Face masks influence emotion judgments of facial expressions:

A drift-diffusion model

W. Craig Williams*, Eisha Haque[†], Becky Mai[†], & Vinod Venkatraman

Center for Applied Research in Decision Making,

Fox School of Business, Temple University

*Address correspondence to:

W. Craig Williams

Center for Applied Research in Decision Making

Fox School of Business, Temple University, Philadelphia, PA 19122

wcraig.williams@temple.edu

[†]These authors contributed equally to this work and their order was determined alphabetically.

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Pre-registrations will be made publicly available on AsPredicted prior to publication. Data from experiments, analysis scripts, plots, and task code will be made available on GitHub: <https://github.com/wcwill/>.

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Abstract

Face masks slow the spread of SARS-CoV-2, but it has been unknown how masks might reshape social interaction. One important possibility is that masks may influence how individuals communicate emotion through facial expressions. Here, we clarify to what extent—and how—masks influence *facial emotion* communication, through drift-diffusion modeling (DDM). Over two independent pre-registered studies, conducted three and six months into the COVID-19 pandemic, online participants judged expressions of 6 emotions (anger, disgust, fear, happiness, sadness, surprise) with the lower or upper face “masked” or unmasked. Participants in Study 1 ($N = 228$) correctly identified expressions above chance with lower face masks. However, they were less likely—and slower—to correctly identify these expressions relative to without masks, and they accumulated evidence for emotion more slowly—via decreased drift rate in DDM. This pattern replicated and intensified three months later in Study 2 ($N = 264$). These data could inform critical interventions to promote continued mask wearing by addressing concerns about how masks impact communication.

Keywords: COVID-19, decision making, emotion, face perception, social interaction

Since the COVID-19 pandemic began, people around the world started wearing face masks as a simple and effective way to reduce the spread of the SARS-CoV-2 virus. Face masks decrease the amount of coronavirus RNA that individuals exhale (Leung et al., 2020) and mandating masks reduces community spread of the SARS-CoV-2 virus (Lyu & Wehby, 2020) (Mitze, Kosfeld, Rode, & Wälde, 2020). Masks continue to play an essential role in the global response to COVID-19 even as vaccines are being distributed (Paltiel, Schwartz, Zheng, & Walensky, 2020), and individuals will likely wear masks in response to future pandemics and seasonal influenza viruses, coronaviruses, and rhinoviruses. Given their significance for public health, sudden prevalence, and likely staying power, it is critical to better understand how face masks may impact human social interaction worldwide (Betsch et al., 2020).

One important way that face masks may reshape social life is by influencing how individuals communicate emotion through facial expressions. Facial expressions are one of several key channels for conveying emotions to other people (Barrett, Mesquita, & Gendron, 2011). Clear facial emotion communication tracks important outcomes across real-world contexts, from patients experiencing better outcomes after interacting with their doctors (Lorié, Reinero, Phillips, Zhang, & Riess, 2017), to customers perceiving employees as more warm and reporting greater intention to buy from them (Wang, Mao, Li, & Liu, 2017). More broadly, emotion communication scaffolds social life by facilitating cooperation (Zaki & Williams, 2013), learning (Olsson et al., 2016), and the development of new relationships (Williams, Morelli, Ong, & Zaki, 2018). Masking facial expressions could therefore have wide-ranging consequences for emotion communication and social interaction across diverse settings (Spitzer, 2020).

Face masks could impact multiple distinct aspects of how individuals perceive facial expressions. Masks may influence how accurately and how quickly individuals judge facial expressions, and underlying these decision outcomes, masks may further influence how rapidly individuals accumulate evidence for making emotion judgments. For example, individuals may fail to identify masked disgust expressions, and they may be slower to identify these expressions, because they accumulate evidence for disgust more slowly with masks. This evidence accumulation—or *drift rate*—is a key decision-making process that explains differences in both response accuracy and response speed. When individuals accumulate evidence more rapidly, they respond more accurately and give faster correct responses, whereas when individuals accumulate evidence less rapidly, they respond less accurately and give slower correct responses (Ratcliff & McKoon, 2008). Drift rates are estimated using diffusion modeling techniques such as drift-diffusion modeling (DDM) (Ratcliff, Smith, Brown, & McKoon, 2016) (Wiecki, Sofer, & Frank, 2013) (Johnson, Hopwood, Cesario, & Pleskac, 2017), which has been used to model diverse types of judgments (Smith & Krajbich, 2018), such as financial (Amasino, Sullivan, Kranton, & Huettel, 2019), dietary (Sullivan & Huettel, 2021), altruistic (Teoh, Yao, Cunningham, & Hutcherson, 2020), punitive (Son, Bhandari, & FeldmanHall, 2019), and recently emotion judgments (Roberts & Hutcherson, 2019).

Face masks could impact how individuals identify emotion expressions in general or how they identify certain expressions in particular. On the one hand, individuals gaze at both the eyes and the mouth of diverse expressions (Jack, Blais, Scheepers, Schyns, & Caldara, 2009) (Schurgin et al., 2015) (Neta et al., 2017). On the other hand, individuals gaze at these features—and use information from them (Smith, Cottrell, Gosselin, & Schyns, 2005) (Nusseck, Cunningham, Wallraven, & Bühlhoff, 2008) (Wegrzyn, Vogt, Kireclioglu, Schneider, & Kissler,

2017)—to varying degrees for different expressions. Concealing the lower or upper face—as with face masks or sunglasses—could thus have idiosyncratic consequences for emotion communication. For instance, masks may interfere with how individuals communicate disgust, but not anger, whereas sunglasses may interfere with communicating anger, but not disgust.

Research clarifying how face masks impact emotion communication could inform interventions to promote mask wearing and facilitate global behavioral change in response to COVID-19 and future pandemics (Bavel et al., 2020). Many individuals report not wearing masks because they experience difficulties communicating when masked (Bakhit et al., 2021) (Mheidly, Fares, Zalzale, & Fares, 2020). However, little research has examined to what extent—and how—masks may influence facial emotion communication. Such research may assist interventions aimed at promoting mask wearing in at least two ways. First, it could educate the public about the degree to which masks influence emotion communication. Second, by revealing the underlying mechanism, it could generate model-based strategies that individuals may use to compensate for the effects of masks.

Here, we examined how masks influence emotion expression judgments over two independent pre-registered studies (Study 1 $N = 228$, Study 2 $N = 264$) conducted three and six months into the COVID-19 pandemic. Participants in both studies completed 6 rounds of viewing and rating facial expressions of 6 emotions (anger, disgust, fear, happiness, sadness, surprise; within-subjects) with 3 types of “face masks” (lower, upper, none; within-subjects). On each round, participants made binary ratings as quickly and accurately as possible of whether or not faces showed one of the 6 emotions (**Figure 1a**). Lower “masks” blacked-out faces from the nose down, whereas upper “masks” blacked-out faces from the nose up (**Figure 2**).

This design enabled us to test whether individuals are (i) less likely to judge expressions correctly—via increased errors, (ii) slower to judge expressions correctly—via slower response times, and (iii) slower to accumulate evidence for emotion judgments—via slower drift rates, when judging expressions with masks versus without them (**Figure 1b**). Critically, by manipulating both lower and upper “masks,” we tested whether masks shape emotion judgments by hiding the mouth in particular, or by simply hiding one half of the face. Finally, by conducting Study 2 three months after Study 1, we were able to test whether the effects of masks diminished as individuals interacted more often with other individuals wearing masks, or whether these effects intensified as they interacted with other individuals less often due to social distancing.

(a)

This round, you will rate whether each face looks **disgusted** or not.

If the face looks **disgusted**, press the letter **Q**. If the face does **NOT** look disgusted, press the letter **P**.

Please respond as quickly and accurately as possible when you see each face appear.

(b)

Figure 1. Emotion judgment task and modeling. (a) Sample task instructions. On each round, participants rated whether or not faces showed one of six emotions (anger, disgust, fear, happiness, sadness, surprise) by pressing a key with either their left or right hand (key pairing randomly assigned by participant). Emotion rating type was randomized across task rounds. (b) Hypothetical drift-diffusion model (DDM). This example shows how rapidly participants accumulate evidence for disgust—as indicated by *drift rates*—from disgusted expressions without masks (v_{none}) versus disgusted expressions with lower masks (v_{lower}). Here, steeper slopes reflect faster evidence accumulation—via more positive drift rates.

Figure 2. Sample expressions with masks. Participants viewed facial expressions of 6 emotions (anger, disgust, fear, happiness, sadness, surprise) with 3 types of “face masks” (lower, none, upper). On each round, participants viewed one of six blocks of faces, with blocks fully counterbalanced for emotion expressions and masks, and faces presented in random order. Every block included one expression from each actor with all three types of masks. Participants in Study 2 viewed an ethnically diverse set of female and male East Asian, Black, Hispanic, and white faces drawn from the Racially Diverse Affective Expression (RADIATE) face stimulus set.

Method

Participants

We recruited participants from Amazon Mechanical Turk for two studies conducted in July and October of 2020 (Study 1 total $N = 300$; Study 2 total $N = 300$). These target total sample sizes were pre-registered prior to collecting any data and pre-determined to generate high statistical power with the repeated measures designs, as informed by power analysis of Study 1 prior to Study 2 (see *Power Analysis* under *Data Analysis*). Data collection ceased once we reached these target total sample sizes. We collected 300 complete responses for Study 1 and 290 complete responses for Study 2. Ten incomplete responses to Study 2 were not recorded. Participants were at least 18 years of age (Study 1: $M = 38.3$ years, $SD = 11.5$; Study 2: $M = 37.3$ years, $SD = 11.0$) and they represented a diverse sample in terms of gender (Study 1: 37.7% female; Study 2: 42.8% female) and ethnicity (Study 1: 22.4% non-white; Study 2: 29.2% non-white). We obtained informed consent from participants according with the Temple University Institutional Review Board.

Procedure and Design

Experiments were developed using the jsPsych JavaScript library (de Leeuw, 2015), which measures response times with high precision and reliability comparable to lab-based software (de Leeuw & Motz, 2016) (Hilbig, 2016). Participants completed six rounds of viewing and rating facial expressions of 6 emotions (anger, disgust, fear, happiness, sadness, surprise; within-subjects) with 3 types of “face masks” (lower, upper, none; within-subjects). Participants viewed a different block of faces each round, counterbalanced for the 6 expressions and 3 masks, and rated whether or not faces expressed one of 6 emotions (anger, disgust, fear, happiness,

sadness, surprise; within-subjects). Blocks of faces and types of emotion ratings were randomized across task rounds and participants viewed faces in random order within each round. On each trial, participants viewed a centered fixation cross for 1000 milliseconds, followed by a face with the tip of the nose centered to the preceding fixation cross. Participants rated whether or not each face expressed a given emotion as quickly and accurately as possible by pressing a key with either their left or right hand (**Figure 1a**). Response options were randomly assigned to the left and right hands for each participant. Prior to starting each round of trials, participants were required to pass instruction checks confirming that they knew which emotion they would rate that round and which key corresponded to each response option.

Stimuli

Six blocks of faces were fully counterbalanced for emotion expressions and “face masks” such that participants made all 6 ratings of all 6 expressions with all 3 masks. We selected 36 white female and male actors from the Radboud Faces Database for Study 1 (Langner et al., 2010) and 18 East Asian, Black, Hispanic, and white female and male actors from the Racially Diverse Affective Expression (RADIATE) face stimulus set for Study 2 (Conley et al., 2018). To create lower and upper masks, faces were split in half at the tip of the nose and either the lower half or the upper half of each face image was blacked-out (**Figure 2**). This generated 648 total faces for Study 1 and 324 total faces for Study 2. Each block of faces included one expression from each actor, with all three masks, for 108 faces per block in Study 1 and 54 faces per block in Study 2. Critically, this counterbalanced blocks of faces for expressions and masks, as well as for actors, actors’ gender, and in Study 2, actors’ ethnicity.

Data Analysis

Power Analysis

To determine a target total sample size that would generate high statistical power in Study 2, we conducted a power analysis of Study 1 in G*Power (Faul, Erdfelder, Buchner, & Lang, 2009). Here, we examined participants' emotion ratings on trials where they could have made false negative errors—that is, trials where they viewed expressions congruent with the emotion they rated. For each expression, we selected the mask vs. no mask contrast with the largest effect (lower: disgust, happiness, sadness, surprise; upper: anger, fear) and we calculated odds ratios by taking the exponent of the corresponding *b* values (**Table 1**). Power analysis revealed that a target final $N = 230$ would achieve 95% power for detecting five of these six effects in two-tailed binomial logistic regression models ($\alpha = .05$). We pre-registered this target final sample size and a target total $N = 300$ based on the rate of failed attention checks in Study 1.

Exclusions

For both studies, we pre-registered that we would exclude participants who failed attention checks, resulting in the exclusion of 72 participants from Study 1 (final $N = 228$) and 26 participants from Study 2 (final $N = 264$). We also pre-registered that we would exclude trials with response times less than 100 milliseconds (Whelan, 2008). Hierarchical drift-diffusion models required further excluding trials with response times in the top 0.5% of all trials (>9303 milliseconds in Study 1 and >5737 milliseconds in Study 2).

Statistics

We pre-registered the following analyses testing whether masks influenced how accurately participants rated expressions, how quickly they rated expressions, and how rapidly they accumulated evidence for rating expressions. Analyses of false negative errors examined trials where participants viewed emotion expressions congruent with the emotion they judged that round—that is, trials where participants either correctly identified expressions (e.g. rating disgust expressions as disgusted) or failed to correctly identify them (e.g. rating disgust expressions incorrectly as not disgusted). We analyzed emotion ratings, response times, and drift rates, for all 6 congruent pairings of expressions and judgments. In contrast, analyses of false positive errors examined trials where participants viewed expressions incongruent with the emotion they judged that round—that is, trials where participants either correctly distinguished between expressions (e.g. rating disgust expressions as not angry) or misidentified them (e.g. rating disgust expressions incorrectly as angry). We analyzed emotion ratings for all 30 incongruent pairings of expressions and judgments. When masks influenced these ratings, we further analyzed response times for that incongruent pairing, and when masks influenced these response times, we further analyzed drift rates for that pairing.

Analyses of emotion ratings tested the main effects of masks, collapsing across expressions, and within each type of emotion expression. Emotion ratings were analyzed through two-tailed mixed effect binomial logistic regression models including participant intercepts as random effects. Analyses of response times tested the interaction between masks and rating accuracy, as well as the simple main effects of masks for correct and incorrect ratings, collapsing across expressions and within each expression type. Response times were analyzed through two-tailed mixed effect linear regression models including participant intercepts as

random effects. Response times were log-transformed to correct for their inherent skewness and flipped (i.e. multiplied by -1) for plotting purposes. Regression coefficients and 95% confidence intervals were estimated through bootstrapped regression analyses using 1,000 iterations (Preacher & Hayes, 2004).

Analyses of drift rates tested the main effects of masks, across expressions overall and within each expression type (**Figure 1b**). Drift rates were estimated through hierarchical Bayesian estimation of drift-diffusion model parameters (HDDM) using Markov chain Monte Carlo (MCMC) sampling methods (Ratcliff et al., 2016) (Wiecki et al., 2013) (Johnson et al., 2017). These models estimated posterior distributions of regression coefficients for the effects of masks over drift rate (v) parameters and included participant intercepts as random effects. In addition, these models also estimated parameters for response bias (z), boundary separation (a), non-decision time (t), and inter-trial variability in these parameters and drift rate (sz , sa , st , sv) as covariates. Parameter coefficients and 95% credible intervals were estimated by drawing 5,000 samples from posterior distributions and discarding the initial 200 ‘burn-in’ samples. Bayesian hypothesis testing compared the posterior distributions of drift rate coefficients across mask conditions and estimated the probability that they differed from each other and the probability that they differed from 0.

Transparency and Openness

We pre-registered target sample sizes, exclusion criteria, task design, and analyses for both experiments. We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study. Pre-registrations will be made publicly available

on AsPredicted prior to publication. Data from experiments, analysis scripts, plots, and task code will be made available on GitHub: <https://github.com/wcwill/>.

Results

Over two sets of pre-registered analyses, we tested the influence of masks over how accurately participants rated expressions, how quickly they made these ratings, and how rapidly they accumulated evidence for emotion from expressions. Here, we report analyses of false negative errors—that is, trials where participants viewed expressions congruent to the emotion they judged, and could have failed to correctly identify expressions (see *Appendix B* for analyses of false positive errors). Analyses of emotion ratings compared how accurately participants identified expressions with lower and upper masks versus chance (50%), versus expressions without masks, and versus one another, as increasingly conservative tests. Response time analyses compared how quickly participants made correct and incorrect ratings of expressions with lower and upper masks, versus expressions without masks and versus each other. Analyses of drift rates compared how rapidly participants accumulated evidence for emotion from expressions with lower and upper masks versus null drift rate (0), versus expressions without masks, and versus one another, as increasingly conservative tests.

False Negative Errors

Failing to Identify Expressions with Lower Masks

Emotion Ratings. Participants correctly identified all 6 types of expressions above chance with lower masks in Study 1. However, participants were less accurate identifying expressions with lower masks, versus expressions without masks, collapsing across emotions

(**Figure 3a, Table 1**). Specifically, they were less accurate identifying expressions of disgust, fear, happiness, sadness, and surprise, but not anger, with lower masks relative to without masks (**Figure 4**).

Emotion Rating RTs. Participants were slower to correctly identify expressions with lower masks than without masks, collapsing across emotions, as revealed by an interaction between mask conditions and emotion ratings (**Figure 3b**). In particular, participants were slower to correctly identify expressions of disgust, happiness, sadness, and surprise, with lower masks versus without masks, and as shown by interactions for disgusted, happy, and surprised expressions (**Figure 5, Table 2**). Conversely, they were faster to correctly identify fearful expressions with lower masks, versus without masks, and they showed no significant difference for angry expressions.

Emotion Rating Drift Rates. Participants accumulated evidence towards identifying all 6 types of expressions correctly with lower masks, all $P(\text{lower mask} < 0) < .0001$. However, consistent with their decreased accuracy and speed, participants accumulated evidence more slowly from expressions with lower masks than from expressions without masks, collapsing across emotions (**Figure 3c**). Specifically, they accumulated evidence for disgust, fear, happiness, sadness, and surprise, more slowly from expressions with lower masks versus without masks, all $P(\text{lower mask} > \text{none}) < .0001$; but not anger (**Figure 6**).

Figure 3. Correct judgments vs. false negative errors. Effects of masks over (a,d) emotion ratings whereby higher mean values reflect increased accuracy, (b,e) emotion rating RTs (flipped; lower masks vs. no masks) whereby higher mean values reflect faster responses, and (c,f) drift rate coefficients whereby higher coefficient values reflect increased drift rate towards correct judgments. Error bars depict 95% confidence intervals (a,b,d,e) and 95% credible intervals (c,f).

Figure 4. Mean emotion ratings by masks: correct ratings vs. false negative errors rating (a) angry, (b) disgusted, (c) fearful, (d) happy, (e) sad, and (f) surprised faces (Study 1). Higher mean values reflect increased accuracy and decreased false negative errors. Error bars depict 95% confidence intervals.

Table 1						
<i>Failing to identify expressions: Face mask effects over emotion ratings.</i>						
---	Study 1			Study 2		
---	<i>b</i>	<i>CI</i>	<i>z</i>	<i>b</i>	<i>CI</i>	<i>z</i>
All faces	---	---	---	---	---	---
Lower mask > none	-.76	[-.92, -.60]	-9.16***	-1.11	[-1.37, -.86]	-8.68***
Lower mask > upper	-.036	[-.21, .14]	-.42	-.50	[-.77, -.23]	-3.57***
Upper mask > none	-.73	[-.89, -.56]	-8.72***	-.60	[-.86, -.35]	-4.70***
Angry faces	---	---	---	---	---	---
Lower mask > none	.083	[-.28, .44]	.45	-.16	[-.48, .14]	-1.05
Lower mask > upper	1.62	[1.29, 1.95]	9.43***	1.21	[.94, 1.48]	8.83***
Upper mask > none	-1.55	[-1.93, -1.18]	-8.34***	-1.39	[-1.67, -1.12]	-9.86***
Disgusted faces	---	---	---	---	---	---
Lower mask > none	-1.59	[-1.83, -1.35]	-12.96***	-1.64	[-2.16, -1.17]	-6.38***
Lower mask > upper	-1.39	[-1.66, -1.12]	-11.15***	-1.33	[-1.84, -.79]	-4.74***
Upper mask > none	-.18	[-.44, .061]	-1.45	-.29	[-.76, .21]	-1.11
Fearful faces	---	---	---	---	---	---
Lower mask > none	-.63	[-.88, -.37]	-4.89***	-.75	[-1.36, -.15]	-2.61**
Lower mask > upper	.84	[.59, 1.07]	6.85***	.35	[-.23, .91]	1.17
Upper mask > none	-1.47	[-1.73, -1.21]	-11.44***	-1.12	[-1.67, -.53]	-3.93***
Happy faces	---	---	---	---	---	---
Lower mask > none	-.76	[-1.07, -.46]	-4.84***	-1.20	[-1.70, -.72]	-4.57***
Lower mask > upper	-.54	[-.85, -.24]	-3.36***	-1.11	[-1.61, -.61]	-4.15***
Upper mask > none	-.23	[-.54, .10]	-1.40	-.062	[-.58, .44]	-.23
Sad faces	---	---	---	---	---	---
Lower mask > none	-1.24	[-1.56, -.92]	-7.70***	-1.65	[-2.09, -1.16]	-6.89***
Lower mask > upper	-.81	[-1.10, -.50]	-5.11***	-1.33	[-1.90, -.78]	-5.01***
Upper mask > none	-.43	[-.74, -.088]	-2.63**	-.29	[-.76, .23]	-1.21
Surprised faces	---	---	---	---	---	---
Lower mask > none	-1.10	[-1.42, -.78]	-6.54***	-1.78	[-2.50, -.98]	-4.76***
Upper mask > none	-.21	[-.53, .092]	-1.28	-1.13	[-2.00, -.32]	-2.66**
Upper mask > none	-.88	[-1.20, -.53]	-5.24***	-.67	[-1.39, .078]	-1.80
<i>Note: * $p < .05$. ** $p < .01$. *** $p < .001$. $CI = .95$.</i>

Figure 5. Mean emotion rating RTs (flipped) by masks and emotion ratings: correct rating RTs vs. false negative error RTs rating (a) angry, (b) disgusted, (c) fearful, (d) happy, (e) sad, and (f) surprised faces, with lower masks vs. no masks (Study 1). Higher mean values reflect faster responses. Error bars depict 95% confidence intervals.

Table 2						
<i>Failing to identify expressions: Lower face mask effects over emotion rating RTs.</i>						
---	Study 1			Study 2		
---	<i>b</i>	<i>CI</i>	<i>t</i>	<i>b</i>	<i>CI</i>	<i>t</i>
All faces	---	---	---	---	---	---
Face mask * rating	-.026	[-.040, -.011]	-3.22**	-.010	[-.029, .01]	-1.10
Correct: lower > none	-.026	[-.034, -.019]	-7.07***	-.032	[-.040, -.024]	-7.97***
Incorrect: lower > none	.00	[-.017, .016]	-.015	-.016	[-.037, .004]	-1.64
Angry faces	---	---	---	---	---	---
Face mask * rating	.024	[-.014, .059]	1.28	.045	[-.012, .10]	1.48
Correct: lower > none	.006	[-.012, .023]	.66	.017	[-.001, .036]	1.69
Incorrect: lower > none	-.023	[-.060, .016]	-1.21	-.048	[-.012, .026]	-1.24
Disgusted faces	---	---	---	---	---	---
Face mask * rating	-.10	[-.15, -.062]	-5.11***	-.047	[-.090, -.003]	-2.04*
Correct: lower > none	-.066	[-.084, -.049]	-7.73***	-.066	[-.091, -.039]	-5.22***
Incorrect: lower > none	.029	[-.012, .072]	1.43	-.016	[-.049, .020]	-.84
Fearful faces	---	---	---	---	---	---
Face mask * rating	.012	[-.023, .047]	.65	.022	[-.021, .061]	1.00
Correct: lower > none	.024	[.005, .040]	2.72**	-.019	[-.033, -.002]	-2.39*
Incorrect: lower > none	.009	[-.025, .044]	.49	-.035	[-.088, .021]	-1.22
Happy faces	---	---	---	---	---	---
Face mask * rating	-.053	[-.093, -.008]	-2.50*	-.048	[-.093, -.005]	-2.27*
Correct: lower > none	-.051	[-.066, -.038]	-7.37***	-.072	[-.086, -.058]	-9.63***
Incorrect: lower > none	-.007	[-.061, .051]	-.25	-.018	[-.060, .026]	-.79
Sad faces	---	---	---	---	---	---
Face mask * rating	.00	[-.039, .037]	-.050	-.031	[-.075, .012]	-1.34
Correct: lower > none	-.054	[-.070, -.039]	-6.71***	-.061	[-.079, -.044]	-6.17***
Incorrect: lower > none	-.062	[-.10, -.017]	-3.01**	-.034	[-.084, .013]	-1.39
Surprised faces	---	---	---	---	---	---
Face mask * rating	-.074	[-.11, -.035]	-3.60***	-.015	[-.057, .026]	-.68
Correct: lower > none	-.030	[-.046, -.015]	-3.56***	-.028	[-.044, -.009]	-3.18**
Incorrect: lower > none	.033	[-.016, .083]	1.35	-.023	[-.071, .029]	-.90
<i>Note: * $p < .05$. ** $p < .01$. *** $p < .001$. $CI = .95$.</i>

Figure 6. Drift rate coefficients by masks: drift rate towards correct judgments vs. false negative errors rating (a) angry, (b) disgusted, (c) fearful, (d) happy, (e) sad, and (f) surprised faces (Study 1). Higher coefficient values reflect increased drift rate towards correct judgments and decreased drift rate towards false negative errors. Error bars depict 95% credible intervals.

Failing to Identify Expressions with Upper Masks

Emotion Ratings. Participants in Study 1 correctly identified expressions of disgust, happiness, sadness, and surprise, above chance with upper masks, but not anger or fear.

However, participants were less accurate identifying expressions with upper masks than without masks, across emotions overall (**Figure 3a, Table 1**). Here, they were less accurate identifying expressions of anger, fear, sadness, and surprise, but not disgust or happiness (**Figure 4**).

Emotion Rating RTs. Participants did not significantly differ in their speed for correctly identifying expressions with upper masks, in comparison to without masks, collapsing across emotions (**Table 3**). Nevertheless, they were slower to correctly identify angry and surprised expressions—but no other expressions—with upper masks in comparison to without masks, and as revealed by an interaction between masks and emotion ratings for surprised expressions (**Figure 7**).

Emotion Rating Drift Rates. Participants accumulated evidence towards correctly identifying all 6 types of expressions with upper masks, all $P(\text{upper mask} < 0) < .0001$. However, consistent with their decreased speed and accuracy, participants accumulated evidence more slowly from expressions with upper masks, versus without masks, across emotions overall (**Figure 3c**). Specifically, they accumulated evidence for anger, fear, sadness, surprise, all $P(\text{upper mask} > \text{none}) < .0001$; disgust, $P(\text{upper mask} > \text{none}) = .0029$; and happiness, $P(\text{upper mask} > \text{none}) = .029$; more slowly with upper masks relative to without masks (**Figure 6**).

Figure 7. Mean emotion rating RTs (flipped) by masks and emotion ratings: correct rating RTs vs. false negative error RTs rating (a) angry, (b) disgusted, (c) fearful, (d) happy, (e) sad, and (f) surprised faces, with upper masks vs. no masks (Study 1). Higher mean values reflect faster responses. Error bars depict 95% confidence intervals.

Table 3						
<i>Failing to identify expressions: Upper face mask effects over emotion rating RTs.</i>						
---	Study 1			Study 2		
---	<i>b</i>	<i>CI</i>	<i>t</i>	<i>b</i>	<i>CI</i>	<i>t</i>
All faces	---	---	---	---	---	---
Face mask * rating	-.003	[-.020, .013]	-.42	-.009	[-.027, .010]	-.94
Correct: upper > none	-.006	[-.013, .002]	-1.53	-.021	[-.028, -.014]	-5.42***
Incorrect: upper > none	-.001	[-.019, .017]	-.14	-.006	[-.027, .014]	-.60
Angry faces	---	---	---	---	---	---
Face mask * rating	-.013	[-.048, .019]	-.77	-.014	[-.064, .035]	-.56
Correct: upper > none	-.033	[-.052, -.014]	-3.41***	-.037	[-.057, -.015]	-3.56***
Incorrect: upper > none	-.018	[-.050, .010]	-1.20	-.038	[-.083, .013]	-1.51
Disgusted faces	---	---	---	---	---	---
Face mask * rating	-.051	[-.092, -.012]	-2.57*	.035	[-.005, .075]	1.70
Correct: upper > none	-.006	[-.021, .007]	-.89	.005	[-.011, .021]	.56
Incorrect: upper > none	.043	[-.008, .094]	1.69	-.037	[-.08, .008]	-1.68
Fearful faces	---	---	---	---	---	---
Face mask * rating	-.026	[-.065, .015]	-1.31	-.021	[-.065, .022]	-.94
Correct: upper > none	-.011	[-.029, .008]	-1.10	-.060	[-.078, -.043]	-6.62**
Incorrect: upper > none	.006	[-.030, .045]	.32	-.021	[-.064, .018]	-.99
Happy faces	---	---	---	---	---	---
Face mask * rating	-.029	[-.070, .011]	-1.40	-.038	[-.083, .007]	-1.61
Correct: upper > none	-.003	[-.016, .010]	-.42	-.030	[-.043, -.015]	-4.08***
Incorrect: upper > none	.026	[-.028, .083]	.92	-.006	[-.056, .040]	-.24
Sad faces	---	---	---	---	---	---
Face mask * rating	.017	[-.021, .053]	.90	-.033	[-.080, .012]	-1.48
Correct: upper > none	-.009	[-.023, .006]	-1.25	-.014	[-.029, .001]	-1.79
Incorrect: upper > none	-.029	[-.073, .012]	-1.33	.032	[-.022, .088]	1.11
Surprised faces	---	---	---	---	---	---
Face mask * rating	-.057	[-.10, -.017]	-2.64**	-.033	[-.077, .011]	-1.44
Correct: upper > none	-.025	[-.040, -.010]	-3.05**	-.013	[-.029, .002]	-1.62
Incorrect: upper > none	.017	[-.042, .075]	.58	.017	[-.039, .069]	.60
<i>Note: * $p < .05$. ** $p < .01$. *** $p < .001$. $CI = .95$.</i>						

Failing to Identify Expressions with Lower versus Upper Masks

Emotion Ratings. Collapsing across emotions, participants did not significantly differ in their accuracy identifying expressions with lower versus upper masks in Study 1 (**Table 1**). Nonetheless, participants were less accurate identifying disgusted, happy, and sad expressions with lower masks versus with upper masks (**Figure 4**). By contrast, they were less accurate identifying angry and fearful expressions with upper masks as compared to lower masks.

Emotion Rating RTs. Participants were slower to correctly identify expressions with lower masks versus with upper masks, across emotions overall, and as indicated by an interaction (**Table 4**). In particular, they were slower to correctly identify disgusted, happy, and sad expressions with lower masks, versus with upper masks, and as revealed by an interaction for disgusted expressions (**Figure 8**). Conversely, they were slower to correctly identify angry and fearful expressions with upper masks in comparison to with lower masks.

Emotion Rating Drift Rates. Participants also accumulated evidence more slowly from expressions with lower masks, as compared to upper masks, collapsing across emotions, $P(\text{lower mask} > \text{upper mask}) = .017$ (**Figure 3c**). Specifically, they accumulated evidence more slowly from expressions of disgust, happiness, sadness, all $P(\text{lower mask} > \text{upper mask}) < .0001$; and surprise, $P(\text{lower mask} > \text{upper mask}) = .0052$; with lower masks relative to upper masks (**Figure 6**). By contrast, participants accumulated evidence for anger and fear more slowly from expressions with upper masks as compared to lower masks, both $P(\text{upper mask} > \text{lower mask}) < .0001$.

Figure 8. Mean emotion rating RTs (flipped) by masks and emotion ratings: correct rating RTs vs. false negative error RTs rating (a) angry, (b) disgusted, (c) fearful, (d) happy, (e) sad, and (f) surprised faces, with lower masks vs. upper masks (Study 1). Higher mean values reflect faster responses. Error bars depict 95% confidence intervals.

Table 4						
<i>Failing to identify expressions: Lower vs. upper face mask effects over emotion rating RTs.</i>						
---	Study 1			Study 2		
---	<i>b</i>	<i>CI</i>	<i>t</i>	<i>b</i>	<i>CI</i>	<i>t</i>
All faces	---	---	---	---	---	---
Face mask * rating	-.022	[-.036, -.007]	-2.79**	-.002	[-.018, .016]	-.23
Correct: lower > upper	-.019	[-.027, -.012]	-4.94***	-.011	[-.019, -.003]	-2.62**
Incorrect: lower > upper	.003	[-.011, .018]	.41	-.008	[-.023, .009]	-.96
Angry faces	---	---	---	---	---	---
Face mask * rating	.029	[-.008, .066]	1.63	.060	[.014, .10]	2.67**
Correct: lower > upper	.033	[.015, .051]	3.40***	.055	[.038, .073]	6.03***
Incorrect: lower > upper	.004	[-.038, .027]	-.23	.005	[-.041, .057]	.22
Disgusted faces	---	---	---	---	---	---
Face mask * rating	-.043	[-.079, -.006]	-2.25*	-.091	[-.14, -.048]	-4.28***
Correct: lower > upper	-.057	[-.075, -.039]	-6.35***	-.077	[-.10, -.052]	-6.21***
Incorrect: lower > upper	-.017	[-.055, .023]	-.86	.013	[-.019, .044]	.78
Fearful faces	---	---	---	---	---	---
Face mask * rating	.029	[-.008, .063]	1.61	.046	[.0052, .084]	2.19*
Correct: lower > upper	.030	[.012, .049]	3.22**	.044	[.025, .063]	4.74***
Incorrect: lower > upper	.004	[-.029, .034]	.23	-.006	[-.048, .035]	-.27
Happy faces	---	---	---	---	---	---
Face mask * rating	-.031	[-.070, .010]	-1.46	-.006	[-.049, .040]	-.24
Correct: lower > upper	-.046	[-.061, -.032]	-6.28***	-.040	[-.057, -.023]	-4.59***
Incorrect: lower > upper	-.013	[-.066, .038]	-.48	-.031	[-.078, .013]	-1.35
Sad faces	---	---	---	---	---	---
Face mask * rating	-.016	[-.051, .021]	-.89	-.007	[-.048, .035]	-.32
Correct: lower > upper	-.040	[-.057, -.022]	-4.58***	-.045	[-.064, -.025]	-4.63***
Incorrect: lower > upper	-.024	[-.058, .010]	-1.37	-.042	[-.083, -.001]	-1.93
Surprised faces	---	---	---	---	---	---
Face mask * rating	.001	[-.043, .038]	-.055	.005	[-.033, .043]	.25
Correct: lower > upper	.00	[-.017, .019]	.098	-.016	[-.033, .003]	-1.85
Incorrect: lower > upper	.00	[-.043, .044]	.015	-.026	[-.069, .015]	-1.28
<i>Note: * $p < .05$. ** $p < .01$. *** $p < .001$. $CI = .95$.</i>						

False Negative Errors: Summary

Participants in Study 1 rated expressions above chance overall with both lower and upper masks and they accumulated evidence towards correctly identifying masked expressions.

However, participants were worse at perceiving expressions of disgust, happiness, sadness, and surprise with lower masks relative to without masks, and worse at perceiving expressions of anger and surprise with upper masks as compared to without masks—as indicated by decreased accuracy, speed, and rate of evidence accumulation. Similarly, participants were also worse at judging disgusted, happy, and sad expressions with lower versus upper masks, and worse at judging angry and fearful expressions with upper versus lower masks—via reduced accuracy, speed, and rate of evidence accumulation.

Participants in Study 2 closely replicated this pattern three months later when judging an ethnically diverse set of facial expressions (*Appendix A*). They also rated expressions above chance with lower and upper masks, and accumulated evidence in favor of correctly identifying these expressions. Nonetheless, they too were worse at judging all expressions except anger with lower masks as compared to without masks, and worse at judging expressions of anger and fear with upper masks relative to without masks—as reflected by decreased accuracy, speed, and drift rate. These participants were likewise worse at perceiving disgusted, happy, and sad expressions with lower versus upper masks, and worse at perceiving angry expressions with upper versus lower masks—via reduced accuracy, speed, and drift rate.

False Negative Errors Over the COVID-19 Pandemic

These influences of masks intensified over three months, as participants showed stronger effects of lower masks—but not upper masks—at six months into the COVID-19 pandemic in Study 2,

versus three months in Study 1. Collapsing across emotions, participants were slower to accumulate evidence for emotion from expressions with lower masks—relative to expressions without masks—in Study 2 ($b = -.65$, 95% CI $[-.71, -.59]$; **Figure 3f**) versus in Study 1 ($b = -.38$, 95% CI $[-.41, -.34]$; **Figure 3c**), $P(\text{lower mask}_2 - \text{none}_2 > \text{lower mask}_1 - \text{none}_1) < .0001$. This pattern held for expressions of fear (Study 2: $b = -.42$, 95% CI $[-.57, -.27]$; Study 1: $b = -.21$, 95% CI $[-.31, -.11]$; $P(\text{lower mask}_2 - \text{none}_2 > \text{lower mask}_1 - \text{none}_1) = .0075$), happiness (Study 2: $b = -1.12$, 95% CI $[-1.28, -.95]$; Study 1: $b = -.61$, 95% CI $[-.72, -.50]$; $P(\text{lower mask}_2 - \text{none}_2 > \text{lower mask}_1 - \text{none}_1) < .0001$), sadness (Study 2: $b = -1.12$, 95% CI $[-1.27, -.97]$; Study 1: $b = -.71$, 95% CI $[-.82, -.60]$; $P(\text{lower mask}_2 - \text{none}_2 > \text{lower mask}_1 - \text{none}_1) < .0001$), and surprise (Study 2: $b = -.91$, 95% CI $[-1.07, -.76]$; Study 1: $b = -.64$, 95% CI $[-.75, -.53]$; $P(\text{lower mask}_2 - \text{none}_2 > \text{lower mask}_1 - \text{none}_1) = .0019$); but not anger or disgust (**Figure 4, Figure A3**).

Conversely, participants showed no significant differences across studies in evidence accumulation for expressions with upper masks—relative to expressions without masks—for any of the six emotions, or when collapsing across emotions.

False Positive Errors

Masks also influenced how participants distinguished between expressions (*Appendix B*). With lower masks, relative to without masks, participants in Study 1 were more likely to misperceive surprised expressions as angry, sad expressions as surprised, and all expressions except fear as happy—as reflected by decreased accuracy, speed, and rate of evidence accumulation. However, they were also less likely to misperceive fearful expressions as disgusted or sad with lower masks as compared to without masks—via increased accuracy, speed, and drift rate. With upper masks, in comparison to without masks, participants were less likely to misperceive surprised

expressions as fearful, fearful expressions as surprised, disgusted expressions as angry, angry expressions as disgusted, and angry and sad expressions as fearful—via increased accuracy, speed, and drift rate.

Study 2 replicated many of these effects after three months with participants judging an ethnically diverse set of faces. With lower masks, as compared to without masks, participants were more likely to misjudge surprised expressions as angry, angry expressions as surprised, sad expressions as happy, happy expressions as sad, and surprised expressions as sad—as shown by decreased accuracy, speed, and rate of evidence accumulation. However, they were less likely to misjudge angry expressions as sad, and disgusted expressions as surprised, with lower masks relative to without masks—via increased accuracy, speed, and drift rate. With upper masks, in comparison to without masks, participants were less likely to misjudge surprised expressions as fearful, fearful expressions as surprised, and angry expressions as disgusted, sad expressions as surprised or fearful—via increased accuracy, speed, and evidence accumulation rate.

Discussion

Across two pre-registered studies collected three and six months into the COVID-19 pandemic, we tested whether masks influence how individuals perceive facial expressions of emotion by comparing (i) how accurately individuals judge expressions, (ii) how quickly they make these judgments, and (iii) how rapidly they accumulate evidence for emotion, with and without masks. Participants identified expressions above chance with lower “face masks” and they accumulated evidence towards judging these expressions correctly. However, participants were also less likely—and slower—to identify expressions correctly with lower masks, and they accumulated evidence of emotion more slowly, as compared to without masks. This pattern replicated and

intensified in a new sample collected three months later. In sum, individuals perceive facial expressions relatively accurately with masks, and yet masks influence communication by slowing the rate at which individuals accumulate evidence of emotion.

By clarifying how masks impact facial emotion communication, these findings could inform interventions to promote mask wearing. Face masks slow the spread of the SARS-CoV-2 virus (Howard et al., 2021) and they continue to play a role in the global response to COVID-19 (Paltiel et al., 2020), as they likely will for future pandemics and seasonal viruses. However, many individuals have reported not wearing masks due to experiencing difficulties with communication (Bakhit et al., 2021) (Mheidly et al., 2020). On the one hand, these data show that masks do influence how individuals perceive facial expressions, helping to explain why individuals experience difficulties at times. On the other hand, these data also show that individuals perceive facial expressions well above chance with masks, even without any real-world context, suggesting that concerns over communicating emotion while masked may be overstated. These findings could be used in interventions that acknowledge the challenges individuals may experience, but that also highlight how effectively individuals still communicate emotion when masked (Hornik et al., 2021).

This research examines emotion perception as a process that unfolds over time and points to settings in which individuals may misperceive masked expressions (Kirkland & Cunningham, 2012). Participants were not only less accurate, but also slower at identifying masked expressions, because masks slowed the speed with which they accumulated evidence for emotion. Here, by applying drift-diffusion modeling (DDM) (Ratcliff et al., 2016) (Wiecki et al., 2013) (Johnson et al., 2017), this work extends recent evidence that individuals judge expressions less accurately with face masks (Carbon, 2020) (Ruba & Pollak, 2020) (Marini,

Ansani, Paglieri, Caruana, & Viola, 2021), by demonstrating that masks also influence the speed of these judgments, and revealing evidence accumulation as the mechanism underlying both of these effects. This suggests that individuals may struggle to perceive masked expressions under time pressure, such as when they quickly pass other people in the grocery store or other brief interactions. Future studies could examine how face masks may impact consumer behavior in these time-sensitive settings.

By showing that masks influence evidence accumulation, this work further predicts that individuals may communicate more effectively by simply taking their time. Face masks influence how individuals judge expressions by slowing the rate at which they accumulate emotion evidence. However, individuals require varying *amounts* of evidence to reach these decisions, depending upon whether they prioritize speed or accuracy when judging emotion (Lindquist, Barrett, Bliss-Moreau, & Russell, 2006). When individuals deprioritize speed, they require more evidence—by increasing the *boundary separation* between evidence thresholds for each response option—and they make fewer errors as a result (Ratcliff & McKoon, 2008) (Zhang & Rowe, 2014). Here, deprioritizing speed should give individuals time to accumulate more evidence and judge masked expressions more accurately, and thus compensate for masks slowing evidence accumulation. Future investigations could test this model-based prediction by explicitly instructing participants to prioritize either accuracy or speed when judging masked expressions. If successful, this data-driven ‘take your time’ strategy could also be used in interventions to promote mask wearing.

Masks influenced how individuals perceived facial expressions to a greater extent at six versus three months into the COVID-19 pandemic. Participants were slower to accumulate evidence of emotion from expressions with lower masks, relative to expressions without masks,

at six months into the pandemic as compared to an independent sample collected three months earlier. However, these groups did not significantly differ in how rapidly they accumulated evidence from expressions with upper masks. This suggests that the effects of masks may have intensified as individuals socially distanced and interacted face-to-face less often (Barrick, Thornton, & Tamir, 2021). How might individuals have adapted to seeing fewer faces in general and fewer lower faces in particular? One possibility is they may have relied more upon context, for example by using more information from individuals' body postures and their surroundings (Barrett et al., 2011) (Aviezer, Ensenberg, & Hassin, 2017).

These data also generate fundamental insights into how individuals infer emotion from facial expressions. When directly compared, lower masks interfered more with how participants perceived disgusted, happy, and sad expressions, whereas upper masks interfered more with how they perceived angry expressions. Here, upper masks provide an important control by clarifying when lower masks influence emotion judgments by hiding the mouth in particular, versus when they simply conceal half of the face. In combination with DDM, this design builds on prior research examining how individuals gaze towards the eyes and mouth of different expressions (Jack et al., 2009) (Schurgin et al., 2015) (Neta et al., 2017), and how they use information from these features when judging them (Smith et al., 2005) (Nusseck et al., 2008) (Wegrzyn et al., 2017), by further examining how rapidly they accumulate evidence for emotion judgments from these features.

More broadly, this work contributes to theoretical perspectives on communication and social influence by highlighting evidence accumulation as a key mechanism linking social perception and decision-making. Communicative theories propose that individuals produce facial expressions to influence others' inferences and behavior (Crivelli & Fridlund, 2018)

(Martin, Rychlowska, Wood, & Niedenthal, 2017). For instance, “target” individuals generate larger and clearer facial expressions when conveying their experiences to other people (Williams et al., 2021). Here, we show that “observer” individuals likewise accumulate evidence for emotion more rapidly from increasingly visible expressions, and that they are more likely—and faster—to perceive these expressions correctly. Evidence accumulation thus provides a core mechanism for facilitating clear communication between targets and observers. Future experiments could explore how evidence accumulation underlies other types of social judgments (Chanes, Wormwood, Betz, & Barrett, 2018) and helps individuals connect and cooperate across diverse real-world environments (Zaki & Williams, 2013) (Williams et al., 2018), ranging from classrooms (Spitzer, 2020) to doctors’ offices (Lorié et al., 2017) and consumer settings (Wang et al., 2017).

As individuals around the world began wearing face masks, they also adapted to how masks influence social interaction. Hospitality staff practiced “smizing”—smiling with the eyes—to convey warm feelings while masked (Murphy, 2020). Just as individuals adapt how they produce expressions behind masks, our findings predict they might also adapt how they perceive masked expressions to improve communication from start to finish.

Context

Face masks continue to be vital in the global response to COVID-19, as over half of all people worldwide have yet to receive any vaccine, and even vaccinated individuals may transmit highly contagious variants without masks. However, many individuals report not wearing masks due to communication challenges. Here, participants were slower to accumulate evidence for emotion from masked expressions relative to without masks, and yet they still accumulated evidence towards successfully identifying expressions overall. These findings explain why individuals can experience difficulties communicating with masks, but also highlight how effectively they communicate nonetheless. By revealing evidence accumulation as the underlying mechanism, this work further suggests that time-sensitive situations may risk miscommunication with masks. However, it also generates the model-based prediction that masked individuals may communicate more effectively when they simply take their time.

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Author Contributions

W.C.W. contributed to study design and implementation, data acquisition, data analysis, and manuscript preparation. E.H. and B.M. contributed to study implementation and data analysis. V.V. contributed to study design and manuscript preparation. All authors provided comments and approved of the final manuscript.

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Appendix A

False Negative Errors

Study 2

Failing to Identify Expressions with Lower Masks

Emotion Ratings. Participants in Study 2 rated all expressions except disgust correctly on average with lower masks, largely replicating the results of Study 1 (**Figure 3d**). These participants also rated expressions less accurately with lower masks than without masks, collapsing across emotions, and in particular for expressions of disgust, fear, happiness, sadness, and surprise, but not anger (**Table 1, Figure A1**).

Emotion Rating RTs. Replicating Study 1, participants in Study 2 were also slower to identify expressions correctly with lower masks, versus without masks, collapsing across emotions (**Figure 3e**). Participants were slower to correctly identify expressions of disgust, fear, happiness, sadness, and surprise, but not anger, with lower masks as compared to without masks, and as indicated by interactions for disgusted and happy expressions (**Table 2, Figure A2**).

Emotion Rating Drift Rates. Replicating Study 1, participants in Study 2 also accumulated evidence in the direction of correctly rating all 6 types of expressions with lower masks, all $P(\text{lower mask} < 0) < .0001$. Participants also accumulated evidence from expressions with lower masks more slowly, versus without masks, across emotions overall (**Figure 3f**), and in particular for disgust, fear, happiness, sadness, and surprise, all $P(\text{lower mask} > \text{none}) < .0001$; but not anger (**Figure A3**).

Failing to Identify Expressions with Upper Masks

Emotion Ratings. Participants in Study 2 correctly rated all 6 types of expressions above chance with upper masks, again largely replicating the results of Study 1 (**Figure 3d**). Participants were less accurate rating expressions with upper masks as compared to without masks, collapsing across emotions, and in particular for expressions of anger and fear, but not disgust, happiness, sadness, or surprise (**Table 1, Figure A1**).

Emotion Rating RTs. In contrast to Study 1, participants were slower to correctly identify expressions with upper masks, in comparison to without masks, collapsing across emotions (**Table 4**). Specifically, participants were slower to correctly identify angry, fearful, and happy expressions—but not other types of expressions—with upper masks as compared to without masks.

Emotion Rating Drift Rates. Replicating the findings of Study 1, participants in Study 2 accumulated evidence in the direction of correctly rating all 6 types of expressions with upper masks, all $P(\text{lower mask} < 0) < .0001$. Participants accumulated evidence more slowly from expressions with upper masks than without masks, collapsing across emotions, $P(\text{upper mask} > \text{none}) < .0001$ (**Figure 3f**), and specifically for anger, fear, surprise, all $P(\text{upper mask} > \text{none}) < .0001$; disgust, $P(\text{upper mask} > \text{none}) = .034$; happiness, $P(\text{upper mask} > \text{none}) = .0004$; and sadness, $P(\text{upper mask} > \text{none}) = .0006$ (**Figure A3**).

Failing to Identify Expressions with Lower versus Upper Masks

Emotion Ratings. In contrast to Study 1, participants in Study 2 were less accurate rating expressions with lower versus upper masks, collapsing across emotions (**Table 1**). Specifically, participants rated expressions of disgust, happiness, sadness, and surprise less

accurately with lower masks versus with upper masks (**Figure A1**). Conversely, participants were less accurate rating angry expressions with upper masks as compared to lower masks.

Emotion Rating RTs. Replicating Study 1, participants were also slower to correctly identify expressions with lower masks versus with upper masks, collapsing across emotions (**Table 3**), and in particular for disgusted, happy, and sad expressions, and as shown by an interaction for disgusted expressions. By contrast, participants were slower to correctly identify angry and fearful expressions with upper masks in comparison to lower masks, and as indicated by interactions.

Emotion Rating Drift Rates. Again replicating the results of Study 1, participants also accumulated evidence more slowly from expressions with lower masks versus with upper masks, overall across emotions (**Figure 3f**). In particular, participants accumulated evidence for disgust, happiness, sadness, and surprise more slowly with lower masks than with upper masks, all $P(\text{lower mask} > \text{upper mask}) < .0001$ (**Figure A3**). Conversely, participants accumulated evidence more slowly for anger and fear from expressions with upper masks than with lower masks, both $P(\text{upper mask} > \text{lower mask}) < .0001$.

Figure A1. Mean emotion ratings by masks: correct ratings vs. false negative errors rating (a) angry, (b) disgusted, (c) fearful, (d) happy, (e) sad, and (f) surprised faces (Study 2). Higher mean values reflect increased accuracy and decreased false negative errors. Error bars depict 95% confidence intervals.

Figure A2. Mean emotion rating RTs (flipped) by masks and emotion ratings: correct rating RTs vs. false negative error RTs rating (a) angry, (b) disgusted, (c) fearful, (d) happy, (e) sad, and (f) surprised faces, with lower masks vs. no masks (Study 2). Higher mean values reflect faster responses. Error bars depict 95% confidence intervals.

Figure A3. Drift rate coefficients by masks: drift rate towards correct judgments vs. false negative errors rating (a) angry, (b) disgusted, (c) fearful, (d) happy, (e) sad, and (f) surprised faces (Study 2). Higher coefficient values reflect increased drift rate towards correct judgments and decreased drift rate towards false negative errors. Error bars depict 95% credible intervals.

Appendix B

False Positive Errors

Study 1

Misidentifying Expressions with Lower Masks

Anger Judgments. Participants were less likely to judge expressions of disgust, happiness, and surprise, as not angry with lower masks as compared to without masks (**Table B1**), and slower to judge surprised expressions as not angry, $b = -.030$, $t = -3.95$, $p < .001$, 95% CI $[-.046, -.015]$. They also accumulated evidence that surprised expressions were not angry more slowly with lower masks ($b = 1.53$, 95% CI $[1.43, 1.63]$) versus without masks ($b = 1.77$, 95% CI $[1.54, 2.01]$), $P(\text{lower mask} > \text{none}) < .0001$.

Disgust Judgments. Participants judged angry expressions as not disgusted less often with lower masks, in comparison to without masks (**Table B2**). However, they were also faster to judge angry expressions as not disgusted with lower masks versus without masks, $b = .021$, $t = 2.21$, $p = .027$, 95% CI $[.001, .038]$.

Conversely, participants judged fearful expressions as not disgusted more often with lower masks versus without masks—and more quickly, $b = .045$, $t = 4.89$, $p < .001$, 95% CI $[.028, .063]$, and they were also faster to accumulate evidence that fearful expressions were not disgusted with lower masks ($b = .85$, 95% CI $[.75, .95]$) than without masks ($b = .17$, 95% CI $[.004, .34]$), $P(\text{lower mask} < \text{none}) < .0001$.

Fear Judgments. Participants judged angry and sad expressions as not fearful less often with lower masks than without masks (**Table B3**), but they showed no significant differences in the speed of these ratings.

Happiness Judgments. Participants were less likely to judge angry, disgusted, sad, and surprised expressions as not happy with lower masks relative to without masks (**Table B4**)—and slower for expressions of anger ($b = -.017, t = -2.42, p = .016, 95\% \text{ CI } [-.031, -.003]$), disgust ($b = -.028, t = -4.02, p < .001, 95\% \text{ CI } [-.042, -.014]$), sadness ($b = -.033, t = -5.31, p < .001, 95\% \text{ CI } [-.045, -.022]$), and surprise ($b = -.018, t = -2.45, p = .014, 95\% \text{ CI } [-.034, -.003]$). In addition, they also accumulated evidence that expressions were not happy more slowly with lower masks versus without masks, for expressions of anger (lower mask: $b = 2.36, 95\% \text{ CI } [2.24, 2.47]$; none: $b = 2.60, 95\% \text{ CI } [2.31, 2.88]$), disgust (lower mask: $b = 1.91, 95\% \text{ CI } [1.78, 2.03]$; none: $b = 2.34, 95\% \text{ CI } [2.10, 2.59]$), sadness (lower mask: $b = 2.08, 95\% \text{ CI } [1.96, 2.19]$; none: $b = 2.55, 95\% \text{ CI } [2.30, 2.83]$), and surprise (lower mask: $b = 1.61, 95\% \text{ CI } [1.49, 1.73]$; none: $b = 1.90, 95\% \text{ CI } [1.68, 2.12]$), all $P(\text{lower mask} > \text{none}) < .0001$.

Sadness Judgments. Participants judged happy expressions as not sad less frequently with lower masks as compared to without masks (**Table B5**), but they did not significantly differ in their speed making these ratings.

In contrast, participants judged angry and fearful expressions as not sad more frequently with lower masks versus without masks—and they were faster to judge fearful expressions as not sad, $b = .030, t = 3.28, p = .0011, 95\% \text{ CI } [.013, .048]$. In addition, participants accumulated evidence that fearful expressions were not sad more quickly with lower masks ($b = .99, 95\% \text{ CI } [.88, 1.09]$) than without masks ($b = .65, 95\% \text{ CI } [.48, .84]$), $P(\text{lower mask} < \text{none}) < .0001$.

Surprise Judgments. Participants were less likely to judge fearful and sad expressions as not surprised with lower masks in comparison to without masks (**Table B6**)—and slower to judge sad expressions as not surprised, $b = -.023, t = -2.88, p = .0041, 95\% \text{ CI } [-.039, -.008]$. Participants also accumulated evidence that sad expressions were not surprised more slowly with

lower masks ($b = 1.47$, 95% CI [1.37, 1.58]) than without masks ($b = 1.79$, 95% CI [1.58, 2.01]), $P(\text{lower mask} > \text{none}) < .0001$.

Misidentifying Expressions with Upper Masks

Anger Judgments. Participants rated sad expressions as not angry less often with upper masks, as compared to without masks, but they showed no significant differences in how quickly they rated sad expressions.

By contrast, participants rated disgusted expressions as not angry more often with upper masks than without masks—and more quickly, $b = .051$, $t = 4.61$, $p < .001$, 95% CI [.027, .072]—and they were faster to accumulate evidence that disgusted expressions were not angry with upper masks ($b = .13$, 95% CI [.036, .23]) versus without masks ($b = -.17$, 95% CI [-.31, -.028]), $P(\text{upper mask} < \text{none}) < .0001$.

Disgust Judgments. Participants were less likely to rate fearful expressions as not disgusted with upper masks, versus without masks, but they did not significantly differ in their speed making these ratings.

Conversely, participants were more likely to rate angry expressions as not disgusted with upper masks than without masks—and faster, $b = .052$, $t = 5.90$, $p < .001$, 95% CI [.034, .069]—and they accumulated evidence more quickly that angry expressions were not disgusted with upper masks ($b = .89$, 95% CI [.78, .99]) as compared to without masks ($b = .51$, 95% CI [.32, .70]), $P(\text{upper mask} < \text{none}) < .0001$.

Fear Judgments. Participants rated angry, sad, and surprised expressions as not fearful more frequently with upper masks relative to without masks—and more quickly for expressions of anger ($b = .039$, $t = 4.87$, $p < .001$, 95% CI [.023, .056]), sadness ($b = .025$, $t = 2.86$, $p =$

.0043, 95% CI [.008, .044]), and surprise ($b = .039$, $t = 2.81$, $p = .0051$, 95% CI [.012, .064]).

They were also faster to accumulate evidence that expressions were not fearful with upper masks versus without masks, for expressions of anger (upper mask: $b = 1.30$, 95% CI [1.19, 1.40]; none: $b = 1.04$, 95% CI [.83, 1.25]), sadness (upper mask: $b = .93$, 95% CI [.83, 1.04]; none: $b = .70$, 95% CI [.51, .89]), and surprise (upper mask: $b = -.015$, 95% CI [-.11, .078]; none: $b = -.33$, 95% CI [-.49, -.17]), all $P(\text{upper mask} < \text{none}) < .0001$.

Happiness Judgments. Participants rated angry expressions as not happy less often with upper masks in comparison to without masks, but they showed no significant differences in how quickly they made these ratings.

Sadness Judgments. Participants were less likely to rate angry and fearful expressions as not sad with upper masks than without masks, but they did not significantly differ in their speed making these ratings.

Surprise Judgments. Participants rated angry and fearful expressions as not surprised more often with upper masks versus without masks—and they rated fearful expressions as not surprised more quickly, $b = .068$, $t = 6.62$, $p < .001$, 95% CI [.047, .086]. In addition, participants were also faster to accumulate evidence that fearful expressions were not surprised with upper masks ($b = .92$, 95% CI [.82, 1.02]) than without masks ($b = .018$, 95% CI [-.11, .15]), $P(\text{upper mask} < \text{none}) < .0001$.

Misidentifying Expressions with Lower versus Upper Masks

Anger Judgments. Participants were less likely to judge disgusted and happy expressions as not angry with lower masks than with upper masks—and slower for both disgusted ($b = -.035$, $t = -2.56$, $p = .011$, 95% CI [-.059, -.006]) and happy ($b = -.024$, $t = -3.31$, p

< .001, 95% CI [-.038, -.010]) expressions. They also accumulated evidence more slowly that expressions were not angry with lower versus upper masks, for expressions of disgust (lower mask: $b = -.80$, 95% CI [-.90, -.71]; upper mask: $b = .13$, 95% CI [.036, .23]) and happiness (lower mask: $b = 2.20$, 95% CI [2.08, 2.31]; upper mask: $b = 2.49$, 95% CI [2.38, 2.60]), both $P(\text{lower mask} > \text{upper mask}) < .0001$.

By contrast, participants were less likely to judge fearful expressions as not angry with upper versus lower masks, but they did not show significant differences in their speed making these ratings.

Disgust Judgments. Participants judged angry expressions as not disgusted less often with lower masks relative to with upper masks—and more slowly, $b = -.035$, $t = -4.25$, $p < .001$, 95% CI [-.052, -.019]—and they were slower to accumulate evidence that angry expressions were not disgusted with lower masks ($b = .43$, 95% CI [.34, .53]) as compared to with upper masks ($b = .89$, 95% CI [.78, .99]), $P(\text{lower mask} > \text{upper mask}) < .0001$.

In contrast, participants judged fearful and surprised expressions as not disgusted less often with upper masks than with lower masks—and they were slower for fearful expressions, $b = .033$, $t = 3.06$, $p = .0022$, 95% CI [.011, .054]. Consistently, participants also accumulated evidence more slowly that fearful expressions were not disgusted with upper masks ($b = -.14$, 95% CI [-.23, -.044]) in comparison to with lower masks ($b = .85$, 95% CI [.75, .95]), $P(\text{upper mask} > \text{lower mask}) < .0001$.

Fear Judgments. Participants judged angry, happy, sad, and surprised expressions as not fearful less often with lower masks as compared to with upper masks—and they were slower for expressions of anger ($b = -.043$, $t = -5.09$, $p < .001$, 95% CI [-.060, -.027]), happiness ($b = -.018$, $t = 2.36$, $p = .019$, 95% CI [-.033, -.003]), and sadness ($b = -.027$, $t = -2.98$, $p = .0029$, 95%

CI [-.045, -.009]). They also accumulated evidence more slowly that expressions were not fearful with lower versus upper masks, for angry (lower mask: $b = .89$, 95% CI [.79, .99]; upper mask: $b = 1.30$, 95% CI [1.19, 1.40]), happy (lower mask: $b = 2.02$, 95% CI [1.91, 2.13]; upper mask: $b = 2.25$, 95% CI [2.14, 2.37]), and sad (lower mask: $b = .44$, 95% CI [.34, .54]; upper mask: $b = .93$, 95% CI [.83, 1.04]) expressions, all $P(\text{lower mask} > \text{upper mask}) < .0001$.

Happiness Judgments. Participants were less likely to judge disgusted and surprised expressions as not happy with lower masks than with upper masks—and slower for both disgusted ($b = -.021$, $t = -3.21$, $p = .0014$, 95% CI [-.035, -.009]) and surprised ($b = -.025$, $t = -3.67$, $p < .001$, 95% CI [-.038, -.011]) expressions. Likewise, they also accumulated evidence more slowly that expressions were not happy with lower versus upper masks, for expressions of disgust (lower mask: $b = 1.91$, 95% CI [1.78, 2.03]; upper mask: $b = 2.19$, 95% CI [2.07, 2.32]) and surprise (lower mask: $b = 1.61$, 95% CI [1.49, 1.73]; upper mask: $b = 1.95$, 95% CI [1.83, 2.07]), both $P(\text{lower mask} > \text{upper mask}) < .0001$.

Sadness Judgments. Participants were less likely to judge happy expressions as not sad with lower masks in comparison to with upper masks—and slower, $b = -.016$, $t = -2.22$, $p = .027$, 95% CI [-.032, -.002]—and they accumulated evidence more slowly that happy expressions were not sad with lower masks ($b = 2.13$, 95% CI [2.01, 2.25]) than with upper masks ($b = 2.38$, 95% CI [2.26, 2.50]), $P(\text{lower mask} > \text{upper mask}) < .0001$.

Conversely, participants were less likely to judge angry and fearful expressions as not sad with upper masks as compared to with lower masks—and slower for both angry ($b = .031$, $t = 2.56$, $p = .011$, 95% CI [.006, .053]) and fearful ($b = .031$, $t = 3.70$, $p < .001$, 95% CI [.015, .049]) expressions. They also accumulated evidence more slowly that expressions were not sad with upper versus lower masks, for expressions of anger (upper mask: $b = .017$, 95% CI [-.080,

.11]; lower mask: $b = .56$, 95% CI [.46, .65]) and fear (upper mask: $b = .40$, 95% CI [.29, .50]; lower mask: $b = .99$, 95% CI [.88, 1.09]), both $P(\text{upper mask} > \text{lower mask}) < .0001$.

Surprise Judgments. Participants judged all five other types of expressions as not surprised less often with lower masks than with upper masks—and more slowly for expressions of anger ($b = -.021$, $t = -2.77$, $p = .0057$, 95% CI [-.036, -.007]), disgust ($b = -.016$, $t = -2.17$, $p = .030$, 95% CI [-.030, -.002]), fear ($b = -.033$, $t = -2.82$, $p = .0049$, 95% CI [-.056, -.010]), happiness ($b = -.042$, $t = -4.76$, $p < .001$, 95% CI [-.059, -.022]), and sadness ($b = -.058$, $t = -7.33$, $p < .001$, 95% CI [-.075, -.044]). In addition, they were slower to accumulate evidence that expressions were not surprised with lower versus upper masks, for angry (lower mask: $b = 1.79$, 95% CI [1.68, 1.90]; upper mask: $b = 2.06$, 95% CI [1.95, 2.16]), disgusted (lower mask: $b = 1.64$, 95% CI [1.53, 1.75]; upper mask: $b = 1.84$, 95% CI [1.73, 1.94]), fearful (lower mask: $b = -.69$, 95% CI [-.79, -.59]; upper mask: $b = .92$, 95% CI [.82, 1.02]), happy (lower mask: $b = 1.61$, 95% CI [1.50, 1.71]; upper mask: $b = 1.91$, 95% CI [1.80, 2.01]), and sad (lower mask: $b = 1.47$, 95% CI [1.37, 1.58]; upper mask: $b = 2.02$, 95% CI [1.90, 2.13]) expressions, all $P(\text{lower mask} > \text{upper mask}) < .0001$.

Study 2

Misidentifying Expressions with Lower Masks

Anger Judgments. Participants rated disgusted, fearful, and surprised expressions as not angry less frequently with lower masks relative to without masks (**Table B1**)—and more slowly for surprised expressions, $b = -.027$, $t = -3.02$, $p = .0026$, 95% CI [-.044, -.010]. In addition, participants were also slower to accumulate evidence that surprised expressions were not angry

with lower masks ($b = 2.16$, 95% CI [2.02, 2.32]) than without masks ($b = 2.58$, 95% CI [2.33, 2.83]), $P(\text{lower mask} > \text{none}) < .0001$.

Disgust Judgments. Participants rated fearful expressions as not disgusted less often with lower masks than without masks (**Table B2**). However, they were also faster to rate fearful expressions as not disgusted, with lower masks versus without masks, $b = .048$, $t = 4.30$, $p < .001$, 95% CI [.026, .071].

Fear Judgments. Participants were less likely to rate angry expressions as not fearful with lower masks in comparison to without masks (**Table B3**), but they did not significantly differ in their speed making these ratings.

Happiness Judgments. Participants rated sad expressions as not happy less frequently with lower masks relative to without masks (**Table B4**)—and more slowly, $b = -.031$, $t = -3.57$, $p < .001$, 95% CI [-.049, -.014], and they were slower to accumulate evidence that sad expressions were not happy with lower masks ($b = 2.28$, 95% CI [2.11, 2.45]) than without masks ($b = 2.73$, 95% CI [2.44, 3.03]), $P(\text{lower mask} > \text{none}) < .0001$.

Sadness Judgments. Participants were less likely to rate expressions of disgust, happiness, and surprise, as not sad with lower masks as compared to without masks (**Table B5**)—and slower for both happy ($b = -.027$, $t = -3.40$, $p < .001$, 95% CI [-.043, -.011]) and surprised ($b = -.031$, $t = -3.28$, $p = .0011$, 95% CI [-.049, -.012]) expressions. Consistently, they also accumulated evidence more slowly that these expressions were not sad with lower masks than without masks, for expressions of happiness (lower mask: $b = 2.31$, 95% CI [2.13, 2.48]; none: $b = 2.79$, 95% CI [2.56, 3.03]) and surprise (lower mask: $b = 1.80$, 95% CI [1.65, 1.94]; none: $b = 2.15$, 95% CI [1.92, 2.38]), both $P(\text{lower mask} > \text{none}) < .0001$.

By contrast, participants were more likely to rate angry expressions as not sad with lower masks than without masks—and faster, $b = .049$, $t = 4.93$, $p < .001$, 95% CI [.030, .068], and they accumulated evidence more quickly that angry expressions were not sad with lower masks ($b = 1.15$, 95% CI [1.00, 1.29]) than without masks ($b = 0.65$, 95% CI [.48, .82]), $P(\text{lower mask} < \text{none}) < .0001$.

Surprise Judgments. Participants rated angry expressions as not surprised less often with lower masks as compared to without masks (**Table B6**)—and less quickly, $b = -.027$, $t = -3.37$, $p < .001$, 95% CI [-.043, -.012], and they were slower to accumulate evidence that angry expressions were not surprised with lower masks ($b = 1.80$, 95% CI [1.64, 1.96]) than without masks ($b = 2.27$, 95% CI [2.03, 2.50]), $P(\text{lower mask} > \text{none}) < .0001$.

Conversely, participants rated disgusted expressions as not surprised more often with lower masks than without masks—and faster, $b = .055$, $t = 5.29$, $p < .001$, 95% CI [.034, .076], and they accumulated evidence more quickly that disgusted expressions were not surprised with lower masks ($b = 1.37$, 95% CI [1.22, 1.52]) versus without masks ($b = .77$, 95% CI [.59, .96]), $P(\text{lower mask} < \text{none}) < .0001$.

Misidentifying Expressions with Upper Masks

Anger Judgments. There were no significant differences in how often participants misidentified expressions as angry with upper masks relative to without masks.

Disgust Judgments. Participants judged fearful expressions as not disgusted less often with upper masks, in comparison to without masks, but they did not significantly differ in their speed making these ratings.

In contrast, participants judged angry expressions as not disgusted more often with upper masks relative to without masks—and more quickly, $b = .043$, $t = 4.81$, $p < .001$, 95% CI [.027, .061], and they were faster to accumulate evidence that angry expressions were not disgusted with upper masks ($b = 1.08$, 95% CI [.93, 1.22]) than without masks ($b = .67$, 95% CI [.50, .83]), $P(\text{upper mask} < \text{none}) < .0001$.

Fear Judgments. Participants were more likely to judge sad and surprised expressions as not fearful with upper masks than without masks—and faster for both sad ($b = .026$, $t = 3.05$, $p = .0024$, 95% CI [.009, .044]) and surprised ($b = .038$, $t = 2.40$, $p = .017$, 95% CI [.004, .069]) expressions. Likewise, they also accumulated evidence more quickly that these expressions were not fearful with upper masks versus without masks, for expressions of sadness (upper mask: $b = 1.49$, 95% CI [1.34, 1.64]; none: $b = 1.08$, 95% CI [.92, 1.26]) and surprise (upper mask: $b = -.14$, 95% CI [-.28, -.009]; none: $b = -.54$, 95% CI [-.68, -.40]), both $P(\text{upper mask} < \text{none}) < .0001$.

Happiness Judgments. We did not detect significant differences in how frequently participants misidentified expressions as happy with upper masks compared to without masks.

Sadness Judgments. Participants judged angry expressions as not sad less frequently with upper masks versus without masks, but they showed no significant differences in how quickly they made these ratings.

Surprise Judgments. Participants judged fearful and sad expressions as not surprised more often with upper masks than without masks—and more quickly for both fearful ($b = .040$, $t = 2.54$, $p = .012$, 95% CI [.010, .071]) and sad ($b = .017$, $t = 2.15$, $p = .032$, 95% CI [.002, .032]) expressions. They were also faster to accumulate evidence that these expressions were not surprised with upper masks versus without masks, for expressions of fear (upper mask: $b = -.070$,

95% CI [-.20, .064]; none: $b = -.51$, 95% CI [-.65, -.36]; $P(\text{upper mask} < \text{none}) < .0001$) and sadness (upper mask: $b = 2.69$, 95% CI [2.52, 2.86]; none: $b = 2.38$, 95% CI [2.12, 2.62]; $P(\text{upper mask} < \text{none}) = .0002$).

Misidentifying Expressions with Lower versus Upper Masks

Anger Judgments. Participants were less likely to rate disgusted, happy, and surprised expressions as not angry with lower masks relative to with upper masks—and slower for disgusted ($b = -.044$, $t = -3.21$, $p < .01$, 95% CI [-.073, -.019]), happy ($b = -.020$, $t = -2.84$, $p = .0046$, 95% CI [-.034, -.006]), and surprised ($b = -.021$, $t = -2.33$, $p = .020$, 95% CI [-.039, -.002]) expressions. In addition, they accumulated evidence more slowly that these expressions were not angry with lower versus upper masks, for expressions of disgust (lower mask: $b = -.59$, 95% CI [-.73, -.44]; upper mask: $b = .84$, 95% CI [.70, .98]), happiness (lower mask: $b = 2.56$, 95% CI [2.39, 2.73]; upper mask: $b = 2.91$, 95% CI [2.74, 3.09]), and surprise (lower mask: $b = 2.17$, 95% CI [2.02, 2.32]; upper mask: $b = 2.53$, 95% CI [2.38, 2.68]), all $P(\text{lower mask} > \text{upper mask}) < .0001$.

Disgust Judgments. Participants were less likely to rate angry expressions as not disgusted with lower masks as compared to with upper masks—and slower, $b = -.033$, $t = -3.57$, $p < .001$, 95% CI [-.049, -.016], and they accumulated evidence that angry expressions were not disgusted more slowly with lower ($b = .65$, 95% CI [.51, .79]) versus upper masks ($b = 1.08$, 95% CI [.93, 1.22]), $P(\text{lower mask} > \text{upper mask}) < .0001$.

Conversely, participants were less likely to rate fearful expressions as not disgusted with upper masks in comparison to with lower masks—and slower, $b = .044$, $t = 3.96$, $p < .001$, 95% CI [.023, .065], and they accumulated evidence that fearful expressions were not disgusted more

slowly with upper ($b = .11$, 95% CI $[-.025, .24]$) versus lower masks ($b = .87$, 95% CI $[.73, 1.01]$), $P(\text{upper mask} > \text{lower mask}) < .0001$.

Fear Judgments. Participants rated angry and sad expressions as not fearful less frequently with lower masks than with upper masks—and more slowly for both angry ($b = -.033$, $t = -4.12$, $p < .001$, 95% CI $[-.049, -.017]$) and sad ($b = -.022$, $t = -2.43$, $p = .015$, 95% CI $[-.038, -.004]$) expressions. Consistently, they were also slower to accumulate evidence that these expressions were not fearful with lower versus upper masks, for expressions of anger (lower mask: $b = 1.57$, 95% CI $[1.41, 1.71]$; upper mask: $b = 2.18$, 95% CI $[2.03, 2.33]$) and sadness (lower mask: $b = .67$, 95% CI $[.52, .82]$; upper mask: $b = 1.49$, 95% CI $[1.34, 1.64]$), both $P(\text{lower mask} > \text{upper mask}) < .0001$.

Happiness Judgments. Participants rated sad expressions as not happy less often with lower masks in comparison to with upper masks—and more slowly, $b = -.029$, $t = -3.41$, $p < .001$, 95% CI $[-.045, -.011]$, and they were slower to accumulate evidence that sad expressions were not happy with lower masks ($b = 2.28$, 95% CI $[2.11, 2.45]$) versus upper masks ($b = 2.75$, 95% CI $[2.57, 2.94]$), $P(\text{lower mask} > \text{upper mask}) < .0001$.

Sadness Judgments. Participants were less likely to rate disgusted, happy, and surprised expressions as not sad with lower masks relative to with upper masks—and slower for disgusted ($b = -.020$, $t = -2.27$, $p = .023$, 95% CI $[-.037, -.002]$), happy ($b = -.030$, $t = -3.83$, $p < .001$, 95% CI $[-.046, -.014]$), and surprised ($b = -.031$, $t = -3.30$, $p = .0010$, 95% CI $[-.050, -.012]$) expressions. They also accumulated evidence that these expressions were not sad more slowly with lower versus upper masks, for expressions of disgust (lower mask: $b = 1.27$, 95% CI $[1.13, 1.42]$; upper mask: $b = 1.79$, 95% CI $[1.63, 1.94]$), happiness (lower mask: $b = 2.31$, 95% CI $[2.13, 2.48]$; upper mask: $b = 2.85$, 95% CI $[2.68, 3.01]$), and surprise (lower mask: $b = 1.80$,

95% CI [1.65, 1.94]; upper mask: $b = 2.23$, 95% CI [2.09, 2.38]), $P(\text{lower mask} > \text{upper mask}) < .0001$.

By contrast, participants were less likely to rate angry expressions as not sad with upper masks as compared to with lower masks—and slower, $b = .055$, $t = 5.26$, $p < .001$, 95% CI [.033, .074], and they accumulated evidence that angry expressions were not sad more slowly with upper ($b = .28$, 95% CI [.14, .42]) versus lower masks ($b = 1.15$, 95% CI [1.00, 1.29]), $P(\text{upper mask} > \text{lower mask}) < .0001$.

Surprise Judgments. Participants rated angry, fearful, and sad expressions as not surprised less frequently with lower masks than with upper masks—and more slowly for angry ($b = -.043$, $t = -5.89$, $p < .001$, 95% CI [-.057, -.028]) and sad ($b = -.042$, $t = -5.20$, $p < .001$, 95% CI [-.058, -.026]) expressions. In addition, they were slower to accumulate evidence that these expressions were not surprised with lower versus upper masks, for expressions of anger (lower mask: $b = 1.80$, 95% CI [1.64, 1.96]; upper mask: $b = 2.65$, 95% CI [2.48, 2.82]) and sadness (lower mask: $b = 1.94$, 95% CI [1.77, 2.10]; upper mask: $b = 2.69$, 95% CI [2.52, 2.86]), $P(\text{lower mask} > \text{upper mask}) < .0001$.

In contrast, participants rated disgusted expressions as not surprised less often with upper masks relative to with lower masks—and more slowly, $b = .031$, $t = 3.56$, $p < .001$, 95% CI [.014, .049], and they were also slower to accumulate evidence that disgusted expressions were not surprised with upper ($b = .85$, 95% CI [.71, 1.00]) versus lower masks ($b = 1.37$, 95% CI [1.22, 1.52]), $P(\text{upper mask} > \text{lower mask}) < .0001$.

Table B1						
<i>Misidentifying expressions: Face mask effects over anger ratings.</i>						
---	Study 1			Study 2		
---	<i>b</i>	<i>CI</i>	<i>z</i>	<i>b</i>	<i>CI</i>	<i>z</i>
Disgusted faces	---	---	---	---	---	---
Lower mask > none	-1.41	[-1.73, -1.09]	-8.35***	-2.41	[-3.27, -1.58]	-5.62***
Lower mask > upper	-1.93	[-2.25, -1.63]	-11.79***	-2.58	[-3.32, -1.74]	-6.31***
Upper mask > none	.56	[.22, .88]	3.39***	.37	[-.50, 1.22]	.86
Fearful faces	---	---	---	---	---	---
Lower mask > none	.24	[-.14, .51]	1.73	-.82	[-1.44, -.14]	-2.49*
Lower mask > upper	.35	[.086, .65]	2.56*	-.34	[-.96, .33]	-1.01
Upper mask > none	-.13	[-.39, .11]	-1.00	-.45	[-1.09, .27]	-1.37
Happy faces	---	---	---	---	---	---
Lower mask > none	-.50	[-1.07, -.054]	-2.08*	-.78	[-2.08, .13]	-1.61
Lower mask > upper	-.33	[-.64, -.018]	-2.07*	-.97	[-2.89, -.095]	-2.69**
Upper mask > none	.077	[-.47, .66]	.30	.10	[-1.06, 1.18]	.21
Sad faces	---	---	---	---	---	---
Lower mask > none	-.20	[-.57, .14]	-1.10	-.39	[-1.17, .45]	-.93
Lower mask > upper	.18	[-.066, .42]	1.44	-.056	[-.80, .77]	-.14
Upper mask > none	-.48	[-.80, -.10]	-2.60**	-.34	[-1.15, .52]	-.81
Surprised faces	---	---	---	---	---	---
Lower mask > none	-.33	[-.64, -.028]	-2.08*	-1.04	[-2.01, -.48]	-3.35***
Lower mask > upper	-.17	[-.56, .21]	-1.02	-1.32	[-2.44, -.87]	-4.02***
Upper mask > none	-.15	[-.49, .20]	-.94	.26	[-.46, 1.03]	.78
<i>Note: * $p < .05$. ** $p < .01$. *** $p < .001$. $CI = .95$.</i>						

Table B2						
<i>Misidentifying expressions: Face mask effects over disgust ratings.</i>						
---	Study 1			Study 2		
---	<i>b</i>	<i>CI</i>	<i>z</i>	<i>b</i>	<i>CI</i>	<i>z</i>
Angry faces	---	---	---	---	---	---
Lower mask > none	-.25	[-.51, -.022]	-2.00*	-.075	[-.73, .58]	-.23
Lower mask > upper	-.90	[-1.17, -.63]	-6.97***	-.79	[-1.49, -.074]	-2.27*
Upper mask > none	.69	[.43, .94]	5.29***	.75	[.075, 1.39]	2.21*
Fearful faces	---	---	---	---	---	---
Lower mask > none	1.30	[1.00, 1.60]	8.36***	.60	[.055, 1.10]	2.27*
Lower mask > upper	1.78	[1.48, 2.09]	11.32***	1.31	[.79, 1.82]	5.09***
Upper mask > none	-.55	[-.83, -.27]	-3.70***	-.76	[-1.32, -.21]	-2.93**
Happy faces	---	---	---	---	---	---
Lower mask > none	-.25	[-.69, .20]	-1.32	.16	[-.79, 1.23]	.36
Lower mask > upper	.027	[-.47, .51]	.22	-.53	[-1.99, .43]	-1.14
Upper mask > none	-.26	[-.71, .18]	-1.39	.74	[-.13, 1.91]	1.65
Sad faces	---	---	---	---	---	---
Lower mask > none	-.006	[-.25, .24]	-.042	-.31	[-.96, .42]	-.90
Lower mask > upper	-.14	[-.38, .13]	-1.05	-.16	[-.85, .55]	-.43
Upper mask > none	.13	[-.13, .38]	1.01	-.14	[-.83, .53]	-.42
Surprised faces	---	---	---	---	---	---
Lower mask > none	.26	[-.030, .54]	1.78	.17	[-.28, .65]	.71
Lower mask > upper	.35	[.084, .66]	2.50*	-.026	[-.48, .43]	-.11
Upper mask > none	-.096	[-.38, .19]	-.67	.19	[-.22, .68]	.81
<i>Note: * $p < .05$. ** $p < .01$. *** $p < .001$. $CI = .95$.</i>						

Table B3						
<i>Misidentifying expressions: Face mask effects over fear ratings.</i>						
---	Study 1			Study 2		
---	<i>b</i>	<i>CI</i>	<i>z</i>	<i>b</i>	<i>CI</i>	<i>z</i>
Angry faces	---	---	---	---	---	---
Lower mask > none	-.36	[-.65, -.083]	-2.45*	-.58	[-1.07, -.063]	-2.23*
Lower mask > upper	-.63	[-.90, -.32]	-4.18***	-1.01	[-1.55, -.46]	-3.66***
Upper mask > none	.31	[.026, .63]	2.04*	.47	[-.084, .99]	1.67
Disgusted faces	---	---	---	---	---	---
Lower mask > none	.21	[-.087, .89]	1.44	.074	[-.53, .67]	.24
Lower mask > upper	.088	[-.19, .37]	.61	.084	[-.53, .75]	.26
Upper mask > none	.11	[-.19, .39]	.79	-.034	[-.61, .55]	-.11
Happy faces	---	---	---	---	---	---
Lower mask > none	-.26	[-.75, .17]	-1.38	-.68	[-1.77, .087]	-1.65
Lower mask > upper	-.43	[-.99, -.010]	-2.17*	-.48	[-1.41, .15]	-1.42
Upper mask > none	.15	[-.30, .62]	.76	-.23	[-1.22, .60]	-.55
Sad faces	---	---	---	---	---	---
Lower mask > none	-.53	[-.79, -.27]	-3.97***	-.69	[-1.45, .012]	-1.85
Lower mask > upper	-.88	[-1.11, -.59]	-6.33***	-1.36	[-2.14, -.58]	-3.47***
Upper mask > none	.37	[.098, .64]	2.69**	.79	[.008, 1.52]	2.05*
Surprised faces	---	---	---	---	---	---
Lower mask > none	-.027	[-.31, .25]	-.19	.29	[-.33, .96]	.87
Lower mask > upper	-.68	[-.98, -.39]	-4.58***	-.44	[-1.02, .17]	-1.43
Upper mask > none	.67	[.38, .97]	4.58***	.75	[.091, 1.38]	2.28*
<i>Note: * $p < .05$. ** $p < .01$. *** $p < .001$. $CI = .95$.</i>						

Table B4						
<i>Misidentifying expressions: Face mask effects over happiness ratings.</i>						
---	Study 1			Study 2		
---	<i>b</i>	<i>CI</i>	<i>z</i>	<i>b</i>	<i>CI</i>	<i>z</i>
Angry faces	---	---	---	---	---	---
Lower mask > none	-.72	[-1.35, -.23]	-2.62**	-.075	[-1.17, .97]	-.15
Lower mask > upper	.11	[-.48, .75]	.41	-.37	[-1.96, .84]	-.59
Upper mask > none	-.82	[-1.51, -.32]	-3.02**	.14	[-.85, 1.20]	.26
Disgusted faces	---	---	---	---	---	---
Lower mask > none	-.93	[-1.61, -.40]	-3.24**	-.56	[-1.87, .59]	-1.02
Lower mask > upper	-.76	[-1.60, -.19]	-2.55*	.009	[-1.54, 1.57]	.016
Upper mask > none	-.17	[-.75, .42]	-.57	-.55	[-1.95, .59]	-1.00
Fearful faces	---	---	---	---	---	---
Lower mask > none	-.34	[-.98, .25]	-1.16	-.47	[-1.42, .28]	-1.16
Lower mask > upper	-.47	[-1.24, .17]	-1.44	.17	[-.65, 1.06]	.46
Upper mask > none	.075	[-.56, .69]	.25	-.66	[-1.57, .17]	-1.66
Sad faces	---	---	---	---	---	---
Lower mask > none	-.89	[-1.48, -.44]	-3.56***	-1.06	[-2.39, -.27]	-2.18*
Lower mask > upper	-.44	[-.99, .027]	-1.82	-1.33	[-3.42, -.51]	-2.46*
Upper mask > none	-.48	[-1.09, .00]	-1.87	.31	[-.72, 1.42]	.58
Surprised faces	---	---	---	---	---	---
Lower mask > none	-.53	[-1.03, -.078]	-2.23*	.26	[-.58, 1.11]	.59
Lower mask > upper	-.52	[-1.07, -.064]	-2.23*	.010	[-.83, .74]	.024
Upper mask > none	-.013	[-.54, .48]	-.053	.27	[-.53, 1.08]	.63
<i>Note: * $p < .05$. ** $p < .01$. *** $p < .001$. $CI = .95$.</i>						

Table B5						
<i>Misidentifying expressions: Face mask effects over sadness ratings.</i>						
---	Study 1			Study 2		
---	<i>b</i>	<i>CI</i>	<i>z</i>	<i>b</i>	<i>CI</i>	<i>z</i>
Angry faces	---	---	---	---	---	---
Lower mask > none	.67	[.24, 1.10]	3.26**	.70	[-.097, 1.30]	2.23*
Lower mask > upper	1.28	[.90, 1.66]	6.54***	1.36	[.75, 2.01]	4.45***
Upper mask > none	-.64	[-1.03, -.25]	-3.18**	-.71	[-1.30, -.13]	-2.30*
Disgusted faces	---	---	---	---	---	---
Lower mask > none	.20	[-.13, .53]	1.18	-.84	[-1.58, -.084]	-2.34*
Lower mask > upper	.28	[-.051, .65]	1.60	-1.02	[-1.69, -.33]	-2.86**
Upper mask > none	-.072	[-.39, .27]	-.44	.20	[-.50, .92]	.54
Fearful faces	---	---	---	---	---	---
Lower mask > none	.69	[.27, 1.11]	3.40***	-.28	[-.99, .46]	-.72
Lower mask > upper	1.17	[.82, 1.56]	5.96***	.41	[-.34, 1.15]	1.07
Upper mask > none	-.58	[-.99, -.17]	-2.93**	-.71	[-1.42, -.018]	-1.81
Happy faces	---	---	---	---	---	---
Lower mask > none	-.58	[-1.09, -.14]	-2.95**	-1.13	[-2.21, -.61]	-3.21**
Lower mask > upper	-.54	[-1.11, -.092]	-2.75**	-1.51	[-3.03, -1.04]	-3.77***
Upper mask > none	-.019	[-.49, .42]	-.095	.21	[-.49, 1.00]	.56
Surprised faces	---	---	---	---	---	---
Lower mask > none	-.15	[-.48, .20]	-.85	-.77	[-1.53, -.13]	-2.20*
Lower mask > upper	-.13	[-.43, .17]	-.84	-.79	[-1.22, -.41]	-3.92***
Upper mask > none	-.006	[-.36, .36]	-.037	-.040	[-.80, .64]	-.11
<i>Note: * $p < .05$. ** $p < .01$. *** $p < .001$. $CI = .95$.</i>						

Table B6						
<i>Misidentifying expressions: Face mask effects over surprise ratings.</i>						
---	Study 1			Study 2		
---	<i>b</i>	<i>CI</i>	<i>z</i>	<i>b</i>	<i>CI</i>	<i>z</i>
Angry faces	---	---	---	---	---	---
Lower mask > none	-.15	[-.60, .30]	-.82	-1.05	[-2.42, -.16]	-2.34*
Lower mask > upper	-.54	[-1.07, -.14]	-2.92**	-1.84	[-4.38, -1.14]	-3.60***
Upper mask > none	.39	[-.026, .88]	2.14*	.85	[-.057, 2.33]	1.76
Disgusted faces	---	---	---	---	---	---
Lower mask > none	-.16	[-.48, .19]	-.95	1.21	[.38, 2.00]	2.94**
Lower mask > upper	-.35	[-.73, .021]	-2.04*	.98	[.16, 1.85]	2.30*
Upper mask > none	.19	[-.14, .56]	1.11	.15	[-.65, .89]	.38
Fearful faces	---	---	---	---	---	---
Lower mask > none	-1.36	[-1.74, -1.02]	-7.82***	-.28	[-1.02, .53]	-.74
Lower mask > upper	-3.07	[-3.47, -2.67]	-14.94***	-1.14	[-1.88, -.35]	-2.91**
Upper mask > none	1.78	[1.42, 2.13]	9.78***	.88	[.13, 1.64]	2.33*
Happy faces	---	---	---	---	---	---
Lower mask > none	-.28	[-.58, .012]	-1.90	.003	[-.65, .74]	.011
Lower mask > upper	-.48	[-.77, -.21]	-3.31***	-.050	[-.68, .56]	-.19
Upper mask > none	.22	[-.078, .52]	1.48	.073	[-.56, .77]	.24
Sad faces	---	---	---	---	---	---
Lower mask > none	-.62	[-1.00, -.27]	-3.15**	-.56	[-2.04, .59]	-1.11
Lower mask > upper	-.63	[-.95, -.30]	-3.93***	-2.07	[-8.29, -.85]	-2.94**
Upper mask > none	.057	[-.34, .44]	.28	1.20	[.20, 2.91]	2.18*
<i>Note: * $p < .05$. ** $p < .01$. *** $p < .001$. $CI = .95$.</i>						