The impact of face masks on emotion recognition performance and perception of threat

Face masks, emotion recognition and perception of threat

Melina Grahlow^{1,2*}, Claudia Rupp³ & Birgit Derntl^{1,4,5}

¹ Department of Psychiatry and Psychotherapy, University of Tübingen, Tübingen, Germany

² Graduate Training Centre of Neuroscience, University of Tübingen, Tübingen, Germany

³ Department of Psychiatry, Psychotherapy and Psychosomatics, Medical University of Innsbruck, Innsbruck, Austria

⁴ Tübingen Neuro Campus, University of Tübingen, Tübingen, Germany

⁵ Lead Graduate School, University of Tübingen, Tübingen, Germany

*Corresponding author

E-mail: melina.grahlow@med.uni-tuebingen.de (MG)

Abstract

Facial emotion recognition is crucial for social interaction. However, in times of a global pandemic, where wearing a face mask covering mouth and nose is widely encouraged to prevent the spread of disease, successful emotion recognition may be challenging. In Study 1, we investigated whether emotion recognition, assessed by a validated emotion recognition task, is impaired for faces wearing a mask compared to uncovered faces, in a sample of 790 participants between 18 and 89 years. Additionally, perception of threat for faces with and without mask was assessed. We found impaired emotion recognition for faces wearing a mask compared to faces without mask, especially for those depicting anger, sadness and disgust. Further, we observed that perception of threat was altered for faces wearing a mask. In Study 2, we compared emotion recognition performance for faces with and without face mask to faces that are occluded by something other than a mask, i.e. a bubble as well as only showing the upper part of the faces. We found that, for most emotions and especially for disgust, there seems to be an effect that can be ascribed to the face mask specifically, both for emotion recognition performance and perception of threat. Methodological constraints as well as the importance of wearing a mask despite temporarily compromised social interaction are discussed.

Introduction

The congenital and cross-cultural ability to recognise facial emotional expressions is considered a prerequisite for successful social interaction (1). In times of a global pandemic, people are widely encouraged to wear face masks covering mouth and nose in order to minimise risk of infection. However, this preventive measure might crucially affect social interaction: As wearing a face mask leaves only the upper areas of the face visible, namely eyes and forehead, this raises the question whether covering lower facial areas might interfere with successful emotion recognition.

To investigate emotion recognition in faces, participants are typically presented with photographs of emotional expressions (2) and are asked to judge the respective emotion. Most studies investigate the recognition of basic emotions, such as anger, fear, happiness, sadness and disgust (3). Recognition accuracy has been found to generally differ between emotions: Happiness, the only positive of the basic emotions and hence probably the most distinct, has been found to be the emotion easiest to recognise (4–6). Fear, on the other hand, seems to be recognised less accurately than other basic emotions (5,7). Further, there have been reports of systematic mistakes in emotion recognition with fear and surprise (5), as well as anger and disgust (8) being frequently confused. This may be due to the same facial action units being active during expression of several emotions, e.g. lowered eyebrows and narrowed eyes during expression of both anger and disgust (9,10).

Several studies have stressed the importance of facial areas in emotion recognition. During free inspection of faces, observers tend to focus mostly on the eye region (11). Emotion recognition is most accurate if participants are presented with full face displays, less accurate when only the lower region of the face can be seen and the least accurate if participants only see the upper region of the face (12). However, the importance of lower and upper facial areas for emotion recognition seems to depend on the emotion itself (3,13). The lower region of the face has been found to be superior in recognition of happiness and anger, while the upper region of the face seems to be especially important for recognition of angry, fearful and sad expressions (14–16). More recent research investigating the importance of facial action units applied eye tracking and confirmed that observers strongly rely on the mouth region when recognising happiness and disgust but focus more on the eyes upon recognition of anger, fear and sadness (17). However, literature on facial action units and which areas are especially important for emotion-specific recognition is not conclusive: The

general pattern of which facial area is important for recognition of which emotion is inconsistent and seems to at least partly depend on the measure (18).

Considering that emotion recognition seems to be impaired if faces are partly occluded, this raises the question whether face masks could also influence how these equivocal facial expressions are perceived. As facial expressions convey information about the emotional state of a person and therefore have a crucial communicative function (19), possible behavioural intentions might be misread when wearing a mask. Further, faces covered by masks may be perceived as more threatening, not least because (surgical) face masks are usually worn in the context of disease and might therefore be interpreted as a health threat. For instance, it has been found that a surgeon's mask seems to interfere with the communication to the patient (20): This could render certain situations to be perceived as more threatening due to impaired verbal and non-verbal communication about topics related to disease. In turn, this might leave the mask as a symbol for a generally more threatening environment. Furthermore, it has recently been found that surgical face masks have a detrimental effect on face matching performance (21), which might further add to an increased perception of threat due to the impaired ability to recognise both unfamiliar and even familiar faces.

While there is a large amount of studies investigating emotion recognition in faces that are not occluded or in faces that are partly masked, using for example the Bubbles technique (22), there are only very few studies looking at the impact of face masks specifically on emotion recognition accuracy. It has been suggested that reading of facial emotions is irritated by the presence of a mask (23), however, this was tested in a relatively small sample and further studies including a control group assessing mask-specific effects are necessary. Another study investigated the effect of face masks and sunglasses (an occlusion individuals tend to have more experience with) on emotion recognition and found that, while recognition performance was reduced in both cases, there was little difference in recognition accuracy between the mask and the sunglasses conditions (24). This suggests that there might be a general effect of any type of occlusion of the face rather than an effect specific to the face mask. This remains to be investigated more closely as sunglasses normally only cover the eye region; face masks, however, cover the lower half of the face, thus both occlusion types potentially hindering recognition of different facial emotional expressions. Furthermore, we are not aware of any studies investigating whether emotional faces wearing face masks are perceived as more threatening than faces without a mask.

The aim of the present study thus was to investigate whether emotion recognition is more difficult for faces wearing a face mask covering mouth and nose than for uncovered faces. In Study 1, we assessed emotion recognition by use of an adapted version of a validated emotion recognition task ('Vienna Emotion Recognition Tasks', VERT-K; (25)), where we digitally added surgical masks to the original facial stimuli. We expected impaired emotion recognition for masked faces compared to un-masked faces. Additionally, we were interested in whether wearing a face mask affects the perception of threat and therefore included an exploratory part where we assumed that faces with a mask would be perceived as more threatening than faces that are fully visible. In Study 2, we extended the findings of Study 1 and assessed whether emotion recognition performance for faces covered by a face mask differs from recognition performance for faces where only the upper half is presented (Study 2a) and for faces where a bubble occludes the lower facial regions (Study 2b). Similar to Study 1, we also investigated whether the perception of threat is affected.

Using convenience sampling, we recruited a large sample of individuals who completed both studies online achieving our overall aim of the current study was to investigate the influence of a (surgical) face mask on emotion recognition performance and perception of threat.

Study 1

In Study 1, we investigated whether emotion recognition, assessed by an adapted version of a validated emotion recognition task, is more difficult for faces wearing a face mask covering mouth and nose than for uncovered faces. Additionally, we assessed whether faces wearing a face mask are perceived as more threatening than faces without a mask.

Method

Sample

790 participants (636 females) between 18 and 89 years ($M = 30.85$, $SD = 12.68$) participated in the study. Subjects were recruited through the universities' mailing lists and through advertisements in groups in social media (e.g. Facebook). The study was conducted online and the participants' data was collected anonymously. The study was approved by the ethics committee of the Medical Faculty of the Eberhard Karls Universität Tübingen (252/2020BO2) and all research was performed in accordance with the relevant guidelines

and regulations. Participants took part voluntarily and provided written informed consent before participation.

Materials

The study was conducted via an online questionnaire that was generated using SoSci Survey (26) and was made available to users via www.soscsurvey.de between April 14 and June 14, 2020.

To assess emotion recognition in faces with and without a face mask, an adapted version of an emotion discrimination task ('Vienna Emotion Recognition Tasks', VERT-K (25)) was applied. The VERT-K is a computer-based task and consists of 36 coloured photographs of facial expressions of Caucasians portraying five basic emotions (anger, fear, happiness, sadness and disgust) as well as neutral expressions. The photographs were originally taken from a standardised stimulus set (see (2) for development of stimuli) and have been validated for the German-speaking population (27). The stimulus set consists of six evoked expressions per facial category, which are balanced for sex of poser (18 female and 18 male faces) with each poser appearing only once.

For Study 1, the VERT-K was extended by duplicating the stimulus set and by digitally adding a face mask covering mouth and nose to the duplicated faces, resulting in a total of 72 stimuli (36 without face mask and the same 36 with face mask). We chose an image of a typical white surgical face mask, fitted it to match the length and width of the respective face and superimposed the mask onto the original stimuli so that it covered the face from just below the eyes, i.e. onset of the nose, downwards. This was done using Adobe Photoshop (Adobe Inc., CA, USA). The original black background of the stimuli was replaced with a grey background to reduce contrast to the white face masks and the size of the stimuli was standardised (14.50 cm x 12.70 cm). See Fig 1 for exemplary stimuli without and with face mask. To ensure viability, the final 72 stimuli were split into two versions of 36 stimuli so that each poser was only seen once in each version (if poser A was wearing a face mask in version A, they were presented without a face mask in version B). Both versions were balanced for emotion, sex and age of poser, as well as face mask and stimuli were presented in a pseudo-randomised order making sure that no more than two masked faces were presented in a row and that the same emotion was not depicted more than three times in a row (see S1 Table). Participants were quasi-randomly assigned to one of the two versions. They were instructed to recognise the respective emotion depicted and to select their answer

in a forced-choice answering format where all categories were present (anger, fear, happiness, sadness, disgust and neutral).

To assess whether faces wearing a mask are perceived as more threatening than faces without a mask, a Visual Analogue Scale (VAS) was applied. Participants were asked to indicate how they perceived each face on a scale ranging from 0 (*not threatening at all*) to 100 (*extremely threatening*). For each item, the VAS was presented sequentially after forced-choice assessment of emotion recognition. There was no time limit for giving a response. At the end of the online questionnaire, participants provided demographic data such as age and sex.

Fig 1. Exemplary stimuli of the adapted Vienna Emotion Recognition Tasks (VERT-K).

(a) A female poser showing an angry expression and (b) a male poser showing a happy expression.

Statistical analysis

Statistical analyses were performed using SPSS 25 (IBM SPSS Statistics) with alpha set to .05. Despite minor deviations from normality (visual inspection and Kolmogorov-Smirnoff tests), we relied on parametric tests including analysis of variance (ANOVA) as these are adequate due to the reasonably large sample size (28).

The number of correct responses (i.e. correctly identified emotions) was calculated for each item. To eliminate possible stimulus-driven effects, difference scores of correct responses for faces with mask vs. no mask were calculated for each item separately: Scores of emotion recognition accuracy for faces without a mask were subtracted from scores of recognition accuracy for faces with a mask and subsequently averaged for each emotion. Negative difference scores indicated lower emotion recognition accuracy for faces with mask compared to faces without mask and positive difference scores indicated higher recognition accuracy for faces with mask compared to faces without mask. To test whether emotion

recognition performance differs dependent on face mask (difference scores for mask vs. no mask), one-sample *t*-tests (two-tailed) were conducted in total and for each emotion separately. To analyse whether emotion recognition performance (difference scores for mask vs. no mask) differs between emotions, we relied on a repeated-measures ANOVA with *emotion* (anger, fear, happiness, sadness, disgust and neutral) as a within-subject factor. Where sphericity was violated, Greenhouse-Geisser adjusted values are reported. Post-hoc tests with Bonferroni correction were calculated for significant results. We further report estimates of effect size for significant results using partial-eta-squared.

To test whether participants perceive faces wearing a mask as more threatening than faces without a mask, difference scores for faces with mask vs. no mask were calculated from individual ratings on the VAS: Rating scores of threat for faces without mask were subtracted from rating scores for faces with mask and subsequently averaged for each emotion. Negative difference scores indicated lower ratings of threat for faces with mask compared to faces without mask and positive difference scores indicated higher ratings of threat for faces with mask compared to faces without mask. To analyse whether participants perceive faces differently dependent on face mask (difference scores for mask vs. no mask), one-sample *t*-tests (two-tailed) were conducted in total and for each emotion separately. To investigate differences in perception of threat (difference scores for mask vs. no mask) between emotions, we performed another repeated-measures ANOVA with *emotion* as within-subject factor. Where sphericity was violated, Greenhouse-Geisser adjusted values are reported. Post-hoc tests with Bonferroni correction were calculated for significant results. We further report estimates of effect size for significant results using partial-eta-squared.

Results

Facial emotion recognition and face mask

Fig 2 depicts the mean difference scores (mask vs. no mask) of emotion recognition performance for the facial emotion recognition task. The one-sample *t*-test revealed significant results, indicating that, in total, emotion recognition accuracy was significantly lower for faces with mask compared to faces without mask, $t(5) = -4.89, p = .005$. Upon investigation of the separate emotions, lower accuracy for faces with mask compared to faces without mask was shown for anger, sadness and disgust separately (all $p < .05$) but not for fearful, happy, and neutral faces (all $p > .05$), see S2 Table for details. The ANOVA revealed a significant effect of emotion, $F(1, 5) = 5.32, p = .002, \eta_p^2 = .515$. Follow-up comparisons

showed that difference scores for recognition of disgust (mask vs. no mask) were significantly larger than scores for recognition of all other emotions apart from anger (fear, happiness, sadness and neutral; all $p < .05$), see S3 Table for p -values. This indicated that the difference in recognition accuracy with mask vs. without mask was largest for emotion recognition in faces showing disgust. S1 Fig additionally depicts the pattern of errors, i.e. misinterpretations of each emotion as another emotion (please see supplement).

Fig 2. Difference scores (mask vs. no mask) of facial emotion recognition performance. Mean difference scores (in percent) with error bars (standard deviation) of emotion recognition accuracy for the separate emotions and across all (total) for faces with mask vs. no mask ($n = 790$). Negative difference scores indicate lower emotion recognition accuracy for faces with mask compared to faces without mask and positive difference scores indicate higher recognition accuracy for faces with mask compared to faces without mask. *: $p < .05$.

Perception of threat and face mask

Fig 3 depicts the mean difference scores (mask vs. no mask) of threat ratings. While there was no significant effect in total, $t(5) = 0.46$, $p = .666$, the one-sample t -tests revealed significant results for anger, happiness and sadness (all $p < .05$), see S4 Table for details. This indicated that happy and sad faces were perceived as significantly more threatening with mask compared to without mask but that perception of threat was significantly lower for angry faces with mask compared to without mask. There was no significant effect for fearful, disgusted and neutral faces (all $ps > .401$). The ANOVA did not reveal a significant effect of

emotion, $F(1, 5) = 2.40, p = .066$, suggesting no significant overall difference in threat ratings between the emotions. To check whether the same effects can be found for correctly recognised faces only, we performed the same analysis as described above for rating of threat including only faces which were correctly recognised by participants. The one-sample t -tests revealed significant results for happiness, $t(5) = 3.06, p = .028$, and sadness, $t(5) = 2.74, p = .041$, but not for anger, $t(5) = -1.13, p = .309$, see S2 Fig and S5 Table for details. This indicated that perception of threat was significantly higher for correctly identified happy and sad faces with mask compared to without mask but there was no significant effect for correctly identified angry faces with mask vs. without mask. The ANOVA did not reveal a significant effect of emotion, $F(1, 5) = 0.47, p = .796$, suggesting again no significant difference in threat ratings between the emotions.

Fig 3. Difference scores (mask vs. no mask) of perception of threat.

Mean difference scores of rating of threat on a Visual Analogue Scale (VAS) with error bars (standard deviation) for the separate emotions and across all (total) for faces with and without a face mask ($n = 790$). Negative difference scores indicate lower ratings of threat for faces with mask compared to faces without mask and positive difference scores indicate higher ratings of threat for faces with mask compared to faces without mask. *: $p < .05$.

Discussion

The findings from Study 1 suggest that emotion recognition is more difficult for faces wearing a face mask covering mouth and nose than for uncovered faces. In line with our hypothesis, we observed that emotion recognition was less accurate when faces were presented with a mask. This was especially the case for faces showing angry, sad and disgusted expressions. This finding is in accordance with previous research showing that emotion recognition is more difficult if the lower region of the face is occluded (12), though we can now extend this suggestion to also be true for (surgical) face masks. We observed the largest decline in recognition performance due to the mask for faces expressing disgust. This supports previous reports indicating that different facial action units are important for recognition of different emotions, with the lower part of the face including the nose region being especially relevant for recognition of disgust (17). Recognition of happiness, in turn, for which the lower facial regions were suggested to be important as well (16), was not significantly affected. This might be due to happiness being the only positive and therefore most distinct emotion tested in this study and generally being found to be recognised easily (6). We did not find significant differences in recognition performance due to the mask for fearful and neutral faces. This is in line with previous findings indicating that, for recognition of fear, observers rely more on the eyes than on the mouth region, hence, recognition performance would not be affected as much by occlusion of the lower face by a mask. Further, it seems as if for faces showing neutral expressions, occlusion of the lower regions does not impair recognition performance. While happy expressions were rarely confused with any other emotion, especially anger and sadness were frequently misinterpreted as disgust, which is partly in line with previous research reporting systematic mistakes in emotion recognition (8). Vice versa, disgust was often mistaken for sadness, both with and without face mask.

In Study 1, we further found significant differences in the perception of threat dependent on face mask for faces showing anger, happiness and sadness. While angry faces were rated as less threatening, happy and sad facial expressions were perceived as more threatening with mask than without. This could be explained by certain facial action units in the lower areas being occluded, leaving only the eyes and forehead visible: During expression of happiness and sadness, the eyes become smaller and wrinkles form around the eyes which might in turn be perceived as more threatening without the mouth yielding additional information, as narrowed eyes usually express anger (10). The analysis including

only correctly identified emotional expressions supports these results, especially for happiness and sadness, and even shows stronger differences in perception of threat dependent on mask for faces depicting disgust.

A question not addressed by Study 1 is whether the impaired emotion recognition performance observed when comparing recognition rates for masked and un-masked faces is specific to the face mask. It is not yet clear whether the effects are due to simply occluding the lower facial areas or if there might be a mask-specific effect as well. Therefore, we conducted two control experiments testing whether there is a mask-specific effect on emotion recognition accuracy.

Study 2

In Study 2, we sought to extend the findings from Study 1 (with stimuli ‘mask’ and ‘original’) and to assess whether emotion recognition performance for faces covered by a mask differs from recognition performance for faces where only the upper half is presented (Study 2a; ‘half’) and for faces where a bubble obscures the lower facial regions (Study 2b; ‘bubble’). Study 2a and 2b were run in parallel and perception of threat was investigated again.

Method

Sample

395 participants (289 females) between 18 and 70 years ($M = 29.16$, $SD = 11.12$) participated in Study 2a and 388 participants (298 females) between 18 and 65 years ($M = 28.94$, $SD = 10.83$) took part in Study 2b. Subjects were recruited through the universities’ mailing lists. The experiment was conducted online and the participants’ data was collected anonymously. Participants took part voluntarily and provided written informed consent before participation.

Materials

Just as Study 1, Study 2 was conducted via online questionnaires that were generated using SoSci Survey (26) and were made available to users via www.soscisurvey.de between September 14 and October 14, 2020.

To assess emotion recognition in faces that are partly occluded by something other than a face mask, the 36 stimuli of the VERT-K were adapted in two different ways. For

Study 2a, the original stimuli were cut off just beneath the eyes so that only the poser's upper face was visible. For Study 2b, a skin-toned bubble obscuring the mouth and nose area of the poser was digitally added to the original images via Adobe Photoshop. As in Study 1, the original black background was replaced with a grey background. See Fig 4 for exemplary stimuli used in Study 2a and 2b. Participants were quasi-randomly assigned to one of the study versions and were presented with one of the two adapted stimulus sets each consisting of 36 images in a pseudo-randomised order. As in Study 1, participants were instructed to recognise the respective emotion depicted and to select their answer in a forced-choice answering format where all categories were present (anger, fear, happiness, sadness, disgust and neutral). Again, a VAS ranging from 0 (*not threatening at all*) to 100 (*extremely threatening*) was applied to assess perception of threat for each facial stimulus.

Fig 4. Exemplary stimuli of the adapted Vienna Emotion Recognition Tasks (VERT-K). Stimuli as used in (a) Study 2a ('half') and (b) Study 2b ('bubble').

Statistical analyses

Statistical analyses were performed using SPSS 25 (IBM SPSS Statistics) with alpha set to .05. Separately for Study 2a and Study 2b, the number of correct responses was calculated for each emotion, resulting in a mean score of emotion recognition accuracy (percent correct) for each participant per emotion for half faces (Study 2a) and faces with a bubble obscuring mouth and nose (Study 2b). Additionally, the mean scores of emotion recognition accuracy for masked and un-masked ('original') faces obtained in Study 1 were calculated and included for further analyses.

We relied on a 6×4 analysis of variance (ANOVA) with *emotion* (anger, fear, happiness, sadness, disgust and neutral) and *version* (half, bubble, mask and original) as factors, to analyse differences in emotion recognition dependent on the study version, i.e. on the type of occlusion of the lower facial areas. For significant interactions, we performed

separate emotion-specific ANOVAs. Where sphericity was violated, Greenhouse-Geisser adjusted values are reported. Post-hoc tests with Bonferroni correction were calculated for significant results. We further report estimates of effect size for significant results using partial-eta-squared.

To test for differences in perception of threat between the study versions, individual ratings on the VAS were averaged, resulting in a mean score of perception of threat for each participant per emotion for each study version. These scores were analysed using a 6×4 ANOVA with the same factors as stated above. For significant interactions, separate ANOVAs were performed for each emotion. Where sphericity was violated, Greenhouse-Geisser adjusted values are reported. Post-hoc tests with Bonferroni correction were calculated for significant results. We further report estimates of effect size for significant results using partial-eta-squared.

Results

Facial emotion recognition and study version

Fig 5 depicts the descriptive statistics of the performance in the facial emotion recognition task for each study version (Study 2a: half; Study 2b: bubble; Study 1: mask, original). The ANOVA revealed a significant interaction between emotion and version, $F(15, 14154) = 199.77, p < .001, \eta_p^2 = .175$. To disentangle this significant interaction, we performed six ANOVAs, one for each emotion, revealing significant differences between the study versions for anger, $F(3, 2359) = 244.62, p < .001, \eta_p^2 = .237$, fear, $F(3, 2359) = 21.53, p < .001, \eta_p^2 = .027$, happiness, $F(3, 2359) = 102.48, p < .001, \eta_p^2 = .115$, sadness, $F(3, 2359) = 176.80, p < .001, \eta_p^2 = .184$, disgust, $F(3, 2359) = 1562.24, p < .001, \eta_p^2 = .665$, and neutral, $F(3, 2359) = 14.48, p < .001, \eta_p^2 = .018$. Follow-up comparisons of emotion recognition in each study version separately for each emotion showed that recognition accuracy of all emotions was significantly lower in the half, bubble and mask versions compared to the original study version (all $p < .05$). Additionally, recognition of fearful and neutral faces was significantly less accurate in the half version compared to the mask version (both $p < .01$). For happy faces, recognition accuracy was significantly lower in the half version and in the bubble version compared to the mask version (both $p < .01$), however, for disgusted expressions, recognition accuracy was significantly higher in the half and the bubble version compared to the mask version (both $p < .001$). There were no significant differences in

recognition accuracy between the half and the bubble version for any emotion (all $p > .05$). See S6 Table for details.

Fig 5. Performance in the facial emotion recognition task for each study version.

Mean emotion recognition accuracy (percent correct) with error bars (standard error) for the separate emotions and across all (total) for each study version. Study 2a: half ($n = 395$); Study 2b: bubble ($n = 388$), Study 1: mask and original ($n = 790$). Recognition accuracy of all emotions was significantly lower in the half, bubble and mask versions compared to the original study version (all $p < .05$). Significance is indicated only for comparisons of mask with half and bubble. **: $p < .01$, ***: $p < .001$.

Perception of threat and study version

Fig 6 depicts the descriptive statistics of the perception of threat for each study version (Study 2a: half; Study 2b: bubble; Study 1: mask, original). The ANOVA revealed a significant interaction between emotion and version, $F(15, 14154) = 48.56, p < .001, \eta_p^2 = .049$. To disentangle the significant interaction, we performed six ANOVAs, one for each emotion, revealing significant differences between the study versions for anger, $F(3, 2359) = 104.20, p < .001, \eta_p^2 = .117$, happiness, $F(3, 2359) = 18.57, p < .001, \eta_p^2 = .023$, sadness, $F(3, 2359) = 40.74, p < .001, \eta_p^2 = .049$, disgust, $F(3, 2359) = 97.58, p < .001, \eta_p^2 = .110$, and neutral, $F(3, 2359) = 6.73, p < .001, \eta_p^2 = .008$, but not for fear, $F(3, 2359) = 2.08, p = .100$. Follow-up comparisons of perception of threat in each study version separately for each

emotion showed that faces with a happy, sad and disgusted expression were rated as significantly more threatening in the mask version compared to the original version (all $p < .001$). Contrarily, faces with an angry expression were rated as significantly less threatening in the mask version, as well as in the half and bubble version, compared to the original version (all $p < .001$). Sad and neutral faces were rated as significantly more threatening in the mask version compared to the bubble version (both $p < .001$) but not compared to the half version (both $p > .05$), whereas faces with a disgusted expression were rated as significantly more threatening in the mask version compared to the half and bubble version (both $p < .001$). See S7 Table for details.

Fig 6. Ratings of perception of threat for each study version.

Mean rating of threat on a Visual Analogue Scale (VAS) with error bars (standard error) for the separate emotions and across all (total) for each study version. Study 2a: half ($n = 395$); Study 2b: bubble ($n = 388$), Study 1: mask and original ($n = 790$). Significance is indicated only for comparisons of mask with half and bubble. ***: $p < .001$.

Discussion

The findings from Study 2 extend the results from Study 1 and suggest that emotion recognition performance for faces covered by a mask differs from emotion recognition performance for faces occluded by something other than a face mask. We observed

differences in recognition performance for fear, happiness and neutral expressions when comparing faces with a mask to faces where only the upper half was presented: Emotions were recognised more accurately when the face was wearing a mask. This finding may be due to the fact that, for half faces, a larger area of the face was occluded than for faces with a mask. In comparison to faces cut off beneath the eyes, the mask could have allowed for a vague idea about the outer shape of the lower face and whether the mouth might be open or closed. This might in turn have affected emotion-specific recognition rates.

However, we found a different pattern for disgust: Recognition rates for this emotion were higher for half faces and faces occluded by a bubble compared to masked faces. Especially this finding seems to be an effect specific to the face mask. It might be that it is possible to still surmise certain facial features that are particularly important for recognition of disgust in half faces and faces obscured by a bubble but not in faces with a mask. Previous research has shown that, for identification of certain emotions, some rather small action units have a higher importance for successful recognition than others (17): For disgust, these particular action units seem to be grouped around the mouth. This would include raising the lip and plucking it, which would in turn also result in a wrinkled nose. Especially the wrinkled nose may still be discerned in half faces cut off at the onset of the nose and in faces occluded by a bubble only partly obscuring the cheeks but not in faces broadly covered by a surgical face mask.

Upon investigation of differences in perception of threat, when comparing masked faces to faces occluded by a bubble, we observed that sad and neutral expressions were rated as more threatening with a mask compared to when they were occluded by a bubble. Furthermore, we found that disgusted expressions were rated as more threatening when the face was wearing a mask than when it was occluded by a bubble as well as when only the upper half was presented. Especially with regard to disgust, it may be that certain facial areas covered by the face mask do not only negatively influence emotion recognition rates but thus render the facial expression highly equivocal which might then result in elevated perception of threat.

General Discussion

The aim of the present research was to determine whether the accuracy in recognising facial emotional expressions is affected by wearing face masks covering mouth and nose compared to faces without a mask (Study 1). Emotion recognition was assessed by an

adapted version of a validated emotion recognition task, the VERT-K, investigating the recognition of the basic emotions anger, fear, happiness, sadness, disgust and neutral expressions. We expected emotion recognition to be less accurate for faces with a mask compared to faces without a mask. It was further investigated whether faces wearing a mask are perceived as more threatening than faces without a mask. In Study 2, the findings of Study 1 were extended as we investigated whether emotion recognition performance and perception of threat for faces covered by a mask differs from recognition performance and perception of threat for faces where only the upper half is presented and for faces where a bubble occludes the lower facial regions.

We found that emotion recognition was less accurate for faces wearing a mask covering mouth and nose (Study 1) and that this effect is not only due to occluding the lower part of the face in general, but that especially recognition of disgust seems to be impaired when wearing a face mask (Study 2).

The present study was able to confirm previous findings on impaired emotion recognition upon occlusion of the lower part of the face (12,23,24) by showing that emotion recognition performance was poorer for all types of occluded stimuli (mask, half faces, and obscuring bubbles) compared to faces that are fully visible. While a recent study found only little difference in emotion recognition accuracy between faces wearing a mask and faces wearing sunglasses (24), we were able to report a specific effect of a certain kind of occlusion, namely the (surgical) face mask, especially for disgust. Not only did we observe mask-specific effects on emotion recognition performance, our results further revealed no significant difference in emotion recognition rates between the two control experiments using other types of occlusion (Study 2a and 2b). The present study's results suggest that findings on emotion recognition in the context of occlusion should be interpreted with regard to the nature of the occlusion used in the respective study, as it might play a bigger role than previously assumed.

In comparison with recent reports on the effect of face masks on emotion recognition, our results once more illustrate that the general pattern of which facial action unit is important for recognition of which emotion at least partly depends on the measure (18): While one study presented real images of people wearing masks for a limited duration (1000 ms) and conducted a control experiment with another type of occlusion (24), another study used stimuli with masks superimposed on existing images and presented them without time limit but did not control for general effects by another type of occlusion (23). In line with our findings, both studies reported impaired emotion recognition performance for faces with face

mask, however, the results for the specific emotions and their implications concerning the importance of facial action units differ and should be interpreted with regard to the methodological differences.

Several methodological constraints have to be considered. As the stimulus set used in the current study was created several years ago, the quality of some stimuli could potentially be improved. Moreover, in the current paradigm, static images of faces were used, whereas, in a natural environment, emotional expressions would be observed within a certain context supported by gestures and movement. The intensity of facial expressions was high and it would be interesting to explore how facial expressions with lesser intensity will be recognised. For future studies, it is worth considering using video recordings of faces, as emotion recognition has been found to be more accurate for moving displays (12) and findings can be generalised more reliably. Furthermore, as was done in a previous study (24), the effect of other types of facial occlusion individuals tend to have more experience with, such as sunglasses or a niqab, should be considered.

Another limitation of the present research is that, while the stimulus material used was validated for a German-speaking, i.e. Western, population, we did not assess the participants' ethnicity or cultural background. Previous studies have shown that recognition of basic emotions might actually not be culturally universal, as often assumed (29), but that facial expressions may be perceived and decoded differently dependent on the observer's culture and may especially differ between the Western and Eastern culture (30). However, the vast majority of the study samples in the present research was German-speaking (Study 1: 94%, Study 2: 100%). This allows for the assumption that the stimulus material used was adequately matched to our participants' ethnic background. Nevertheless, future studies should consider assessing ethnicity, as assessment of the individual cultural background could inform about how accepting and familiar the observer is with face masks, as in East Asia, for instance, it has been customary to wear a mask in public for quite some time. For observers with an Asian background, faces with a mask may therefore not seem as threatening, bizarre or novel as they may seem to observers with a different cultural background. Future studies should therefore control for possible cultural effects and differences depending on ethnicity in connection with the stimulus material.

Another interesting factor that was not investigated in detail in the current research due to the nature of online sampling but that has been shown to influence emotion recognition, is the sex of the observer. Findings concerning sex differences in emotion recognition remain inconsistent, though most report higher recognition rates in females than

males (12,31,32) (but see (27,33) for no differences). It should be noted that between 73% to 80% of our participant sample were female, which might account for generally higher recognition rates than would be found in samples with a more equal sex ratio. Future studies on emotion recognition in the context of face masks might therefore be interested in considering the possible influence of sex and gender, as well as other interesting sociodemographic factors such as age (e.g. 34,35).

To conclude, we were able to show that wearing a face mask affects social interaction in terms of impaired emotion recognition accuracy and altered perception of threat. However, we may want to accept these limitations, as there are many positive consequences of wearing face masks, such as touching one's face less often (36), which could in turn prevent the spread of infectious diseases.

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Supporting Information

S1 Fig. Misinterpretation of emotions in the facial emotion recognition task.

Mean responses in the emotion recognition task (in percent) for (a) anger, (b) fear, (c) happiness, (d) sadness, (e) disgust and (f) neutral with depiction of misinterpretations of one emotion as another emotion in total and for faces with and without face mask separately (n = 790).

S2 Fig. Difference scores (mask vs. no mask) of perception of threat for correct responses only.

Mean difference scores of rating of threat on a Visual Analogue Scale (VAS) with error bars (standard deviation) for correct responses only, for the separate emotions and across all (total) for faces with and without a face mask (n = 790). Negative difference scores indicate lower ratings of threat for faces with mask compared to faces without mask and positive difference scores indicate higher ratings of threat for faces with mask compared to faces without mask. *: $p < .05$.

S1 Table. Pseudo-randomised order of stimuli for the two versions A and B used in Study 1. The 72 adapted stimuli used in Study 1 were split into two versions of 36 stimuli so that each poser was only seen once in each version (if male poser ‘anger & old’ was wearing

a mask in version A, the same stimulus was presented without a face mask in version B). Both versions were balanced for emotion, sex, age and face mask and the order of stimuli was drawn randomly. Stimuli with face masks are typeset in italics, original stimuli in roman type.

S2 Table. Emotion-specific results from *t*-tests on emotion recognition performance dependent on face mask.

Results from one-sample *t*-tests on emotion recognition performance (difference scores for mask vs. no mask, in percent) for each emotion ($n = 790$).

* $p < .05$

S3 Table. Differences in emotion recognition performance dependent on emotion.

All values depicted are *p*-values ($\alpha = .05$). Significant effects obtained through analysis of variance (ANOVA) were followed up with Bonferroni-corrected paired-samples *t*-tests to analyse differences in emotion recognition performance (difference scores for mask vs. no mask) dependent on emotion ($n = 790$). Significant results ($p < .05$) are typeset in bold.

S4 Table. Emotion-specific results from *t*-tests on perception of threat dependent on face mask.

Results from one-sample *t*-tests on rating of threat on a Visual Analogue Scale with a range from 0 to 100 (difference scores for mask vs. no mask) for each emotion ($n = 790$).

* $p < .05$

S5 Table. Emotion-specific results from *t*-tests on perception of threat dependent on face mask, for correct responses only.

Results from one-sample *t*-tests on rating of threat on a Visual Analogue Scale with a range from 0 to 100 (difference scores for mask vs. no mask) for each emotion, for correct responses only ($n = 790$).

* $p < .05$

S6 Table. Differences in emotion recognition accuracy (percent correct) between the study versions.

Significant effects obtained through analysis of variance were followed up with Bonferroni-corrected multiple comparisons to analyse differences in emotion recognition accuracy

(percent correct) between the study versions for each emotion separately. Study 1: original and mask (n = 790); Study 2a: half (n = 395); Study 2b: bubble (n = 388).

* $p < .05$

S7 Table. Differences in rating of threat between the study versions.

Significant effects obtained through analysis of variance were followed up with Bonferroni-corrected multiple comparisons to analyse differences in rating of threat on a Visual Analogue Scale with a range from 0 to 100 between the study versions for each emotion separately. Study 1: original and mask (n = 790); Study 2a: half (n = 395); Study 2b: bubble (n = 388).

* $p < .05$