Personal Space Regulation by the Human Amygdala

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Supplementary Text

Lesion study:

All participants were tested in the same room by the same experimenter. Care was taken to ensure that the experimental setup remained identical across participants. We compared SM to 20 neurologically and psychiatrically healthy individuals recruited from the community (6 males; mean age = 36.8±9.9 years, range = 21.9-51.0, 10 Caucasian, 3 African-American, 4 Asian, 1 Hispanic, 2 Other). This included a subgroup of 5 controls matched to SM on age, gender, race, and level of education.

Subjects were asked to stand with their toes on a line that was marked on the floor while the same female experimenter walked at a natural gait towards them. Subjects were asked to tell the experimenter to stop at their preferred distance. This was fine-tuned as subjects could have the experimenter move slightly further backward or forward. The final distance was measured with a digital laser measurer (Bosch, model DLR165K, error ±0.003m).

All subjects completed a total of 32 trials. In the first 16 trials, the experimenter was always the one moving, and in the second 16, the subject was always the one moving.

Within each half, each trial type was repeated 4 times. All trials were administered in a fixed order. There were no gender effects in the controls.

To quantify statistically SM's abnormal interpersonal distance preference for the main trial type of interest (see Main Text), we first removed the 3 largest outlier subjects (see **Fig. 1a**), even though these data points are in support of our claim that SM has an unusually small distance preference. The t-values reported in the main text were calculated using a modified t-test procedure, suitable for comparing data from a single subject with a small normative sample[1].

To ensure that SM's abnormal distance preferences were not due to familiarity effects, we tested 2 additional participants matched for SM's level of familiarity with the experimenter (as well as for gender and race). Both subjects preferred greater distances than did SM (0.56±0.04m and 0.78±0.08m, collapsed across all trial types). Even a close friend of the experimenter preferred a distance (0.64±0.04m) greater than did SM, who knew the experimenter for less than 1 week. Furthermore, SM's distance preference did not change with a familiar male experimenter (0.34±0.02m) or with a less familiar male experimenter using an abbreviated version of the experiment (0.33±0.03m).

We carried out additional versions of the main experiment. SM's abnormal distance preference was confirmed across each variation [starting close together and withdrawing vs. starting apart (SM = 0.36±0.04/0.34±0.03m (mean±standard deviation), controls = 0.81±0.29/0.75±0.29m); eye-contact vs. no eye-contact (SM = 0.34±0.03/0.36±0.04m, controls = 0.78±0.28/0.78±0.28m); subject moving vs. experimenter moving (SM = 0.36±0.02/0.34±0.04m, controls = 0.81±0.31/0.76±0.27m); values reported are collapsed

across the other factors; all conditions together (SM = 0.35±0.03m; controls = 0.78±0.29m)].

A 3-way ANOVA with control subjects (excluding the 3 outliers) revealed significant main effects of starting position [$F(1,16)=112.8$, $p<0.001$] and person moving [$F(1,16)=22.25$, $p<0.001$], but not eye contact [$F(1,16)=0.37$, $p=0.55$], on interpersonal distances. Control participants preferred significantly larger interpersonal distances when starting close compared to starting far apart (mean difference = 0.062±0.02m; range = 0.025 to 0.122m). SM failed to show this relative difference across conditions, and actually showed the smallest difference between these two conditions out of any participant (difference = –0.018±0.015m; $Z=1.82$, $p=0.034$; $t(16)=1.77$, $p=.048$, one-tailed). Control participants also preferred significantly larger distances when they approached the experimenter compared to when the experimenter approached them (mean difference = 0.039±0.03m; range = –0.024 to 0.14m). Here, SM's relative difference across these conditions was not significantly different from controls (difference = 0.022±0.02m, $Z=-0.50$, $p=0.31$; $t(16)=-0.45$, $p=0.33$, one-tailed), though only 3/17 subjects demonstrated less of a difference than her.

FMRI study:

In order to provide converging evidence for the role of the amygdala in interpersonal distance, we recruited 8 neurotypical males from the Los Angeles area for participation in an fMRI study (mean age = 29.2 years; range = 18-44 years; 5 Caucasian, 1 African American, 1 Hispanic, 1 Asian). We explained to the participants that we were interested in examining how the brain responds to knowing that another person is either

close to them or far from them. They were told that an experimenter would actually be in the MRI room with them at all times, and that the experimenter would be at 1of 3 pre-defined locations. The position of the experimenter would be relayed to the participant via text on the screen and a person speaking to them via MRI-compatible headphones, but that they would not be able to see the experimenter. We explained to subjects that this was because we were "not interested in how the brain responds to the sight of someone at various locations, but rather, how the brain responds to knowing that someone was at various locations." All participants understood this explanation, and were reassured that no deception would be used at any time during the experiment (which was true). They were told that their task was simply to be fully aware of the location of the experimenter, relative to their position, at all times, and to be aware of how they felt. There was no mention of the words "discomfort" or "personal space" at any time, and none of these participants participated as controls for the behavioral experiment.

Before scanning, the procedure was explained and acted out in a mock scanner room. During this demonstration (but not during the real experiment), participants were able to see the location of the experimenter. Once lying down and with their head just inside the opening of the mock scanner, the 3 positions were described and shown to the participants. The "Home" position was where the experimenter would be for the majority of time. We chose to include this baseline condition to make the occurrence of the close and far events less common, thus reducing effects of habituation and boredom. This "Home" position was roughly 8 feet away from the junction between the patient table and the opening of the magnet and at a 45° angle away. The "Far" position was approximately 15 feet directly in front of the opening of the magnet. The "Close" position was right at the

junction of the patient table and opening of the magnet, as close as one could stand without touching the patient or the scanner.

After this explanation, participants were introduced to the two experimenters that would be in the scanner room with them (one each during each of the repetitions of the experiment). Because being set-up for scanning often involves physical closeness (and possibly an invasion of one's space), a third person prepared each participant for scanning, so as to limit habituation of closeness to either of the two experimenters. Once in the magnet, a black cloth made from raincoat material was secured to the opening of the bore to block light from passing through, thus preventing participants from seeing the experimenter. Lastly, before scanning began, the experimenter in the room went to the back of the magnet (where the subject was able to see via a mirror) to identify himself as the experimenter for that particular functional run. After scanning, all subjects reported that they maintained awareness of the location of the experimenter at all times.

All MRI data were acquired using a 3 Tesla Trio (Siemens Medical Solutions, Malvern, PA) at the Caltech Brain Imaging Center. Functional data were collected using a T2*-weighted echo-planer imaging sequence with the following parameters: 33 axial slices, interleaved acquisition, repetition time (TR) = 2000ms, echo time (TE) = 30ms, flip angle = 71° (Ernst angle assuming T_1 of gray matter is 1800ms), slice thickness = 3 mm with no gap, and in-plane resolution of 3 mm^2. Each of the two functional runs lasted approximately 4 minutes. In each run, there were 5 "Close" events, 5 "Far" events, and 11 "Home" events. Both the "Close" and "Far" events each lasted 8 seconds, and the duration of the "Home" event was jittered (10, 12, 14, or 16 seconds; mean = 13 secs). To ensure subjects remained awake throughout the study, we monitored their eyes with an MR-

compatible ASL eyetracker (Applied Science Laboratories; Bedford, Massachusetts). Immediately following the functional scans, a dual gradient echo sequence was used to acquire B_0 fieldmap data to allow for retrospective correction of spatial distortion. T_1-weighted anatomical images were also acquired using a volumetric MP-RAGE sequence (176 sagittal slices, isotropic voxel size = 1 mm^3).

Functional analyses were carried out using SPM5 (http://www.fil.ion.ucl.ac.uk/spm). Images for each functional run were pre-processed as follows: the first 2 images were discarded to avoid T1 saturation effects, corrected for timing of slice acquisition, aligned to the first image of each session and then aligned across sessions (thus yielding subject-specific movement parameters), B_0 fieldmaps were used to correct for spatial distortion and for susceptibility-by-motion interaction[2], spatially normalized to an EPI template in MNI space[3], and smoothed with a full-width half-max Gaussian filter of 6 mm. First level design matrices included box-car regressors for both "Close" and "Far" conditions convolved with a canonical hemodynamic response function (HRF), along with movement parameters. Our contrast of interest was "Close – Far", which estimates the brain response to close relative to far interpersonal distances for each individual subject.

These "Close – Far" contrast images were entered into a second-level random effects analysis (1-sample t-test) to assess the significance of amygdala activation across the group using an ROI analysis. The amygdala was defined bilaterally using the Anatomical Automatic Labeling (AAL) template[4], and implemented via the WFU Pickatlas[5] (Version 2.4). Our statistical threshold was set at a cluster-level threshold of $p<0.05$, computed

using an iterative Monte Carlo simulation program (AlphaSim; from Analysis of Functional NeuroImages[6], version AFNI_2007_05_29_1644).

Significant effects were found in both the left and right amygdala (**Fig. 2a**). There was greater amygdala activity in the "Close" condition relative to the "Far" condition. The contrast estimates were then extracted from all significant voxels in both the left and right amygdala (**Fig. 2b**) to show how each individual subject contributed to the overall effect.

References:

(1) Crawford, J.R. & Howell, D.C. *Clin. Neuropsychol.* **12,** 482-486 (1998).

(2) Hutton, C., Deichmann, R., Turner, R., & Andersson, J.L.R. *Proceedings of ISMRM* **12**, Kyoto, Japan (2004).

(3) Friston, K.J., Ashburner, J., Frith, C.D., Poline, J.B., Heather, J.D., Frackowiak, R.S. *Hum Brain Mapp*. **2**, 165-189 (1995).

(4) Tzourio-Mazoyer, N., et al. *Neuroimage* **15**, 273-289 (2002).

(5) Maldjian, J.A., Laurienti, P.J., Kraft, R.A., & Burdette, J.H., *NeuroImage* **19**, 1233-1239 (2003).

(6) Cox, R.W. *Comput. Biomed. Res.* **29**, 162-173 (1996).