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Sharpening of peripersonal space during the COVID-19 pandemic

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Our social world has been transformed by the COVID-19 pandemic. Beyond the direct impact of the pandemic on physical health, the social distancing measures implemented worldwide to slow down disease transmission have dramatically impacted social interactions[1,2]. These measures, including orders to stay at home and to maintain a social distance of at least 2 meters, have been essential to limit the spread of the disease, but they have had severe costs for humans as social animals[2]. Right before and right after the adoption of the most stringent measures in Switzerland in Spring 2020, we were conducting a series of experiments to measure the representation of the so-called peripersonal space — the space immediately surrounding our body, where we normally interact with objects and other individuals[3]. We found that the introduction of social distancing measures led to a reduction in the extent of the peripersonal space and enhanced its segregation between individuals, as if the presence of others in close space would activate an implicit form of freezing response.

We think of peripersonal space as the region of space encoded by a set of neurons in fronto-parietal areas of the brain[4] where sensory information (visual or auditory) about external stimuli is integrated with the processing of somatosensory information to predict potential contacts and prepare responses[3]. The size and shape of peripersonal space representation dynamically adapt as a function of the nature of interactions with external objects[3], including other individuals[5]. Peripersonal space neurons are particularly sensitive to approaching stimuli[4], the valence of which further affects its representation[6], highlighting the role of peripersonal space as a margin of safety during interactions between oneself and one's environment (particularly other people).

We adapted a well-validated multisensory task, widely used to behaviorally measure peripersonal space (Figure 1A). Participants are typically asked to reply as fast as possible to tactile stimulation, while an external visual (or auditory) stimulus is presented as approaching. Although participants are instructed to focus on tactile targets and to ignore the external stimulus, several studies showed that reaction times to touch sped up as a function of the perceived distance of the external object at the time of tactile stimulation[3]. The distance of the visual stimulus from the participants' body at which this multisensory effect occurs — where reaction times to visuo-tactile trials are significantly faster than those to unimodal tactile stimulation — is taken as a proxy of peripersonal space representation. To gather a measure of social peripersonal space during the COVID-19 pandemic, we used approaching avatar faces as visual stimuli in immersive virtual reality, while a mechanical vibration was administered to participants' faces. Participants were asked to press a button as soon as they felt the tactile vibration which, in different conditions, was delivered in isolation (unimodal) or in combination with an approaching avatar (visuo-tactile). In the latter case, in different trials, tactile stimulation was given when the avatar was perceived at one out of five possible distances, from D1 for near to D5 for far, from the participant.

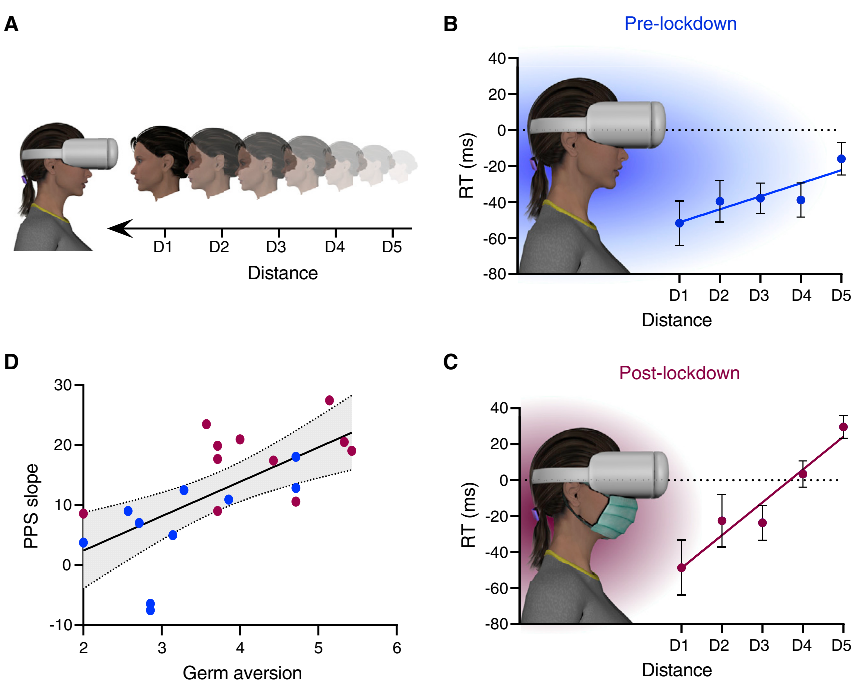

Figure 1. Evolution of peripersonal space representation during the COVID-19 pandemic.
(A) Peripersonal space task. Three cohorts of participants (Pre-Pandemic, Pre-Lockdown and Post-Lockdown) responded as fast as possible to a tactile stimulus on their face administered either while an avatar face was approaching (visuo-tactile trials) or alone (unisensory trials). (B,C). In all cohorts reaction times sped up as the virtual faces approached [Distance: $F(2.59,106.31) = 23.902$, $P < 0.001$, $p\eta^2 = 0.368$], showing the expected peripersonal space effect. The effect varied between the three cohorts [Distance X Cohort: $F(2.59,106.31) = 3.34$, $P = 0.007$, $p\eta^2 = 0.140$]. Both in the Pre-Pandemic (Figure S1) and in the Pre-Lockdown Cohort (B), multimodal reaction times were faster than unimodal ones from D1 to D4 ($P < 0.05$; blue area). In the Post-Lockdown Cohort (C), the difference is significant only at D1 ($P < 0.05$; purple area), indicating a contraction of peripersonal space representation. (D) The change in peripersonal space (indexed as the difference in slopes of the functions) due to the pandemic is related to participants' concerns about the transmission of infectious diseases (from the Germ Aversion scale; standardized $\beta = 0.653$, $t = 3.502$; $P = 0.002$).

Our critical experimental condition is the timing of the assessment with respect to the evolution of the COVID-19 pandemic in Switzerland (Supplemental information). Restrictive measures, including social distancing, working from home, and closing of schools, universities and non-essential stores, were introduced from March 16th to April 26th, 2020. Data were collected: before the COVID-19 outbreak (June–July 2018), the Pre-Pandemic Cohort (N = 15); following the COVID-19 outbreak, but before the adoption of social distancing measures (10 February – 10 March 2020), the Pre-Lockdown Cohort (N = 15); and after the lockdown phase (10 June – 25 July 2020), the Post-Lockdown Cohort (N = 14). Data from Perceived Vulnerability to Disease Scale[7] indicated higher levels of individuals' discomfort and arousal for being in contact with pathogens in the Post-Lockdown as compared to the Pre-Lockdown cohort (Germ aversion subscale; Table S1).

To study the impact of the social distancing measures imposed by the Lockdown on peripersonal space, reaction times to visuo-tactile stimuli were subtracted from those to unimodal stimuli and analysed as a function of the different distances and cohort membership. Globally, our results show the expected peripersonal space effect in all cohorts, with participants becoming faster in responding as the avatars approached[3,4]. Critically, the peripersonal space effect significantly varied between the three cohorts. Multimodal reaction times were significantly faster than unimodal reaction times from D1 to D4 in both the Pre-Pandemic (Figure S1) and in the Pre-Lockdown Cohorts (Figure 1B). In the Post-Lockdown Cohort, however, multimodal reaction times were faster than unimodal reaction times only at D1, the closest distance to the participant's body (Figure 1C). These findings suggest that, after the lockdown period, avatars perceived at farther locations induced less facilitation on tactile processing, showing a shrinking of peripersonal space representation. This effect might appear counterintuitive, considering previous studies showing an enlargement of peripersonal space representation, or an anticipation of time-to-contact estimation, when participants were exposed to looming stimuli they are afraid of[6,8], as to prepare a fight-or-flight reaction. In the present study, however, we did not present participants with stimuli that were threatening *per se* and required an active defensive response, but simply with faces of other individuals, showing a neutral expression. During the pandemic and the lockdown, people have been trained to respond to others by implementing social distancing so to avoid any contact. Thus, we suggest that the shrinkage of peripersonal space representation in the Post-Lockdown Cohort reflects the implementation of such protective behaviours.

This hypothesis predicts a stronger segregation between one's own peripersonal space and the space of the others. To further investigate the change in peripersonal space representation between cohorts, we analysed the slope of the linear function of the multimodal reaction times as a marker of peripersonal space differentiation. Our findings revealed a steeper slope of the peripersonal space in the Post-Lockdown Cohort, while no difference emerged when comparing the other two cohorts (Figure S2). Results from participants after lockdown suggest a stronger near–far differentiation, with an increase of multisensory processing allocated in the limited space around the body, and less interaction for farther distances. The idea these results are a consequence of social distancing imposed by the lockdown is corroborated by a multiple regression analysis aimed at explaining changes in the peripersonal space slope as a function of individual responses to the two subscales of the Perceived vulnerability to disease scale[7] (Supplemental information and Tables S1 and S2). We found that participants who were more afraid of being contaminated by pathogens (as captured by the Germ aversion subscale[7]), and thus more likely implemented protective behaviors to avoid contacts, had steeper slopes in the peripersonal space task, that is a strong segregation between near and far space (Figure 1D).

The described changes in peripersonal space representation between self and others might thus be considered an implicit form of 'freezing' behavior in social contexts[6]. Our interpretation is that, after the lockdown, because of the implementation and interiorization of the importance of social distancing, the gradient of differentiation between one's own space and the space of others became sharper: others do not trigger any anticipatory processing when far away, but a stronger processing when at potential contamination distance. These findings contribute to our understanding of the psychological and social consequences of the COVID-19 pandemic and the associated lockdown measures, and underscores the importance of parallel strategies to promote safe social contacts for mental health and well-being[1].

SUPPLEMENTAL INFORMATION

Supplemental information includes two figures, two tables, experimental procedures, Acknowledgements, Author contributions, and Inclusion and diversity statement and can be found with this article online at https://doi.org/10.1016/j.cub.2021.06.001.

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