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RESEARCH ARTICLE

# Investigating the impact of disposable surgical face-masks on face identity and emotion recognition in adults with autism spectrum disorder

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**Abstract**

With the outburst of the COVID-19 pandemic, disposable surgical face-masks (DSFMs) have been widely adopted as a preventive measure. DSFMs hide the bottom half of the face, thus making identity and emotion recognition very challenging, both in typical and atypical populations. Individuals with autism spectrum disorder (ASD) are often characterized by face processing deficits; thus, DSFMs could pose even a greater challenge for this population compared to typically development (TD) individuals. In this study, 48 ASDs of level 1 and 110 TDs underwent two tasks: (i) the *Old-new face memory task*, which assesses whether DSFMs affect face learning and recognition, and (ii) the *Facial affect task*, which explores DSFMs' effect on emotion recognition. Results from the former show that, when faces were learned without DSFMs, identity recognition of masked faces decreased for both ASDs and TDs. In contrast, when faces were first learned with DSFMs, TDs but *not* ASDs benefited from a "context congruence" effect, that is, faces wearing DSFMs were better recognized if learned wearing DSFMs. In addition, results from the *Facial affect task* show that DSFMs negatively impacted specific emotion recognition in both TDs and ASDs, although differentially between the two groups. DSFMs negatively affected disgust, happiness and sadness recognition in TDs; in contrast, ASDs performance decreased for every emotion except anger. Overall, our study demonstrates a general, although different, disruptive effect on identity and emotion recognition both in ASD and TD population.

**Lay Summary**

"Reading" facial identity and expression of emotions are fundamental aspects for our social interactions. Here, we found that disposable surgical face-masks (DSFMs) particularly affect both these abilities in autistic adults. These findings help the understanding of how DSFMs strongly impact social life in autistic and non-autistic individuals.

**KEYWORDS**

autism spectrum disorder, disposable surgical face-masks (DSFMs), emotion recognition, face memory, face perception

# INTRODUCTION

Since the outburst of the COVID-19 pandemic, disposable surgical face-masks (DSFMs) have been globally adopted to limit the virus transmission. However, by covering the lower half of the face (i.e., nose, mouth), DSFMs strongly affect social cognition in typically development (TD) adults, making face processing a challenging task for the human visual system (Freud et al., 2020; Noyes et al., 2021; Ventura et al., 2023). DSFMs could even have a stronger impact on clinical conditions characterized by impairments in social cognition, such as Autism Spectrum Disorder (ASD), a neurodevelopmental disorder characterized by difficulties in social relationships, repetitive behavior patterns, and restricted interests (American Psychiatric Association, DSM-5 Task Force, 2013).

Two independent cognitive and anatomical routes mediate human face perception (Bruce & Young, 1986; Haxby et al., 2000). The first (the "identity route") is responsible for identity perception and is mostly affected in people with impairments in the ventral visual stream, such as in prosopagnosia (i.e., difficulty in face learning and recognition) (Monti et al., 2019; Rivolta et al., 2014), whereas the second (the "emotion route") mediates facial expressions recognition and it is generally compromised after limbic lesions (Feinstein et al., 2011; Hornak et al., 2003; Takeda et al., 2009). Both routes rely on face-sensitive perceptual mechanisms known as "holistic," which allow the perception of a face as a whole, rather than a sum of individual face parts (Bonemei et al., 2018; McKone et al., 2009; Palermo et al., 2011).

Much research demonstrated that face processing is aberrant in ASDs (Zhao et al., 2016), who exhibit difficulties in both identity (Teunisse & Gelder, 2003) and emotion (Philip et al., 2010) perception (but see Naumann et al., 2018; Tracy et al., 2011 for a different perspective). A recent meta-analysis (Griffin et al., 2021) indicates consistent deficits in ASDs' "identity route," with two main hypothesis explaining this impairments: some argue ASDs exhibit a *quantitative* impairment, that is a lack of cognitive operations and/or neural mechanisms that are essential for typical face processing, which undermines the integration of single components of a stimulus into a whole (Behrmann et al., 2006; Dimitriou et al., 2015; Weigelt et al., 2012); others suggest a *qualitative* impairment, meaning that ASDs possess typical neural and cognitive mechanisms for face processing, but employ these operations differently than TDs (Tanaka & Sung, 2016; Tang et al., 2015). ASDs seem biased toward local and featural information (Lahaie et al., 2006; Tang et al., 2015), and toward the lower region of the face, specifically the mouth (Fedor et al., 2018; Jones et al., 2008; Joseph & Tanaka, 2003); this tendency could make recognition difficult, considering that eyes represent a determinant in face identity recognition (Peterson & Eckstein, 2012; Schyns et al., 2002).

Also, deficits of the "emotion route" have been previously reported in ASDs (Berggren et al., 2016; Griffiths et al., 2019; Gross, 2004), albeit results are quite mixed (Evers et al., 2014; Tracy et al., 2011). Since each emotion displays specific facial features and patterns, the ability to recognize facial expressions may not solely rely on holistic processing, as it can also involve local (i.e., featural) mechanisms (Calvo & Nummenmaa, 2008), which represents ASDs' primary processing strategy (Dakin & Frith, 2005; de Jong et al., 2008). However, given their tendency to avoid the eyes (Tanaka & Sung, 2016), covering the lower region of the face with DSFMs might pose a great challenge for facial expression recognition (FER).

Typical face processing (i.e., holistic processing) can be "artificially" disrupted in TDs when a part of the face is concealed, thus leading to face perception difficulties, such as in faces wearing burqa (Kret & de Gelder, 2012), sunglasses (Graham & Ritchie, 2019; Kotsia et al., 2008), ski mask (Manley et al., 2019) and DSFMs (Ventura et al., 2023). This suggests that ASDs could be even more vulnerable than TDs to the massive use of DSFMs in everyday social situations; it has been already shown that DSFMs and lifestyle changes due to public health measures led to more difficulties in social cognition and communication in ASD subjects, particularly the ones presenting higher pre-pandemic restricted interest and repetitive behavior characteristics (Tamon et al., 2022). Concerning identity and emotion recognition, the only study so far available on ASDs' "identity route" reported disruptive effects of DSFMs for faces initially learned unobstructed; on the contrary, when faces were memorized with DSFMs, ASDs showed an advantage in recognizing masked faces; thus, DSFMs' effect seems to be mediated by the encoding context (Tso et al., 2022). Concerning the "emotion route," TDs with *high autistic traits* were less accurate and confident in FER of faces with DSFMs as compared to those with low autistic traits (Pazhoohi et al., 2021; Ramachandra & Longacre, 2022); however, these studies were conducted on healthy participants undergoing an assessment for autistic traits, and their results cannot be easily extended to ASDs.

Given the theoretical and clinical implications that the perception of faces with DSFMs poses for the ASD population, our study aimed to ascertain the impact of DSFM on the "identity route" and on the "emotion route" in ASD. For this reason, we adopted two tasks that tapped into different cognitive functions (i.e., identity vs. emotion) (Ventura et al., 2023) in TD and ASD participants. We hypothesized that, by covering the lower half of the face, DSFMs could impair recognition performances for both identity and emotion, being particularly detrimental for the ASD population.

# METHODS

## Participants

A total of 48 participants diagnosed with level 1 ASD (27 Males; *M* age: 27) and IQ > 60 (*M* = 98; SD = 21) were recruited from the Regional Center for Adults with Autism in the Piedmont region. All subject in the experimental group received a formal clinical diagnosis according to DSM-5 criteria (APA, 2013), based on clinical anamnesis, clinical interview, psychiatric interview, psychopathology assessment, cognitive assessment with Wechsler Adult Intelligence Scale (WAIS-IV) (Wechsler, 2008) or Leiter-3 (Roid et al., 2013), diagnostic evaluation with Autism Diagnostic Interview (ADI-R) (Rutter et al., 2003) and Autism Diagnostic Observation Schedule-Second Edition (ADOS-2) (Lord et al., 2012) or Autism Asperger Diagnostic Scale (RAADS) (Ritvo et al., 2011). Fifteen participants presented comorbidity with other clinical conditions (see Supporting Information for additional clinical information about our sample of ASDs). Data from 110 TD participants (44 Males; *M* age = 24.4) were also included. The ASD and TD groups did not differ in age and M/F ratio.

To test identity and emotion recognition abilities, two independent tasks were programmed with the PsyToolkit platform (Stoet, 2010) and administered in a counterbalanced order. All participants provided informed consent before completing the experiments. Training sessions for both tasks were also administered to assure familiarization with the procedure. Due to the pandemic-related restrictions, both experiments were run remotely (i.e., via a one-time accessible link). To check on the proper execution and fulfillment of the tasks, participants were asked to share their computer screen with the researchers.

## Experiment 1—Old-new face memory task

### Materials and procedure

To assess face recognition with and without DSFMs, an *Old-new face memory task* was administered. The task consisted of two blocks, each composed of a learning and an actual testing phase. In the learning phase of Block 1, six face stimuli without DSFMs were presented, and participants had 30 s to memorize them. In the testing phase, participants had to recognize the six previously shown identities among six distractors by answering, for each face, if it was one of the previously learned or not (i.e., old vs. new). Each stimulus in the testing phase was displayed twice, both with and without DSFMs, for a total of 24 trials.

Block 2 had the same structure as Block 1. However, new identities were used (both in the learning and test phase) and faces in the learning phase were presented with DSFMs (see Figure 1). The stimuli were selected from the "Chicago Face Database 2015" (Ma et al., 2015) and presented in colors, in the foreground, and with a white background. Features from the original pictures such as hair and ears were not altered in order to ensure ecological validity. Moreover, all the selected face stimuli were from Caucasian male adults, in order to avoid ethnic, age, and gender biases (McKone et al., 2011, Wang et al., 2014). DSFMs were digitally added to

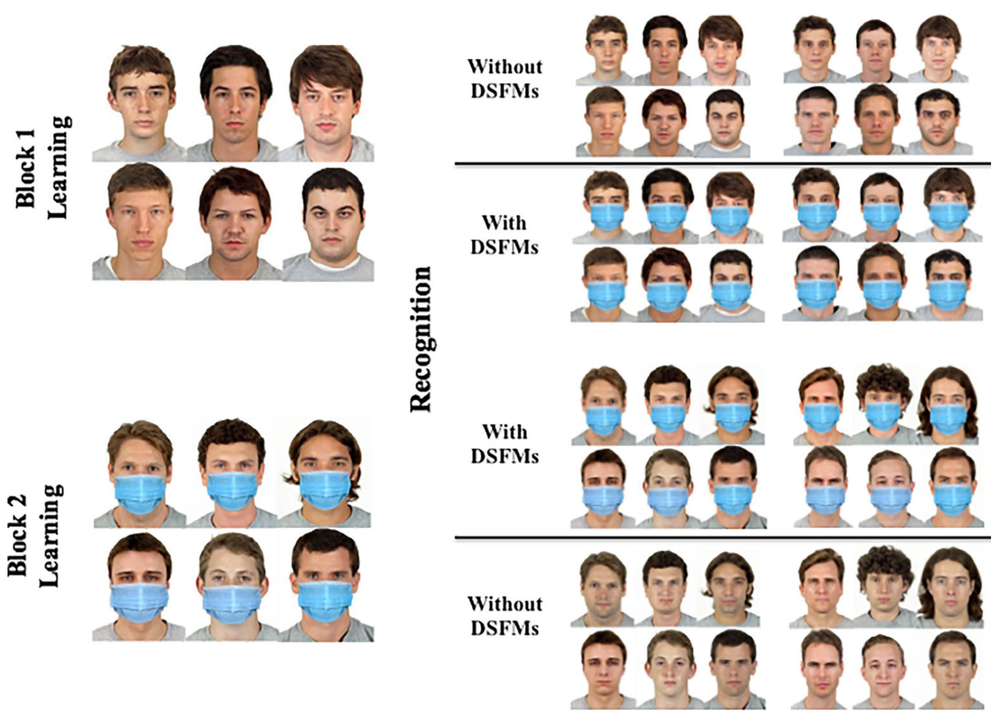


**FIGURE 1** Old-new face memory task. Stimuli from Experiment 1. Block 1 consisted of learning phase without disposable surgical face-masks (DSFMs) and test with and without DSFMs. Block 2 consisted of a learning phase with DSFMs and a test with and without DSFMs. Participants had to pick out which faces they saw during the learning phase.

the stimuli using the “MaskOn your profile for Covid-19 Safety” (Kapwing, 2021; https://www.kapwing.com).

## Data analysis

Data were analyzed based on principles of Signal Detection Theory (Green & Swets, 1966) using $d'$ score, a measure of sensitivity. $d'$ *is* unaffected by response bias, since it takes into account false alarms. Specifically, $d'$ was calculated by subtracting the z scores for false alarm (FA) responses from $z$ scores for correct responses (hits—$H$) [$d' = z(H) - z(\text{FA})$] (Stanislaw & Todorov, 1999), where $d' = 0$ indicates no discriminatory ability, while increasing values of $d'$ refer to a greater sensitivity to a given signal. Response bias was calculated as the $\beta$ value, obtained with the following equation: $\ln(\beta) = cd' = -1/2\,[z(H)^2 - z(\text{FA})^2]$. An observer who is maximizing $H$ while minimizing FA will have a $\beta$ that is equal to 1.00 (i.e., no bias). A value of $\beta$ below 1.00 represents a liberal tendency, that is, to report most of the times that the target is present, while value of $\beta$ above 1.0 represents a conservative tendency, that is, to report most of the times that the target is absent (Gardner et al., 1984). $d'$ and $\beta$ calculations were carried out using *R*’s psycho package (vo. 6.1.; Makowski, 2018).

Data from the *Old-new face memory task* were analyzed using a three-way analysis of variance (ANOVA) on $d'$ scores to examine the main effects and interactions of the factors “group” (TD vs. ASD), “learning” (without DSFMs vs. with DSFMs), and “test” (face recognition without DSFMs vs. with DSFMs). Post-hoc analyses were Bonferroni corrected. ANOVA and post-hoc analyses were carried out using SPSS (Version 26.0).

## Results

We here report all main effects and interactions. However, for clarity reasons, only for the three-way interactions we also report post-hoc comparisons. The three-way ANOVA showed a main effect of learning [$F(1{,}1000) = 51.39$, $p < 0.001$, $\eta^2_p = 0.248$], a main effect of test [$F(1{,}1000) = 11.15$, $p = 0.001$, $\eta^2_p = 0.067$], and a main effect of group [$F(1{,}156) = 64.48$, $p < 0.001$, $\eta^2_p = 0.292$]. Statistically significant interactions emerged between learning and test [$F(1{,}100) = 87.08$, $p < 0.001$, $\eta^2_p = 0.358$], learning and group [$F(1{,}100) = 15.26$, $p < 0.001$, $\eta^2_p = 0.08$] and test and group [$F(1{,}100) = 8.14$, $p = 0.005$, $\eta^2_p = 0.05$].

There was a statistically significant three-way interaction between learning, test and group [$F(1{,}100) = 42.4$, $p < 0.001$, $\eta^2_p = 0.214$]. Between-group post-hoc comparisons showed that when learning phase was without DSFMs, TDs performances were better both without DSFMs ($M = 2.12$, SEM $= 0.08$) and with DSFMs ($M = 1.28$, SEM $= 0.08$) than ASDs performances without ($M = 1.39$, SEM $= 0.12$) and with DSFMs ($M = 0.93$, SEM $= 0.13$) (all *p*s $<0.029$). When faces were learned with DSFMs, TDs performances were better both without ($M = 1.07$, SEM $= 0.07$) and with DSFMs ($M = 1.85$, SEM $= 0.08$), compared to ASDs without ($M = 0.44$, SEM $= 0.11$) and with DSFMs ($M = 0.26$, SEM $= 0.12$) (all *p*s $<0.029$) (Figure 2). Within group post-hoc comparison showed that both TD and ASD participants exhibited better performances without DSFMs than with DSFMs when faces were learned without DSFM. Moreover, TD participants exhibited better performances with DSFMs when faces were learned in the same modality (all *p*s $<0.001$). In contrast, no significant differences emerged on ASD performances with and without DSFM when faces were learned with DSFMs ($p = 0.159$) (Figure 3) (see Supporting Information for Response bias ($\beta$) analysis).

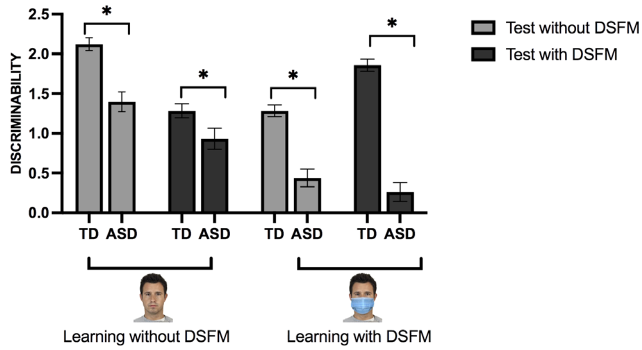


**FIGURE 2** Identity discrimination rates ($d'$) based on group (autism spectrum disorder [ASD] vs. typically development [TD]) both without disposable surgical face-masks (DSFMs) and with DSFMs condition for Block 1 and Block 2.

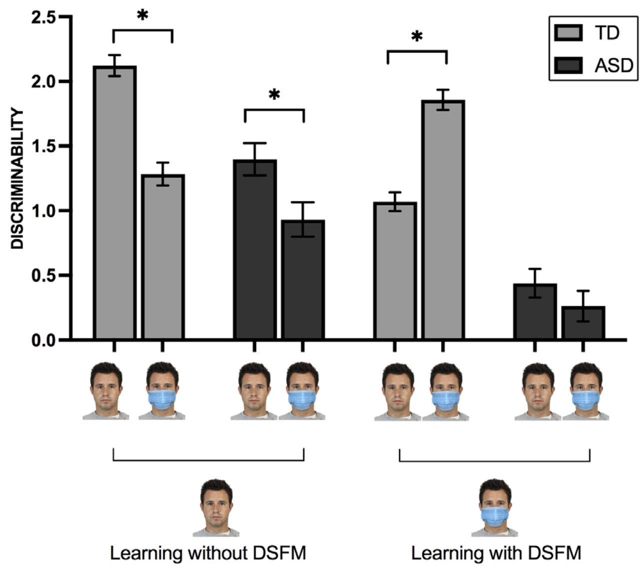


**FIGURE 3** Identity discrimination rates ($d'$) based on test (without disposable surgical face-masks [DSFMs] vs. with DSFMs) in autism spectrum disorder (ASD) and typically development (TD) for Block 1 and Block 2.

In summary, these data indicate that face recognition without DSFMs was easier for both ASDs and TDs only if faces were learned without DSFMs. By contrast, when faces were first learned with DSFMs, TDs' face recognition performance was better when the test phase matched the encoding condition (i.e., with DSFMs), while ASDs performance did not differ between faces with and without DSFMs. Thus, ASDs did not benefit from the match between learning and test phases when DSFMs were present.

## Experiment 2—Facial affect recognition

### Materials and procedure

The *Facial affect task* consisted of 60 stimuli of Caucasian faces, selected from the Karolinska Directed Emotional Faces (KDEF) database (Lundqvist et al., 1998). All the stimuli showed Caucasian male adults, in order to avoid ethnic, age, and gender biases (Wang et al., 2014). DSFMs were digitally added to half of the selected faces with "MaskOn your profile for Covid-19 Safety" software (https://www.kapwing.com). The stimuli included six different male identities for each basic emotion (disgust, fear, happiness, sadness, anger); each identity was presented five times, both with and without DSFMs, for a total of 60 trials (Figure 4). Surprise was excluded because of its hedonically neutral connotation (Reisenzein et al., 2019). Stimuli were displayed for 3.5 s, and participants had to label the emotion by choosing from a list including five options, within 10 s (Figure 4). The time limits aimed at simulating everyday life situations in which emotional expressions are perceived in a few seconds (Tracy & Matsumoto, 2008) (i.e., typically between 0.5 and 4 s) (Ekman, 2003).

### Data analysis

Data from the *Facial affect task* were analyzed using a three-way ANOVA based on *d'* including factors "group" (ASD vs. TD), "emotion" (disgust, fear, happiness, sadness, and anger) and "condition" (without DSFM vs. with DSFM). Post-hoc analyses were Bonferroni corrected. Moreover, we created two confusion matrices by counting the true positives and misclassifications during the recognition of emotions for all subjects, in order to assess recognition accuracy and misclassification for each emotion specifically, both with and without DSFMs (Figures 7 and 8).

### Results

The three-way ANOVA showed a main effect of emotion [$F(4,1000) = 374.49$, $p < 0.001$, $\eta^2_p = 0.706$], a main effect of the condition [$F(1,1000) = 204.23$, $p < 0.001$, $\eta^2_p = 0.567$] and a main effect of group [$F(1,156) = 9.78$, $p < 0.001$, $\eta^2_p = 0.059$]. A statistically significant interaction emerged between emotion and condition [$F(4,1000) = 96.57$, $p < 0.001$, $\eta^2_p = 0.382$]. The interactions between group x condition [$F(1,1000) = 2.25$, $p = 0.135$, $\eta^2_p = 0.004$], and emotion x group [$F(4,3.664) = 1.32$, $p = 0.259$, $\eta^2_p = 0.008$] were not statistically significant.

There was a statistically significant three-way interaction between emotion, condition and group [$F(4,1000) = 3.68$, $p < 0.01$, $\eta^2_p = 0.023$]. Between group post-hoc comparisons showed that TD performances for disgust without DSFMs ($M = 2.48$, SEM $= 0.06$) were significantly better than the ASD ones ($M = 2.19$, SEM $= 0.09$) ($p = 0.012$). No significant differences emerged between TD and ASD for fear, happiness, sadness and anger recognition without DSFMs (all

**FIGURE 4** Facial affect task. Sample stimuli from Experiment 2. Each basic emotion (happiness, disgust, fear, anger, and sadness) was presented with and without disposable surgical face-masks (DSFMs).

$ps > 0.05$). TD performances with DSFM for fear ($M = 2.24$, SEM $= 0.06$), happiness ($M = 3.05$, SEM $= 0.05$), and sadness ($M = 1.69$, SEM $= 0.05$) were better than the ASD ones (fear: $M = 2.03$, SEM $= 0.09$; happiness: $M = 2.68$, SEM $= 0.08$; sadness: $M = 1.49$, SEM $= 0.08$) (all $ps < 0.05$) (Figure 5).

Within group post-hoc comparison showed that TD performance for disgust ($M = 0.93$, SEM $= 0.06$), happiness ($M = 3.05$, SEM $= 0.05$) and sadness ($M = 1.68$, SEM $= 0.05$) with DSFMs was significantly worse than recognition without DSFMs (disgust: $M = 2.48$, SEM $= 0.06$; happiness: $M = 3.47$, SEM $= 0.02$; sadness: $M = 2.27$, SEM $= 0.06$) (all $ps < 0.001$). There were no differences for fear and anger recognition with and without DSFMs (all $ps > 0.17$). ASDs performance decreased significantly for disgust recognition with DSFMs ($M = 0.77$, SEM $= 0.09$) than without ($M = 2.19$, SEM $= 0.09$), fear with DSFMs ($M = 2.02$, SEM $= 0.09$) than without ($M = 2.27$, SEM $= 0.08$), happiness with DSFMs ($M = 2.69$, SEM $= 0.08$) than without ($M = 3.46$, SEM $= 0.02$) and sadness with ($M = 1.49$, SEM $= 0.07$) than without DSFMs ($M = 2.12$, SEM $= 0.09$) (all $ps < 0.03$). There were no differences in ASDs anger recognition with and without DSFMs ($p = 0.60$) (Figure 6) (see Supporting Information for Response bias ($\beta$) analysis).

In summary, these data indicate that ASDs and TDs possess a similar ability of emotional expression recognition; moreover, DSFMs affect specific emotion recognition in both TDs and ASDs, although the expression affected differs between the two groups. Specifically, TDs recognized fear, happiness, and sadness with DSFMs better than ASDs. TDs exhibited better performances for disgust, happiness, and sadness perception without DSFMs, while ASDs performance with DSFMs decreased for disgust, happiness, sadness and fear. Anger recognition in TDs and ASDs was not affected in both conditions.

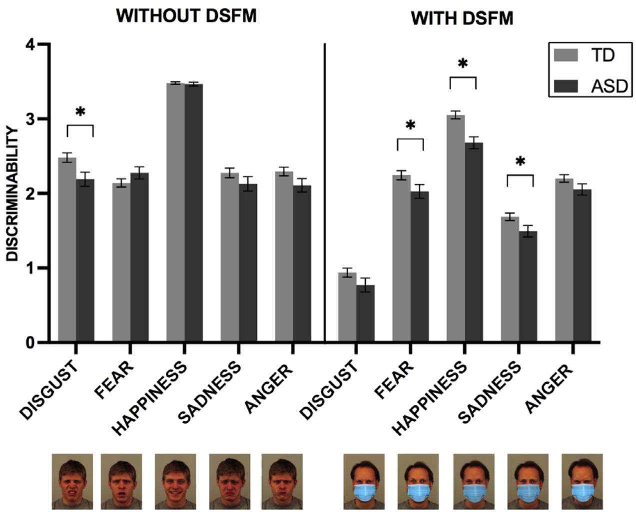


**FIGURE 5** Emotion discrimination rates ($d'$) based on group (autism spectrum disorder [ASD] vs. typically development [TD]) both with and without disposable surgical face-masks (DSFMs).

# DISCUSSION

DSFMs have been widely adopted over the last 2 years to prevent the spread of COVID-19. However, DSFMs

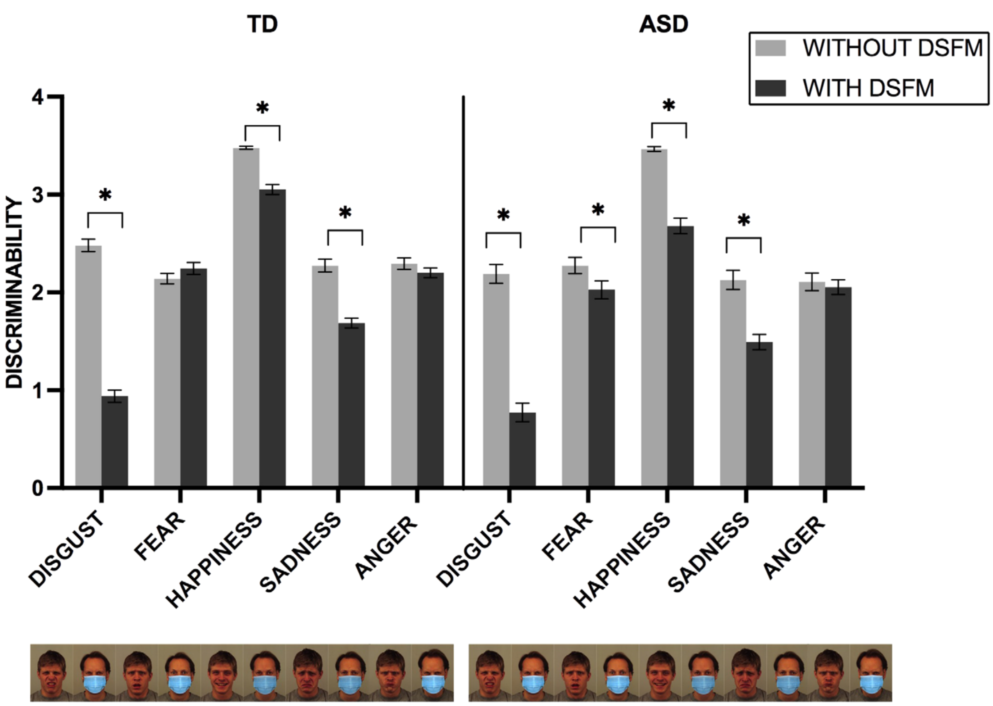


**FIGURE 6** Emotion discrimination rates ($d'$) based on condition (without disposable surgical face-masks [DSFMs] vs. with DSFMs) in autism spectrum disorder (ASD) and typically development (TD).

drastically reduce the availability of facial information, thus impairing identity and emotion recognition (Carragher & Hancock, 2020; Freud et al., 2020; Grenville & Dwyer, 2022; Noyes et al., 2021; Ventura et al., 2023). This phenomenon, albeit extensively explored in TDs, has only been marginally investigated in clinical populations, especially those presenting social deficits. Our study, thus, aimed to shed light on the issue by testing the effects of DSFMs on identity and emotion recognition in ASDs.

## Unfamiliar face learning and recognition

Our results show a general disruptive effect of DSFMs, with obstructed faces being recognized worse than those without DSFMs. Indeed, the upper half of the face is particularly informative for face recognition compared to the lower part (Dal Martello & Maloney, 2006). Despite this, covering nose, mouth and chin significantly reduces recognition accuracy (Freud et al., 2020). This might be due to the disruption of holistic processes that occurs when a face is partially covered (Tanaka & Farah, 1993); additionally, this effect seems to persist with different type of masks (e.g., cloth masks, transparent masks) (Freud et al., 2020; Marini et al., 2021). Does this apply for both the typical and atypical populations?

ASDs showed an overall worse performance than TDs. This is in line with previous findings suggesting that individuals with ASD exhibit both qualitative and quantitative differences in face identity processing compared to the healthy population (Tang et al., 2015). Effectively, behavioral findings report face memory deficits (Griffin et al., 2021), while neuroimaging evidence shows abnormalities in the temporal processing of faces (McPartland et al., 2004; Schultz, 2005). Moreover, ASDs engage atypical face recognition strategies (i.e., local strategy) (Joseph & Tanaka, 2003), which could reduce the ability to correctly encode and recognize a face (Tanaka et al., 2003). Indeed, ASDs in our sample exhibited poorer identity recognition performances than TDs, even when faces were completely available (Behrmann et al., 2006; Boucher & Lewis, 1992). This is corroborated by evidence indicating that a high-levels of autistic traits are associated with reduced holistic processes (and increased analytic skills), which predict face recognition abilities (Tanaka et al., 2003; Tso et al., 2022).

Learning faces without DSFMs affected test performances via a “context congruence” effect (i.e., better performances without DSFMs) in both TD and ASD participants. However, when faces were studied with DSMFs, only TDs exhibited congruent performances (i.e., higher recognition of faces with DSFMs), while the ASD group showed comparable and very low face recognition performance with and without DSFMs. This implies that (i) the lack of perceptual information (i.e., the DSFMs presence) in the learning stage was particularly detrimental for ASD participants’ due to a pre-existing (social) processing impairment, and (ii) learning obstructed faces posed a high demand exceeding ASDs’ processing capacity (i.e., in line with the Complex Information-Processing model, Minshew & Goldstein, 1998).

Concerning the first interpretation, it is possible that recognizing obstructed faces when learned with DSFMs was easier for TDs due to an efficient switch in encoding strategies. Indeed, a shift from a global (holistic) to a more local (featural) processing mode could facilitate the processing of partially covered faces in TDs (Hsiao et al., 2022). Given the general local processing superiority reported in the ASD population (Lahaie et al., 2006; Tang et al., 2015), good performances in recognizing faces with DSFMs when they were previously learned with DSFMs were possible, given the “local” nature of the encoding of obstructed faces. However, ASDs performed almost equally low with and without DSFMs. Our results can be explained in light of ASD′ deficits in processing social stimuli, particularly faces. Effectively, ASDs exhibit altered memory performances for faces but not for other stimuli categories (Arkush et al., 2013). Specifically, the eyes region is perceived as threatening and over-arousing by ASDs (i.e., the eye-avoidance hypothesis) (Cuve et al., 2018), who exhibit a reduced number and duration of fixations toward the eyes, together with increased fixation toward the mouth (Tang et al., 2015). Since the presence of DSFM turned the eyes into the only available facial cue for identity learning and recognition, ASD atypical gaze patterns might have resulted in decreased recognition even if the task required a focus on local elements.

Alternatively, a well-established hypothesis on ASD neurophysiological functioning defines it as an information processing disorder (Minshew & Goldstein, 1998) characterized by an impairment of high-order demanding processes (e.g., complex memory, complex language, complex social cues elaboration and reasoning domains) and relative intact or superior performances in simple tasks (Williams et al., 2015). We could hypothesize that learning faces with DSFMs represented a highly demanding task exceeding ASDs’ high-order processing capacity (Kumar, 2013). Given the specific impairment of this clinical population with (i) socially relevant cues and (ii) high-demanding memory tasks, both our hypotheses could explain the absence of a “congruence advantage” with DSFM in ASD are plausible.

Only one study has previously investigated the effect of DSFM on face memory in the ASD population (Tso et al., 2022). Our results from the learning condition without DSFM are in line with those of this work. However, when faces were learned with DSFMs, Tso et al. (2022) found no significant differences in performances with and without DSFM in TDs. Moreover, they reported higher performances with DSFMs than without for ASDs, which is opposite to our results. This disagreement might stem from the sample size discrepancy, and differences between the adopted stimuli (i.e., different databases, and absence vs. inclusion of peripheral head features). Additionally, cultural differences should be taken into account when comparing these results. First, while in Western countries the use of face-masks in everyday life was extremely uncommon before the COVID-19 emergency, this does not apply to several Eastern countries—and especially for China (see Tso et al., 2022), due to the SARS outbreak of 2003 (Hansstein & Echegaray, 2018). Consequently, during COVID-19 pandemic Asian people were inclined to a strong, rapid and adequate adoption of DSFMs (Tso & Cowling, 2020), contrary to the majority of western people (Hearne & Niño, 2022). Furthermore, several studies highlight significant cultural visual strategies differences regarding face perception and recognition (Caldara, 2017; Caldara et al., 2010; Rodger et al., 2010). Western Caucasians (WC) exhibit a greater triangular scanning pattern of the eyes and mouth, looking predominantly to the eyes, while East Asians (EA) show more nose fixations, thus, they rely on extrafoveal vision to extract visual information from the eyes and the mouth by fixating the central region of the face (i.e., nose) (Caldara, 2017; Miellet et al., 2013). Despite the distinct gaze scan path, the overall face recognition performance seems to be comparable among WC and EA (Miellet et al., 2012); however, some differences might arise under unusual identification conditions, as in the case of DSFMs. When faces are masked or occluded, WC's higher reliance on eyes could lead to an encoding strategy based strongly on this feature, which might produce the "context congruence" benefit we found in our study; that is, when faces were first learned with DSFMs, participants might be distracted by "task-irrelevant" facial features (i.e., nose and mouth) when recognizing the same faces unobstructed. On the contrary, EA's strategy fixation on the central part of the face could lead to a more global recognition strategy (Kelly et al., 2011), and consequently no differences were observed within masked and unmasked faces. Since these cultural habits might have an impact on people's way of perceiving and dealing with DSFMs, we believe the generalization of results concerning socially relevant phenomena across cultures should be cautious.

## Facial affect recognition

Overall, our results show better emotion recognition without DSFMs, in line with the hypothesis for their disruptive effects on facial expressions perception (Grundmann et al., 2021; Pazhoohi et al., 2021; Ventura et al., 2023). However, we did not find any significant difference in emotion recognition without DSFMs between TDs and ASDs, except for disgust, which was significantly worse for ASDs. While some studies showed that individuals with ASD have no difficulties at recognizing basic emotions (Stagg et al., 2022; Wright et al., 2008), others reported a deficit for specific emotions only (e.g., disgust) (Wallace et al., 2008), or for subtle and complex expressions (i.e., secondary emotions) (Humphreys et al., 2007). Moreover, facial emotion recognition issues in ASDs seem to decrease in adulthood, despite not reaching a level of typicality (Kuusikko et al., 2009). Thus, ASDs might adopt a different but equally effective strategy than TDs for facial expressions that is dissociable from a basic social cognition deficit (Rutherford & McIntosh, 2007). In light of these evidences, we might speculate that the type of stimuli in our task (i.e., basic emotions shown at 100% intensity), and the age of our ASD sample (i.e., adults), led to comparable performances in TDs and ASDs when the expressions were not obstructed by DSFMs. This could support the idea that emotion recognition deficits in ASDs vary across the lifespan and might differ on the basis of the emotion displayed (Yeung, 2022).

Another potential explanation is that different emotions can be discriminated based on specific face areas (Calvo & Nummenmaa, 2008). As compared to TDs, ASDs seem to mainly rely on featural strategies. Hence, being able to match basic emotions with specific facial features could lead to relatively good performance among ASDs (Rutherford & McIntosh, 2007; Tsang, 2018). Functional magnetic imaging (fMRI) highlights that, compared to TDs, ASDs show weak activity in various "face-areas," while showing higher activity in other regions not directly involved in face perception (e.g., superior parietal lobule) (Baron-Cohen et al., 1999; Gitelman et al., 2000, 2002; Hubl et al., 2003). Thus, ASDs could adopt atypical visuospatial strategies to process faces, potentially focusing on facial features rather than configurations. As emerged from our findings, these potential different strategies between TDs and ASDs did not impact performances, except for disgust. Although disgust is mainly detected from the mouth (Ekman & Friesen, 2003), and ASDs focus on the mouth region more than TDs (Hobson et al., 1988; Klin et al., 2002), our result could depend on the late-emerging nature of disgust. Indeed, most children misinterpret disgust expressions as anger (Rottman, 2014). Thus, disgust recognition might be less automatic, and based on higher attentional resources than other basic emotions (Zheng & Hsiao, 2020).

Considering emotion recognition with DFSMs, ASDs' discriminability ability decreased significantly compared to TDs for happiness, fear and sadness, while performances were comparable for disgust and anger. Happiness recognition impairment could be caused by the obstruction of the mouth, which is the core feature of happiness (i.e., conveying the smile, Malatesta et al., 2022). On the contrary, fear and sadness are mainly recognized by the eyes (Beaudry et al., 2014), which are clearly visible even with the DSFMs; however, given the

ASDs attenuated reliance on the eyes, recognizing these emotions might be harder if avoiding the upper part of the face. Disgust recognition performance with DSFMs decreased noticeably in both groups, despite the differences between them was not significant; this common difficulty could arise from mouth and nose concealment, which are disgust's idiosyncratic traits (Ekman & Friesen, 2003). In addition, masked faces showing disgust were often misinterpreted as angry by both TDs and ASDs (Figures 7 and 8), in line with previous findings reporting systematic confusion between these two expressions (Pochedly et al., 2012). Anger was also discriminated equally well between TDs and ASDs, both with and without DSFMs. From an evolutionary perspective, the ability to quickly detect threatening social stimuli (such as angry faces) is highly important to avoid conflict (Isomura et al., 2014); indeed, TDs detect anger quickly and efficiently compared to other emotions (Shasteen et al., 2014). Moreover, previous research suggested that anger conveys local features that could work as emotion-evoking stimuli, which result in rapid and efficient processing also in ASDs (Isomura et al., 2014). This could explain why anger was unaffected by DSFMs presence in our samples.

When comparing emotion recognition with and without DSFMs in each group separately, DSFMs showed a general detrimental effect, especially for ASDs. Indeed, DSFMs lead to a poorer performance in ASDs for every emotion except for anger. As already mentioned, adults with autism have more difficulties in facial emotion recognition when the lower part of the face is omitted, or in general when recognition is based on the eyes only (Baron-Cohen et al., 1997; Gross, 2004). FER requires the main facial features to be available; if not, it is essential to adopt the appropriate processing strategies based on the available perceptual information (Zhang et al., 2022). With DSFMs, recognition has to be based mainly on the eye region. However, ASDs' abnormalities in face scanning, and specifically their tendency to avoid eyes, could result in poorer recognition when only the upper part of the face is available (Tsang, 2018), as shown in our study. Furthermore, people with ASD may process and recognize emotional expression via compensatory cognitive strategies rather than automatic affective processing; this means that their tendency to detect and report local features leads to a less intuitive and more explicit rule-based strategy for identifying facial expressions. For instance, ASDs recognize a sad expression by

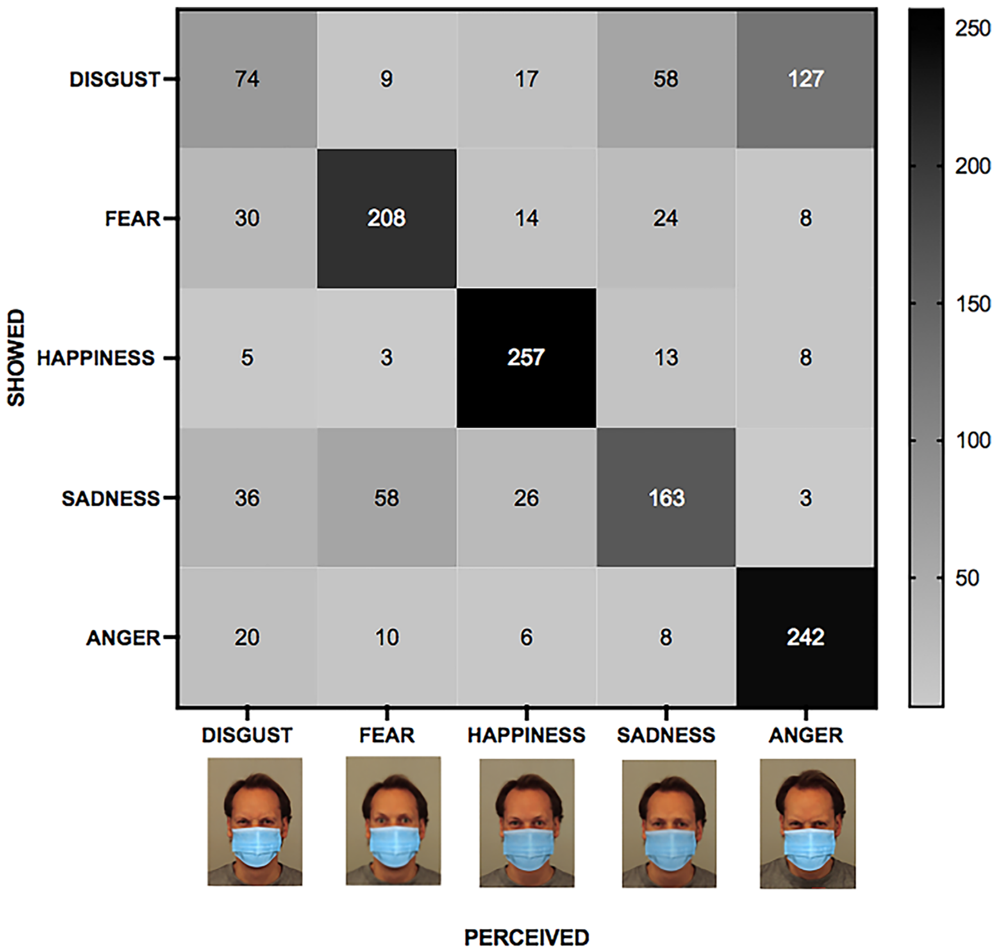


**FIGURE 7** Heat map of the confusion matrix for the "with disposable surgical face-masks (DSFMs)" condition for typically development individuals (TDs).

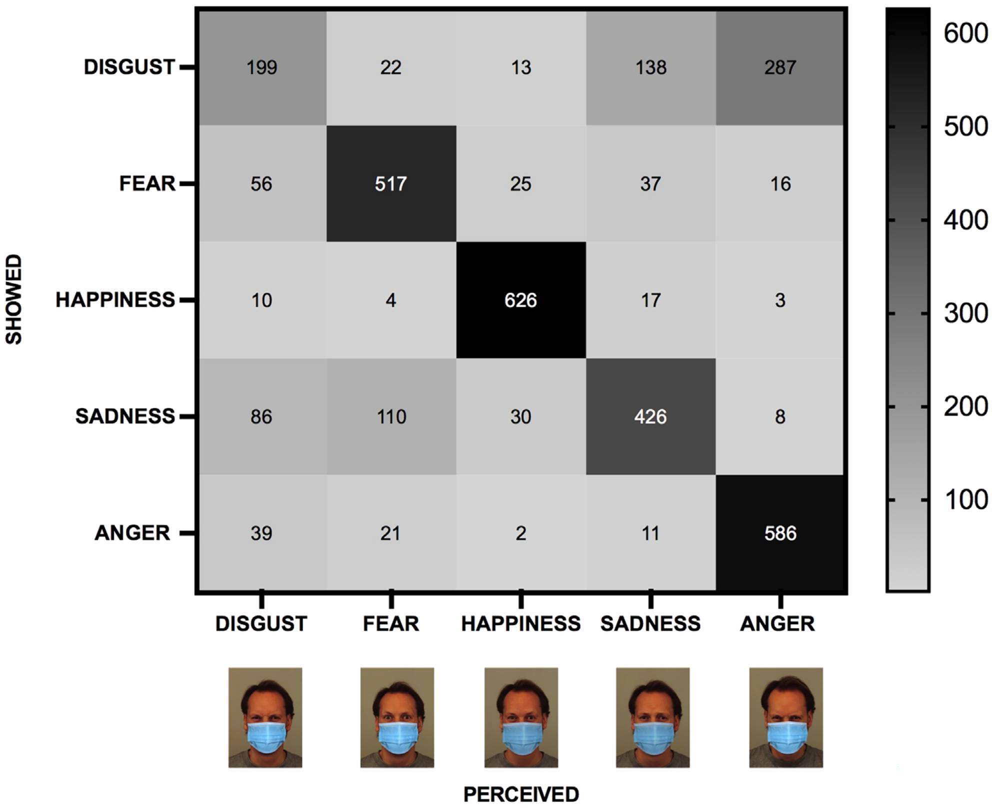


**FIGURE 8** Heat map of the confusion matrix for the "with disposable surgical face-masks (DSFMs)" condition for autism spectrum disorders (ASDs).

remembering the corners of the mouth pointed down and lowered eyebrows. The more these characteristics are visible or exaggerated, the more the expression will match the rule they use to categorize an emotion (Rutherford & McIntosh, 2007). This theory is in line with the idea that emotions can be correctly identified even using specific face features (Liu et al., 2019), albeit this modality might not be as efficient as putting features together into a coherent whole. Nevertheless, these compensatory rule-based strategies may be inadequate for high-demand tasks (which seem to be impaired in ASDs), such as the recognition of subtle emotional expressions (Rump et al., 2009; Wong et al., 2012) or expressions partially obstructed by DSFMs.

Finally, it should be highlighted that, albeit we examined standard masks effect, emotion recognition impairment could be generalized to other types of masks, like the N95 and cloth masks (Langbehn et al., 2022), but not to transparent masks, which seem to spare the capability to recognize others' emotion (Marini et al., 2021).

## CONCLUSION, LIMITATIONS, AND FUTURE DIRECTIONS

Overall, our results suggest that wearing DSFMs differentially affects identity and emotion recognition in ASDs as compared to TDs. Our study (i) corroborates previous evidence on DSFMs' detrimental effect on face memory and emotion recognition in the general population (Noyes et al., 2021), (ii) shows that DSFMs pose a higher disadvantage for ASDs than TDs in recognizing faces, (iii) provides evidence for DSFMs' differential effect on emotion recognition between TDs' and ASDs' performances, and (iv) represents the first evidence for DSFMs' effects on the ASD population in Western society. Given that ASD is characterized by two core symptom domains which are directly impacted by the pandemic, our findings could have few practical implications: face occlusion (as DSFMs) might pose a new social challenge and exacerbate ASDs' already atypical social communication and interaction, and, more broadly, their psychological states. As a matter of fact, increasing difficulties in recognizing others' identity and/or emotion, together with other prevention measures which sometimes are needed (e.g., isolation), might lead ASDs to be even less willing to interact with other people and thus experience increased anxiety, low mood and loneliness (Asbury et al., 2021; Oomen et al., 2021); moreover, they might also experience an overwhelming sense of loss of valuable social experiences, as already reported for online interactions which compromised the back-and-forth flow of one-to-one social interaction (Pellicano et al., 2022).

Some limitations should be highlighted. First, the tasks adopted included static images, whereas, in real life, emotional expressions are dynamic and conveyed together with gestures and other non-verbal cues. Moreover, cultural influences cannot be excluded, with our sample including Italian people only. Keeping external face features (such as hair) in the task stimuli could be a potential limit, since it might have facilitated face recognition, although ensuring ecological validity. Additionally, all participants with ASD in this study were high-functioning patients. Thus, generalizations to the broader spectrum of autism should be cautious.

There are some follow-up questions that should be addressed in future research. It could be useful to investigate eye-movements, as well as to collect direct measures of holistic/analytic strategies (e.g., composite face effect and/or face-inversion effect) to understand the strategy ASDs employ when processing a masked face. Additionally, more subtle tests of facial emotion recognition could be adopted (e.g., secondary emotion or low intensity emotion), in order to accurately replicate real life conditions. Finally, the broader impact of mask-wearing in real life should be examined in order to explore a possible relationship between DSFMs impact on face processing and other aspects of social life.

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## CONFLICT OF INTEREST STATEMENT

The authors declare no competing interests relevant to the content of this article.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

## ETHICS STATEMENT

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Ethics Committee of the University of Bari "Aldo Moro" (protocol number: ET-19-01).

## CONSENT STATEMENT

Informed consent was obtained from all individual participants included in the study.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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