Supplemental information: Sharpening of peripersonal space during the COVID-19 pandemic

Silvia Serino, Sara Trabanelli, Camilla Jandus, Julia Fellrath, Petr Grivaz, Maria Paola Paladino, Andrea Serino

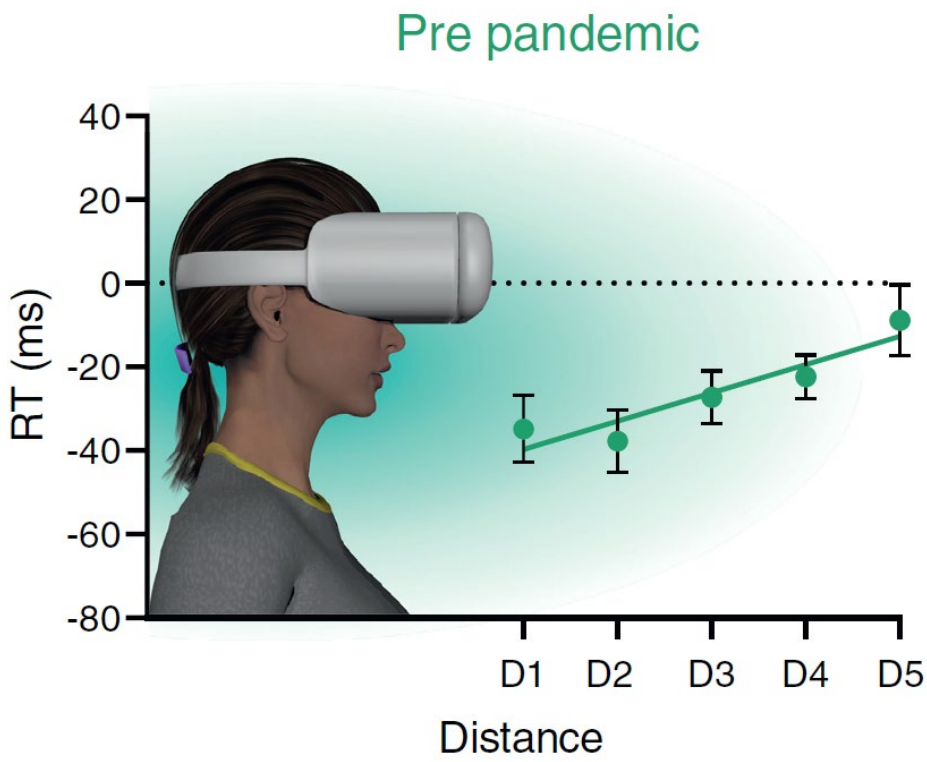

Figure S1. Peripersonal space representation before the COVID-19 outbreak. In the Pre-Pandemic Cohort, multimodal reaction times were faster than unimodal ones from D1 to D4 ($P < 0.05$, FDR corrected), as illustrated by the green area.

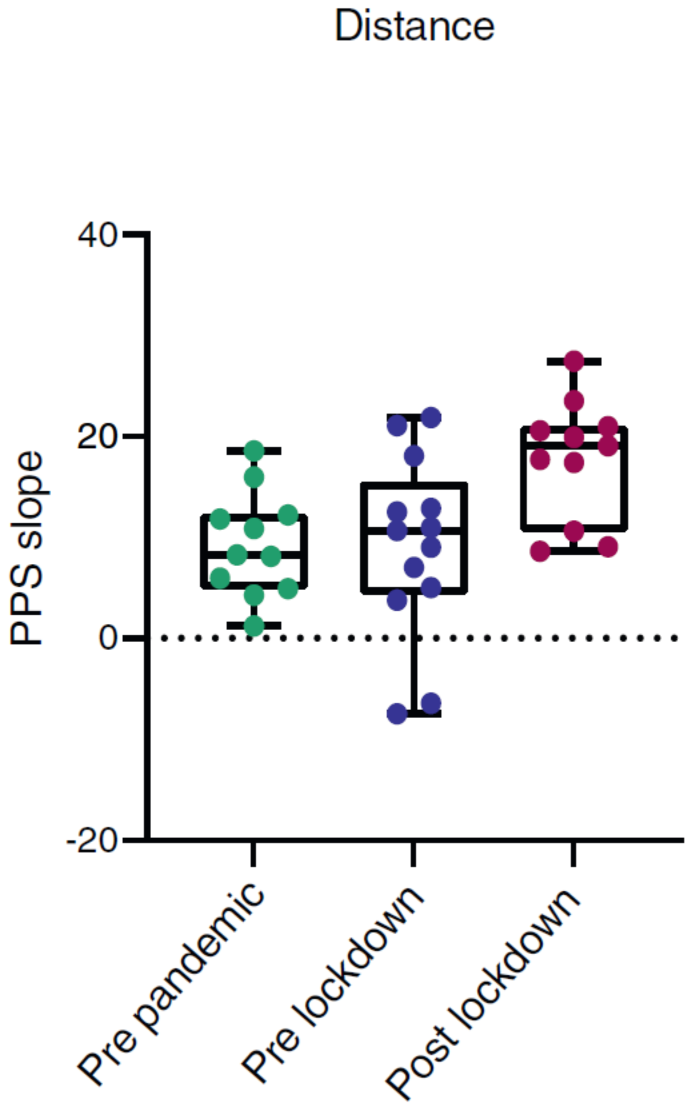

Figure S2. The change in near-far segregation of peripersonal space is shown by steeper slopes in the Post-Lockdown Cohort. ANOVA on slopes with three Cohorts [$F(2,32) = 5.40$, $P = 0.010$, $p\eta^2 = 0.252$]; Post-Lockdown Cohort versus Pre-Pandemic Cohort, $P=0.027$; versus Pre-Lockdown Cohort, $P=0.018$.

	Pre-Lockdown Cohort	Post-Lockdown Cohort	Comparison
Perceived Infectability	2.53 (0.756)	3.30 (1.36)	t(22)=1.61; P=0.122
Germ Aversion	3.27 (0.90)	4.22 (1.09)	t(22)=2.24; P=0.035

Table S1. The responses of study participants for the subscale "Perceived Infectability" and "Germ Aversion" in the Pre-Lockdown Cohort and in the Post-Lockdown Cohort. Findings indicated a significant higher level of emotional discomforts in presence of germs in participants after the lockdown phase, as compared to the pre-lockdown one. Increased level of perceived vulnerability to disease was also observed in this cohort, although the comparison with scores from participants in the Pre-Lockdown group is not statistically significant. Data are presented as mean and standard deviation (SD).

	R^2	Corrected R^2	Standardized β	*t*	P
Slope values	0.748	0.559			
Perceived Infectability			0.147	0.786	0.441
Germ Aversion			0.653	3.502	0.002

1Model=F (2,19)=12.057; P<0.001

Table S2. Linear multiple regression on slope values as functions of scores on "Perceived Infectability" and "Germ Aversion"[1]

Supplemental experimental procedures

Participants

A total of 44 right-handed participants [19 females; mean age: 26.7, (SD=5.17)] participated in the experiment. Data were collected at three different time points with the respect to the evolution of COVID-19 pandemic and social distancing measures adopted in Switzerland to contain the spread of the disease: (a) before the COVID-19 outbreak (June-July 2018) - Pre-pandemic Cohort (N=15, 7 females); (b) prior the adoption of social distancing measures following the COVID-19 outbreak (10 February-10 March 2020) – Pre-Lockdown Cohort (N=15, 5 females) and (c) after the lockdown phase (10 June - 25 July 2020) - Post-Lockdown Cohort (N=14[1], 7 females).

All participants were recruited through the participant management software "Sona-Systems" (https://www.sona-systems.com/). None reported to have a current and/or history of neurological and/or psychiatric disorders. All participants reported normal or corrected-to-normal vision. Most participants in the Post-Lockdown Cohort said that they had followed social/physical distancing measures during the lockdown period "always" (N=7, 50%) or "often" (N=4, 28.6%).

Based on previous experiments[S1,S2], an averaged effect size f = 0.403 was expected. We estimated a sample size of 15 participants per group, with a desired power of 0.95 (1 − β) on within comparisons (correlations among repeated measures: 0.5, number of repeated measures: 4), by means of G*Power 3.1 software. The experiment was conducted in accordance with the principles of the 1964 Declaration of Helsinki and approved by the ethical committee "Commission cantonale d'éthique de la recherche sur l'être humain" in Vaud, Switzerland (Project-ID 2017-01588). All participants were financially reimbursed for their participation (20 Swiss Francs/hour) and gave written informed consent prior to participating.

Apparatus and stimuli

The size and extension of the Peripersonal Space was assessed with a modified version of the well-validated multisensory task described in Serino et al[S3]. Here, we asked participants to respond as fast as they can once they perceived a mild tactile stimulation on their faces, while they observed a task-irrelevant looming visual stimulus entering their PPS (Figure 1A). By modulating the delay between the trial onset and tactile stimulation, touch was delivered when the looming visual stimulus was perceived at five different distances (D5-D1, from far to near; see below) from the participant. Visual stimuli consisted of female or male avatar faces, gender-matched with the participants, with a neutral expression. They were developed using Poser software (version 10; Smith Micro Software, Aliso Viejo, California, USA, (https://www.posersoftware.com/) and presented in immersive Virtual Reality with a head-mounted display (Oculus Rift SDK, Oculus VR, 100° field of view, 960 x 1080 pixels, refresh rate of 60 Hz). The avatars used for this experiment have been previously validated.[S4,S5] Tactile stimuli

[1] One participant was excluded because she/he took part already to the experiment in the Pre-pandemic group.

consisted in mechanical vibrations (duration: 250ms) delivered to participants' faces (Precision Microdrives™, Pico Vibe Vibration Motor, diameter 10 mm). Vibrators were placed bilaterally on participants' cheeks with a medical tape, and they were controlled with a custom-made interface, which sampled at 10kHz the participants' responses at each tactile stimulation. The experiment was implemented in ExpyVR, a software for designing and running Virtual Reality-based experiments, and available online at https://www.epfl.ch/labs/lnco/research/expyvr/) and it ran on a Windows-based PC (Dell XPS 8930, Dell, Round rock, Texas, USA).

Design and procedure

The peripersonal space task was composed of two blocks of 84 trials. Each block was composed of four types of trials: visuo-tactile trials, unisensory trials, visual-only trials, and attentional trials. In visuo-tactile trials (N=40), tactile stimuli were administered at five different time delays from the onset of the visual stimulation (D5=0.5s; D4=1s; D3= 1.5s; D2= 2s; D1=2.5s). Accordingly, the avatar face is perceived at one of five possible distances (D1 ≈ 45 cm, the nearest point; D2 ≈ 80 cm; D3 ≈ 115 cm; D4 ≈ 150 cm; D5 ≈ 185 cm, the farthest point). At the beginning of each trial, the avatar face could appear in one of three possible (counterbalanced) positions: centrally, on the left or on the right periphery (10°). The face moved in the sagittal plane starting from this apparent initial position at ≈ 9m from the participant to a position at ≈ 0.30m from the participant, where it remained still for 1s. In unisensory trials, the tactile stimulation was presented without the corresponding visual stimulus at one of the same five temporal delays previously described. The remaining trials are 20 visual-only trials, in which the approaching avatar face approached towards the participant without the corresponding tactile stimulation (“catch trials”). To be sure that participants were looking at the avatars, 4 attentional trials were included, whereby approaching avatars were presented with a red dot on their forehead. Each block lasted approximately 7 minutes. Participants were instructed to press a button placed on the table in front of them with the right hand as fast as possible when they perceived the tactile stimulation on their faces, and to ignore the approaching virtual faces; they were also told to verbally signal the appearance of a red dot on avatar faces (in attentional trials). To measure the extent of participant’s peripersonal space, reaction times to tactile stimuli in the unimodal condition were compared to those in the visuo-tactile condition when the avatar was at different distances in order to identify at which distance from the participant the approaching visual stimuli induced a well-defined multisensory effect on tactile processing[S3,S6] (see analyses for further details).

The study followed a mixed design in which three different cohorts were assessed at three different time points with respect to the COVID-19 pandemic in Switzerland and associated Swiss restrictive measures: Pre-pandemic Cohort (N=15), Pre-Lockdown Cohort (N=15) and Post-Lockdown Cohort (N=14). The Swiss national lockdown restrictive measures were introduced from 16th March to 26th April 2020 (precise information can be found online[S7]). Social distancing measures were strictly implemented, schools, universities, and all non-essential stores were closed, social gatherings and public events of more than five people were prohibited, working from home was explicitly adopted. After April 26th, all Swiss Universities and research centers started to slowly allow researchers to return to work, under strict sanitary protocols. Accordingly, participants in the Post-Lockdown Cohort were asked to follow strict sanitary rules and social distancing measures to participate in the experiment: before the experiment, the experimenter ensured that they were aware and informed about the safety procedures. Both experimenter and study participants always wore a protection face mask, regularly disinfected their hands, respected a 2-meter safety distance.

Self-report questionnaires

Participants in the Pre- and Post-Lockdown Cohort were presented with a questionnaire to evaluate their subjective perception of vulnerability in relation with COVID-19 pandemic. They filled the Perceived Vulnerability to Disease[S8], a 15-item questionnaire on 5-points Likert scale to measure individual beliefs about one's own susceptibility to disease (Perceived Infectability) and emotional discomfort in presence of transmission of potential pathogens (Germ Aversion).

Data analysis

First, changes in the perceived vulnerability to disease and in the subjective perceived discomfort in presence to potential pathogens between participants in Pre-Lockdown and Post-Lockdown Cohort were analyzed with independent t-test (Table S1).

Performance in the peripersonal space task was analyzed in terms of reaction times to the tactile stimulation. As a first check, reaction times slower than 1000 ms were excluded from the analyses. Moreover, reaction times higher or lower than 2 standard deviations for each block were considered as outliers and excluded from subsequent analyses. To obtain a general measure of multisensory processing, in line with previous studies [S3,S6], for each participant, we subtracted averaged RTs to unimodal trials from RTs to visuo-tactile trials at each distance (D1-D5). Consequently, negative unimodal-corrected reaction times indicated a multisensory facilitation. Unimodal-corrected reaction times were submitted to a repeated-measure ANOVA with Distance (D1; D2; D3; D4; D5) as the within-subject factor and Cohort (Pre-Pandemic Cohort; Pre-Lockdown Cohort; Post-Lockdown Cohort) as a between-subjects factor. When the assumption of sphericity was violated as assessed by Mauchly's test of sphericity, the Greenhouse-Geisser correction was applied. Separately for each cohort, one sample t-test again 0 (FDR corrected) were carried out to identify at which distances multimodal RTs were significantly faster than unimodal RTs as a proxy of the extension of peripersonal space (Figure S1 and Figure 1B-C).

To further characterize the peripersonal space representation during the COVID-pandemic, unimodal-corrected reaction times were fitted to a linear function and the relative slopes were extracted as indexes of segregation between the peripersonal and extrapersonal space [S6,S9]. The linear function was described by the following equation: $y(x)=y0+ k \cdot x$; where x represents the independent variable (i.e., the timing of tactile stimulation in ms), y the dependent variable (i.e., the reaction time), *y0* represents the intercept at x=0 and *k* is the slope of the linear function. Accordingly, the estimated parameters were the intercept (*y0*) and the slope (*k*). Slope values were submitted to an ANOVA with Cohort (Pre-Pandemic Cohort; Pre-Lockdown Cohort; Post-Lockdown Neutral Cohort) as between-factor (Figure S2). Bonferroni-corrected post-hoc comparisons were carried to examine differences between the three cohorts (Figure S2). We included in these analyses only data that the linear function roughly fitted, as indicated by an R^2 value > 0.2.[S6,S9] One participant was excluded since outlier.

Finally, a linear multiple regression analysis (method: enter) was conducted to identify potential factors associated with a modulation of peripersonal space representation during the COVID-pandemic, with peripersonal space slope values entered as criterion variable and scores of the Perceived Infectability and Germ Aversion entered as predictors (Figure 1D and Table S2).

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Author contributions

Conceptualization, S.S. and A.S.; Methodology, S.S., J.F., P.G., M.P.P. & A.S.; Investigation, S.S., J.F. & P.G.; Writing – Original Draft, S.S., A.S.; Writing – Review & Editing, S.T., C.J., J.F., M.P.P.; Software, P.G.; Visualization, S.T.; Funding Acquisition, A.S.; Supervision, C.J., M.P.P. & A.S.

Declaration of interests

The authors declare no competing interests.

Inclusion and diversity

We worked to ensure gender balance in the recruitment of human subjects. We worked to ensure that the study questionnaires were prepared in an inclusive way. One or more of the authors of this paper received support from a program designed to increase minority representation in science.

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