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Self-Transcendent Values and Neural Responses to Threatening Health Messages

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Abstract

Objective—Prioritizing self-transcendent values such as family and friends, over non-transcendent values such as wealth and privilege, is associated with lower stress response. In this study, we tested whether having self-transcendent values can reduce specific responses in the brain in the context of potentially threatening health communications.

Methods—Sedentary adults (n=67) who would likely feel threatened by health messages that highlight the risk of sedentary behavior were recruited. Participants indicated the degree to which they prioritize self-transcendent values over non-transcendent values. Using functional magnetic resonance imaging (fMRI), participants' neural response to health messages were assessed within neural regions implicated in threat responses, including bilateral amygdala and anterior insula (AI).

Results—A tendency to prioritize self-transcendent over non-transcendent values was associated with lower reactivity during exposure to health messages within anatomically defined regions of left amygdala ($t(55)=-.66$, $p=.010$, CI [−.08, −.01]), right amygdala ($t(55)= -2.22$, $p=.031$, CI [−.06, 0.0]), and left AI ($t(55)=-2.17$, $p=.034$, CI [−.04, 0.0]), as well as a mask functionally defined to be associated with 'threat' using an automated meta-analysis ($t(55)= -2.04$, $p=.046$, CI [−.05, 0.0]). No significant effect was obtained within the right AI ($t(55)= -1.38$, $p=.17$, CI [−.04, .01]). These effects were partially enhanced by reinforcing important values through self-affirmation, remained significant after accounting for self-reported social connection, and were specific to health message processing (vs. generic self-related information).

Conclusions—Attenuated neural reactivity to potentially threatening health messages may be a novel way that prioritizing self-transcendent values could lead to positive health behaviors.

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Keywords

health communication; self-transcendence; amygdala; anterior insula; threat; physical activity

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Self-transcendence, generally defined as the process of psychological expansion beyond self-boundaries (1, 2), is associated with mental and physical health benefits, including improved subjective wellbeing (3–6), and decreased depression (7, 8) and suicidality (9). Recent models of self-transcendence focus on interpersonal values ("supportive or harmonious connections with others (10)") as a main channel to self-transcendent experience. Prioritizing self-transcendent (e.g., interpersonal) values such as family and friends over non-transcendent values such as wealth or privilege is associated with positive health behaviors. For example, feelings of love and interpersonal connection increased receptivity to potentially threatening information about the harmful effect of smoking among smokers (11). In a follow-up study, reflecting on transcendent values (compassion, supporting others) versus non-transcendent values (wealth, power) prior to social exclusion led to increased self-control in the form of consuming fewer unhealthy cookies (10). We propose that holding transcendent values may be associated with differential responses to potentially threatening health information, and define threat response as affective reactivity to incoming information that could potentially undermine one's self-worth. Threat response can, in turn, trigger defensiveness (vs. receptivity), likely leading to rejection of the useful information.

In this study, threat response is operationalized by the degree to which individuals show heightened activity within brain areas previously associated with threat processing when presented with potentially threatening health messages. This response can be assessed at the neural level using functional magnetic resonance imaging (fMRI). We focus on regions from an automated meta-analysis of 170 studies on threat responses (12), that showed robust bilateral amygdala activity as well as smaller clusters in insula, anterior cingulate, periaqueductal grey and ventromedial prefrontal cortex. The amygdala encodes salient affective stimuli (13) and is critically involved in processing of unpleasant stimuli (14, 15), and threat detection and fear-related processing (for meta-analyses, see (16, 17)). The anterior insula (AI) projects to the amygdala, and also is implicated in threat/fear response (18). In addition, imminent threat can elicit activity within the periaqueductal grey (19), and ventromedial prefrontal cortex is implicated in psychological regulation of threat (19–21).

In addition to prioriotizing self transcedent values, reflecting on personally important values can also make people less defensive (more receptive) to otherwise threatening information (see (22) for a review). For example, writing about one's core values preceding exposure to potential threats buffered threat-related physiological responses such as threat-potentiated startle response (23) and epinephrine response, a hormone involved in the fight-or-flight response (24). As such, actively reflecting on values may increase the strength of the link between holding self-transcendent values and reduced threat response.

Another commonly studied pathway linking transcendent values and health is perceived social connection (25, 26). Holding transcendent values, however, may lead to beneficial outcomes beyond those conferred by social connection (e.g., increased receptivity to healthy

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behaviors). Thus, it is important to determine the unique role of transcendent values in processing health messages, accounting for social connection separately. It is also possible that individuals with high transcendent values may show generalized deactivation within the neural areas associated with threat processing regardless of the context. Therefore, it is important to determine whether holding self-transcendent values is associated with diminished threat response specifically to messages encouraging behavior change, or more broadly when processing any type of self-relevant information.

The Current Study

In the current study, we propose that self-transcendent values (vs. non-transcendent values) may be associated with attenuated brain responses in regions previously associated with threat in the context of health communication. We use functional magnetic resonance imaging (fMRI) to test whether having a greater tendency to hold and esteem transcendent values is associated with lower activity within brain regions implicated in threat processing during exposure to potentially threatening, yet beneficial, health information.

Sedentary adults were presented with health information highlighting the risk of sedentary behavior. The target population was chosen based on evidence that physical inactivity is a major risk factor for a number of adverse health outcomes (27, 28), and that physical activity is associated with health benefits independent of BMI (29, 30). As with other health behavior contexts (31), high-risk individuals (i.e., sedentary populations) may experience threats to self-worth and react defensively when confronted with health risk messages (32, 33). In turn, this may lead individuals at risk to dismiss important health information.

A self-affirmation manipulation (in which participants reflect on their core values prior to health message exposure) was used to further test whether reflecting on core values may further strengthen the link between holding trasncedent values and decreased threat-related neural processing. In addition, the unique role of transcendent values in processing health messages was tested, accounting for social connection separately. Finally, to determine whether individuals with high transcendent values show generalized deactivation within the neural areas previously associated with threat processing regardless of the context, neural responses to processing general self-relevant information were examined.

Methods

Participants

A community sample of sedentary adults (*n*=67; mean age=33.42 years, *SD*=13.04; 41 females; 44 White, 12 Black, 3 Asian, 1 Hispanic, 7 Other; Table 1) was recruited for a study on “daily activities” to avoid selection bias related to physical activity. Participants responded to online advertisement and flyers by completing an online pre-study screening survey. Eligibility criteria, based on self-reports collected via survey, included: 1) engagement in less than 195 minutes of walking, moderate, and vigorous physical activity throughout the prior seven days from the time of participation (using a short form International Physical Activity Questionnaire [IPAQ]), 2) standard fMRI scanning criteria (also confirmed by research staff; no metal in body, not claustrophobic, not pregnant/

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nursing, right-handed), 3) no history of stroke or other neurological disorders, 4) no active coronary artery disease, significant arrhythmia, or uncontrolled hypertension, 5) no current use of psychotropic medications, and 6) no history of post-traumatic stress disorder or admission to a psychiatric hospital within the past year. Participants also reported their height and weight from which the body mass index (BMI) was calculated, but BMI was not used as an inclusion criterion; rather it was included in statistical models as a covariate when indicated. Research assistants contacted eligible participants via phone to reconfirm their eligibility and schedule study visits.

Across two visits (time 1 [T1], time 2 [T2]), six participants did not complete the study, and the final sample in this report consisted of 67 participants at T1 and 61 at T2. In addition, 3 participants were excluded due to excessive movement (n=2) or technical difficulties in scanning (n=1), resulting in a final sample of 58 participants with both self-reports and neuroimaging data from relevant tasks.

This study was a part of a larger investigation on neural predictors of health outcome change (reported in Falk et al., 2015 (34); Cascio et al., 2016 (35); Kang et al., 2016 (36)). Of these investigations, only the Falk et al. paper focuses on the same neuroimaging data reported here. However, Falk et al. focus on the main effects of the affirmation manipulation and do not report on any individual differences related to the types of values that participants prioritized. None of the prior reports examined self-transcendent value effects on neural activity during the message exposure.

Procedure

Participants completed a pre-study screening to verify eligibility, a baseline appointment (T1), an intervention appointment (T2), and an end-point appointment. Only the T1 and T2 data are presented in the current report. Please see the Supplemental Digital Content 1 for a detailed study protocol. Data were collected between June 2012 and August 2013. All experimenters who worked with participants and participants themselves were blind to the study hypotheses throughout the study. During the pre-study screening, participants self-reported their level of physical activity throughout the prior week to identify individuals most likely to feel threatened in response to health risk messages. Participants also self-reported their weight and height from which BMI scores were derived. Eligible participants visited the laboratory for the baseline appointment (T1), and an fMRI appointment (T2) approximately 1 week later (M=9.35 days, SD=6.16). At T1, participants provided informed consents and completed transcendent value ranking, self-reported perceived social connection and health status, and provided demographic information. At the T2 fMRI appointment, participants completed the self-related processing task, self-affirmation task (random assignment to either the affirmation or control condition), and health messages task, followed by self-reporting current affect outside the scanner. Once finished, participants were debriefed, paid, and thanked for their participation. All self-reports and scanner tasks were embedded among other surveys and tasks. All survey data were collected with a desktop computer using an online survey tool (Qualtrics). All scanner tasks were presented on an fMRI-compatible screen at 800 * 600-pixel resolution using Presentation (NeuroBehavioral Systems). In-scanner responses were collected using a five-button

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response device attached to participant's right wrist. The protocol was approved by the University of Michigan institutional review board.

Measures and Tasks

Self-report measures

Transcendent value ranking: Participants provided a ranking of potential values at T1. Prioritizing self-transcendent values was operationalized by the order in which people ranked their connection with family and friends by importance among seven other non-transcendent/non-interpersonally focused values (money, politics, religion, spontaneity, creativity, humor, independence). Rankings for the family/friend category (range=1–8) were then reverse-coded so that the higher scores represent greater consideration for self-transcendent values to be important in life.

Social connection: Perceived social connection obtained at T1 was examined and controlled for in later analysis. The 8-item subscale from the Social Connectedness Scale (SCS; (37) measures the degree of interpersonal closeness/distance individuals feel between themselves and other people and society ("Even among my friends, there is no sense of brother/sisterhood."), rated on a 1 (*not at all true of me*) to 5 (*very true of me*) scale. All scores were coded so that the higher scores reflect greater degrees of perceived social connection. Internal consistency in the current study (α=.94) was high.

Current affect: To complement the neural results, self-reported positive and negative affect following the fMRI scan (that included the health message exposure) was assessed using the Positive and Negative Affect Scale (PANAS; (38) consisting of 15 individual positive emotion terms (interested, excited, strong, happy, relieved, enthusiastic, pleased, proud, alert, content, inspired, joyful, determined, attentive, active) and 15 negative emotion terms (frustrated, upset, distressed, guilty, miserable, scared, hostile, irritable, disappointed, ashamed, nervous, troubled, jittery, unhappy, afraid) rated on a 1 (*not at all*) to 5 (*extremely*) scale. From this, mean positive and negative affect composites were created. Internal consistency scores for positive (α=.93) and negative (α=.87) emotion items were high.

Health: Participants' baseline physical and psychological health were assessed at T1, including general quality of life and depression. The RAND 36-Item Health Survey measures eight health concepts, including physical functioning, bodily pain, role limitations due to physical health problems, role limitations due to personal or emotional problems, emotional wellbeing, social functioning, energy/fatigue, and general health perceptions. All questions were scored on a scale of 0 to 100, with 100 representing the highest level of functioning possible. Internal consistency scores across subscales in this study were adequate on average (α_{mean}=.85, α_{range}=.44–.88). In addition, depression was measured by the 21-item Beck Depression Inventory (39). Scores are summed to reflect current depressive symptoms, ranging from 0 to 63. Internal consistency score (α=.92) was high.

Demographics: At the end of T1, participants reported their age, sex, ethnicity, and years of education. For detailed analyses of demographic information in relations to the main study aims, please see Supplemental Digital Content 2.

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fMRI scanner tasks

Self-related processing task: We used a well-validated self-related processing task (40, 41), which was the first task performed during the T2 fMRI session, to engage general self-relevant and non-threatening information processing. Participants were presented with positive and negative trait adjectives taken from Anderson word trait list (42), and judged the self-relevance ("does the adjective describe you?"). Participants also judged other-relevance and valence of the words. Each condition repeated in six blocks, and each block contained six trials for a total of 36 trials per condition. The same 36 words (18 negative and 18 positive) were judged in each condition, and the order of word presentation was counterbalanced. Six trials within a block consisted of 3 trials with positive adjectives and 3 with negative adjectives. Each adjective was presented for 3s, and each block was preceded by a 3s orientation screen identifying the condition participants were in, and blocks were separated by 2.5s of fixation.

Self-affirmation task: A scanner-adapted self-affirmation task (35), designed based on standard affirmation paradigms ((22) for a review), was used to remind and reinforce values. During the T2 fMRI appointment, participants were randomly assigned to either reflect on their top (affirmation condition) or bottom (control condition) values ranked at T1, by completing the self-affirmation task. Those in the affirmation condition were provided with an opportunity to think about situations that allowed them to express and connect with their highest ranked value (e.g., if family and friends were the top-ranked value, "Think of a situation when you might have fun with family and friends"), as well as value-neutral and non-transcendent control situations (e.g., "Think of a situation when you might check the weather"). Participants in the control condition were presented with a series of situations pertaining to their lowest ranked value as well as the within subject control situations (identical to the control situations presented in the affirmation condition). The fMRI data from the self-affirmation task are not presented in the current report (35).

Health messages task: While in an fMRI scanner, participants received 50 self-relevant and potentially threatening health messages targeting sedentary, high-BMI adults (e.g., "A lack of activity can be linked to a shorter life," "Getting more activity can help you sleep better at night."). Messages were presented across two runs (25 health messages in each run) in a randomized order. Each message block consisted of an initial suggestion (5s), followed by a reason why participants should be less sedentary or more active, how participants might implement the suggestions, and messages highlighting increased risk for chronic disease due to sedentary lifestyle and elevated BMI (7s). The end of each block included a brief reflection period (6s) in which participants were encouraged to envision how they might apply the message in their own life. Blocks were separated by fixation rest periods (2.5s); every seventh block contained a longer (12s) block of rest. The task also included blocks with advice regarding other daily behaviors unrelated to physical activity that are not the focus of the current investigation (n=20; task timing same). Detailed task descriptions and materials are available on http://cn.asc.upenn.edu/wp-content/uploads/2013/07/Task-Description.docx.zip.

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Analysis

A series of models were computed to test the hypothesized relationships between transcendent values and reduced threat responses in the brain, with condition (affirmation, control) as a covariate when appropriate. The coefficient of determination (R^2, $R^2_{adjusted}$), beta coefficients (β), and 95% confidence intervals (CI) are reported for significant results. All reported p values are two-tailed. All analyses were performed in R (v3.0.1, www.r-project.org) using the R-studio interface (v0.98.1103) and the Statistical Package for Social Science software (IBM SPSS Statistics 21).

fMRI data—The imaging data were acquired on a 3-T GE Signa MRI scanner. Participants were self-guided through one run of self-related processing (188 volumes), one run of self-affirmation (323 volumes; not presented here), two runs of the health messages tasks (308 volumes each; 616 volumes total), and one additional task (325 volumes, not reported here). For the first six participants, slightly longer versions of the tasks were used, with two runs of 209 volumes each for self-affirmation, and three runs of 257 volumes each for health messages tasks.

A spoiled gradient echo (SPGR) sequence recorded high-resolution T1-weighted structural images (124 slices; slice thickness, 1.02 × 1.02 × 1.2 mm). In-plane T1-weighted overlay images were acquired (43 slices; slice thickness, 3mm; voxel size, 0.86 × 0.86 × 3.0mm) to allow two-stage coregistration. The functional images were recorded using a reverse spiral sequence (repetition time, 2,000ms; echo time, 30ms; flip angle, 90°; 43 axial slices; field of view, 220mm; slice thickness, 3mm; voxel size, 3.44 × 3.44 × 3.0mm).

The anatomical and functional data were acquired and preprocessed using a standard processing stream using Statistical Parametric Mapping (SPM8; Wellcome Department of Cognitive Neurology, Institute of Neurology, London, UK) for all stages apart from the initial despiking, which was carried out using the 3dDespike program as implemented in the AFNI toolbox. Differences in time of acquisition across the 43 slices were corrected using a sinc interpolation algorithm with the first slice as reference. Then motion artifacts were corrected through spatial alignment to the first slice of each volume. Next the mean image across all blood oxygen level-dependent (BOLD) functional images was coregistered with the in-plane T1 image, and then the high-resolution T1 SPGR image was coregistered to the in-plane T1 image. Following coregistration, the high-resolution T1 images were segmented into white and gray matter, allowing the skull to be removed. Structural and functional images were then normalized to the MNI template (“MNI152_T1_1mm_brain.nii”) provided by the FMRIB Software Library (FSL). In the final preprocessing step, the functional images were smoothed using a Gaussian kernel (8-mm FWHM). To allow for the stabilization of the BOLD signal, the first five volumes (10s) of each run were discarded before analysis. Movement parameters (a total of six rigid-body parameters, three for translation and three for rotation) derived from spatial realignment were included as nuisance regressors in all first-level models. Data were high pass filtered with a cutoff of 128s.

Fixed-effects models of the self-related processing task were constructed using a single boxcar function for each block. To parallel the health messages task modeling, the contrast

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of conditions in which participants considered the self-relevance of words versus rest was used. Fixation and condition preparation periods were considered baseline rest. Second-level random-effects models were constructed by averaging across participants and were subjected to further ROI analysis (described below).

The health messages task was modeled including regressors for each message type (why to be active, why to be less sedentary, how to be active, how to be less sedentary, risk messages, why to perform other daily activities, how to perform other daily activities) and the corresponding response periods. A contrast was computed for each participant by averaging across the 50 health messages highlighting risk, being more active, and being less sedentary, and comparing activity during those messages to rest. Second-level random-effects models were constructed by averaging across participants and were submitted to a further ROI analysis (described below).

The primary a priori hypotheses focused on the amygdala and the AI, regions that have been associated with threat-related processing in a number of prior investigations (16–18, 43–48). Bilateral amygdala were defined using the SPM toolbox Wake Forest University (WFU) PickAtlas (49) and converted to ROIs with MarsBar. Bilateral AI were defined as all voxels within each left and right insula masks provided by PickAtlas that were anterior to the y=0 plane. Parameter estimates of activity within the ROIs during non-threatening self processing (‘self > rest’ trials in the self-related processing task) and during potentially threatening health messages (‘health messages > rest’ in the health messages task) were extracted using MarsBaR (50), and converted to percent signal change.

To complement the structurally defined ROIs, a functionally defined ROI was created from the online database Neurosynth (www.neurosynth.org) (12). Neurosynth automatically synthesizes published fMRI data (413,429 activations reported in 11,406 studies as of October 2016). Using meta-analytic procedures, Neurosynth allows the users to search common activation patterns during psychological states with representational search terms. The primary analysis focused on the reverse inference map derived from the search term ‘threat’ (using Neurosynth’s default threshold $p<.01$, corrected). This map included robust activity in the bilateral amygdala, and additional voxels in the insula, anterior cinculate cortex, periaqueductal gray, and ventromedial prefrontal cortex associated with threat processing for reverse inferences.

In addition to the primary a priori hypothesized ROI analyses, whole brain searches were done for regions associated with self-transcendent value processing, outside of those hypothesized. For all whole brain results, 3dClustSim was used to calculate the cluster threshold for the areas outside of the ROIs (http://afni.nimh.nih.gov/pub/dist/doc/program_help/3dClustSim.html). The estimated smoothness from each analysis was used as generated in SPM (15.5, 15.5, 13.4 for the main analysis). Based on the results from 3dClustSim, k=126 was applied for the whole brain outside of the ROIs and k=21 for the anterior insula ($p<.005$). Given the small volume of the amygdala, uncorrected results at $p<.005$ are reported for amygdala. No regions outside of the ROIs survived cluster correction in this whole brain analysis.

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Associations between neural responses and self-transcendent values—The percent signal change results from each ROI described above were then used in regression analyses to examine the links between prioritizing self-transcendent values and neural response to potentially threatening health information. First, five regression analyses were conducted, each with the individual difference in transcendent value ranking as a predictor variable and neural activity in the left amygdala, right amygdala, left AI, right AI, and Neurosynth ‘threat’ map as dependent variables. Second, the value × condition interaction was tested to determine whether reinforcing core values using a self-affirmation manipulation strengthens the association between transcendent values and neural responses within the ROIs. Five regression analyses were conducted with centered value ranking, centered condition (affirmation, control), and the value × condition product term simultaneously as predictors of each of the five ROI scores. Third, to test whether this association is independent of perceived social connection, the same regressions were rerun with value ranking as a predictor and ROI scores as outcomes, including social connection as a covariate. Finally, to test the specificity of the effect, parallel regression analyses were conducted with value ranking as a predictor and ROI scores obtained while processing self-relevant but non-threatening generic information as outcome variables.

Results

The association between prioritizing self-transcendent values and neural responses to health messages

First, the links between self-transcendent value ranking and threat responses within the amygdala, AI, and meta-analytically defined (i.e., Neurosynth) ‘threat’ mask during exposure to health messages were tested. As predicted, high transcendent value ranking was associated with attenuated activity within the bilateral amygdala, bilateral AI and Neurosynth ‘threat’ mask in response to the health messages (Figure 1, Table 2). Linear regression analyses controlling for randomly assigned condition revealed that higher transcendent value rankings were associated with lower activity during health messages within the left amygdala, R^2=.13, $R^2_{adjusted}$=.10, β=−.34, t(55)=−2.66, p=.010, 95% CI [−.08, −.01], right amygdala, R^2=.10, $R^2_{adjusted}$=.07, β=−.29, t(55)=−2.22, p=.031, 95% CI [−.06, 0.0], left AI, R^2=.08, $R^2_{adjusted}$=.05, β=−.29, t(55)=−2.17, p=.034, 95% CI [−.04, 0.0], and the Neurosynth ‘threat’ mask, R^2=.11, $R^2_{adjusted}$=.07, β=−.27, t(55)=−2.04, p=.046, 95% CI [−.05, 0.0]. No significant effect was obtained within the right AI, R^2=.03, $R^2_{adjusted}$=0, β=−.19, t(55)= −1.38, p=.17, 95% CI [−.04, .01].

Whole brain effects of transcendent values on decreased brain activity during exposure to health messages reinforced the effects observed in the ROI analysis. No regions survived the whole brain cluster correction and results in Table 3 illustrate clusters within the ROIs only. The whole brain results for main effects of the health messages task are included in the Supplemental Digital Content 3-1. In addition, analyses examining baseline demographics and exercise related variables as potential covariates and moderators of the relationships reported above are reported in Supplemental Digital Content 2.

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The self-transcendent value and affirmation interaction

We tested whether making core values salient using the randomly assigned self-affirmation manipulation (reflect on highest ranked value vs. lowest ranked value) further strengthens the link between of transcendent value rankings and decreased neural threat responses. A marginally significant transcendent value × affirmation (affirmed, control) interaction was observed for the activity within the right amygdala, R^2=.16, $R^2_{adjusted}$=.11, β=−1.16, t(54)=−1.93, p=.059, 95% CI [−.06, 0.0], and Neurosynth 'threat' mask, R^2=.17, $R^2_{adjusted}$=.13, β=−1.23, t(54)=−2.07, p=.043, 95% CI [−.06, 0.0].

Specifically, those with greater transcendent values showed more attenuated activity within the right amygdala in response to health messages only when they were reminded of their important values, R^2=.19, β=−.44, t(28)=−2.57, p=.016, 95% CI [−.09, −.01], but not when the values were not affirmed, R^2=0, β=.06, t(27)=.28, p=.78, 95% CI [−.04, .05]. Similarly, a greater tendency to prioritize transcendent values was associated with lower activity within the Neurosynth's reverse-inferenced map of 'threat' only when core values were affirmed, R^2=.21, β=−.45, t(28)=−2.67, p=.013, 95% CI [−.08, −.01], but not when the values were not affirmed, R^2=.01, β=.10, t(27)=.50, p=.62, 95% CI [−.03, .05]. No significant value × affirmation interactions were observed for the left amygdala or bilateral AI (ps>.20).

The unique role of self-transcendent values, accounting for social connection

Next, the unique role of self-transcendent values independent of social connection was examined. Social connection was not correlated with transcendent value rankings (r=.07, p=.63), and was not associated with responses within the neural ROIs (rs=.−.05, −.01, .07, .14, .01, ps=.69, .99, .63, .31, 93, for left amygdala, right amygdala, left AI, right AI, and the Neurosynth 'threat' mask). After controlling for the perceived social connection as a covariate, the association between transcendent value rankings and neural responses within the ROIs remained parallel to those obtained when not controlling for perceived social connection (Table 2). Social connection was negatively associated with self-reported negative affect, r=−.44, p=.001, but not correlated with self-reported positive affect, r=.19, p=.16.

Specificity of the effect

Additional analyses were performed to test whether the effects of interest were selective for activity in the specified ROIs during exposure to health messages, or whether they reflect general deactivation in these regions across all self-related processing among individuals with high transcendent values. For instance, those with high transcendent values may show generalized deactivation within the specified ROIs when processing self-related information. To test this alternative possibility, activity within the target ROIs was examined during self-relevant information processing in a separate self-related processing task (whole brain results are included in the Supplemental Digital Content 3-1). Linear regression analyses using the same ROIs reported above revealed no significant links between transcendent value rankings and activity within the left amygdala (p=.98), right amygdala (p=.67), left AI (p=.99), right AI (p=.78), or the 'threat' map from Neurosynth (p=.96) while processing general self-relevant information. In addition, activation across the Neurosynth's reverse 'threat' map, 'health messages > rest', and 'self > rest' contrasts are compared in Supplemental Digital Content 3-2.

Self-reported affect

We tested the association between each of the variables described above and self-reported positive and negative affect after message exposure. Activity within the neural ROIs was not significantly associated with average positive (*p*s>.20) or negative (*p*s>.10) affect composite scores. When individual emotion items were examined, however, greater activity within key regions of interest during health messages was associated with later feeling more frustrated (left amygdala: r=.32, p=.022), troubled (left amygdala, left AI, right AI, Neurosynth mask: r=.28, .36, .32, .30, p=.051, .010, .024, .034, respectively), less interested (left amygdala, right amygdala, Neurosynth mask: r=−.30, −.31, =.28, p=.035, .030, .052, respectively), and less enthusiastic (right amygdala, right insula: r=−.27, −.27, p=.060, .063, respectively). Transcendent value rankings were not significantly associated with the self-reported positive or negative affect composite scores (*p*s>.40), though as noted above, perceived social connection was associated with reduced negative affect (r=−.44, p=.001).

In addition, baseline depression was not significantly associated with value rankings (p=.99), or with the activity within any of the neural ROIs, including left amygdala (p=.76), right amygdala (p=.55), left AI (p=.48), right AI (p=.64), or the Neurosynth 'threat' mask (p=.87).

Discussion

In the current study, we tested whether prioritizing self-transcendent values over other non-transcendent values is associated with decreased neural responses to potentially threatening health information. Having high transcendent values was associated with attenuated neural responses within the bilateral amygdala and left AI during exposure to health messages. Supporting the interpretation of this neural activity in terms of threat response, having high transcendent values was also associated with attenuated neural responses within regions derived from an automated meta-analytic reverse inference map of the term 'threat', based on 170 studies from the Neurosynth database. This effect was reinforced within the right amygdala (marginal) and the Neurosynth 'threat' map by explicitly cueing reflection on the core values through an affirmation task. The transcendent value effect remained significant after accounting for social connection, and was specific to processing health information.

Linking self-transcendent values and threat processing

Previous reports linked self-transcendent values and positive health behaviors (10, 11). The current data are consistent with the idea that having transcendent values is associated with less defensiveness in response to health messages that challenge one's behavior, but nonetheless contain beneficial information. The transcendent value effect was significant within a region of interest based on an automated meta-analytic reverse inference map of 'threat'. A central assumption of our study is that sedentary adults should be particularly defensive in response to health messages, however, our sample does not allow us to directly test this assumption. Although additional data are needed to establish tighter links to threat processes in particular, and to establish a causal direction, this finding may inform future

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efforts to localize specific neural regions associated with defensive responding to self-relevant persuasive messages.

Prior studies have focused primarily on how socially mediated emotion regulation attenuates threat responses in the presence of another person, or when calling to mind specific social resources. For example, holding a spouse's hand (vs. a stranger's hand or no hand) predicted decreased threat processing in the face of electric shock (51), and this effect was strengthened by high motivation to connect with a romantic partner (52). Likewise, providing social support to a loved one in close proximity has also been associated with attenuated neural responses to threat (53). Beyond physical proximity to loved ones, pictures of a romantic partner also attenuated threat reactivity (54). Together, the extant literature has demonstrated ways in which social connection is associated with reduced neural reactivity to threats.

The current results suggest an additional pathway through which holding more generalized other-directed values that transcend self-boundaries can provide benefits by diminishing neural threat responses to otherwise beneficial information. More broadly, it is possible that prioritizing self-transcendent values can preempt self-focused defensiveness through the process of psychological expansion beyond self-boundaries (1, 2). Prior research supports the notion that pursuing values beyond one's self-interest may allow people to transcend concerns about self-inadequacy, which then can reduce defensiveness (11). The distinction between having social connection and prioritizing transcending values highlights one possible explanation for their distinct effects, where the latter may chronically reduce self-focus and hence the need to defend the self. Future studies that employ experimental designs to control focus on transcendent values can help better interpret the mechanisms and directionality of the current effects.

Moderation effects by demographics

Female participants and individuals with lower BMI in our sample were more likely to rank transcendent values higher over other values. Participants' sex, but not BMI, moderated the link between transcendent value ranking and neural responses to health messages. Please see the Supplemental Digital Content 2 for further discussions about the moderation effects by demographics.

Enhancing self-transcendent value effects through affirmation, beyond social connection

Reminding participants of their highest values partially strengthened the link between transcendent values and brain responses in the right amygdala and the Neurosynth 'threat' map. This suggests that the associations between transcendent values and some brain responses may be altered by motivational states. Converging with research on physical or imagined presence of close others buffering deleterious effects of threat (e.g., a partner holding hands (51); partner in the room (53); pictures of a partner (54)), reminding participants of their high values marginally enhanced the buffering effects in the right amygdala and in the Neurosynth 'threat' mask. Conscious reflection on core values, however, may be more important for some sub-pathways; holding high transcendent values diminished responses in all ROIs regardless of whether the values were actively affirmed

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with an external task or not. This suggests at least some degree of automaticity in the link between prioritizing self-transcendent values and neural responses within key brain systems, which may ultimately suggest one source of power in such values. Indeed, we observed that consequences of prioritizing family and friends are distinct from perceiving high levels of social connection; hence, self-transcendent values may function with or without the online awareness or presence of close others.

Self-transcendent values and perceived social connection also diverged in their relationships to key outcome variables. Higher social connection was associated with lower self-reported negative affect generally, but social connection was not robustly associated with the specific processing of health messages in the target brain regions. By contrast, transcendent value ranking was a stronger predictor of attenuated responses in key brain regions, but not robustly associated with self-reported negative affect. These findings are also consistent with the idea that high levels of perceived social connection can influence conscious perception and management of emotion, whereas transcendent values may operate outside of conscious awareness or regulation. It is also possible that transcendent values may buffer more specific threats, such as self-relevant health information. For example, actively pursuing self-transcendent values may bring additional benefits to having social connection by providing motivation and direction to persevere through potentially threatening challenges.

The current study did not collect state affect at baseline, leaving ambiguity in the link between transcendent values and changes in affect following health message exposure. However, transcendent values were not associated with the baseline depression scores, suggesting that the self-reported negative affect following health messages is likely state negative affect (vs. generalized negative affectivity). Future studies may collect state affect at multiple time points to examine temporal relationships among these variables.

Finally, our operationalization of self-transcendence focused on interpersonal values; inherent in this operationalization is prioritizing social and interpersonal values over material rewards, which may be a key component of the type of self-transcendence under study. This may also include altruistic over selfish motivations, or other key ingredients that cannot be distinguished from the current intervention. As such, we encourage future studies to examine distinct types of transcendence that may or may not involve interpersonal values, in order to test potentially divergent neural pathways and associated outcomes.

Specificity of the effect

The self-transcendent value effect was specific to processing self-relevant, potentially threatening health (vs. general self-related) information. Having high transcendent values may therefore be distinct from other traits also linked to healthy emotion processing, such as mindfulness associated with generalized deactivation within the amygdala (55). This specificity suggests that transcendent value effects may be particularly beneficial in potentially threatening contexts, and interventions that encourage cultivating self-transcendent values may complement existing intervention strategies that target problems associated with processing psychological threat.

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Conclusion

The current research offers direct, novel evidence that prioritizing self-transcendent values is associated with lower amygdala and AI response, as well as lower response in a set of brain regions associated with 'threat' in a large-scale, automated meta-analysis, to potentially threatening information. These findings suggest that one way through which transcendent values benefit health may be by reducing neural indicators of threat in response to health messaging. These data add to a growing body of literature on the benefits of interpersonal, transcendent values. Self-transcendent values should also be considered as an active individual difference variable in future intervention strategies and theories of affective processing and health communication.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Acronyms

AI	anterior insula
BDI	Beck Depression Inventory
BMI	Body Mass Index
BOLD	blood oxygen level-dependent
CI	confidence interval
FSL	FMRIB Software Library
IPAQ	International Physical Activity Questionnaire
fMRI	functional magnetic resonance imaging
PANAS	Positive and Negative Affect Scale
RAND	The RAND 36-Item Health Survey
ROI(s)	region(s) of interest
SCS	Social Connectedness Scale

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SPM	Statistical Parametric Mapping
T1	time 1
T2	time 2

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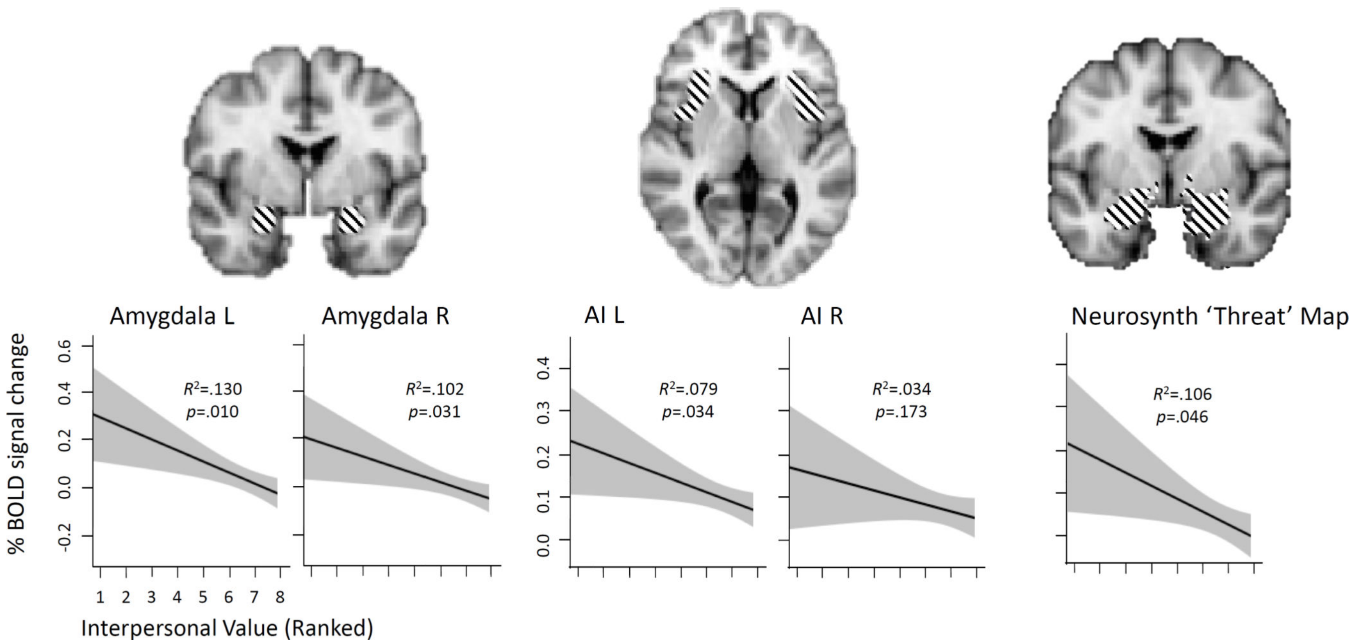

Figure 1.

People who highly rank self-transcendent values demonstrate lower threat responses during exposure to potentially threatening health information. Brain activity within the a priori regions of interest (ROIs), including bilateral amygdala, bilateral anterior insula, and the Neurosynth's reverse inference map of 'threat', during exposure to health messages are shown (n=57). 95% confidence intervals are displayed in shades. Note: Amygdala L=left amygdala; Amygdala R=right amygdala; AI L=left anterior insula; AI R=right anterior insula

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Table 1

Baseline demographic and health-related characteristics.

Demographicmean	Mean/ Sample Size	Range
Age (Yrs)	33.42 (13.04)	18–64
Female	41 (61.2%)	-
Caucasian	44 (65.7%)	-
Education (Yrs)	16.63 (3.44)	12–22
Baseline Characteristics		
BMI	27.99 (6.84)	18.20–54.86
Weekly exercise minutes (IPAQ)	123.53 (49.52)	0–195
Depression (BDI)	28.16 (8.17)	21–62
Health (RAND)		
physical functioning	91.94 (13.31)	30–100
bodily pain	85.45 (14.60)	32.50–100
role limitations (physical)	94.40 (14.96)	25–100
role limitations (emotional)	94.03 (16.34)	33.33–100
emotional wellbeing	74 (20.14)	16–100
social functioning	79.48 (15.95)	12.50–87.50
energy/fatigue	57.50 (17.01)	10–95
general health perceptions	70.45 (17.55)	20–100

Note: N=67, Mean values and sample sizes are displayed with standard deviations and percentages, respectively, in parentheses where applicable.

BDI=Beck Depression Inventory; BMI=Body Mass Index; IPAQ=International Physical Activity Questionnaire (short-form, self-reported during the pre-study screening); RAND=The RAND 36-Item Health Survey.

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Table 2

Separate linear regression results, with self-transcendent value ranking as a predictor variable for activity within each of the threat-responsive ROIs during exposure to health messages.

ROIs	R^2		β		*t*		*p*	
		w/SC		w/SC		w/SC		w/SC
L amygdala	.130	.131	−.340	−.338	−2.660	−2.617	.010	.012
R amygdala	.102	.102	−.288	−.289	−2.217	−2.202	.031	.032
L AI	.079	.086	−.285	−.291	−2.170	−2.194	.034	.033
R AI	.034	.055	−.186	−.195	−1.380	−1.450	.173	.153
Neurosynth 'threat' map	.106	.106	−.265	−.267	−2.043	−2.036	.046	.047

Note: N=57, AI=anterior insula; L=left; R=right; ROI=region of interest; w/SC=Values accounting for social connection.

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Table 3

Decreased activity during health message exposure associated with self-transcendent value ranking.

Region	*x*	*y*	*z*	*size*	*t*
L insula	−37	−16	19	31	4.38
R insula/stg	60	5	−2	94	4.01
R amygdala	29	1	−23	8	3.12
L amygdala	−23	−9	−23	4	2.79

Note: N=57, No regions survived the whole brain cluster correction and the results illustrate clusters within the ROIs only. Small volume corrected results for bilateral AI (p=.005, k=21, corresponding to p<.05, corrected) and uncorrected results for bilateral amygdala are reported at p<.005.

L=left; R=right; stg=superior temporal gyrus.