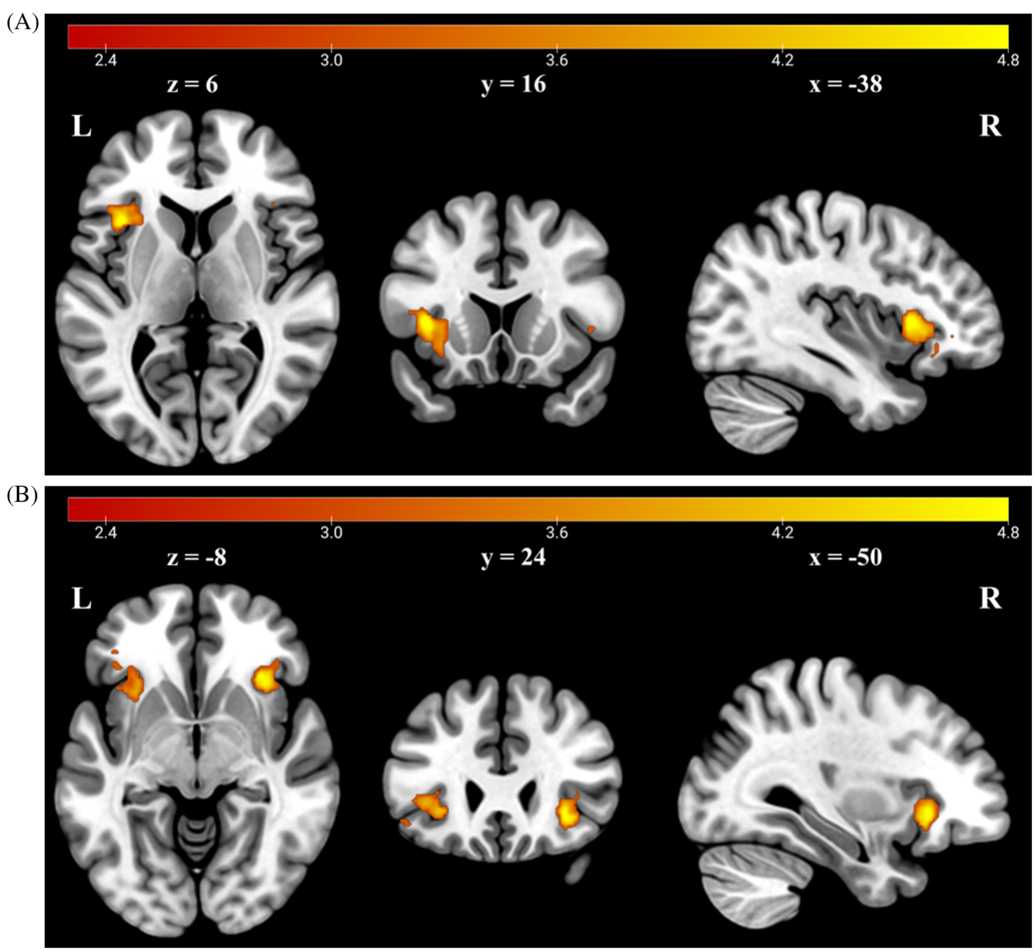
*Note*. MNI = Montreal Neurological Institute; IFGorb = inferior frontal gyrus orbital part.

in individuals with higher depression symptomatology may reflect an increased reliance on negativity bias to decipher the emotional state of ambiguous facial stimuli such as those covered with a mask.

This study has several limitations. Though the overall sample is fairly large, the neuroimaging sample is small, which meant we were underpowered to test interaction effects with the neural data. This smaller fMRI sample impacted our ability to detect effects and required us to combine fathers and their children in a single analysis. However, upon comparing participants in our analyses, we observed no significant differences related to participant type or age group, leading us to conclude that combining the samples is appropriate for our analysis. Although the nested relationship between fathers and their children further complicates our analyses, we controlled for this relationship statistically, and results remained consistent. The study timing also may limit

**Figure 8**

*Whole-Brain Sad Mask > Sad Unmask: Two Significant Activation Clusters in the Insula and Inferior Frontal Gyrus Orbital Part*




*Note*. This figure displays the sagittal, coronal, and axial views of whole-brain activation for sad mask > sad unmask contrast. Analyses are cluster-corrected at $z = 3.1$ ($n = 23$ fathers, 18 children). L = left; R = right. A and B correspond to the significant activation clusters shown in Table 7. See the online article for the color version of this figure.

**Table 8**
*Insular Cortex ROI Sad Mask > Sad Unmask: Two Significant Activation Cluster (Hypothesis 2b)*

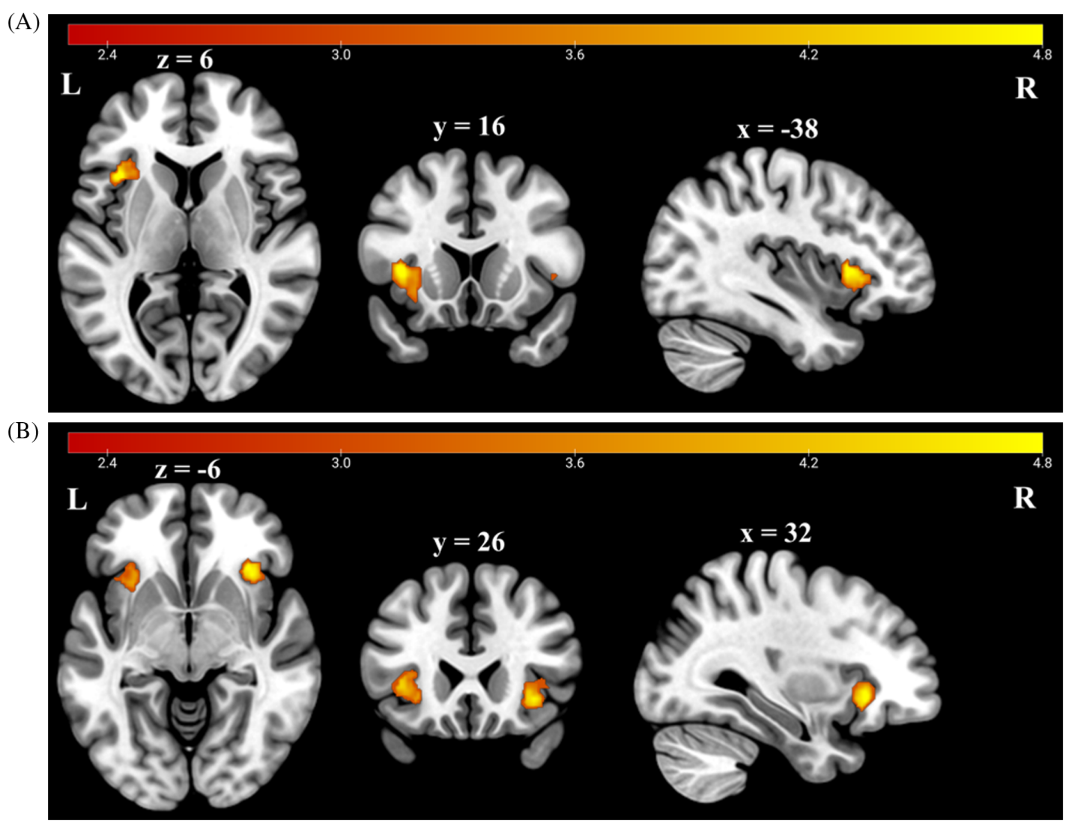
| | | | MNI coordinate | | | |
|---|---|---|---|---|---|---|
| Cluster index | Area | Voxel | Z-max | *x* | *y* | *z* |
| A | Left insula | 404 | 5.21 | −38 | 16 | 6 |
| A | Left insula | | 4.26 | −32 | 26 | −4 |
| A | Left insula | | 4.12 | −30 | 14 | 0 |
| A | Left insula | | 4.11 | −30 | 20 | −8 |
| A | Left insula | | 3.91 | −32 | 10 | −2 |
| A | Left insula | | 3.81 | −32 | 24 | 6 |
| B | Right insula | 193 | 5.22 | 32 | 26 | −6 |
| B | Right insula | | 4.89 | 34 | 22 | −6 |
| B | Right insula | | 3.62 | 44 | 20 | 0 |

*Note.* ROI = region of interest; MNI = Montreal Neurological Institute.

generalizability, as data were collected between 2022 and 2023 when mask exposure was lower than during the pandemic's peak and continuing to decline. Although our analyses revealed that neither mask exposure nor the timing of participation across the pandemic significantly influenced our behavioral and neural findings for emotion recognition of masked or unmasked faces. This suggests that our results may be generalizable to understand the implications of face masks regardless of recent experience. In addition, our study was conducted with participants residing in Los Angeles, which may limit the generalizability of the findings. Although Los Angeles is diverse, our sample size and design did not allow for an in-depth analysis of cultural variations. Future research should explore whether similar results are found in different regions and cultural settings to determine the broader applicability of these findings. In addition to sample and timing limitations, the stimulus characteristics limit some of our inferences from the study. Static facial stimuli, though standardizable, lack ecological validity. In real-world social situations, body language, voice tone, and other stimuli are available to inform emotion processing, even when masks obscure parts of the face.

Despite these limitations, this study represents a novel step in understanding the impact of masking on emotion processing in children and adults and lays the foundation for understanding the implications of widespread masking during the COVID-19

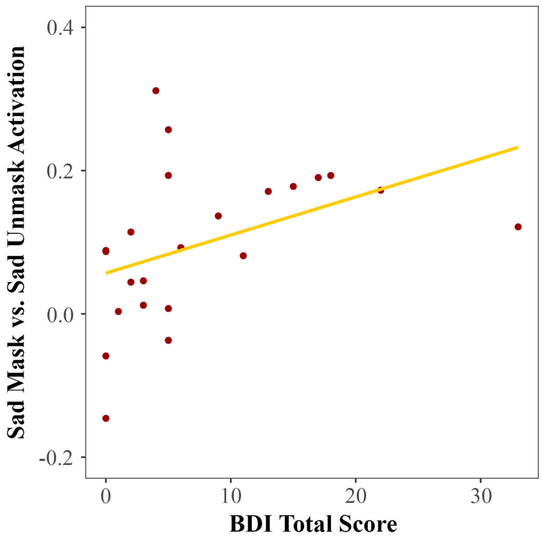
**Figure 9**
*Insular Cortex Region of Interest Sad Mask > Sad Unmask: Two Significant Activation Cluster*




*Note.* This figure displays the sagittal, coronal, and axial views of insular cortex region of interest analysis for mask > unmask contrast. Analyses are cluster-corrected at z = 3.1 (*n* = 23 fathers, 18 children). L = left; R = right. A and B correspond to the significant activation clusters shown in Table 8. See the online article for the color version of this figure.

**Figure 10**

*Higher Levels of Depressive Symptoms Associated With Greater Activation in Insula and Inferior Frontal Gyrus Orbital Partfor Sad Mask > Sad Unmask*




*Note.* This scatterplot illustrates the positive correlation between depressive symptoms and neural activation in the insula and inferior frontal gyrus orbital part for the sad masked > sad unmasked contrast ($n = 23$ fathers). A robustness check was conducted by omitting one potential outlier, and the results remained unchanged. BDI = Beck Depression Inventory–II. See the online article for the color version of this figure.

pandemic. The study contributes to the literature as the largest comprehensive behavioral and neural investigation of facial emotion recognition in masked and unmasked faces using a structured task that other investigators can adopt. It uses multimodal data from two sites and three distinct age groups. We sampled from the greater Los Angeles area, where mask-wearing rates have been higher than in many parts of the country and focused on groups with higher-than-usual exposure to daily mask-wearing (school-aged children and their parents, and college students). We used standardized facial stimuli that represent a diverse set of ethnicities and ages, and we sought to extend the same level of standardization by carefully matching the child and adult facial stimuli based on emotional accuracy scores.

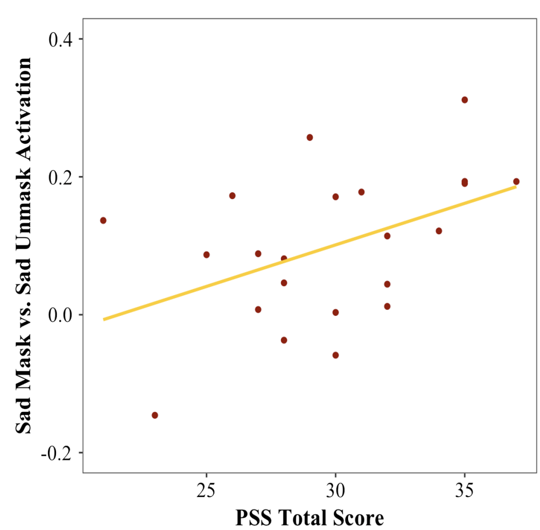
Although our findings shed light on masked face processing using static stimuli, more work is needed to understand how masks affect real-world social behavior in naturalistic contexts. Given that emotions are complex forms of expression integrating highly dynamic sensory processes (Keltner et al., 2019; Krumhuber et al., 2023), future work should explore how limiting one modality of emotional expression (e.g., by covering the face) prompts the recruitment of other sensory processing systems to recognize emotions. While our study found no significant differences in RTs for correct or incorrect trials between masked and unmasked conditions, future work should investigate whether these RTs might result from different underlying neural processes. In addition, culture is known to modulate the expression and perception of emotion (Chen et al., 2024). Although our study included a diverse sample from Los Angeles, it was not designed to assess cross-cultural differences in the perception of masked emotions. Future research should compare different locations nationally and internationally to assess whether deficits in classifying emotions under masks are consistent across varying cultural contexts.

Widespread face masking in Westernized countries starting in 2020 represents a natural experiment that warrants further study. In particular, understanding how social interactions may be constrained or altered when individuals are masked can help us to understand the trade-offs between re-opening workplaces and schools versus remaining virtual. This research can also help us to understand one influence on changing social dynamics in the wake of the global pandemic. Longitudinal studies of children's emotion recognition and social development are especially important, particularly neuroimaging studies that investigate the functional development of mentalizing networks and social perception regions in conjunction with masking experience.

In conclusion, our study provides valuable insights into the challenges of emotion recognition with face masks in three samples across development using multimethod approaches. While acknowledging the critical role of masks in safeguarding public health during pandemics, we found that masks, particularly when concealing sad expressions, pose unique challenges for behavioral recognition and neural processing. This work underscores the need for strategies to mitigate these challenges and serves as a basis for further research into the interplay between facial masking and emotion recognition and their implications for social and mental well-being.

**Figure 11**

*Higher Levels of Perceived Stress Associated With Greater Activation in Insula and Inferior Frontal Gyrus Orbital Part for Sad Mask > Sad Unmask*




*Note.* This scatterplot illustrates the positive correlation between perceived stress levels and neural activation in the insula and inferior frontal gyrus orbital part for the sad masked > sad unmasked contrast ($n = 22$ fathers). PSS = Perceived Stress Scale. See the online article for the color version of this figure.

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