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Facemasks reduce face trustworthiness perceived by deaf individuals

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During the COVID-19 pandemic, most people wore facemasks to protect themselves and others. Whilst this was recommendable, unfortunately facemasks represented a critical problem for deaf people by preventing lipreading. Moreover, the mouth region represents a crucial source of information for inferring emotional states as well as for visually-based social first impressions. An interesting question is whether facemasks impact on social inferences, such as trustworthiness judgments, in a similar vein in deaf and hearing individuals. Our results showed that overall deaf individuals performed similarly to hearing controls in the evaluation of different levels of trustworthiness of computer-generated faces manipulated for trustworthiness. However, deaf individuals judged faces with facemasks to be overall less trustworthy than hearing participants. We interpret this result as suggesting that, for deaf individuals, occluding the mouth area prevents the processing of perceptual information from mouthing and mouth gestures, thus blocking a holistic representation of the face, which in turn hinders communication and limits social exchanges for deaf individuals.

Keywords Trustworthiness, Facemask, Deafness, Social perception, Lipreading

Since the COVID-19 pandemic, surgical facemasks, which cover the lower part of the face (making the mouth, nose and chin invisible), have become increasingly widespread. While the effectiveness of facemasks in preventing the spread of viruses is well-established (e.g.[1]), researchers in the psychological field have begun exploring the impact of facemasks on social perception and interactions (e.g.[2–4]). The impact of facemasks may be especially significant for the deaf community, given the crucial role that lipreading plays in the social interactions of deaf and hard-of-hearing individuals (e.g.[5,6]). In particular, deaf signers must attend to the mouth region of the face for both sign language adverbial expressions and lipreading[7,8]. Also, deaf individuals with hearing aids or cochlear implants rely on lipreading to understand better what is being heard[9]. Moreover, all deaf and hard-of-hearing individuals rely on lipreading and mimicking to some extent in their communication (e.g.[10]), and they all present difficulties with muffled speech due to facemasks[11]. In line with this, recent experiments showed that facemasks alter social processes, such as emotion recognition (i.e., low accuracy in recognizing happiness;[12] as well as speech perception (i.e., worse comprehension;[13], more in deaf than hearing individuals. Furthermore, during sign comprehension, deaf signers reported feeling less effort and a greater sense of understanding when interacting with someone without a facemask, compared to when the other person was wearing one[14].

Regardless of hearing status, fully processing faces visually is essential for evaluating trustworthiness. People tend to assess trustworthiness rapidly (i.e., within 100 milliseconds;[15] because this judgment plays a crucial role in social interactions (e.g.[16]), as it helps individuals decide whether to engage in a conversation, what to say, how sincere to be, or whether to proceed with an economic transaction. Reading trustworthiness on an individual's face involves scanning the eye, mouth, and nose[17]. Indeed, trustworthy faces share specific features, such as open eyes, higher inner eyebrows (i.e., ∧-shaped) in association with a smiling mouth (i.e., U-shaped) and pronounced cheekbones, while, on the other hand, untrustworthy faces are characterized by oppositive attributes, as smaller and apart eyes, lower inner eyebrows (i.e., ∨-shaped) in association with angry mouth (i.e., ∩-shaped) and sagging cheeks[18,19]. Interestingly, it seems that trustworthiness evaluations are most strongly associated with mouth attributes (i.e., a greater contribution of the smile relative to the eyes;[16,19,20], likely because the mouth contains the most expressive facial muscles[21]. Judgments of trustworthiness can significantly influence our everyday social life by shaping our behaviour toward others. Previous studies have shown that first impressions strongly affect trust decisions[22], as demonstrated in Trust Game paradigms[23]. Indeed, implicit evaluations of facial trustworthiness can even predict the level of financial risk individuals are willing to take in such games[24].

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Recent studies that examined masked and unmasked faces across varying trustworthiness levels found that facemasks reduce the influence of facial appearance on trustworthiness assessments (e.g.[25–27]). Specifically, facemasks made untrustworthy faces appear less untrustworthy and trustworthy faces seem less trustworthy. Moreover, it seems that individuals feel less confidence in their trustworthiness evaluation about faces presented with facemasks[27]; for a general overview of the effect of facemasks on social perception see[2,3].

Consistent evidence shows that lack of visual experience may lower the extent to which blind people trust others[28,29]. For instance, blind individuals are less prone to trust a person when the first impression they formed about the person was negative[29]. In turn, whether deafness affects trustworthiness evaluations has been mostly unexplored. It also remains to be seen whether and how the presence of a facemask may influence these evaluations differently in deaf and hearing individuals. A preliminary study by Lau et al.[10] reported no significant differences in how deaf individuals judged the trustworthiness of masked versus unmasked faces, but no direct comparison was performed with a control hearing group (in turn, performance of deaf participants was compared with other previously published data on hearing individuals, Lau & Huckauf[30], with the two groups being not matched as tested in two independent studies). In light of paucity of prior scientific evidence on whether auditory sensory deprivation affects face trustworthiness' evaluation, and whether this is affected by facemasks, we carried out an experiment to directly compare a group of deaf signers and matched hearing adults. Considering that deaf individuals rely more on mouth processing than hearing individuals during social interactions[31,32], we expect that deaf individuals may report lower trustworthiness evaluations when interacting with someone wearing a facemask, compared to hearing participants. This would also be in line with prior studies reporting that facemasks reduce recognition of positive facial expressions more in deaf than hearing individuals (e.g.[12]).

Materials and methods

Participants

Twenty-three bilateral deaf participants (13 females and 10 males; mean age: 51.3, standard deviation = 14.2) with a severe (i.e., between 71 and 90 dB) or profound (i.e., > 91 dB) hearing loss and twenty-three normal-hearing participants (13 females and 10 males; mean age = 51, standard deviation = 13.21) took part in the experiment. A power analysis conducted using G-Power 3.1 software indicated that for our experimental design, a total sample of 32 individuals (i.e., 16 individuals per each group) is required to obtain 90% of power at a significance threshold α of 0.05, with an expected large effect size of f(U) = 0.36 ($\eta^2 p$ = 0.12) based on data of a prior study on emotion recognition in deaf and hearing individuals[33], experiment 2). The two groups were matched for gender and age ($t(44) = 0.08$, $p = .93$). Each participant undergoes an anamnestic interview, which follows the ethical guidelines approved by the Ethical committee, to assess their medical history. None of them reported a history of neuro-psychiatric conditions or was currently taking any medication interfering with cognitive functioning and they all had normal or corrected-to-normal visual acuity. Deaf participants were early deaf (they lost their hearing within the first 3 years of life), except for 6 participants who were clinically classified as deaf between the age of 4 and 6 (see Table 1 for details on deaf participants).

All deaf participants were signers using Italian Sign Language (LIS), and all hearing participants had no experience with LIS. Importantly, all deaf participants communicated orally, and they used lip reading to interact with others. Twelve deaf participants wore cochlear implants (at least in one ear). The experiment was approved by Research Integrity and Ethics Committee of the University of Bergamo (Bergamo, Italy); participants provided written informed consent and were treated in accordance with the Declaration of Helsinki. The experiment was not pre-registered.

Stimuli and experimental task

Experimental stimuli consisted of bald Caucasian male faces displayed in frontal pose and with a neutral expression. The stimuli were selected from a database of computer-generated face identities that vary on seven levels of trustworthiness (for further details on stimuli characteristics and stimuli creation, see[16]. From this database, we selected 12 different identities. For each identity, we used three levels of trustworthiness, i.e., the most-trustworthy, the least-trustworthy, and the face neutral for trustworthiness; for a total of 36 stimuli.

The 36 pictures were modified ad hoc by adding a realistic facemask to each face to create an equal block of face stimuli wearing facemasks (as in[12]. Thus, our entire stimulus set comprised 72 stimuli: half depicting faces wearing facemasks (36 facemask stimuli: 12 most-trustworthy, 12 least-trustworthy and 12 neutral for trustworthiness) and half depicting faces without facemasks (the original 36 face stimuli: 12 most-trustworthy, 12 least-trustworthy and 12 neutral for trustworthiness). See Fig. 1 for examples of the face stimuli and experimental trials.

Participants seated in front of a PC screen, at an approximate distance of 57 cm. During the task, they were asked to evaluate the trustworthiness of each face using a continuous analogical scale. The left end of the rating bar corresponded to a "not at all trustworthy" judgment, the right end of the rating bar corresponded to an "extremely trustworthy" judgment (Fig. 1B). Participants were instructed to express their judgment by selecting a point on a line ranging from "not at all trustworthy" to "extremely trustworthy" with a mouse click using their right hand. The mouse cursor was a fully vertical arrow that moved only horizontally. The initial position of the cursor was in the middle of the analogical scale. During the experiment, faces with and without masks were presented in two distinct blocks. Specifically, one block included only masked faces, while the other included only unmasked faces; order was counterbalanced across participants. Participants were instructed to be as accurate and fast as possible. The face remained visible on the screen for as long as the response was given, and no time limits were imposed to provide an answer. Before starting the experiment, written instructions were given to the participants, and they could ask questions and received detailed answers to their concerns. A

N	Gender	Age	Etiology	Onset	Cochlear implants
s01	Male	70	Measles	4	No
s02	Female	28	Unknown	5	Yes
s03	Female	52	Congenital	0	Yes
s04	Male	50	Congenital	0	Yes
s05	Male	59	Measles	2	No
s06	Female	48	Congenital	5	Yes
s07	Female	53	Prenatal rubella	0	Yes
s08	Female	58	Unknown	4	Yes
s09	Female	53	Congenital	1	Yes
s10	Female	45	Congenital	0	No
s11	Female	38	Meningitis	3	Yes
s12	Male	66	Congenital	0	No
s13	Male	36	Congenital	0	No
s14	Male	73	Febrile illness	4	No
s15	Male	72	Febrile illness	2	No
s16	Male	62	Pertussis	2	No
s17	Male	75	Congenital	0	No
s18	Female	51	Viral illness	6	Yes
s19	Female	25	Congenital	0	No
s20	Female	33	Congenital	0	Yes
s21	Female	48	Congenital	0	No
s22	Male	46	Ototoxic medication	1	Yes
s23	Female	40	Congenital	0	Yes

Table 1. Characteristics of deaf participants.

LIS interpreter was present during the experimental sessions with deaf participants. After the presentation of the instructions, participants could familiarize with the task in 4 practice trials (half showing faces wearing a facemask). After these trials, all participants reported having a clear understanding of the task and proceeded to the experimental phase. The entire experiment lasted approximately 40 min, including the initial instructions and the final debriefing session.

Results

The position of the mouse cursor along the bar was automatically converted by the software to percentage rating scores (whole numbers, without decimals), where a 0 score corresponded to the mouse cursor positioned at the left end of the rating bar and a 100 score corresponded to the mouse cursor positioned at the right end of the rating bar (e.g.[34,35]). This conversion was carried out by the software, and participants were not aware of the numerical values associated with their selections.

For all analyses, a $p < .05$ was taken as the criterion for significance, and an eta squared ($\eta^2 p$) was used as a measure of effect size. For all post hoc tests, Bonferroni correction was applied.

The dependent variable was the mean trustworthiness score (ranging from 0 to 100) assigned by each participant (see Fig. 2). Mean trustworthiness scores were analyzed via a mixed repeated measures ANOVA with Facemask (2 levels: facemask/no-facemask) and Trustworthiness level (3 levels: least-trustworthy/neutral/most-trustworthy) as within-subject factors and Group (deaf vs. hearing) as a between-subject factor.

As expected, we found a significant main effect of Trustworthiness level, $F(2,88) = 61.65$, $p < .001$, $\eta^2_\rho =$ 0.58, indicating that participants evaluated most-trustworthy faces (M = 42.6, SD = 17.7) as more trustworthy compared to neutral (M = 39.3, SD = 17.6; $t(44)=2.75$, $p=.007$) and least-trustworthy (M = 30, SD = 17.6; $t(44)=10.69$, $p<.001$) faces; and neutral faces as more trustworthy than least-trustworthy faces ($t(44)=7.94$, $p<.001$), supporting the validity of the stimulus set we used[16].

The main effect of Facemask, $F(1,44)=6.23$, $p=.016$, $\eta^2_\rho = .12$, the main effect of Group, $F(1,44)=9.67$, $p=.003$, $\eta^2_\rho =0.18$, and the interaction Group × Facemask, $F(1,44)=9.77$, $p=.003$, $\eta^2_\rho = .18$, were all significant. The main effects of Facemask and Group were qualified by their significant interaction. Specifically, post-hoc t-tests showed no group differences in evaluating faces without facemasks, $t(44)=1.04$, $p=1$ (deaf: M = 38, SD = 21.2; hearing: M = 43.6, SD = 16.2), whereas the two groups provided significantly different evaluation for faces wearing facemasks, $t(44)=4.28$, $p<.001$ (deaf: M = 22.3, SD = 18.3; hearing: M = 45.3, SD = 16.8). Also, whereas hearing individuals evaluated similarly faces wearing a mask or not wearing a mask, $t(44)=0.44$, $p=1$, deaf participants judged faces wearing a mask as significantly less trustworthy than faces fully visible, $t(44)=3.97$, $p=.002$.

The interaction Facemask × Trustworthiness level was also significant, $F(2,88)=18.98$, $p<.001$, $\eta^2_\rho =$ 0.30. Post hoc t-tests showed that the facemask reduced perceived trustworthiness level of most-trustworthy faces (M = 36.5, SD = 21.2 for faces wearing a mask vs. M = 48.6, SD = 19.5 for faces with no masks), $t(44)=4.07$,

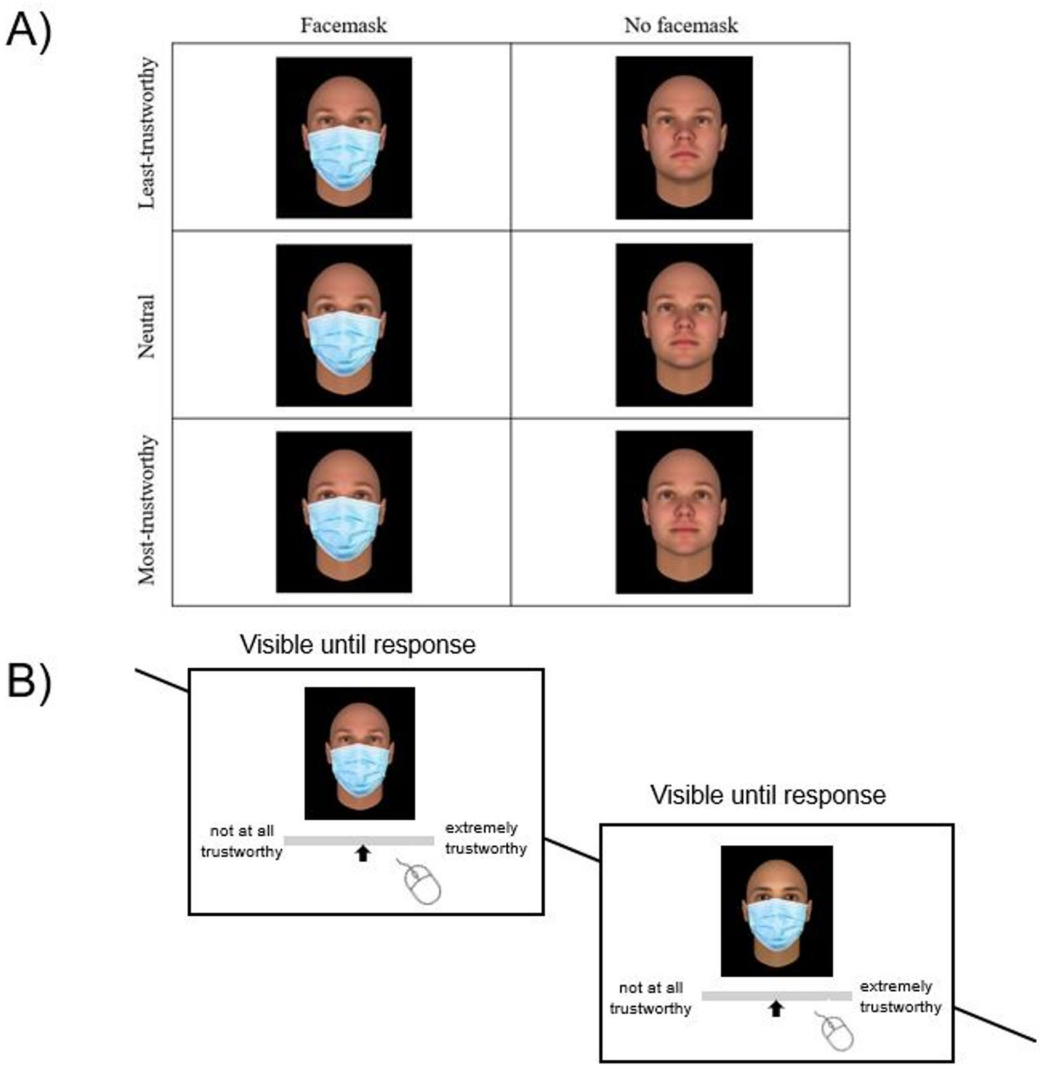

Fig. 1. (**A**) Examples of face stimuli used in the experiment varying for trustworthiness level and use of a facemask. (**B**) Examples of experimental trials. Face stimuli were selected from a larger database[16]; https://tlab.uchicago.edu/databases/).

p=.002. In contrast, for both least-trustworthy, $t(44)$=0.38, p=.1, and neutral faces, $t(44)$=2.56, p=.19, there was no difference in trustworthiness evaluation between masked and unmasked faces. No other interactions were significant: Trustworthiness level × Group, $F(2,88)$=0.31, p=.73, and Trustworthiness level × Facemask × Group, $F(2,88)$=0.27, p=.76.

These findings remained consistent when the analysis was restricted to deaf participants and their hearing counterparts under the age of 65 (total sample: 36 participants; 18 deaf and 18 hearing individuals; age range: 25–62 years).

Discussion

In this study, we investigated face trustworthiness evaluation and whether this is affected by facemasks in a group of deaf signers and matched control hearing participants. We found that deaf and hearing participants rated the trustworthiness of unmasked faces similarly; however, when faces were masked, deaf participants consistently assigned lower trustworthiness ratings than their hearing counterparts.

Our experiment showed that deaf participants evaluate different levels of face trustworthiness in the same way as hearing individuals in the condition without a facemask. Our findings of similar trustworthiness evaluation regardless hearing status for normal faces (with no masks) align with prior studies showing that deaf individuals, especially those who use sign language, may compensate for the lack of auditory input, performing similarly (or even better) to their hearing peers in visual tasks addressing social perception processes, such as face processing[36], face identity judgments[37] and emotion recognition[33,38–40]. Accordingly, neuroimaging studies, such as McCullough et al.[41]; for a recent meta-analysis see[42], have revealed that, when engaging in social perception tasks, deaf signers and hearing individuals exhibit similar patterns of brain activation. Indeed, convergent evidence suggests that deaf individuals are proficient in tasks that rely mainly on visual social perception whereas

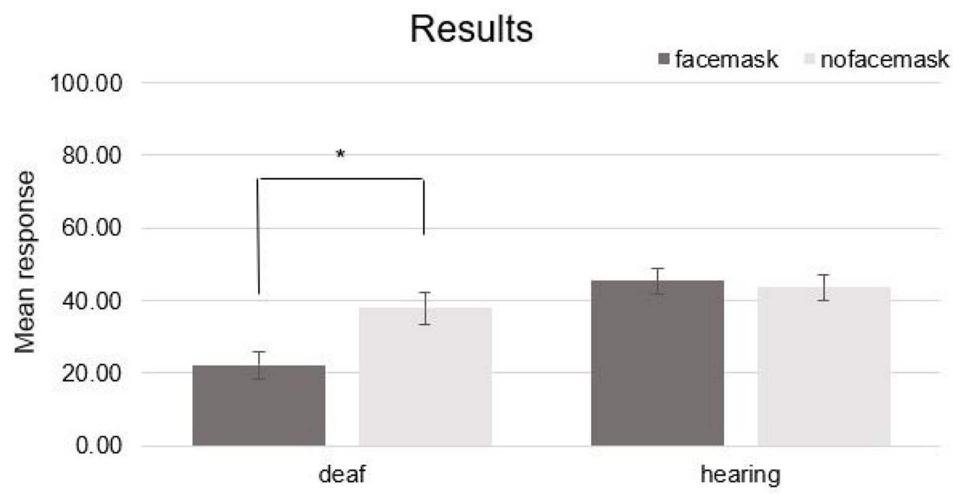

Fig. 2. Mean trustworthiness evaluation scores (range 0-100) for faces with no mask and faces wearing a mask as a function of hearing status (deaf/hearing). The asterisks indicate significant pairwise comparisons ($p < .05$). Error bars reflect ± 1 SEM.

they may show impairments in tasks employing more mentalistic and perspective-taking skills[43]. This difficulty likely depends on the fact that mentalistic tasks involve language abilities, thus stressing the reduced emotional disclosure and conversational activity, as well as a delay in language and narrative skills acquisition, frequently reported by deaf children[43,44]; especially those wearing CIs with late cochlear implantation;[45].

If our data confirms that deaf individuals perform as hearing individuals in social perception tasks using visual material with minimal linguistic requirements, other evidence suggests that auditory deprivation may affect trustworthiness decisions when these are measured with different procedures. Recently, Oleszkiewicz[46] assessed trust level using the Balance of Social Exchanges Scale, which measures the perceived benefit of social exchanges (e.g., agreement with "I benefit from most of my social contact") and the Interpersonal Trust Scale, which assesses the proportion to trust (e.g., agreement with "Most people can be trusted"), and found that deaf individuals have less general trust in others and perceive their social exchange as more imbalanced and unfair, than hearing individuals. The author interpreted this finding as likely guided by the feeling of isolation and stigma reported by deaf individuals for the non-supportive environment rather than a lack of social perception abilities. Importantly, while our task focused on social perception using facial stimuli, Oleszkiewicz's study[46] examined participants' trust behavior through self-report measures. This methodological difference likely contributed to the divergent findings: whereas our results highlight similarities between deaf and hearing individuals in visual tasks involving social perception, Oleszkiewicz's findings point to differences in social tasks that depend more heavily on language skills and emotional disclosure. Moreover, while our task primarily focused on social perception, Oleszkiewicz's study[46] emphasized participants' social interactions, which are likely to be more directly influenced by feelings of isolation and loneliness.

Critically, our findings also showed that deaf participants judged faces wearing face masks as less trustworthy than faces with no masks, whereas this effect was not evident in the hearing control group. In processing faces also during verbal communication, deaf individuals preferentially focus on the lower part of the face[47] and pay increased attention to the mouth when compared to hearing people[48,49]. By convering the lower part of the face, masks may thus compromise access to a key source of social information for a deaf person. Consistent with our findings, previous data showed that the negative effect of facemasks is stronger in deaf individuals than hearing controls during other social perception tasks, such as facial emotion recognition[12].

Moreover, our results support the key role of holistic face processing (i.e., the tendency to process faces as a configurational object; e.g.[50,51], in deaf individuals. Previous research has already demonstrated that deaf participants rely more on holistic processing during face discrimination, as assessed by the inversion effect (e.g.[52,53]), during the face recognition task[54,55]. Considering that facemasks, which create a discontinuity between the upper and the lower part of the face, reduce holistic face processing[56,57] (but see[58] for opposed findings), it is unsurprising that this disruption has a more significant impact on face processing in deaf individuals compared to their hearing counterparts. Consistently, Giovanelli et al.[14] reported that deaf participants presented difficulty in processing faces wearing both obscured and *transparent facemasks* (in which the mouth region is visible). This difficulty stems from a disruption of their holistic face-processing abilities rather than from a lack of visual information from the mouth region, considering that the mouth is still visible with a transparent facemask.

Furthermore, in interpreting our findings, it is important to consider that facemasks, occluding the mouth, hinder communication in deaf individuals by blocking the perceptual and linguistic information from mouthing and mouth gestures[59,60]. For this reason, wearing a facemask may be perceived by deaf individuals as a lack of willingness to communicate with them, limiting their social interactions and their independence in social environments (e.g.[61,62]). Accordingly, deaf signers reported reduced effort and a greater sense of understanding when communicating with individuals not wearing a facemask, compared to those who were[14]. Moreover, when communication is hindered by external conditions - even when unintentional - it becomes more difficult to form a positive impression of the other person's trustworthiness. This is because the ease and naturalness of communication play a fundamental role in how trust is established[63]. During the final debriefing sessions, our deaf participants consistently expressed significant challenges in interacting with individuals wearing facemasks, leading to feelings of distrust and frustration toward those who refused to lower their masks for better communication.

It is important to recognize the significant practical implications of our findings accounting for individual differences in social context. For example, adopting a greater social distance[7] and removing facemask for conversation may be a more respectful way to interact with people with different communication modes, which is mainly based on visual inputs as the sign language[33,42]. This type of research is therefore essential, as it helps to identify the challenges faced by individuals with sensory impairments and to explore practical solutions aimed at enhancing their overall quality of life. This issue is particularly critical for deaf children and adolescents, especially with respect to their integration into educational settings. In this context, our findings highlight the importance of full facial visibility for deaf individuals, as it can greatly facilitate social communication and foster the development of trust in people with auditory sensory deprivation. Note that deaf individuals frequently report feelings of exclusion and isolation from the hearing community (e.g[64,65]). These social challenges intensified during the pandemic, primarily due to the barriers presented by facemasks, which hindered their opportunities for social interaction (e.g.[66,67]). Our research indicates that facemasks diminish trustworthiness evaluation more in deaf than in hearing individuals. The detrimental impact of masking on the social lives of deaf individuals deserves societal attention. This concern becomes even more pressing when considering deaf children, who may face exacerbated social challenges due to facemask usage, potentially hindering their social development (for an overview of the difficulties faced by deaf children during the pandemic, see[68].

Contrary to our result, Lau et al.[10] reported no difference in deaf participants for trustworthiness evaluation between faces with or without facemasks, and they also reported a tendency to rate masked faces as more approachable. The authors argue that their unexpected result is likely guided by the fact that their deaf signer participants may evaluate facemasks positively due to societal norms. Consequently, a more medical interpretation is that facemasks may lead to lower trustworthiness evaluation in our deaf individuals because of their relationship with illness and interpretation of facemasks. A limitation of our experiments is that we did not consider individual variability in interpreting facemasks and its possible effect on trustworthiness judgments. For example, some participants considered wearing a facemask as a signal of respect for the safety norms[69,70], while other individuals felt a negative sensation when interacting with someone wearing a facemask because they did not believe in its protective effect (e.g.[71]), or because they associated facemask with illness, infection, and potential contagion (e.g.[72]). Based on previous research reporting that the negative effect of facemasks is stronger in deaf individuals than hearing controls during facial emotion recognition[12], we contend that our findings are not only attributable to a disparity in the medical interpretation of facemasks between deaf and hearing individuals. A key factor contributing to the reduced perception of trustworthiness appears to be the disruption of natural and effortless communication. For deaf individuals, visual access to the mouth and lip movements is essential for effective communication; without it, understanding the interlocutor becomes significantly more difficult. Our findings highlight a strong link between communicative competence - the ability to understand and be understood, and thus to recognize others' intentions and thoughts - and the formation of interpersonal trust. This suggests that trust in others may be mediated by the capacity for mutual communication[63]. This insight is particularly significant and merits further exploration, including among hearing populations. Nevertheless, future studies should consider individual differences in how facemasks are interpreted when evaluating their impact on social perception in deaf participants.

In conclusion, we conducted an experiment to clarify the impact of facemasks on trustworthiness judgments in deaf individuals. Our primary findings are twofold. Firstly, our data indicates that deafness does not inherently alter the perception of face trustworthiness: deaf participants assess varying levels of trustworthiness similarly to hearing individuals when they can fully process the face. However, our second key finding reveals that facemask diminishes the evaluation of others' trustworthiness more in deaf individuals than in hearing individuals. This effect likely occurs because wearing a facemask prevents the processing of perceptual information from mouthing and mouth gestures, blocking a holistic representation of the face, hindering communication and thus limiting social exchanges for deaf individuals. Future research should consider the influence of individual variability in these processes.

Data availability

The datasets generated during the current study are available from the corresponding author on request.

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MA: Conceptualization, Investigation, Data Collection, Analysis, Methodology, Writing – original draft; AC: Conceptualization, Investigation, Methodology, Writing – reviewing and editing; CF: Conceptualization, Investigation, Methodology, Writing – reviewing and editing; TI: Conceptualization, Investigation, Methodology, Writing – reviewing and editing; ZC: Conceptualization, Investigation, Supervision, Analysis, Methodology, Writing – original draft;

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Declarations

Competing interests

The authors declare no competing interests.

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