Supplementary Materials

The Neural Correlates of Social Connection

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<u>*Supplementary Methods and Analyses*</u>

In the main text, we report behavioral and neural responses related to the active on-line generation of social connection, compared to a neutral control task. Here, we report supplementary analyses and results related to a different question: how does cultivating feelings of social connection change responses toward previously unknown individuals? We identify these changes in two ways: examining changes in explicit social evaluations from pre- to post-social connection tasks, and identifying changes in neural response during the trait judgment task.

Measuring changes in explicit evaluation of different individuals. In order to assess pre- to post-imagery task behavioral changes in response to different individuals, the explicit evaluation task (see the main text for details) was repeated once before and once after all scanning tasks. We examined change in the principal component scores derived from ratings of connection, positivity, similarity, and physical attractiveness before and after scanning.

Measuring changes in neural response to different individuals. In order to assess pre- to post-imagery task neural changes in response to different individuals, we repeated the trait-judgment scanning task (see the main text for details), once just before and once just after completion of the social connection and neutral control imagery exercises. We then conducted an expanded version of GLM 3 (described in the Methods section of the main text) in order to assess changes

in response to the social-connection target, neutral control target, and non-target individuals. The GLM consisted of the following regressors: R1) self trials pre-task, R2) social connection target trials pre-task, R3) neutral imagery target trials pre-task, R4) non-target trials pre-task, R5) self trials post-task, R6) social connection target trials post-task, R7) imagery target trials post-task, and R8) non-target trials post-task. Regressors were modeled as stick functions indicating the onsets of all words judged with respect to the relevant person and convolved with the canonical form of the HRF. All other details are as in GLM 3 reported in the main text. Changes in response that were specific to the social-connection target were calculated as ([R6 – R7] – [R2 – R3].

Supplementary Results

Influence of generating social connection on subsequent evaluations of others. We first sought to assess whether the cultivation of social-connection might induce changes in explicit evaluations of other individuals, either by changing non-specific responses to others, or by specifically altering responses to the target of social connection. To do so, we examined changes in the individual evaluations of positivity/connection from pre- to post-scan using a 4 (individual: self, social connection target, imagery target, non-target) x 2 (time: pre vs. post) repeated-measures ANOVA. This analysis showed significant main effects of individual ($P = .001$) and time ($P = .02$) that were qualified by a marginally significant individual x time interaction ($P = .06$).

Although this analysis thus failed to reveal effects of the social connection exercises at conventional levels of significance, we nevertheless report here the results of post-hoc comparisons deconstructing this interaction for the sake of completeness, and to test for the predicted effects of social connection exercises on feelings toward their target.

An analysis of changes in explicit positivity indicated that it increased significantly for the social connection target compared to baseline (M_{Pre} = -1.06, s.e. = 0.54, M_{Post} = .24, s.e. = 0.53, paired-t_{18} = 2.85, P = .01) and marginally for the neutral control target (M_{Pre} = -1.7, s.e. = 0.50, M_{Post} = -.9, se. = 0.53, paired-t_{18} = 1.88, P = .08). Changes were not significant for the non-target (M_{Pre} = -1.87, s.e. = 0.45, M_{Post} = -1.78, s.e. = 0.62, paired-t_{18} = .2, P = n.s.), or self (M_{Pre} = 3.52, s.e. = 0.38, M_{Post} = 3.56, s.e. = 0.41, paired-t_{18} = .26, P = n.s.). Direct comparison of the change scores for specific individuals (i.e. post- vs. pre-scan positivity for one individual vs. another) indicated that positivity increased significantly more for the social-connection target compared to the non-target (paired-t_{18} = 2.16, P = .04) but was not significantly greater than the change in positivity to the neutral control target (paired-t_{18} = .85, P = n.s.).

Retrospective differences in feelings of social connection experienced during the social connection compared to neutral control task were positively correlated with subsequent changes in explicit positivity toward the social connection target, although this relationship fell short of significance (Pearson's r = .36, P =.13).

Changes in pre- to post-imagery task neural response to the individual target of social connection during trait judgments. We observed no significant changes in neural activation to the target of social connection compared to the target of the neutral control visualization exercise, either at a whole-brain level, or small-volume corrected within the functionally defined medial prefrontal region related to self-reflective processing.

Consequences of successful cultivation of social connectedness. Although we did not find a significant overall change in responses to the social-connection target after the imagery tasks, we

anticipated that responses to the social-connection target might depend on the degree of successful generation of feelings of social connectedness. We therefore correlated self-reported feelings of connectedness with post-task changes in BOLD response to the social-connection and neutral control targets. No regions were significant at a whole-brain corrected level. However, at a more liberal uncorrected per-voxel threshold of $P < .005$, this analysis identified a correlation in several regions. Participants who reported feeling greater connection during the meditation compared to imagery tasks showed greater pre- to post-meditation task changes in response to the social connection target compared to the neutral control target in regions including the anterior insula, superior temporal sulcus, precuneus, and inferior parietal cortex (Supplementary Table 1, Supplementary Figure 1A). For visual comparison, we used the large-scale, automated activation database Neurosynth (Yarkoni et al., 2011) to generate a synthetic image of neural activation related to the term "empathy," and compared it to the regions whose response to the social connection target during the non-affective trait judgment task covaried with self-reported success in cultivating social connection. As can be seen in Supplementary Figure 1B, this identified a similar set of regions.

Supplementary Table 1. Correlation between feelings of social-connectedness (social connection vs. neutral control task) and change in neural response (post-imagery trait judgment task vs. pre-imagery trait judgment task) to the social-connection vs. neutral control target.

	Region	Volume (voxels)	x	y	z	T
L	Parietal cortex	150	-57	-21	35	4.35
L	Anterior insula	109	-35	27	6	4.18
L	Superior temporal sulcus	66	-51	-57	10	3.48

Note. Regions are reported at an uncorrected level of p < .005, uncorrected.

Supplementary Figure 1. Effects of generating social connection on subsequent response to others. a) Regions where changes in activation in response to the target of social-connection (compared to the neutral control target) correlated with intensity of feeling social connectedness. b) Neurosynth-generated image of regions commonly associated with empathic responding across multiple studies.
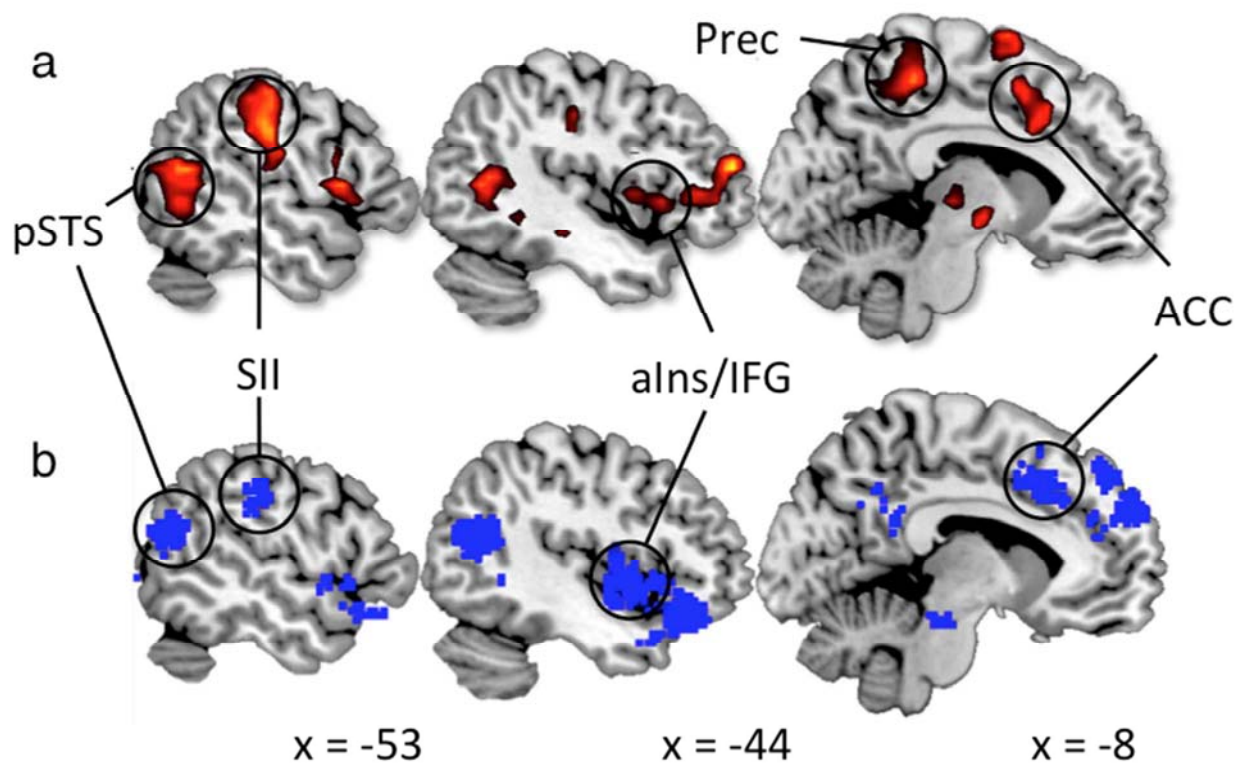
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