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FEATURE ARTICLE

Reading Covered Faces

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Abstract

Covering faces with masks, due to mandatory pandemic safety regulations, we can no longer rely on the habitual daily-life information. This may be thought-provoking for healthy people, but particularly challenging for individuals with neuropsychiatric and neurodevelopmental conditions. *Au fait* research on reading covered faces reveals that: 1) wearing masks hampers facial affect recognition, though it leaves reliable inferring basic emotional expressions; 2) by buffering facial affect, masks lead to narrowing of emotional spectrum and dampen veridical evaluation of counterparts; 3) masks may affect perceived face attractiveness; 4) covered (either by masks or other veils) faces have a certain signal function introducing perceptual biases and prejudices; 5) reading covered faces is gender- and age-specific, being more challenging for males and more variable even in healthy aging; 6) the hampering effects of masks on social cognition occur over the globe; and 7) reading covered faces is likely to be supported by the large-scale assemblies of the neural circuits far beyond the social brain. Challenges and limitations of ongoing research and parallels to the Reading the Mind in the Eyes Test are assessed. Clarification of how masks affect face reading in the real world, where we deal with dynamic faces and have *entrée* to additional valuable social signals such as body language, as well as the specificity of neural networks underlying reading covered faces calls for further tailored research.

Key words: aging, brain communication, covered faces, cultural differences, development, emotion, face mask, face reading, gender and sex, neural circuits, neuropsychiatric conditions, nonverbal visual social cognition, social brain, social distancing

Introduction

Social signals conveyed by dynamic bodies and faces are vital for efficient social cognition and intact interpersonal interaction (e.g., de Gelder et al. 2010; Sokolov et al. 2011, 2020; Atkinson et al., 2012; Kret and de Gelder 2012; Pavlova, 2012, 2017a, 2017b; Pelphrey et al. 2014; van den Stock et al. 2015; Di Giorgio et al. 2017; Pavlova et al., 2017; Tillman et al. 2019; Jack et al. 2021). Yet, we remain in the midst of the COVID-19 pandemic, and our daily-life social cognition is no longer taken for granted. Covering faces with masks, due to mandatory pandemic safety regulations, we are unable to rely on the habitual information. Instead, we are forced to pick and pool together social signals from different sources such as eyes (without faces hidden behind masks) and bodies. This is thought-provoking even for healthy people (Freud et al. 2020; Nestor et al. 2020; Martinelli et al. 2021), but may be particularly challenging for individuals with neuropsychiatric and neurologic conditions such as autism spectrum disorders (ASD), depression, anxiety, frontotemporal dementia or Alzheimer's disease, and for individuals born preterm (van den Stock et al. 2020; Gil and Arroyo-Anlló 2021; Khan et al. 2021; Pavlova et al. 2021; Rankin 2021).

As a replacement for routine reliance on the benefits of friendly open smiles for establishing camaraderie, we have to explore other, often rather subtle social signals. Wearing face masks represents not only one of simple protective tools against contamination (Parida et al. 2020) but also a substantial psychological burden for nonverbal social communication requiring

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Figure 1. Examples of facial affect under whole-face-seen (no mask, NM), transparent mask (TM), and standard mask (SM) conditions. Violin plots depict the emotion recognition accuracy, which is significantly lower in the SM conditions, whereas no difference occurs between the NM and TM conditions. From Marini et al. (2021), the Creative Commons Attribution [CC BY] license.

reading faces with a hidden lower part. Covering face parts of both counterparts of interpersonal interaction may reduce social contagion, bonding, and emotional mimicry. Wearing face masks may lessen empathic responses to emotional states of others. Moreover, it is demanding to accurately read the facial expressions of others and simultaneously keep hidden our own feelings (Schneider et al. 2013). In line with this, reading emotions of others is associated with recognition of feelings in oneself (Israelashvili et al. 2019). Differentiation between true (also known as "Duchenne") and fake ("Botox, Pan Am") smiles is based on complementary streams of information from the upper and lower face parts (Hess and Bourgeois 2010; Eisenbarth and Alpers 2011). This information flow may be impaired by masks, resulting in misinterpretation of social signals and nonefficient interaction. This is of societal value, since people with true smiles are usually estimated as authentic, genuine, attractive, and trustworthy (Gunnery and Ruben 2016; Galinsky et al. 2020), whereas, by contrast, fake smiles hinder interpersonal interaction: better no smile at all than a fake smile. In general, in faces covered by masks, emotions with positive valence become less recognizable, whereas negative emotions are believed to be augmented (Spitzer 2020).

In medical practice, covering faces by masks dampens social interaction (Wiesmann et al. 2021). For instance, wearing masks by medical consultants in public primary care reduces perceived empathy with a far more pronounced negative impact on already established doctor–patient relationships (Wong et al. 2013). Mask-to-mask (or more precisely, eyes-to-eyes instead of face-to-face) clinical interaction calls for special skills in eye reading, in particular, in psychiatric and pediatric health care (Wild and Kornfeld 2021). In this connection, the question arises: Which evidence on reading covered faces is offered by rigorous experimental research?

Reading Covered Faces: Accuracy, Misinterpretation, and Perceptual Bias

A substantial reduction in recognition of faces partly hidden by medical masks is predicted by pre-COVID-19 research on visual processing of faces with an occluded lower area or with removed or hidden face elements (Bassili 1979; Stephan and Caine 2007; Blais et al. 2012; Dhamecha et al. 2014). Covering faces with masks decreases performance on the Cambridge Face Memory Test with high individual variability alongside a clear disadvantage for male observers (Freud et al. 2020). Superimposing surgical masks over the faces (i.e., making the lower part of a face occluded) has a large detrimental effect leading to lessening in face matching for both familiar and unfamiliar faces (Carragher and Hancock 2020; Noyes et al. 2021). This indicates difficulties in face re-identification, exemplifying well-known drives for covering faces by lawbreakers.

Covering the lower part of a face not only disrupts its holistic processing but also can affect a predisposition for detecting a coarse face scheme (such as two eyes above a mouth) emerging early in lifespan or considered to be hardwired in the brain of humans, nonhuman primates, domestic chicks, and even in species without parental care (Rosa-Salva et al. 2010; Taubert et al. 2017; Reid et al. 2018; Buiatti et al. 2019; Versace et al. 2020). In the absence of the lower part, the face scheme and corresponding releasers are presumably not activated. In line with this, tuning to a coarse face scheme in face-like Face-n-Food (slightly bordering on imaginative portraits by Giuseppe Arcimboldo) and Face-n-Thing images is orientation-specific (Pavlova et al. 2020) and is substantially lower in neuropsychiatric and neurodevelopmental conditions such as ASD, schizophrenia, and Williams and Down syndrome (Pavlova et al. 2016a, 2016b, 2017, 2018; Rolf et al. 2020).

In general, the lower region of a face is considered to be pivotal in the recognition of happiness and disgust, the upper region in the recognition of anger and fear, and both are vital for recognition of surprise and sadness. This holds true also for moving faces and point-light faces represented as a set of light dots on moving dark-colored faces (Bassili 1979). For most emotional expressions, complementary streams of information from the upper and lower face parts are required, though under natural conditions observers usually have access to a plentiful amount of facial information.

Several recent online studies focus on reading covered faces. By using static photographs of faces (from the Karolinska Directed Emotional Faces database; https://www.kdef.se/) covered by masks with the help of Photoshop software, Italian observers have been shown to be quite proficient in inferring basic emotions (such as anger, happiness, and fear) with pronounced gender differences: females rate negative emotions

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Figure 2. A female poser expressing the basic emotions. Faces are shown under full-face (top) and covered-by-mask conditions (bottom row). From Carbon (2020), the Creative Commons Attribution [CC BY] license.

as more negative and positive emotions as more positive than males (Calbi et al. 2021). Similar to situations when whole faces are seen, females indicate a greater desirable physical distance from and longer interpersonal distance (less close social bonding) with persons, in particular, males, with angry and ambiguous eyes (Calbi et al. 2021). Face masks not only hamper the categorization of basic emotions of both positive and negative valence, but happy expressions are often mistaken for neutral expressions (a "poker face"), and neutral expressions misperceived as sad expressions (Marini et al. 2021; Fig. 1). Moreover, this study shows that masks increase trust scores assigned to untrustworthy unmasked faces.

In line with this, in an internet-based study with computer-generated characters, a cohort of French participants predominated by women (457 in total/323 females) choose a shorter appropriate for them interpersonal distance with covered neutral faces than with unmasked neutral, happy, or angry ones (Cartaud et al. 2020). Estimated interpersonal distance is generally shorter with female than male posers. It is even more petite in participants either infected with COVID-19 or living in low-risk areas, while it is not affected by the predicted health of protagonists. Neutral characters wearing masks are judged as more trustworthy than with whole-face emotional expressions (angry, neutral, or happy), more threatening and less healthy than with whole-face happy expressions, and more strong-minded than with whole-face happy or neutral expressions (but less strong-minded than those with angry faces). Similarly, Colombian perceivers (1078 participants/821 females) judge mask wearers as more trustworthy and socially desirable, although unhealthier than the same unmasked posers (Olivera-La Rosa et al. 2020). This outcome reflects a certain perceptual bias in processing of faces covered by medical masks.

Face masks confuse German observers in reading emotions: covering by masks basic facial expressions decreases recognition of all (in particular, disgust and happiness) except for neutral and fearful expressions (Carbon 2020; Fig. 2; unmasked faces are from the MPI FACES database). In addition, disgusted faces are often misinterpreted as being angry, and other emotions are misread as neutral expressions. Notably, inferring emotions covered by masks remains still far above chance, though confidence in one's own assessment becomes lower (Carbon 2020). Masks not only diminish the ability to accurately categorize negative facial affect (more in men) but also buffer the impact of negative facial emotions on estimation of trustworthiness, likability, and closeness (Grundmann et al. 2021).

In a sample of German perceivers (165 adults/86.1% females, 53.9% reported to have been under psychiatric treatment at least once in life, and 22.4% under ongoing treatment), mask wearing results in lower evaluation of trustfulness and happiness than the same unmasked calm facial expressions with a straight gaze. The negative bias elicited by medical masks is stronger in those participants who attribute lower protective potential to masks, feel higher burden of wearing them, wear masks infrequently, and experience a higher level of psychological distress (Biermann et al. 2021). In accord with this, college students enrolled in a large public southeastern US university who are compliant with guidelines of mask wearing have higher scores for initiation and maintenance of mask wearing, participatory dialogue, behavioral confidence, emotional transformation, practice for change, changes in the social environment, and significantly lower scores for disadvantage (Davis et al. 2021).

In the pre-COVID-19 period (where wearing masks was already not uncommon in Japan), covering female and male faces by a sanitary mask (and other occluders) reduced perceived attractiveness of good-looking faces (Miyazaki and Kawahara 2016; Fig. 3). Occlusion of the lower part of a face by masks lessens visibility of symmetry, contours, and other cues known to contribute to the perception of face attractiveness [e.g., both Caucasian and Japanese perceivers prefer (rate as more attractive) feminized faces with a round shape and a small nose over average female and male faces (Perrett et al. 1998; see also Pavlova et al. 2016b)]. In turn, covering makes unfavorable features invisible, though only occluders other than masks

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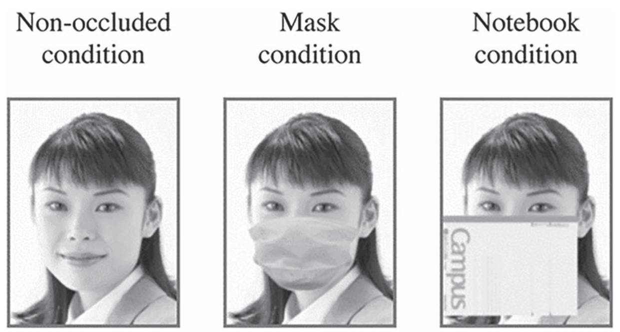

Figure 3. A female poser under full-face (left), covered-by-mask, and covered-by-notebook conditions. Covered good-looking faces are perceived as less attractive under both "covered" conditions, covered by masks faces are perceived as less healthy as compared with the same unmasked faces. From Miyazaki and Kawahara (2016), Copyright © 2016 John Wiley & Sons, Inc., with permission of the publisher.

increase attractiveness of less-attractive faces. Both attractive and nonattractive faces are perceived as unhealthier and more vulnerable to illness (e.g., respiratory allergy) when covered by a sanitary mask (Miyazaki and Kawahara 2016). Two factors (occlusion and unhealthiness bias elicited by a sanitary mask) interact with each other constituting "the sanitary-mask effect" (Miyazaki and Kawahara 2016; Kamatani et al. 2021a). In Japanese population, faces covered by black masks are reported to be perceived more negative compared with masks of white color perceptually symbolizing pollution or purity, respectively (Kamatani et al. 2021b). The COVID-19 pandemic has led to a decrease in unhealthiness ratings of masked faces (both perceived and imagined), presumably because the attitudes toward mask wearing are changing. Now mask wearing is associated merely with the mutual protection of community members, prevention of COVID-19 viral spread, and compliance with social norms rather than with personal health conditions solely (Kamatani et al. 2021a). Nevertheless, covered by medical masks faces are still perceived unhealthier than unmasked ones. Yet, in the course of the COVID-19 pandemic, the effect of a mask on face attractiveness has remained basically unchanged. Mask wearing results in decreasing attractiveness ratings of good-looking faces (as before the pandemic), though the attractiveness ratings of nonattractive faces increase, seemingly because the disadvantageous effect of masks becomes not so noticeable (Kamatani et al. 2021a). These effects are independent of mask color (white or black).

In UK residents, facial affect recognition is modulated stronger by wearing masks than sunglasses. In particular, identification of angriness, fear, disgust, happiness, and surprise (but not sadness and neutral expressions) is substantially poorer on faces covered by masks, whereas wearing sunglasses affects primarily recognition of anger and fear (Noyes et al. 2021; Fig. 4). Yet, the effect of face covering is less noticeable in experts, that is, in individuals highly skilled at recognition of unconcealed faces (Noyes et al. 2021). Therefore, the negative influence of mask wearing on face perception and recognition may become weaker with practice.

Finally, in accord with our expectations (see Introduction), in covered by masks faces, social (or "fake") smiles (typically defined by motion of the mouth solely) become nonsmiles, whereas real "Duchenne" smiles (defined by both the eyes and mouth) are rated significantly less happy and more often misperceived as neutral expressions than unmasked smiles (Sheldon et al. 2021). Moreover, although both (fake and real) masked smiles are rated as displaying more disgust than the unmasked versions, perceived disgust is greater for fake smiles. Yet, the glow of real smiles still shows: even covered real smiles are rated as happy and pleasant (Sheldon et al. 2021).

In summary, the studies available indicate:

1. Reduction in facial affect recognition. Wearing a medical mask profoundly hampers facial affect recognition accuracy (the effect sizes depend on the particular emotion), though it leaves inferring basic emotional expressions above chance level (Carbon 2020; Cartaud et al. 2020; Olivera-La Rosa et al. 2020; Ruba and Pollak 2020; Biermann et al. 2021; Calbi et al. 2021; Gori et al. 2021; Grundmann et al. 2021; Marini et al. 2021; Noyes et al. 2021). Substantial reduction in detection and recognition of facial affect may not only have a profound impact on daily-life social interaction but also on a wide range of professional activities such as evaluation of patients in psychiatric clinical practice, pediatric health care, and schooling.
2. Narrowing of perceived emotional spectrum. Lessening in recognition accuracy and perceived intensity of facial signals as well as recognition errors (mistaking one facial expression for another) may lead to narrowing of emotional spectrum of social interaction. In covered by masks faces, with a high probability, expressions with both positive and negative valence may be misperceived as neutral (Carbon 2020; Cartaud et al. 2020; Marini et al. 2021).
3. Deceptive evaluation of counterparts. Most essential, by buffering facial affect, masks often dampen veridical evaluation of counterparts and lead to deceptive impressions and subsequent inefficient or even potentially hazardous interpersonal interaction. In particular, covering negative emotions can result in intensifying perceived trustworthiness and likability that leads to sinking physical and interpersonal distances (Olivera-La Rosa et al. 2020; Grundmann et al. 2021). In turn, cushioning positive emotional signals, such as true smiles, and differentiation between true and false positive signals (e.g., real and fake smiles) may lead to multiple hitches in establishing social contacts in professional settings (Sheldon et al. 2021; Wiesmann et al. 2021).
4. Impact on perceived face attractiveness. Face masks may affect perceived face attractiveness, resulting in a decrease in attractiveness ratings of good-looking female and male faces and an increase in attractiveness ratings of nonattractive faces, independently of a possible symbolic function of mask color (Kamatani et al. 2021a).
5. Perceptual bias. Faces covered by masks have a certain signal function introducing a perceptual bias or prejudices (such as "mask wearers are socially desirable and responsible") that should be in view when considering the mask impact on social interaction. The influence of face masks on social cognition is modulated by a number of factors such as beliefs in protective masks effects and psychological distress (Biermann et al. 2021). For instance, the effect of masks on perceived attractiveness can be profoundly modulated by prejudices toward medical masks (such as "mask wearers may be unhealthy"), which have become weaker in the course of the COVID-19 pandemic as masks are merely associated with mutual protection of community members and compliance

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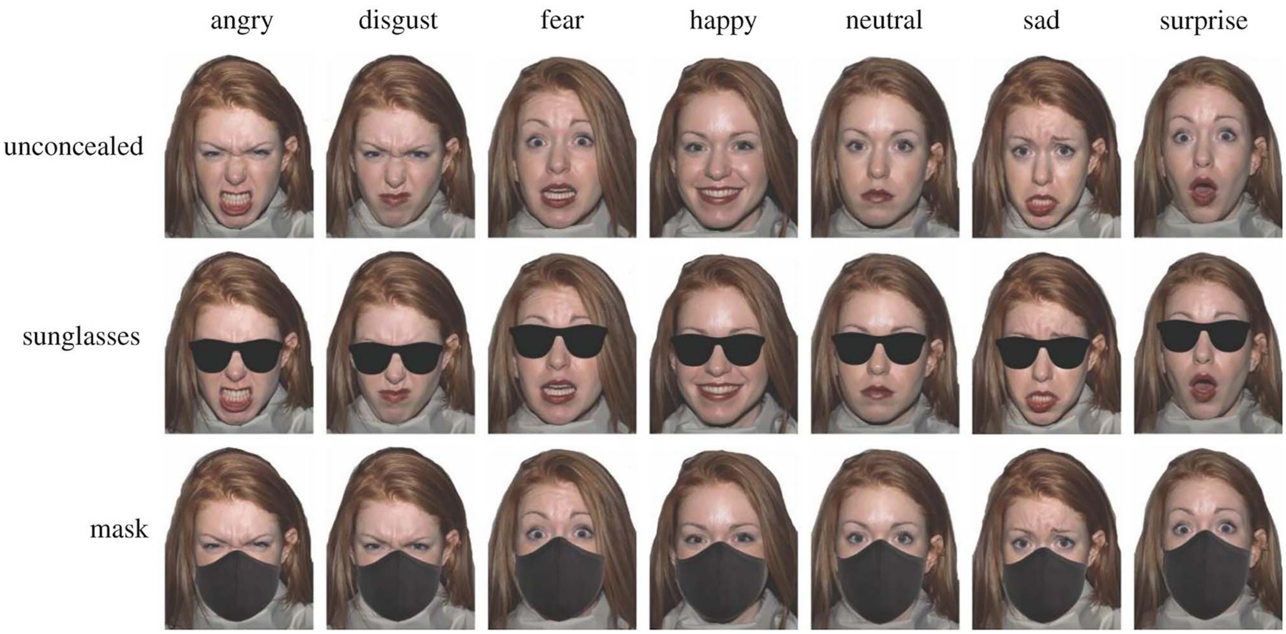

Figure 4. Emotions in unmasked faces, covered by sunglasses faces, and covered by masks faces. A female poser displays the basic emotions (from left to right): angriness, disgust, fear, happiness, neutral expression, sadness, and surprise. From Noyes et al. (2021), the Creative Commons Attribution [CC BY] license.

with social norms (Kamatani et al. 2021). Symbolic meanings of masks as well as fundamental attitudes and beliefs toward mask wearing may affect social behavior at large (Davis et al. 2021; Timpka and Nyce 2021).

Reading Covered Faces: Development, Gender, and Aging

Little is known about developmental impact on reading covered faces, and the findings are not only sparse, but controversial. On one hand, the effect of masks on face reading is reported to be modulated by observers' age: children less than 9 years old are unimpaired in classification of basic facial expressions (Roberson et al. 2012). This dovetails well with the recent report that both deaf (and hard-of-hearing) and typically hearing 6-year-olds pay most attention to the eye region when reading faces expressing basic emotions (Tsou et al. 2020). In racially diverse school-age (7- to 13-years) children, covering faces (taken from the Japanese and Caucasian Facial Expressions of Emotion database) by masks or sunglasses degrades to equal degree inferring basic emotions with negative valence (sadness, fear, and anger), though recognition accuracy is modulated by emotion type (Ruba and Pollak 2020). Yet in childhood, reliable recognition remains possible even when faces are partly covered (Ruba and Pollak 2020). Although face masks affect the ability to infer/label emotions (as well as lead to mistaking one emotion for another) in all age groups (3–5-year-olds, 6–8-year-olds, and adults) of Italian neurotypical participants, difficulties in inferring emotions are significantly more pronounced in children aged 3–5 years (Gori et al. 2021). Older children (aged 6–8 years) are also stronger affected by masks than adults. These findings suggest a potential influence of mask wearing on development of essential social skills such as reading faces, in particular, during transient sensitive periods.

The impact of a face mask on perception and understanding of social signals appears to be gender-specific and age-dependent for both perceivers and posers: reading of covered by masks faces is more challenging for males and in elderly as well as in male and older posers (Carbon 2020; Calbi et al. 2021; Grundmann et al. 2021).

Reading Covered Faces: Cross-Cultural Aspects

The hindering effect of face masks on social cognition (face reading and social judgments such as estimation of personal traits and social distances) appears to occur all over the globe: by now, evidence has been collected in Italian (Calbi et al. 2021; Gori et al. 2021; Marini et al. 2021), German (Carbon 2020; Biermann et al. 2021; Grundmann et al. 2021), Colombian (Spanish-speaking; Olivera-La Rosa et al. 2020), French (Cartaud et al. 2020), UK (Roberson et al. 2012; Noyes et al. 2021), Dutch (Fischer et al. 2012; Kret and de Gelder 2012; Kret and Fischer 2018; Kret et al. 2021), Japanese (Kamatani et al. 2021a), and United Arab Emirates (Kret et al. 2021) cohorts of people as well as in racially diverse children in the USA (Ruba and Pollak 2020). Some parts of the world are more experienced with covered faces: for example, Singapore and Hong Kong suffered flu pandemics in the 1950s and 1960s, while China, Hong Kong, and Taiwan were troubled by the SARS outbreak of the early 2000s with mandatory mask wearing (Johns 2020).

Skills for reading faces covered by masks appear to be shaped not only by experience but also by culture as well as by their interaction, and one can expect that people accustomed to partly veiled faces may be less impaired. The other way around, cultural context can influence reading covered faces. Covering faces by a *niqab* leaving only a region around the eyes open worsens the recognition of happiness and sadness as compared with full-seen faces of females wearing a *hijab*, whereas intensive negative emotions (fear and anger) are well perceived by Western (Dutch) observers also in covered faces (Fischer et al. 2012; Kret and de Gelder 2012). This agrees with the importance

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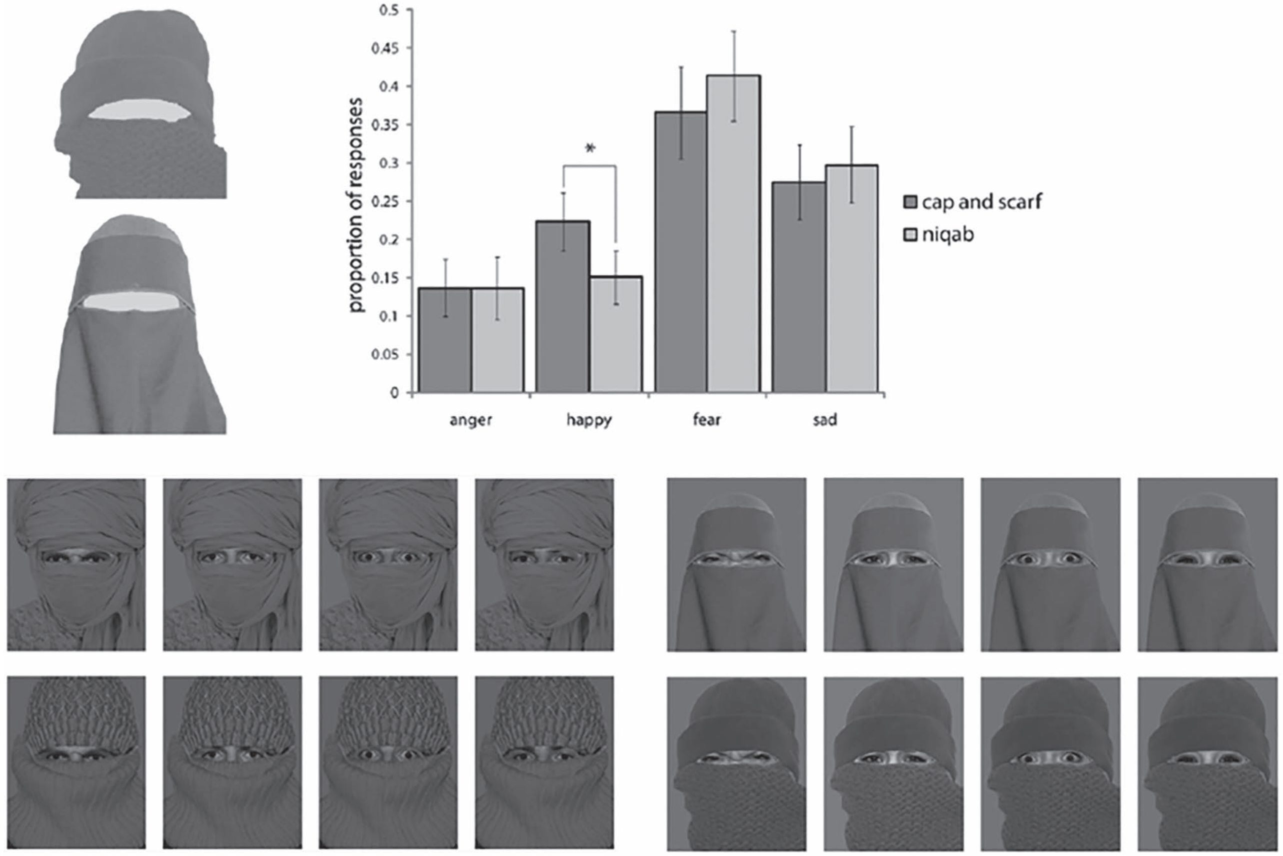

Figure 5. Perceptual bias in reading covered faces. Top: Faces expressing emotions covered either by a Western headdress (a cap-and-scarf) or by a *niqab* (top, left). Though both Western and Islamic headresses leave the same amount of visible information available, faces covered by a *niqab* are perceived by Dutch observers as less happy and tend to be interpreted as more fearful (top, right). From Kret and de Gelder (2012), the Creative Commons Attribution [CC BY] license. Bottom: Faces expressing angriness, sadness, fear, and happiness covered either by a Western headdress (a cap-and-scarf) or by a *turban* or *niqab*. From Kret and Fischer (2018), the Creative Commons Attribution [CC BY] license.

of the eye region for fear expressions (Vuilleumier 2005). Inferring fear is not substantially affected even by wearing a *burqa* with only 20% or 10% of transparency, while happiness and sadness are poorly recognized under these conditions. Remarkably, there is a strong culturally induced bias in reading covered faces. Regardless of attitudes toward Islam and general anxiety level, faces covered by a *niqab* are perceived as less happy and more fearful than covered by a Western headdress (a cap-and-scarf), though the same amount of facial information is available (Kret and de Gelder 2012; Fig. 5). Similarly, the recognition of briefly presented (40 ms) happiness is more accurate when faces are covered by Western compared with Islamic headresses (a *niqab* or *turban*), and sadness is recognized faster as well as more often erroneously assigned to a face covered by an Islamic headdress (Kret and Fischer 2018). However, face covering does not affect the recognition of angriness, as cues signaling this emotional expression (such as furrowing of the brow) are available primarily from the upper face part. These effects are not modulated by oxytocin (Kret and Fischer 2018), an evolutionarily ancient neuropeptide known to facilitate social cognition.

A general effect of a headdress occurs not only in neurotypical individuals but also in patients with major depressive disorder (MDD) of different severity: wearing a cap-and-scarf facilitates recognition of happiness, whereas an Islamic headdress enables a better identification of sadness and fear (Liedtke et al. 2018). MDD patients are slower but not less accurate than neurotypical controls. Wearing different types of face covering may introduce certain perceptual biases. For example, British students (Caucasian, non-Muslim) express more negative attitudes toward a British Muslim woman wearing veils compared with “no veil” conditions, and more negative attitudes toward the full-face veil relative to the *hijab* (Everett et al. 2014). Notably, covering the mouth areas (either by a *niqab* or censoring black bars) leads to greater perceived anxiety in both Dutch participants and individuals from the United Arab Emirates, with less intense perception of happiness and anger (Kret et al. 2021). Yet, the same work shows that faces covered by a *niqab* yield lower emotional intensity ratings than those covered by black bars.

Challenges and Limitations

For several reasons, the outcome of the overviewed research should be taken with caution. First of all, most current experimental work on reading covered faces has been conducted during the ongoing pandemic and, therefore, often represents online research with its well-known advantages (such as relatively large sample sizes, demographic diversity, fast data collection), but also with a number of limitations (a general lack

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of experimenters' control over the settings including lighting conditions, distractions, misunderstanding or misinterpreting the instructions by participants, difficulties in debriefing, prescreen lies, and ethical issues). In addition, the studies may mainly engage individuals with specific computer skills, interests in online information search, and access to necessary equipment, creating a sampling bias. Second, cohorts of participants in many analyzed studies are heavily predominated by females that can potentially lead to an unbalanced study design and some issues with statistical data analysis. For instance, if one subgroup (females) is substantially larger than the other (males), gender comparisons may lead to paradoxical statistical outcomes and preclude proper generalizations of findings.

Displayed versus Natural Emotions

In images and photographs routinely used in experimental settings and face databases, facial affect is either clearly expressed or even exaggerated (Figs 1–4). Moreover, facial emotions are displayed either by professionals (performers and actors) or posers who had been 1) asked and 2) trained to express emotions. These expressions may turn out to be rather different from the natural feelings we experience and express in real life [but see Israelashvili et al. 2021 showing that natural emotional expressions used in the Emotional Accuracy Test are comparable (and correlated) with the Geneva Emotion Recognition Test and Reading the Mind in the Eyes Test (RMET), even when controlling for verbal intelligence quotient]. In naturalistic environments, however, we are usually quite far from extreme affect demonstrations. Instead, perceivers often deal with subtle expressions that are more difficult to detect and categorize. In daily life, therefore, the impact of mask covering on efficient face reading may be even more pronounced.

Basic versus Complex Emotions

Most research on reading covered faces deals with basic emotional expressions such as happiness, angriness, or fear. In daily life, however, emotions are multifaceted and often ambiguous, leading to an increase in individual variability in face reading. For example, we can simultaneously feel and express sadness and happiness: …"I feel sad and light; this sadness of mine is bright…," Aleksandr S. Pushkin (1829) "Upon the hills of Georgia" https://www.best-poems.net/alexander-pushkin/upon-the-hills-of-georgia.html. Yet, individuals who are proficient in reading of basic emotions even in covered faces may potentially exhibit more difficulties in understanding complex multidimensional feelings and mental states.

Artificial Superimposing of Masks on Faces

For purposes of controlled rigorous experimental research, masks are usually superimposed on face photographs by using graphics softwares. In real life, mask wearers may express emotions in a different way, trying to avoid misperception or social distress of counterparts. Furthermore, people may feel high burden of mask wearing and experience discomfort (e.g., difficulties to breathe or articulate) or psychological distress that, in turn, may affect both how mask wearers express their emotions and affective states and how they perceive emotional expressions of counterparts with covered faces.

Dynamic versus Static Faces

In daily life, instead of static face snapshots, we deal with dynamic faces that are much more informative and less ambiguous. Too little is known about reading dynamic faces, in particular, covered by masks. Clarification of the impact of wearing masks in naturalistic environments calls for tailored experimental research.

Beyond Faces

In daily-life social interaction, we have entrée to additional rich sources of nonverbal information such as body language (de Gelder et al. 2010; Sokolov et al., 2011, 2018, 2020; Pavlova 2012; Krüger et al. 2013). The advantage of bodily expressions is that whereas face expressions (similar to a verbal information flow) are believed to be easily kept under control, body movements reveal our true feelings and dispositions. Moreover, when social signals from faces and bodies are dissimilar, face reading is dominated by body language reading (Meeren et al. 2005). In real life, we usually deal with plentiful and often abundant social information that helps to prevent paying high costs for non-adaptive or misleading social interaction. The present analysis focuses on nonverbal social cognition leaving other sources of information (such as prosody) as well as interaction between visual and auditory modalities beyond consideration. Yet in Czech Republic, after a month of reduced access to lip-reading due to mandatory face mask wearing, reliance on other visual cues substantially increased for older persons (Chládková et al. 2021). In addition, one has to bear in mind that the use of protective face masks affects the intelligibility and overall communication: people have to speak with alterations in the perceptual features of their voice, with huskiness and voice volume affected most frequently. In turn, these effects likely impact face perception, emotion recognition, and social interaction (Karagkouni 2021; Yi et al. 2021). Speaking clearly and reducing acoustic noise can help compensate for the loss of intelligibility due to the lack of visual cues and physical distancing (Smiljanic et al. 2021).

Neural Engagement in Reading Faces Covered by Masks

The lack of facial information hidden behind a mask might affect the neural circuits underwriting face perception and affect recognition. Yet, little is known about alterations in brain communication elicited by face covering. It is hypothesized that such an unusual visual experience as daily reading masked faces may trigger a reset mechanism, a renewed ability of the neural networks to undergo a long-term plasticity adaptation (Ferrari et al. 2021; Fig. 6). Long-term usage of face masks can foster experience-dependent synaptic plasticity underpinning face reading. Clarification of the specificity of the neural networks underlying reading covered faces (as compared with unmasked faces) calls for tailored research, which can be guided (at least, partly) by the outcome of earlier brain imaging and lesion studies focusing on reading in the eyes (see Aberrant Reading in the Eyes and Brain Networks Underwriting Reading Covered Faces Sections below).

Some voices and experimental work endorse using transparent face masks that may help to avoid social distress (Mheidly et al. 2020; Ferrari et al. 2021; Gil and Arroyo-Anlló 2021) and collateral harm, sparing the capability to read facial emotions and evaluate personal attribution (Marini et al. 2021). Nevertheless, even transparent masks (TMs) negatively affect face

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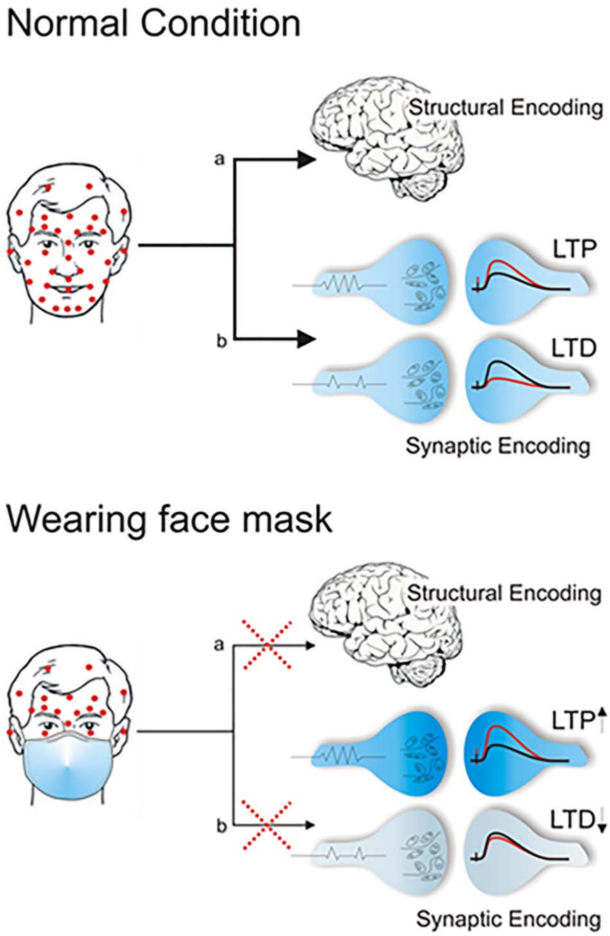

Figure 6. Visual sensory inputs from faces are encoded by the specialized facial networks. At the systems level (*a*), this process implies functional and structural engagement of multiple brain regions, whereas at cellular level (*b*), this promotes the induction of distinct forms of synaptic plasticity, such as long-term potentiation (LTP) and long-term depression (LTD), upper panel. Wearing face masks reduces the amount of information available. Ferrari et al. (2021) suggest that both at the systems and cellular levels, this impairs long-term functional and structural plasticity. In particular, at the synaptic level, LTP induction would be favored, whereas LTD would be impaired. The black traces indicate the excitatory postsynaptic potentials in unmasked conditions; the red traces represent the long-term changes in synaptic efficacy (lower panel). From Ferrari et al. (2021), the Creative Commons Attribution [CC BY] license.

identification (Marini et al. 2021). Another related concern is how effective are TMs in source control (preventing infected persons from transmitting the virus to others) as well as a protective tool to wearers. Possible coping and compensation strategies are also in focus of current research (Mheidly et al. 2020; Molnar-Szakacs et al. 2021). For instance, it is reported that the use of portrait photos with smiling faces (in addition to surgical masks) positively influences patients' estimation of healthcare staff wearing masks: it affects ratings of staff friendliness, but not medical quality of treatment or how well patients feel during treatment (Wiesmann et al. 2021).

Reading Covered Faces and the RMET

The eyes region plays a particularly vital role in inferring people's affective and mental states. Even very short exposure (12.5 ms) is sufficient for emotion recognition in the eyes (Schmidtmann et al. 2020). Although only first steps toward exploring of reading covered faces have been made so far, novel valuable insights can be attained inspecting the RMET (Baron-Cohen et al. 2001), widely used in clinical and neurotypical populations. The standard RMET consists of a set of 36 black-and-white photographs of female and male pairs of eyes (primarily taken from the UK newspapers) along with the corresponding part of a face (portions of surrounding regions including hair style and gaze directions; Fig. 7) with four response options (adjectives describing emotional and mental states) per each item including the correct one. Though the RMET is often criticized for heavy reliance on proficient language command and vocabulary comprehension (e.g., Olderbak et al. 2015; Kittel et al. 2021), the test had been intended to tap affective components of social cognition. The data collected by using the RMET shed light on reading faces covered by masks, as comparable amount of visual information is accessible.

Social Skills Predict Efficient Reading of Covered Faces

Our ability to read in the eyes assessed by the RMET is linked to self-reported empathy and artistic attitudes (Guariglia et al. 2015; Olderbak and Wilhelm 2017; Eddy and Hansen 2020) as well as to emotional intelligence (Megías-Robles et al. 2020). In addition, reading in the eyes is closely related to emotion perception from whole-seen faces (Kittel et al. 2021). RMET performance is

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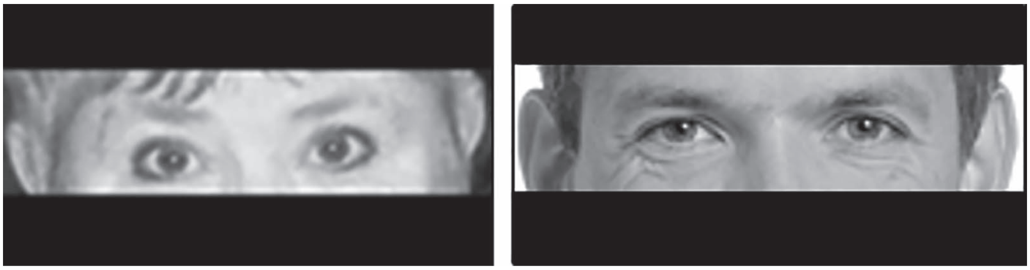

Figure 7. Illustration of images used in exploration of reading in the eyes (with written agreement of both posers).

associated with alexithymia (the inability to identify emotions in the self), and individuals with lower RMET scores are more likely to express aggression (Lee, Nam, et al. 2020). Collectivism is positively related to RMET scores in Palestinian, but not in Italian or German adolescents (Hünefeldt et al. 2021). Reading emotions and affective states in the eyes is firmly connected with other social skills such as body language reading (Alaerts et al. 2011; Miller and Saygin 2013), although this tie appears to be gender-specific, occurring in females solely (Isernia et al. 2020). Already in children aged 7–12 years, accuracy of reading in the eyes is associated with the sensitivity to human body motion (Rice et al. 2016).

Brain Networks Underwriting Reading Covered Faces

Mounting brain imaging data (primarily, structural and functional magnetic resonance imaging (fMRI), and lesion studies) delivers converging evidence in favor of the social brain engagement in the RMET. In particular, such key structures of the social brain as the superior temporal sulcus (STS), amygdala, temporo-parietal junction, and insula in the right hemisphere are strongly engaged (Baron-Cohen et al. 1999; Adams et al. 2010; Moor et al. 2012; Schurz et al. 2014; Overgaauw et al. 2015). Resting-state functional connectivity (RSFC) between the posterior STS and amygdala predicts RMET performance (Yin et al. 2018; Fig. 8).

Parcel-based lesion-symptom mapping, white-matter tract-wise statistical analysis, and disconnectome symptom mapping in stroke patients reveal that low RMET scores are associated with damage to the right posterior frontal gyrus and insula as well as with disconnectivity in white-matter tracts between the frontal and temporo-parietal regions (Domínguez et al. 2019; Fig. 8). Fractional anisotropy (FA) of the right-hemispheric uncinate fasciculus, an association fiber tract connecting the right frontal and anterior temporal lobes and known to support social decision making, is also intimately tied with RMET scoring (Coad et al. 2020). Involvement of brain areas underpinning social decision making such as the dorsomedial prefrontal cortex (dmPFC) is also broadly reported (Moor et al. 2012; Overgaauw et al. 2015; Sato et al. 2016; Domínguez et al. 2019). To the best of our knowledge, no comparison had been made between the neural networks subserving reading whole-seen and covered faces (see also Neural Engagement in Reading Faces Covered by Masks Section above). Yet, it appears plausible that reading partially covered faces requires more attentional resources and greater decision-making load as well as stronger engagement of the brain networks underwriting these abilities. The other way around, individuals with deficient neural circuits underpinning these capabilities may be expected to display difficulties in reading covered faces.

Aberrant Reading in the Eyes

Reading emotions and mental states in the eyes is substantially impaired in a wide range of neuropsychiatric disorders characterized by alterations in social cognition and nonverbal communication such as autism (Baron-Cohen et al. 2001; Baribeau et al. 2015; Del Valle Rubido et al. 2018; Peñuelas-Calvo et al. 2019). This disadvantage is cross-cultural in its nature, occurring, for example, in autistic children from Kolkata, India (Rudra et al. 2016). In the neurotypical population, individuals with higher autistic traits also display weaker RMET performance (Gökçen et al. 2014). RMET scores are lower in schizophrenia including patients with first episode of psychosis (Fernandes et al. 2018; García-Fernández et al. 2020; Kim et al. 2020; Oliver et al. 2021), MDD and social anxiety disorders (Maleki et al. 2020), and alexithymia (Oakley et al. 2016; Rødgaard et al. 2019). Children with attention-deficit/hyperactivity disorder (ADHD) and obsessive–compulsive disorder (OCD) are also impaired (Baribeau et al. 2015). Notably, across children with ASD, ADHD, and OCD, RMET deficits are associated with smaller amygdala/hippocampal volumes (Baribeau et al. 2015).

Patients with early Alzheimer's disease (Heitz et al. 2016), multiple sclerosis (Cotter et al. 2016), behavioral variant of frontotemporal dementia, bvFTD (Pardini et al. 2013; Schroeter et al. 2018), Huntington's disease (Bayliss et al. 2019), Parkinson's disease (Orso et al. 2020), and older individuals with mild cognitive impairment (Michaelian et al. 2019) exhibit difficulties on the RMET. This shows that reading covered faces may be quite challenging for individuals not only with neuropsychiatric, neurological, and neurodevelopmental conditions characterized by altered social cognition, but also for patients with other deficits such as limited attentional resources. In a nutshell, in harmony with brain imaging, the clinical findings reveal that not only the social brain per se but also the neural circuits supporting attention, decision making, and social behavior are required for efficient reading of covered faces.

Gender/Sex Specificity

In accordance with research on masked faces (Reading Covered Faces: Accuracy, Misinterpretation, and Perceptual Bias Section above), females are repeatedly reported to be more proficient on the RMET (Baron-Cohen et al. 2001; Isernia et al. 2020; Megías-Robles et al. 2020; Kynast et al. 2021), though overperformance on the RMET might be also connected with well-developed language skills (Olderbak et al. 2015; Kittel et al. 2021). Female superiority in RMET performance is modulated by difficulty/ambiguity of the items (Guariglia et al. 2015) but appears to be rather independent of culture (Hünefeldt et al. 2021). Recent evidence shows that merely observer's gender (as a social construct), in particular, feminine gender roles,

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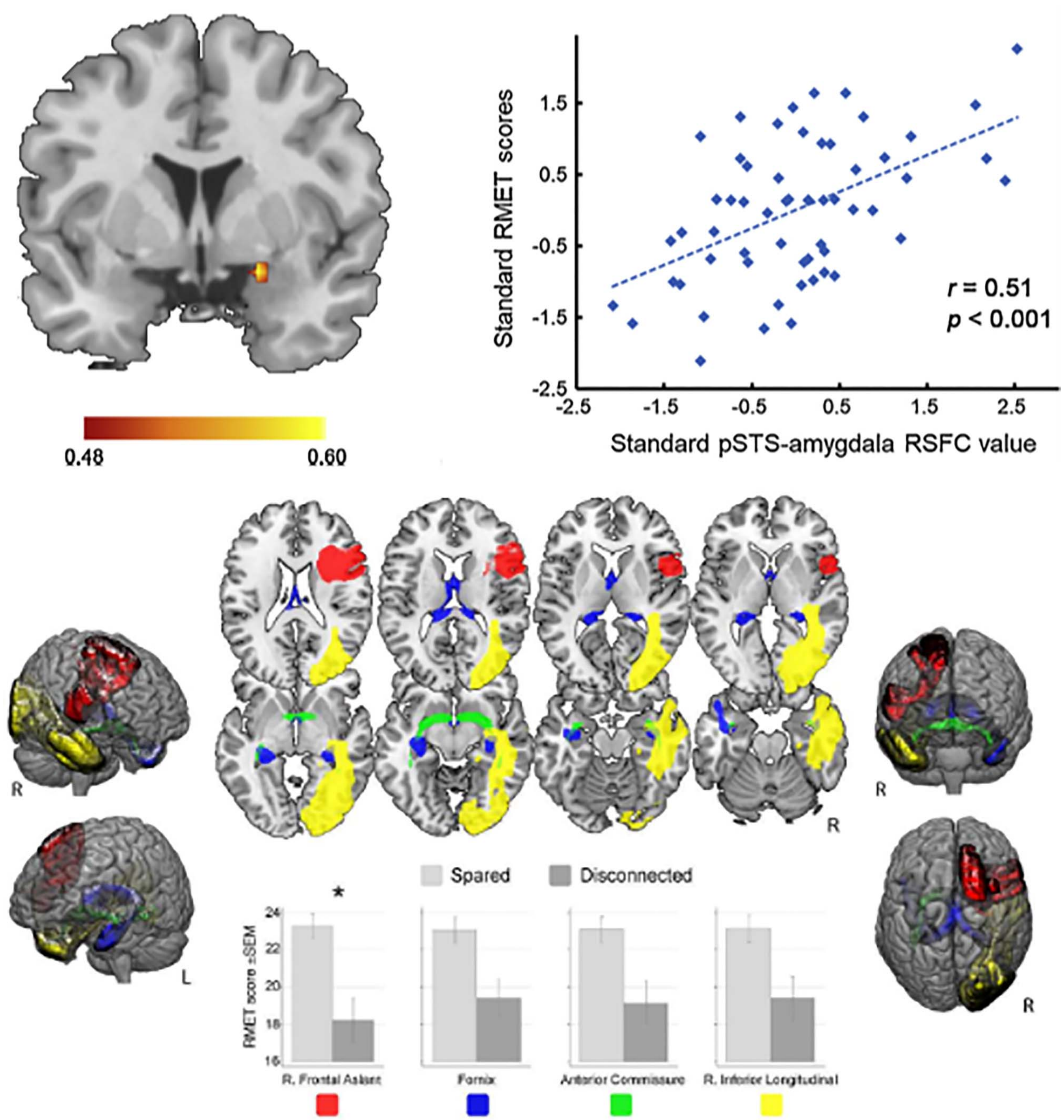

Figure 8. The outcome of brain imaging during the RMET. Top: RMET scores correlate with RSFC values between the left posterior STS and right amygdala (*b*), an fMRI activation of which is shown on the left panel (*a*). From Yin et al. (2018), Copyright©2018 Elsevier B.V., with permission of the publisher. Bottom: Track-wise statistical analysis in stroke patients indicates that lower RMET scores are associated with a greater probability of disconnection in the frontal aslant tract (marked in red), tend to be associated with disconnection in the fornix (blue), anterior commissure (green), and right inferior longitudinal fasciculus (ILF, yellow). The tracts are depicted on axial slices of the ch2bet template in MRIcroGL: from left to right and top to bottom, 20, 14, 8, 2, −4, −10, −16, and −22 (MNI z-coordinates). The tracts are rendered in 3D (right and left sides). From Domínguez et al. (2019), Copyright©2019 Elsevier Ltd, with permission of the publisher.

rather than neurobiological sex, impacts reading in the eyes on the RMET (Vonk et al. 2016). In accord with this, testosterone administration to young women does not affect RMET scoring (Carré et al. 2015). By involving transgender women/men, a lower level of RMET performance is found in transgender men and nonbinary assigned females at birth than in females in the general population (Kung 2020).

Impact of Culture and Age

Accuracy of reading in the eyes is higher when emotions and mental states are expressed and recognized by the same ethnic group, though a cultural in-group effect is modulated by the amount of exposure to the cultural out-group. For instance, difficulties on the RMET (comprising images of Caucasians selected

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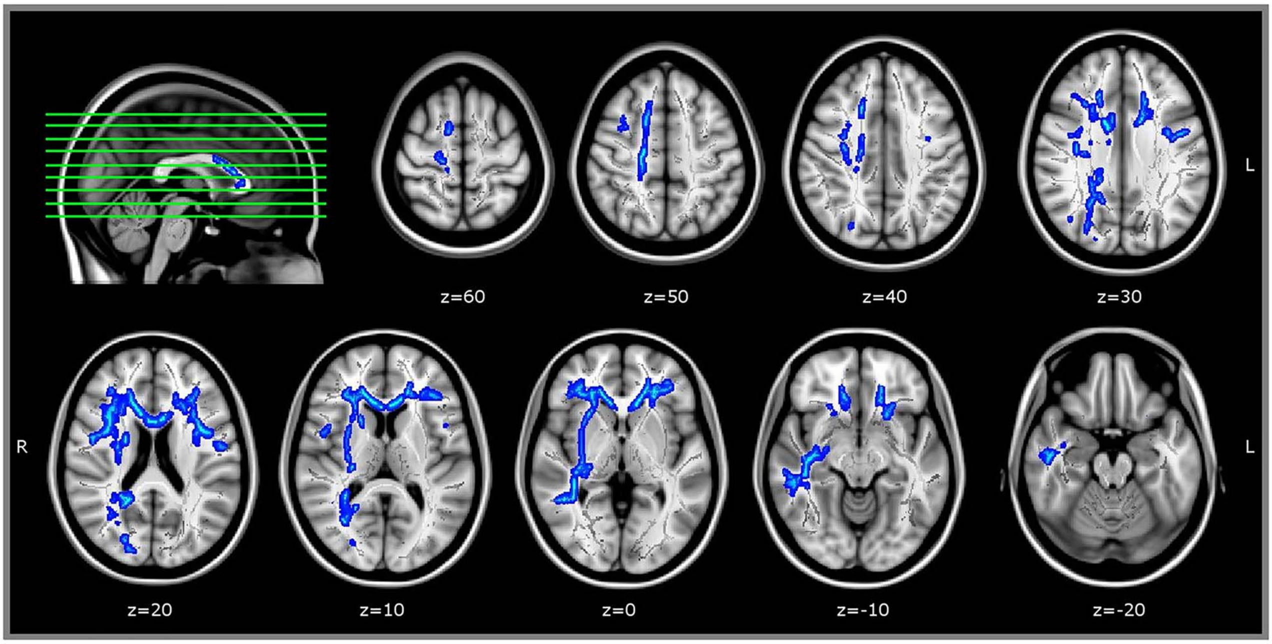

Figure 9. The outcome of the tract-based spatial statistics in healthy aging. White matter regions with significant correlations between FA values and the RMET scoring, $P < 0.05$ corrected (within areas inversely related with age, threshold at $P < 0.05$ corrected). Among them are: the bilateral frontal areas anatomically compatible with the superior longitudinal fasciculus and, only in the right hemisphere, the frontotemporal parts of the superior longitudinal fasciculus, bilateral uncinate fasciculus, right inferior frontooccipital fasciculus, right ILF, and the genu of the corpus callosum (JHU White-matter tractography Atlas, FSL). Coordinates are in MNI space. From Cabinio et al. (2015), the Creative Commons Attribution [CC BY] license.

from the UK newspapers and magazines) are more pronounced in those Singaporean individuals who have had less contact with Caucasians (Martin et al. 2021). In line with this, Palestinian participants score lower on the standard RMET than German and Italian individuals (Hünefeldt et al. 2021). Functional MRI in Caucasian Americans and native Japanese adults reveals greater bilateral recruitment of the posterior STS during same- versus other-culture RMET performance in both cultural groups (Adams et al. 2010).

Nonverbal visual social cognition is widely believed to remain intact in elderly (Moran 2013; Natelson Love et al. 2015; Reiter et al. 2017), though some dissociation occurs between cognitive and affective components (Wang and Su 2013). In accord with this, only a slight or moderate declination with age is reported on the RMET (Henry et al. 2013; Cabinio et al. 2015), though age-related drops in RMET performance can happen as early as in the fifth decade of life (Pardini and Nichelli 2009). Despite the relatively preserved ability for reading in the eyes with age (from 20 to 79 years), an age-related decrease in gray matter volume occurs in a number of brain areas (such as the left superior temporal gyrus, bilateral posterior insula, and left inferior frontal gyrus) along with progressive white matter disconnection of the temporo-parietal portions of the brain (Cabinio et al. 2015; Fig. 9). Age-related decline appears to be profoundly modulated by individual differences: with increasing age, the RMET scoring variance increases in both men and women (Kynast et al. 2021). In older adults, RMET scores are higher with younger age, education, cognitive screening scores, literacy, and social norms scores (Chander et al. 2020; Dodell-Feder et al. 2020; Lee, Jacobsen, et al. 2020). Finally, most recent research indicates the lack of declination or even an increase in RMET scores in healthy aging (Dodell-Feder et al. 2020; Yıldırım et al. 2020).

Résumé

In a nutshell, *au fait* research on reading partially covered faces reveals that: 1) Wearing medical masks hampers facial affect recognition, though inferring basic emotional expressions remains reliable. 2) By buffering both positive and negative facial affect, face masks dampen veridical evaluation of counterparts that may lead to inefficient or even perplexing interpersonal interaction. 3) Faces covered by masks have a certain signal function introducing perceptual biases such as mask wearers can be perceived as either more socially desirable, bizarre or even unhealthy depending on the context. 4) Masks may affect perceived face attractiveness decreasing the attractiveness ratings of good-looking female and male faces and ameliorating the ratings of less attractive faces. 5) Reading covered faces is gender- and age-specific, being more challenging for males and variable even in healthy aging. 6) The hampering effect of face masks on social cognition is likely to be cross-cultural, occurring all over the globe. Reading faces wearing masks is culturally shaped, and people who are accustomed to reading partly veiled faces may be less affected. 7) Reading covered faces is likely to be supported by the large-scale neural circuits, involving not only the social brain, but more widely spread neural communication engaging the networks underwriting attentional resources and social decision making. Clarifying the issue of how masks affect face reading in real life, where we deal with dynamic faces and have entrée to additional social signals such as body language, calls for further tailored research. Investigation of the neural networks underlying reading covered faces (as compared with unmasked faces) can be guided by the outcome of earlier brain imaging and lesion studies focusing on reading in the eyes.

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Benefits of wearing masks in preventing virus transmission likely outweigh the collateral burdens for social cognition, communication, and interaction. Yet, the community has to be aware of potential collateral unintended effects of medical mandates on nonverbal social cognition, particularly, in elderly and preschool age, neuropsychiatric and neurological conditions, and professional domains closely related to social interaction and communication such as education and health care. Attention should be paid to early development of face reading, in particular, during transient sensitive periods and critical time windows. Special efforts should be directed at evaluation, intervention, and training of social skills and reading faces covered by masks. Exploration of social cognition under the current pandemic provides novel valuable insights for the integration of social signals from faces and bodies and using more subtle sources of social information such as reading in the eyes.

Authors' Contribution

Conceived and designed the analysis: M.A.P. Performed the analysis: M.A.P. and A.A.S. Wrote the paper: M.A.P. and A.A.S. Both co-authors contributed to the editing. Supervision of the project: M.A.P.

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References

Adams J, Reginald B, Rule NO, Franklin J, Robert G, Wang E, Stevenson MT, Yoshikawa S, Nomura M, Sato W, et al. 2010. Cross-cultural reading the mind in the eyes: an fMRI investigation. *J Cogn Neurosci*. 22(1):97–108. https://doi.org/10.1162/jocn.2009.21187.

Alaerts K, Nackaerts E, Meyns P, Swinnen SP, Wenderoth N. 2011. Action and emotion recognition from point light displays: an investigation of gender differences. *PLoS One*. 6:e20989. https://doi.org/10.1371/journal.pone.0020989.

Atkinson AP, Vuong QC, Smithson HE. 2012. Modulation of the face- and body-selective visual regions by the motion and emotion of point-light face and body stimuli. *Neuroimage*. 59:1700–1712. https://doi.org/10.1016/j.neuroimage.2011.08.073.

Baribeau DA, Doyle-Thomas KA, Dupuis A, Iaboni A, Crosbie J, McGinn H, Arnold PD, Brian J, Kushki A, Nicolson R, et al. 2015. Examining and comparing social perception abilities across childhood-onset neurodevelopmental disorders. *Am Acad Child Adolesc Psychiatry*. 54(6):479–86.e1. https://doi.org/10.1016/j.jaac.2015.03.016.

Baron-Cohen S, Ring HA, Wheelwright S, Bullmore ET, Brammer MJ, Simmons A, Williams SC. 1999. Social intelligence in the normal and autistic brain: an fMRI study. *Eur J Neurosci*. 11:1891–1898. https://doi.org/10.1046/j.1460-9568.1999.00621.x.

Baron-Cohen S, Wheelwright S, Hill J, Raste Y, Plumb I. 2001. The "Reading the Mind in the Eyes" test revised version: a study with normal adults, and adults with Asperger syndrome or high−functioning autism. *J Child Psychol Psychiatry*. 42:241–251. https://doi.org/10.1111/1469-7610.00715.

Bassili JN. 1979. Emotion recognition: the role of facial movement and the relative importance of upper and lower areas of the face. *J Personal Soc Psychol*. 37:2049–2058. https://doi.org/10.1037//0022-3514.37.11.2049.

Bayliss L, Galvez V, Ochoa-Morales A, Chávez-Oliveros M, Rodríguez-Agudelo Y, Delgado-García G, Boll MC. 2019. Theory of mind impairment in Huntington's disease patients and their relatives. *Arq Neuropsiquiatr*. 77(8):574–578. https://doi.org/10.1590/0004-282X20190092.

Biermann M, Schulze A, Unterseher F, Atanasova K, Watermann P, Krause-Utz A, Stahlberg D, Bohus M, Lis S. 2021. Trustworthiness appraisals of faces wearing a surgical mask during the Covid-19 pandemic in Germany: An experimental study. *PLoS One*. 16(5):e0251393. https://doi.org/10.1371/journal.pone.0251393.

Blais C, Roy C, Fiset D, Arguin M, Gosselin F. 2012. The eyes are not the window to basic emotions. *Neuropsychologia*. 50(12):2830–2838. https://doi.org/10.1016/j.neuropsychologia.2012.08.010.

Buiatti M, Di Giorgio E, Piazza M, Polloni C, Menna G, Taddei F, Baldo E, Vallortigara G. 2019. Cortical route for face like pattern processing in human newborns. *Proc Natl Acad Sci USA*. 116:4625–4630. https://doi.org/10.1073/pnas.1812419116.

Cabinio M, Rossetto F, Blasi V, Savazzi F, Castelli I, Massaro D, Valle A, Nemni R, Clerici M, Marchetti A, et al. 2015. Mind-Reading ability and structural connectivity changes in aging. *Front Psychol*. 6:1808. https://doi.org/10.3389/fpsyg.2015.01808.

Calbi M, Langiulli N, Ferroni F, Montalti M, Kolesnikov A, Gallese V, Umiltà MA. 2021. The consequences of COVID-19 on social interactions: an online study on face covering. *Sci Rep*. 11(1):2601. https://doi.org/10.1038/s41598-021-81780-w.

Carbon CC. 2020. Wearing face masks strongly confuses counterparts in reading emotions. *Front Psychol*. 11:566886. https://doi.org/10.3389/fpsyg.2020.566886.

Carragher DJ, Hancock PJB. 2020. Surgical face masks impair human face matching performance for familiar and unfamiliar faces. *Cogn Res Princ Implic*. 5(1):59. https://doi.org/10.1186/s41235-020-00258-x.

Carré JM, Ortiz TL, Labine B, Moreau BJP, Viding E, Neumann CS, Goldfarb B. 2015. Digit ratio (2D:4D) and psychopathic traits moderate the effect of exogenous testosterone on socio-cognitive processes in men. *Psychoneuroendocrinology*. 62:319–326. https://doi.org/10.1016/j.psyneuen.2015.08.023.

Cartaud A, Quesque F, Coello Y. 2020. Wearing a face mask against Covid-19 results in a reduction of social distancing. *PLoS One*. 15(12):e0243023. https://doi.org/10.1371/journal.pone.0243023.

Chander RJ, Grainger SA, Crawford JD, Mather KA, Numbers K, Cleary R, Kochan NA, Brodaty H, Henry JD, Sachdev PS. 2020. Development of a short-form version of the Reading the Mind in the Eyes Test for assessing theory of mind in older adults. *Int J Geriatr Psychiatry*. 35(11):1322–1330. https://doi.org/10.1002/gps.5369.

Chládková K, Podlipský VJ, Nudga N, Šimáčková Š. 2021. The McGurk effect in the time of pandemic: age-dependent

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adaptation to an environmental loss of visual speech cues. *Psychon Bull Rev*. 28(3):992–1002. https://doi.org/10.3758/s13423-020-01852-2.
Coad BM, Postans M, Hodgetts CJ, Muhlert N, Graham KS, Lawrence AD. 2020. Structural connections support emotional connections: uncinate fasciculus microstructure is related to the ability to decode facial emotion expressions. *Neuropsychologia*. 145:106562. https://doi.org/10.1016/j.neuropsychologia.2017.11.006.
Cotter J, Firth J, Enzinger C, Kontopantelis E, Yung AR, Elliott R, Drake RJ. 2016. Social cognition in multiple sclerosis: a systematic review and meta-analysis. *Neurology*. 87(16):1727–1736. https://doi.org/10.1212/WNL.0000000000003236.
Davis RE, Sharma M, Simon KE, Wilkerson AH. 2021. Conceptualization of college students' COVID-19 related mask-wearing behaviors using the multi-theory model of health behavior change. *Health Promot Perspect*. 11(2):194–201. https://doi.org/10.34172/hpp.2021.24.
de Gelder B, van den Stock J, Meeren HKM, Sinke CBA, Kret ME, Tamietto M. 2010. Standing up for the body. Recent progress in uncovering the networks involved in the perception of bodies and bodily expressions. *Neurosci Biobehav Rev*. 34:513–527. https://doi.org/10.1016/j.neubiorev.2009.10.008.
Del Valle Rubido M, McCracken JT, Hollander E, Shic F, Noeldeke J, Boak L, Khwaja O, Sadikhov S, Fontoura P, Umbricht D. 2018. In search of biomarkers for autism spectrum disorder. *Autism Res*. 11(11):1567–1579. https://doi.org/10.1002/aur.2026.
Dhamecha TI, Singh R, Vatsa M, Kumar A. 2014. Recognizing disguised faces: human and machine evaluation. *PLoS One*. 9:e99212. https://doi.org/10.1371/journal.pone.0099212.
Di Giorgio E, Loveland JL, Mayer U, Rosa-Salva O, Versace E, Vallortigara G. 2017. Filial responses as predisposed and learned preferences: Early attachment in chicks and babies. *Behav Brain Res*. 325(Pt B):90–104. https://doi.org/10.1016/j.bbr.2016.09.018.
Dodell-Feder D, Ressler KJ, Germine LT. 2020. Social cognition or social class and culture? On the interpretation of differences in social cognitive performance. *Psychol Med*. 50(1):133–145. https://doi.org/10.1017/S003329171800404X.
Domínguez DJF, Nott Z, Horne K, Prangley T, Adams AG, Henry JD, Molenberghs P. 2019. Structural and functional brain correlates of theory of mind impairment post-stroke. *Cortex*. 121:427–442. https://doi.org/10.1016/j.cortex.2019.09.017.
Eddy CM, Hansen PC. 2020. Predictors of performance on the Reading the Mind in the Eyes Test. *PLoS One*. 15(7):e0235529. https://doi.org/10.1371/journal.pone.0235529.
Eisenbarth H, Alpers GW. 2011. Happy mouth and sad eyes: scanning emotional facial expressions. *Emotion*. 11:860–865. https://doi.org/10.1037/a0022758.
Everett JAC, Schellhaas FMH, Earp BD, Ando V, Memarzia J, Parise CV, Fell B, Hewstone M. 2014. Covered in stigma? The impact of differing levels of Islamic head-covering on explicit and implicit biases toward Muslim women. *J Appl Soc Psychol*. 45:90–104. https://doi.org/10.1111/jasp.1227.
Fernandes JM, Cajão R, Lopes R, Jerónimo R, Barahona-Corrêa JB. 2018. Social cognition in schizophrenia and autism spectrum disorders: a systematic review and meta-analysis of direct comparisons. *Front Psychiatry*. 9:504. https://doi.org/10.3389/fpsyt.2018.00504.
Ferrari C, Vecchi T, Sciamanna G, Blandini F, Pisani A, Natoli S. 2021. Facemasks and face recognition: potential impact on synaptic plasticity. *Neurobiol Dis*. 153:105319. https://doi.org/10.1016/j.nbd.2021.105319.
Fischer AH, Gillebaart M, Rotteveel M, Becker D, Vliek M. 2012. Veiled emotions: the effect of covered faces on emotion perception and attitudes. *Soc Psychol Personal. Sci*. 3: 266–273. https://doi.org/10.1177/1948550611418534.
Freud E, Stajduhar A, Rosenbaum RS, Avidan G, Ganel T. 2020. The COVID-19 pandemic masks the way people perceive faces. *Sci Rep*. 10(1):22344. https://doi.org/10.1038/s41598-020-78986-9.
Galinsky DF, Erol E, Atanasova K, Bohus M, Krause-Utz A, Lis S. 2020. Do I trust you when you smile? Effects of sex and emotional expression on facial trustworthiness appraisal. *PLoS One*. 15(12):e0243230. https://doi.org/10.1371/journal.pone.0243230.
García-Fernández L, Cabot-Ivorra N, Romero-Ferreiro V, Pérez-Martín J, Rodriguez-Jimenez R. 2020. Differences in theory of mind between early and chronic stages in schizophrenia. *J Psychiatr Res*. 127:35–41. https://doi.org/10.1016/j.jpsychires.2020.05.009.
Gil R, Arroyo-Anlló EM. 2021. Alzheimer's disease and face masks in times of COVID-19. *J Alzheimers Dis*. 79(1):9–14. https://doi.org/10.3233/JAD-201233.
Gökçen E, Petrides KV, Hudry K, Frederickson N, Smillie LD. 2014. Sub-threshold autism traits: the role of trait emotional intelligence and cognitive flexibility. *Br J Psychol*. 105(2):187–199. https://doi.org/10.1111/bjop.12033.
Gori M, Schiatti L, Amadeo MB. 2021. Masking emotions: face masks impair how we read emotions. *Front Psychol*. 12:669432. https://doi.org/10.3389/fpsyg.2021.669432.
Grundmann F, Epstude K, Scheibe S. 2021. Face masks reduce emotion-recognition accuracy and perceived closeness. *PLoS One*. 16(4):e0249792. https://doi.org/10.1371/journal.pone.0249792.
Guariglia P, Piccardi L, Giaimo F, Alaimo S, Miccichè G, Antonucci G. 2015. The eyes test is influenced more by artistic inclination and less by sex. *Front Hum Neurosci*. 9:292. https://doi.org/10.3389/fnhum.2015.00292.
Gunnery SD, Ruben MA. 2016. Perceptions of Duchenne and non-Duchenne smiles: a meta-analysis. *Cogn Emot*. 30(3):501–515. https://doi.org/10.1080/02699931.2015.1018817.
Heitz C, Noblet V, Phillipps C, Cretin B, Vogt N, Philippi N, Kemp J, de Petigny X, Bilger M, Demuynck C, et al. 2016. Cognitive and affective theory of mind in dementia with Lewy bodies and Alzheimer's disease. *Alzheimers Res Ther*. 8(1):10. https://doi.org/10.1186/s13195-016-0179-9.
Henry JD, Phillips LH, Ruffman T, Bailey PE. 2013. A meta-analytic review of age differences in theory of mind. *Psychol Aging*. 28:826–839. https://doi.org/10.1037/a0030677.
Hess U, Bourgeois P. 2010. You smile-I smile: emotion expression in social interaction. *Biol Psychol*. 84:514–520. https://doi.org/10.1016/j.biopsycho.2009.11.001.
Hünefeldt T, Hussein O, Olivetti Belardinelli M. 2021. Cross-cultural differences in intercultural mindreading: evidence from a sample of Palestinian, Italian, and German adolescents. *Psych J*. 10(2):263–274. https://doi.org/10.1002/pchj.417.
Isernia S, Sokolov AN, Fallgatter AJ, Pavlova MA. 2020. Untangling the ties between social cognition and body motion: gender impact. *Front Psychol*. 11:128. https://doi.org/10.3389/fpsyg.2020.00128.
Israelashvili J, Oosterwijk S, Sauter D, Fischer A. 2019. Knowing me, knowing you: emotion differentiation

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in oneself is associated with recognition of others' emotions. *Cogn Emot*. 33(7):1461–1471. https://doi.org/10.1080/02699931.2019.1577221.

Israelashvili J, Pauw LS, Sauter DA, Fischer AH. 2021. Emotion recognition from realistic dynamic emotional expressions cohere with established emotion recognition tests: a proof-of-concept validation of the emotional accuracy test. *J Intell*. 9(2):25. https://doi.org/10.3390/jintelligence9020025.

Jack A, Caw S, Aylward E, Bookheimer SY, Dapretto M, Gaab N, Van Horn JD, Eilbott J, Jacokes Z, Torgerson CM, et al. 2021. A neurogenetic analysis of female autism. *Brain*. 144(6):1911–1926.. https://doi.org/10.1093/brain/awab064.

Johns AJ. 2020. *Interpersonal communication while wearing a face mask*. London: Springer Nature. https://training.springerhealthcare.com/interpersonal-communication-while-wearing-a-face-mask/

Kamatani M, Ito M, Miyazaki Y, Kawahara JI. 2021a. Effects of masks worn to protect against COVID-19 on the perception of facial attractiveness. *i-Perception*. 12(3):1–14. https://doi.org/10.1177/20416695211027920.

Kamatani M, Ito M, Miyazaki Y, Kawahara JI. 2021b. The impact of the COVID-19 epidemic on explicit and implicit attitudes towards black sanitary mask wearers. (In Japanese with English abstract). *Japanese J Psychol*. 92:5. Online ahead of print. https://doi.org/10.4992/jjpsy.92.20046.

Karagkouni O. 2021. The effects of the use of protective face mask on the voice and its relation to self-perceived voice changes. *J Voice*. S0892–1997(21):00149–1. https://doi.org/10.1016/j.jvoice.2021.04.014.

Khan AN, Bilek E, Tomlinson RC, Becker-Haimes EM. 2021. Treating social anxiety in an era of social distancing: adapting exposure therapy for youth during COVID-19. *Cogn Behav Pract*. Online ahead of print. https://doi.org/10.1016/j.cbpra.2020.12.002.

Kim SW, Moon SY, Hwang WJ, Lho SK, Oh S, Lee TY, Kim M, Kwon JS. 2020. Impaired performance on the Reading the Mind in the Eyes Test in first-episode psychosis and clinical high risk for psychosis. *Psychiatry Investig*. 17(12):1200–1206. https://doi.org/10.30773/pi.2020.0264.

Kittel AFD, Olderbak S, Wilhelm O. 2021. Sty in the mind's eye: a meta-analytic investigation of the nomological network and internal consistency of the "Reading the Mind in the Eyes" Test. *Assessment*. 1073191121996469. https://doi.org/10.1177/1073191121996469.

Kret ME, de Gelder B. 2012. Islamic headdress influences how emotion is recognized from the eyes. *Front Psychol*. 3:110. https://doi.org/10.3389/fpsyg.2012.00110.

Kret ME, Fischer AH. 2018. Recognition of facial expressions is moderated by Islamic cues. *Cogn Emot*. 32(3):623–631. https://doi.org/10.1080/02699931.2017.1330253.

Kret ME, Maitner AT, Fischer AH. 2021. Interpreting emotions from women with covered faces: a comparison between a middle Eastern and Western-European sample. *Front Psychol*. 12:620632. https://doi.org/10.3389/fpsyg.2021.620632.

Krüger S, Sokolov AN, Krägeloh-Mann I, Enck P, Pavlova MA. 2013. Emotion through locomotion: gender impact. *PLoS One*. 8(11):e81716. https://doi.org/10.1371/journal.pone.0081716.

Kung KTF. 2020. Autistic traits, systemising, empathising, and theory of mind in transgender and non-binary adults. *Mol Autism*. 11(1):73. https://doi.org/10.1186/s13229-020-00378-7.

Kynast J, Polyakova M, Quinque EM, Hinz A, Villringer A, Schroeter ML. 2021. Age- and sex-specific standard scores for the Reading the Mind in the Eyes Test. *Front Aging Neurosci*. 12:607107. https://doi.org/10.3389/fnagi.2020.607107.

Lee HR, Nam G, Hur JW. 2020. Development and validation of the Korean version of the Reading the Mind in the Eyes Test. *PLoS One*. 15(8):e0238309. https://doi.org/10.1371/journal.pone.0238309.

Lee S, Jacobsen EP, Jia Y, Snitz BE, Chang CH, Ganguli M. 2020. Reading the Mind in the Eyes: A population-based study of social cognition in older adults. *Am J Geriatr Psychiatry*. 29(7):634–642. https://doi.org/10.1016/j.jagp.2020.11.009.

Liedtke C, Kohl W, Kret ME, Koelkebeck K. 2018. Emotion recognition from faces with in- and out-group features in patients with depression. *J Affect Disord*. 227:817–823. https://doi.org/10.1016/j.jad.2017.11.085.

Maleki G, Zabihzadeh A, Richman MJ, Demetrovics Z, Mohammadnejad F. 2020. Decoding and reasoning mental states in major depression and social anxiety disorder. *BMC Psychiatry*. 20(1):463. https://doi.org/10.1186/s12888-020-02873-w.

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

Martin AK, Su P, Meinzer M. 2021. Improving cross-cultural "mind-reading" with electrical brain stimulation. *Neuroscience*. 455:107–112. https://doi.org/10.1016/j.neuroscience.2020.12.007.

Martinelli L, Kopilaš V, Vidmar M, Heavin C, Machado H, Todorović Z, Buzas N, Pot M, Prainsack B, Gajović S. 2021. Face masks during the COVID-19 pandemic: a simple protection tool with many meanings. *Front Public Health*. 8:606635. https://doi.org/10.3389/fpubh.2020.606635.

Meeren HKM, van Heijnsbergen CCRJ, de Gelder B. 2005. Rapid perceptual integration of facial expression and emotional body language. *Proc Natl Acad Sci U S A*. 102(45):16518–16523. https://doi.org/10.1073/pnas.0507650102.

Megías-Robles A, Gutiérrez-Cobo MJ, Cabello R, Gómez-Leal R, Baron-Cohen S, Fernández-Berrocal P. 2020. The 'Reading the Mind in the Eyes' test and emotional intelligence. *R Soc Open Sci*. 7(9):201305. https://doi.org/10.1098/rsos.201305.

Mheidly N, Fares MY, Zalzale H, Fares J. 2020. Effect of face masks on interpersonal communication during the COVID-19 pandemic. *Front Public Health*. 8:582191. https://doi.org/10.3389/fpubh.2020.582191.

Michaelian JC, Mowszowski L, Guastella AJ, Henry JD, Duffy S, McCade D, Naismith SL. 2019. Theory of mind in mild cognitive impairment - relationship with limbic structures and behavioural change. *J Int Neuropsychol Soc*. 25(10):1023–1034. https://doi.org/10.1017/S1355617719000870.

Miller LE, Saygin AP. 2013. Individual differences in the perception of biological motion: links to social cognition and motor imagery. *Cognition*. 128:40–148. https://doi.org/10.1016/j.cognition.2013.03.013.

Miyazaki Y, Kawahara JI. 2016. The sanitary-mask effect on perceived facial attractiveness. *Japanese Psychol Res*. 58:261–272. https://doi.org/10.1111/jpr.12116.

Molnar-Szakacs I, Uddin LQ, Heffernan MB. 2021. The face behind the mask: the future of interpersonal interaction. *Neuron*. 109(12):1918–1920. https://doi.org/10.1016/j.neuron.2021.05.030.

Moor BG, Op de Macks ZA, Güroglu B, Rombouts SARB, Van der Molen MW, Crone EA. 2012. Neurodevelopmental changes of reading the mind in the eyes. *Soc Cogn Affect Neurosci*. 7(1):44–52. https://doi.org/10.1093/scan/nsr020.

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Moran JM. 2013. Lifespan development: the effects of typical aging on theory of mind. *Behav Brain Res*. 237:32–40. https://doi.org/10.1016/j.bbr.2012.09.020.

Natelson Love MC, Ruff G, Geldmacher DS. 2015. Social cognition in older adults: a review of neuropsychology, neurobiology, and functional connectivity. *Med Clin Rev*. 1:6. https://doi.org/10.21767/2471-299X.1000006.

Nestor MS, Fischer D, Arnold D. 2020. "Masking" our emotions: botulinum toxin, facial expression, and well-being in the age of COVID-19. *J Cosmet Dermatol*. 19(9):2154–2160. https://doi.org/10.1111/jocd.13569.

Noyes E, Davis JP, Petrov N, Gray KLH, Ritchie KL. 2021. The effect of face masks and sunglasses on identity and expression recognition with super-recognizers and typical observers. *R Soc Open Sci*. 8(3):201169. https://doi.org/10.1098/rsos.201169.

Oakley BFM, Brewer R, Bird G, Catmur C. 2016. Theory of mind is not theory of emotion: a cautionary note on the Reading the Mind in the Eyes Test. *J Abnorm Psychol*. 125(6):818–823. https://doi.org/10.1037/abn0000182.

Olderbak S, Wilhelm O, Olaru G, Geiger M, Brenneman MW, Roberts RD. 2015. A psychometric analysis of the reading the mind in the eyes test: toward a brief form for research and applied settings. *Front Psychol*. 6:1503. https://doi.org/10.3389/fpsyg.2015.01503.

Olderbak S, Wilhelm O. 2017. Emotion perception and empathy: an individual differences test of relations. *Emotion*. 17(7):1092–1106. https://doi.org/10.1037/emo0000308.

Oliver LD, Moxon-Emre I, Lai MC, Grennan L, Voineskos AN, Ameis SH. 2021. Social cognitive performance in schizophrenia spectrum disorders compared with autism spectrum disorder: a systematic review, meta-analysis, and meta-regression. *JAMA Psychiatry*. 78(3):281–292. https://doi.org/10.1001/jamapsychiatry.2020.3908.

Olivera-La Rosa A, Chuquichambi EG, Ingram GPD. 2020. Keep your (social) distance: pathogen concerns and social perception in the time of COVID-19. *Pers Individ Dif*. 166:110200. https://doi.org/10.1016/j.paid.2020.110200.

Orso B, Arnaldi D, Famà F, Girtler N, Brugnolo A, Doglione E, Filippi L, Massa F, Peira E, Bauckneht M, et al. 2020. Anatomical and neurochemical bases of theory of mind in de novo Parkinson's disease. *Cortex*. 130:401–412. https://doi.org/10.1016/j.cortex.2020.06.012.

Overgaauw S, van Duijvenvoorde ACK, Moor BG, Crone EA. 2015. A longitudinal analysis of neural regions involved in reading the mind in the eyes. *Soc Cogn Affect Neurosci*. 10(5):619–627. https://doi.org/10.1093/scan/nsu095.

Pardini M, Gialloreti LE, Mascolo M, Benassi F, Abate L, Guida S, Viani E, Dal Monte O, Schintu S, Krueger F, et al. 2013. Isolated theory of mind deficits and risk for frontotemporal dementia: a longitudinal pilot study. *J Neurol Neurosurg Psychiatry*. 84(7):818–821. https://doi.org/10.1136/jnnp-2012-303684.

Pardini M, Nichelli PF. 2009. Age-related decline in mentalizing skills across adult life span. *Exp Aging Res*. 35(1):98–106. https://doi.org/10.1080/03610730802545259.

Parida SP, Bhatia V, Roy A. 2020. Masks in COVID-19 pandemic: are we doing it right? *J Family Med Prim Care*. 9(10):5122–5126. https://doi.org/10.4103/jfmpc.jfmpc_657_20.

Pavlova MA, Erb M, Hagberg GE, Loureiro J, Sokolov AN, Scheffler K. 2017. "Wrong way up": temporal and spatial dynamics of the networks for body motion processing at 9.4 T. *Cereb Cortex*. 27(11):5318–5330. https://doi.org/10.1093/cercor/bhx151.

Pavlova MA, Galli J, Pagani F, Micheletti S, Guerreschi M, Sokolov AN, Fallgatter AJ, Fazzi EM. 2018. Social cognition in Down syndrome: face tuning in face-like non-face images. *Front Psychol*. 9:2583. https://doi.org/10.3389/fpsyg.2018.02583.

Pavlova MA, Galli J, Zanetti F, Pagani F, Micheletti S, Rossi A, Sokolov AN, Fallgatter AJ, Fazzi EM. 2021. Social cognition in individuals born preterm. *Sci Rep*. 11(1):14448. https://doi.org/10.1038/s41598-021-93709-4.

Pavlova MA, Guerreschi M, Tagliavento L, Gitti F, Sokolov AN, Fallgatter AJ, Fazzi E. 2017. Social cognition in autism: face tuning. *Sci Rep*. 7(1):2734. https://doi.org/10.1038/s41598-017-02790-1.

Pavlova MA, Heiz J, Sokolov AN, Barisnikov K. 2016a. Social cognition in Williams syndrome: face tuning. *Front Psychol*. 7:1131. https://doi.org/10.3389/fpsyg.2016.01131.

Pavlova MA, Mayer A, Hösl F, Sokolov AN. 2016b. Faces on her and his mind: female and likable. *PLoS One*. 11(6):e0157636. https://doi.org/10.1371/journal.pone.0157636.

Pavlova MA, Romagnano V, Fallgatter AJ, Sokolov AN . 2020. Face pareidolia in the brain: Impact of gender and orientation. *PLoS ONE*. 15(12):e0244516. doi: 10.1371/journal.pone.0244516.

Pavlova MA. 2012. Biological motion processing as a hallmark of social cognition. *Cereb Cortex*. 22(5):981–995. https://doi.org/10.1093/cercor/bhr156.

Pavlova MA. 2017a. Emotion science in the twenty-first century. time, sex, and behavior in emotion science: over and above. *Front Psychol*. 8:1211. https://doi.org/10.3389/fpsyg.2017.01211.

Pavlova MA. 2017b. Sex and gender affect the social brain: beyond simplicity. *J Neurosci Res*. 95:235–250. https://doi.org/10.1002/jnr.23871.

Pelphrey KA, Yang DY, McPartland JC. 2014. Building a social neuroscience of autism spectrum disorder. *Curr Top Behav Neurosci*. 16:215–233. https://doi.org/10.1007/7854_2013_253.

Peñuelas-Calvo I, Sareen A, Sevilla-Llewellyn-Jones J, Fernández-Berrocal P. 2019. The "Reading the Mind in the Eyes" Test in autism-spectrum disorders comparison with healthy controls: a systematic review and meta-analysis. *J Autism Dev Disord*. 49(3):1048–1061. https://doi.org/10.1007/s10803-018-3814-4.

Perrett DI, Lee KJ, Penton-Voak I, Rowland D, Yoshikawa S, Burt DM, Henzi SP, Castles DL, Akamatsu S. 1998. Effects of sexual dimorphism on facial attractiveness. *Nature*. 394:884–887. https://doi.org/10.1038/29772.

Rankin KP. 2021. Measuring behavior and social cognition in FTLD. *Adv Exp Med Biol*. 1281:51–65. https://doi.org/10.1007/978-3-030-51140-1_4.

Reid VM, Dunn K, Young RJ, Amu J, Donovan T, Reissland N. 2018. The human fetus preferentially engages with face-like visual stimuli. *Curr Biol*. 28:824. https://doi.org/10.1016/j.cub.2017.05.044.

Reiter AMF, Kanske P, Eppinger B, Li S-C. 2017. The aging of the social mind - differential effects on components of social understanding. *Sci Rep*. 7:11046. https://doi.org/10.1038/s41598-017-10669-4.

Rice K, Anderson LC, Velnoskey K, Thompson JC, Redcay E. 2016. Biological motion perception links diverse facets of theory of mind during middle childhood. *J Exp Child Psychol*. 146:238–246. https://doi.org/10.1016/j.jecp.2015.09.003.

Roberson D, Kikutani M, Döge P, Whitaker L, Majid A. 2012. Shades of emotion: what the addition of sunglasses or masks to faces reveals about the development of facial expression processing. *Cognition*. 125(2):195–206. https://doi.org/10.1016/j.cognition.2012.06.018.

Downloaded from https://academic.oup.com/cercor/article/32/2/249/6370295 by guest on 12 February 2026

Rødgaard EM, Jensen K, Mottron L. 2019. An opposite pattern of cognitive performance in autistic individuals with and without alexithymia. *J Abnorm Psychol*. 128(7):735–737. https://doi.org/10.1037/abn0000408.

Rolf R, Sokolov AN, Rattay TW, Fallgatter AJ, Pavlova MA. 2020. Face pareidolia in schizophrenia. *Schizophr Res*. 218: 138–145. https://doi.org/10.1016/j.schres.2020.01.019.

Rosa-Salva O, Regolin L, Vallortigara G. 2010. Faces are special for newly hatched chicks: evidence for inborn domain-specific mechanisms underlying spontaneous preferences for face-like stimuli. *Dev Sci*. 13:565–577. https://doi.org/10.1111/j.1467-7687.2009.00914.x.

Ruba AL, Pollak SD. 2020. Children's emotion inferences from masked faces: Implications for social interactions during COVID-19. *PLoS One*. 15(12):e0243708. https://doi.org/10.1371/journal.pone.0243708.

Rudra A, Ram JR, Loucas T, Belmonte MK, Chakrabarti B. 2016. Bengali translation and characterisation of four cognitive and trait measures for autism spectrum conditions in India. *Mol Autism*. 7:50. https://doi.org/10.1186/s13229-016-0111-y.

Sato W, Kochiyama T, Uono S, Sawada R, Kubota Y, Yoshimura S, Toichi M. 2016. Structural neural substrates of Reading the Mind in the Eyes. *Front Hum Neurosci*. 10:151. https://doi.org/10.3389/fnhum.2016.00151.

Schmidtmann G, Logan AJ, Carbon CC, Loong JT, Gold I. 2020. In the blink of an eye: reading mental states from briefly presented eye regions. *Iperception*. 11(5):2041669520961116. https://doi.org/10.1177/2041669520961116.

Schneider KG, Roelie JH, Lynch TR. 2013. That "poker face" just might lose you the game! The impact of expressive suppression and mimicry on sensitivity to facial expressions of emotion. *Emotion*. 13(5):852–866. https://doi.org/10.1037/a0032847.

Schroeter ML, Pawelke S, Bisenius S, Kynast J, Schuemberg K, Polyakova M, Anderl-Straub S, Danek A, Fassbender K, Jahn H, et al. 2018. A modified Reading the Mind in the Eyes Test predicts behavioral variant frontotemporal dementia better than executive function tests. *Front Aging Neurosci*. 10:11. https://doi.org/10.3389/fnagi.2018.00011.

Schurz M, Radua J, Aichhorn M, Richlan F, Perner J. 2014. Fractionating theory of mind: a meta-analysis of functional brain imaging studies. *Neurosci Biobeh Rev*. 42:9–34. https://doi.org/10.1016/j.neubiorev.2014.01.009.

Sheldon KM, Goffredi R, Corcoran M. 2021. The glow still shows: effects of facial masking on perceptions of Duchenne versus social smiles. *Perception*. 50(8):720–727. https://doi.org/10.1177/03010066211027052.

Smiljanic R, Keerstock S, Meemann K, Ransom SM. 2021. Face masks and speaking style affect audio-visual word recognition and memory of native and non-native speech. *J Acoust Soc Am*. 149(6):4013. https://doi.org/10.1121/10.0005191.

Sokolov AA, Krüger S, Enck P, Krägeloh-Mann I, Pavlova MA. 2011. Gender affects body language reading. *Front Psychol*. 2:16. https://doi.org/10.3389/fpsyg.2011.00016.

Sokolov AA, Zeidman P, Erb M, Pollick FE, Fallgatter AJ, Ryvlin P, Friston KJ, Pavlova MA. 2020. Brain circuits signaling the absence of emotion in body language. *Proc Natl Acad Sci USA*. 117(34):20868–20873. https://doi.org/10.1073/pnas.2007141117.

Sokolov AA, Zeidman P, Erb M, Ryvlin P, Friston KJ, Pavlova MA. 2018. Structural and effective brain connectivity underlying biological motion detection. *Proc Natl Acad Sci U S A*. 115(51):E12034–E12042. https://doi.org/10.1073/pnas.1812859115.

Spitzer M. 2020. Masked education? The benefits and burdens of wearing face masks in schools during the current Corona pandemic. *Trends Neurosci Educ*. 20:100138. 10.1016/j.tine.2020.100138.

Stephan BCM, Caine D. 2007. What is in a view? The role of featural information in the recognition of unfamiliar faces across viewpoint transformation. *Perception*. 36:189–198. https://doi.org/10.1068/p5627.

Taubert J, Wardle SG, Flessert M, Leopold DA, Ungerleider LG. 2017. Face pareidolia in the Rhesus monkey. *Curr Biol*. 27:2505–2509.e2. https://doi.org/10.1016/j.cub.2017.06.075.

Tillman R, Gordon I, Naples A, Rolison M, Leckman JF, Feldman R, Pelphrey KA, McPartland JC. 2019. Oxytocin enhances the neural efficiency of social perception. *Front Hum Neurosci*. 13:71. https://doi.org/10.3389/fnhum.2019.00071.

Timpka T, Nyce JM. 2021. Face mask use during the Covid-19 pandemic - the significance of culture and the symbolic meaning of behavior. *Ann Epidemiol*. 59:1–4. doi: https://doi.org/10.1016/j.annepidem.2021.03.012.

Tsou YT, Li B, Kret ME, Sabino da Costa I, Rieffe C. 2020. Reading emotional faces in deaf and hard-of-hearing and typically hearing children. *Emotion*. Online ahead of print. https://doi.org/10.1037/emo0000863.

Van den Stock J, De Winter FL, de Gelder B, Rangarajan JR, Cypers G, Maes F, Sunaert S, Goffin K, Vandenberghe R, Vandenbulcke M. 2015. Impaired recognition of body expressions in the behavioral variant of frontotemporal dementia. *Neuropsychologia*. 75:496–504. https://doi.org/10.1016/j.neuropsychologia.2015.06.035.

Van den Stock J, De Winter FL, Emsell L, Kumfor F, Vandenbulcke M. 2020. Brain-behaviour associations and neural representations of emotions in frontotemporal dementia. *Brain*. 143(3):e17. https://doi.org/10.1093/brain/awaa005.

Versace E, Damini S, Stancher G. 2020. Early preference for face-like stimuli in solitary species as revealed by tortoise hatchlings. *Proc Natl Acad Sci U S A*. 117:24047–24049. https://doi.org/10.1073/pnas.2011453117.

Vonk J, Mayhew P, Zeigler-Hill V. 2016. Gender roles, not anatomical sex, predict social cognitive capacities, such as empathy and perspective-taking. In: Watt DF, Panksepp J, editors. *Psychology and neurobiology of empathy*. Hauppauge, NY, USA: Nova Biomedical Books, pp. 187–209.

Vuilleumier P. 2005. Cognitive science: staring fear in the face. *Nature*. 433:22–23. https://doi.org/10.1038/433022a.

Wang Z, Su Y. 2013. Age-related differences in the performance of theory of mind in older adults: a dissociation of cognitive and affective components. *Psychol Aging*. 28(1):284–291. https://doi.org/10.1037/a0030876.

Wiesmann M, Franz C, Sichtermann T, Minkenberg J, Mathern N, Stockero A, Iordanishvili E, Freiherr J, Hodson J, Habel U, et al. 2021. Seeing faces, when faces can't be seen: wearing portrait photos has a positive effect on how patients perceive medical staff when face masks have to be worn. *PLoS One*. 16(5):e0251445. https://doi.org/10.1371/journal.pone.0251445.

Wild B, Kornfeld B. 2021. Facial recognition: more than just a phone problem. *Pediatr Ann*. 50(2):e52–e54. https://doi.org/10.3928/19382359-20210118-01.

Wong CKM, Yip BHK, Mercer S, Griffiths S, Kung K, Wong MC-S, Chor J, Wong SY-s. 2013. Effect of face masks on empathy and relational continuity: a randomised controlled trial in primary care. *BMC Fam Pract*. 14:200. https://doi.org/10.1186/1471-2296-14-200.

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Yi H, Pingsterhaus A, Song W. 2021. Effects of wearing face masks while using different speaking styles in noise on speech intelligibility during the COVID-19 pandemic. *Front Psychol*. 12:682677. https://doi.org/10.3389/fpsyg.2021.682677.

Yin S, Fu C, Chen A. 2018. The structural and functional correlates underlying individual heterogeneity of reading the mind in the eyes. *Biol Psychol*. 138:179–184. https://doi.org/10.1016/j.biopsycho.2018.09.009.

Yıldırım E, Soncu Büyükişcan E, Gürvit H. 2020. Affective theory of mind in human aging: is there any relation with executive functioning? *Neuropsychol Dev Cogn B Aging Neuropsychol Cogn*. 27(2):207–219. https://doi.org/10.1080/13825585.2019.1602706.

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