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Effects of self-transcendence on neural responses to persuasive messages and health behavior change

Yoona Kang[a,1], Nicole Cooper[a], Prateekshit Pandey[a], Christin Scholz[b], Matthew Brook O'Donnell[a], Matthew D. Lieberman[c], Shelley E. Taylor[c], Victor J. Strecher[d], Sonya Dal Cin[e], Sara Konrath[f], Thad A. Polk[g], Kenneth Resnicow[d], Lawrence An[h], and Emily B. Falk[a,1]

[a]Annenberg School for Communication, University of Pennsylvania, Philadelphia, PA 19104; [b]Amsterdam School of Communication Research, University of Amsterdam, 1018 WV, Amsterdam, The Netherlands; [c]Department of Psychology, University of California, Los Angeles, CA 90095; [d]School of Public Health, University of Michigan, Ann Arbor, MI 48109; [e]Department of Communication Studies, University of Michigan, Ann Arbor, MI 48109; [f]Lilly Family School of Philanthropy, Indiana University, Indianapolis, IN 46202; [g]Department of Psychology, University of Michigan, Ann Arbor, MI 48109; and [h]School of Medicine, University of Michigan, Ann Arbor, MI 48109

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Self-transcendence refers to a shift in mindset from focusing on self-interests to the well-being of others. We offer an integrative neural model of self-transcendence in the context of persuasive messaging by examining the mechanisms of self-transcendence in promoting receptivity to health messages and behavior change. Specifically, we posited that focusing on values and activities that transcend the self can allow people to see that their self-worth is not tied to a specific behavior in question, and in turn become more receptive to subsequent, otherwise threatening health information. To test whether inducing self-transcendent mindsets before message delivery would help overcome defensiveness and increase receptivity, we used two priming tasks, affirmation and compassion, to elicit a transcendent mindset among 220 sedentary adults. As preregistered, those who completed a self-transcendence task before health message exposure, compared with controls, showed greater increases in objectively logged levels of physical activity throughout the following month. In the brain, self-transcendence tasks upregulated activity in a region of the ventromedial prefrontal cortex, chosen for its role in positive valuation and reward processing. During subsequent health message exposure, self-transcendence priming was associated with increased activity in subregions of the ventromedial prefrontal cortex, implicated in self-related processing and positive valuation, which predicted later decreases in sedentary behavior. The present findings suggest that having a positive self-transcendent mindset can increase behavior change, in part by increasing neural receptivity to health messaging.

self-transcendence | self-affirmation | compassion | ventromedial prefrontal cortex | physical activity

Persuasive messages can motivate behavior change, but only if people are receptive (1). A critical barrier to receptivity is that people often feel defensive when reminded of their unhealthy behavior and reject the value of the messages, because acknowledging the problem can undermine one's positive self-image. Recent evidence suggests that having a self-transcendent mindset, characterized by care for others' well-being (2, 3), can help people move away from focusing on the threatened aspects of the self (4), thereby promoting health message receptivity (5). A self-transcendent state is often described to be intrinsically positive and rewarding (6), which can motivate receptive and exploratory mindsets to learn new information (7). Here, we tested two ways of manipulating self-transcendence, self-affirmation and compassion priming, to increase receptivity to persuasive messages and behavior change. We used fMRI to examine neural activity associated with self-transcendence, and linked these neural responses to later behavioral effects of health messaging. Identifying common neural mechanisms (8, 9) across two different types of self-transcendence manipulations can help triangulate the mechanisms of healthy message receptivity and the processes that lead to behavior change.

Our main behavioral outcome of the intervention was objectively logged physical activity, given its critical association with a wide range of health risks (10). Sedentary behavior and moderate to vigorous activity have related yet distinct effects on health, such that being sedentary is a risk factor for poor health independent of physical activity (11–13). Therefore, effects of self-transcendence on sedentary and moderate to vigorous minutes were examined separately.

Self-Affirmation

Self-affirmation theory posits that people are motivated to maintain a sense of self-worth, and that threats to self-worth will be met with resistance. One common threat to self-worth occurs when people encounter self-relevant health messages that require a change in their current behavior. An affirmation task prompts individuals to reflect on important personal values, and can be administered before delivering personally relevant and potentially threatening health messages (e.g., messages highlighting the risk of sedentary lifestyle presented to sedentary individuals) to increase receptivity to these messages (14). The efficacy of self-affirmation has been demonstrated in multiple health domains, including smoking (15), diabetes screening (16),

Significance

People often feel defensive when reminded of their unhealthy behavior. We propose that self-transcendence, encouraged by focusing on others' well-being, can lessen subsequent focus on threatened aspects of the self and increase receptivity. We show that activating self-transcendent mindsets, either by reflecting on self-transcendent values or making positive wishes for others, increased activity in brain regions chosen for their role in positive valuation and reward. Furthermore, during subsequent health message exposure, self-transcendence increased activity in brain regions tracking message receptivity, which predicted later decreases in sedentary behavior. The current findings support the idea that having a positive, other-focused mindset can be a rewarding experience, and may allow people to see the personal value of potentially threatening yet beneficial health messages.

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The authors declare no conflict of interest.

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Data deposition: The data relevant to the central analyses have been deposited on GitHub and are available at https://github.com/cnlab/PhysicalActivity2/tree/master/data. The stimuli and detailed instructions for the main fMRI scanner tasks have been deposited on GitHub and are available at https://github.com/cnlab/PhysicalActivity2/tree/master/tasks.

[1]To whom correspondence may be addressed. Email: yoona.kang@asc.upenn.edu or emily.falk@asc.upenn.edu.

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and drinking behavior (17). In the domain of physical activity, affirmed individuals showed steeper declines in sedentary behavior compared with those unaffirmed throughout the month following a health intervention (5). In the present study, we extend previous research by examining the neural mechanisms of affirming self-transcendent values and linking this to subsequent neural receptivity to physical activity messages.

In previous work, reflecting on core values during an affirmation task recruited regions involved in processing reward and positive value (18), including the ventromedial prefrontal cortex (VMPFC) and ventral striatum (VS) (19), likely corresponding to the positive experience of processing information of personal value. Importantly, reflecting on self-transcendent values beyond self-enhancing interests tends to produce the most powerful affirmation effects on behavior change (20, 21). This suggests that self-transcendence may be one effective means of decreasing subsequent self-focused defensiveness that prevents receptivity to messaging.

In past research, receptivity to persuasive messages has been indexed within regions of the VMPFC that also track the self-relevance and value of stimuli (5, 22, 23). As such, we hypothesized that following the affirmation priming task, we would observe increased activity in functionally defined regions of interest (ROIs), chosen for their role in self-relevance processing, including the VMPFC and posterior cingulate cortex (PCC) (24) during the subsequent message exposure. Furthermore, given evidence for the central role of positive valuation in social influence (25), we also examined parallel relationships between overlapping regions of the VMPFC implicated in valuation and behavior change.

Compassion Practice

Compassion practice involves making directed positive wishes for others by shifting attention from self-interests to the well-being of others. Compassion practice is associated with sympathetic responses to human suffering (26), positive interpersonal and intergroup attitudes (27), and prosocial behavior (28), but it has not been tested in the context of persuasive messaging and behavior change. We tested whether a compassion exercise, without having to bring specific personal values to mind as in affirmation, may also increase receptivity to health messages. Specifically, focusing on the well-being of others may diminish focus on the threatened aspects of the self (4) and, hence, the needs to protect the self-views that often prevent receptivity to health information.

Neuroimaging studies of compassion practice have primarily focused on feelings of connection or empathic pain, and have yielded activity in regions associated with self- and social-related processing (MPFC) (29) and other regions associated with body awareness and empathy (30). We further suggest that making well-wishes for others can be an affectively positive and rewarding experience, and may engage brain regions implicated in positive value/reward [i.e., the VMPFC and VS (6)], similar to self-affirmation. As with affirmation, we also expected that compassion priming would allow people to see self-relevance and hence personal value in otherwise threatening health messages. As such, we hypothesized that as with affirmation, following the compassion task we would observe increased activity in the VMPFC (24) during message exposure.

The Present Study

The present study offers an integrative neural model of self-transcendence and message receptivity. We used two ways of manipulating self-transcendence to triangulate the basic underlying neural mechanisms of health message receptivity. The effect of reflecting on self-transcendent values of the highest importance (affirmation) and making positive wishes (compassion) on health message receptivity was compared with that of a control task that involved reflecting on self-enhancing values of the lowest importance to the participant. We preregistered and tested whether there would be increased neural activity in brain regions chosen for their role in positive value/reward (which we denote as $VMPFC_{value}$ and VS_{value}; defined by ref. 19) during affirmation and compassion practice compared with a control task. During subsequent message exposure, we tested whether both affirmation and compassion priming would increase activity in brain regions chosen for their role in self-related processing (which we denote as the $VMPFC_{self}$ and PCC_{self}, defined by a functional localizer as detailed in *Methods*) and message-consistent behavior change (which we denote as the $VMPFC_{behavior\ change}$, defined by ref. 5), which would subsequently predict increases in physical activity among sedentary adults (Fig. 1). We also examined brain activations implicated in positive valuation during message exposure ($VMPFC_{value}$, VS_{value}), given mounting evidence that self-related and value processes are difficult to dissociate in the VMPFC (31) and evidence that value to self may be key to successful persuasion (25).

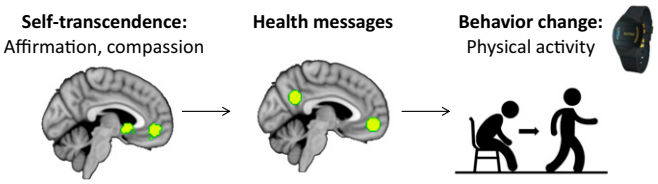

Fig. 1. A conceptual model that specifies the effect of self-transcendence on behavior change.

Results

Neural Activity During Self-Transcendence Priming. To test whether self-transcendent priming elicited activity in brain regions chosen for their role in positive value and reward, we examined brain activity during the priming task for people who were randomly assigned to self-transcendent conditions (affirmation or compassion) each compared with the control condition. Within-subjects contrasts during priming tasks for all participants involved subtracting value-neutral everyday activity control trials from respective trials of interest for each condition (i.e., affirmation: highest value > everyday activity; compassion: well-wishes > everyday activity; control: lowest value > everyday activity) to control for low-level stimulus properties and processes such as reading and thinking about the future. Separate regression models compared neural activity within metaanalytically defined regions of interest implicated in positive value (19) ($VMPFC_{value}$, VS_{value}) across conditions. Activity in the $VMPFC_{value}$ was greater during the affirmation compared to the control task [$\beta = 0.30$, $t(137) = 3.66$, $P < 0.001$]. The compassion task also recruited greater $VMPFC_{value}$ activity compared to the control task [$\beta = 0.29$, $t(96) = 2.92$, $P = 0.004$]. $VMPFC_{value}$ activity did not differ during the affirmation vs. compassion tasks [$\beta = -0.008$, $t(99) = -0.08$, $P = 0.94$]. VS_{value} activity did not differ during the affirmation vs. control [$\beta = 0.06$, $t(137) = 0.75$, $P = 0.46$], compassion vs. control [$\beta = 0.12$, $t(96) = 1.14$, $P = 0.26$], or affirmation vs. compassion tasks [$\beta = -0.04$, $t(99) = -0.37$, $P = 0.71$].

Complementary whole-brain analyses identified positive clusters from six separate contrasts, including within-subjects affirmation, compassion, and control contrasts, and between-subjects affirmation > control, compassion > control, and compassion vs. affirmation contrasts. All three within-subjects contrasts for the affirmation, compassion, and control priming tasks (i.e., reflecting on one's highest values, wishing well for others, and reflecting on one's lowest values, respectively, compared with imagining everyday activities) produced neural activation in the VMPFC ($P < 0.005$, $k = 243$, corresponding to $P < 0.05$, corrected) (Fig. 2 *A*–*C*). Next, we compared activity associated with each of the within-subjects effects reported above between-participants in the affirmation, compassion, and control conditions. Although all three priming tasks engaged within-subjects activity in the VMPFC, this was even greater for the affirmation (Fig. 2*D*) and compassion (Fig. 2*E*) conditions compared with the control condition, consistent with our ROI analysis. VS activity was also greater for affirmation (Fig. 2*D*) and compassion (Fig. 2*E*) conditions compared with the control condition ($P < 0.005$, $k = 243$, corresponding to $P < 0.05$, corrected). When the affirmation and compassion

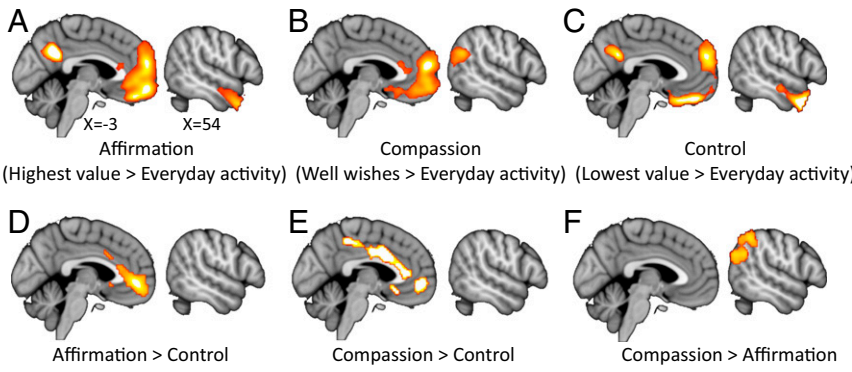

Fig. 2. Within-subjects contrasts of: (*A*) affirmation (highest value > everyday activity trials), (*B*) compassion (well-wishes > everyday activity trials), and (*C*) control (lowest value > everyday activity). Between-subjects contrast of: (*D*) affirmation > control conditions, (*E*) compassion > control conditions, and (*F*) compassion > affirmation conditions ($P < 0.005$, $k = 243$, corresponding to $P < 0.05$, corrected).

participants were directly contrasted, participants in the compassion condition, compared with their affirmation counterparts, recruited greater activity in the right temporal parietal junction (RTPJ) ($P < 0.005$, $k = 243$, corresponding to $P < 0.05$, corrected) during their assigned tasks (Fig. 2*F*). Whole-brain analysis results pooling the self-transcendence tasks (affirmation + compassion > control) also identified activity in the VMPFC, VS, and bilateral TPJ ($P < 0.001$, uncorrected) (*SI Appendix*, Fig. S2 and Table S2).

Effects of Self-Transcendence Priming on Neural Activity During Health Messages and Subsequent Mood. Next, we examined the effect of affirmation and compassion priming on neural activity during the health messages task within ROIs implicated in self-related processing ($VMPFC_{self}$, PCC_{self}) based on our localizer, as well as an ROI in a subregion of the VMPFC ($VMPFC_{behavior\ change}$) defined in previous work linking activity in this region to health behavior change across several studies (5, 22, 23, 31). During the health messages intervention, those who completed the affirmation task before health messages, compared with controls, showed greater activity within the $VMPFC_{self}$ [$\beta = 0.23$, $t(137) = 3.06$, $P = 0.003$], marginally increased activity within the PCC_{self} [$\beta = 0.15$, $t(137) = 1.83$, $P = 0.07$], and significantly greater activity in the $VMPFC_{behavior\ change}$ [$\beta = 0.28$, $t(137) = 3.32$, $P = 0.001$].

Participants in the compassion condition compared with controls also showed greater increases in activity within the $VMPFC_{self}$ [$\beta = 0.23$, $t(96) = 2.22$, $P = 0.03$] and $VMPFC_{behavior\ change}$ [$\beta = 0.23$, $t(96) = 2.23$, $P = 0.03$], but did not differ in PCC_{self} activity [$\beta = 0.12$, $t(96) = 1.13$, $P = 0.26$]. Neural responses during health messages did not differ across those in the affirmation and compassion conditions within the $VMPFC_{self}$ [$\beta = 0.08$, $t(99) = 0.81$, $P = 0.42$], PCC_{self} [$\beta = 0.08$, $t(99) = 0.82$, $P = 0.41$], or $VMPFC_{behavior\ change}$ [$\beta = 0.10$, $t(99) = 1.02$, $P = 0.31$].

We also found significant condition effects on self-reported mood following the messages task, such that self-transcendent conditions (affirmation, compassion) predicted less-negative self-directed mood (i.e., shame) after message exposure (*SI Appendix*). These results were consistent with our hypothesis that both forms of self-transcendence priming may help overcome negative self-focus that prevents message receptivity and increase neural activity-associated behavior change during message exposure, especially within the VMPFC.

The Effect of Self-Transcendence on Changes in Physical Activity. Regression analyses tested effects of the affirmation and compassion priming tasks, compared to the control task, on changes in physical activity from baseline to postintervention controlling for baseline activity and demographic variables. Those who were affirmed showed greater increases than those in the control condition in average moderate/vigorous activity [$\beta = 0.17$, $t(142) = 2.11$, $P = 0.04$]. Affirmation did not impact average changes in sedentary behavior [$\beta = -0.07$, $t(142) = -0.90$, $P = 0.37$]. Those who completed the compassion task, compared with those who completed the control task, showed increases in moderate/vigorous activity [$\beta = 0.19$, $t(106) = 2.10$, $P = 0.04$] and decreases in sedentary behavior [$\beta = -0.22$, $t(106) = -2.33$, $P = 0.02$]. No difference was detected between the affirmation and compassion conditions in terms of changes in moderate/vigorous activity [$\beta = 0.02$, $t(99) = 0.19$, $P = 0.85$] or sedentary behavior [$\beta = 0.15$, $t(99) = 1.70$, $P = 0.09$], although the latter was marginally significant. Thus, we find that both forms of self-transcendence priming have positive effects on later health behavior change.

Neural Responses to Health Messages Predicted Later Changes in Physical Activity. Next, we tested whether activity in the ROIs that differed between affirmation or compassion compared with control conditions during the health messages task predicted later declines in sedentary behavior (Fig. 3) and increases in moderate to vigorous activity (*SI Appendix*, Fig. S3), controlling for baseline activity and demographic variables. Across all conditions, activity in the $VMPFC_{self}$ during the health messages task was associated with marginal increases in moderate/vigorous activity [$\beta = 0.14$, $t(152) = 1.78$, $P = 0.08$] and significant decreases in sedentary behavior [$\beta = -0.17$, $t(152) = -2.12$, $P = 0.04$] (Fig. 3*A*). PCC_{self} activity was associated with a marginal increase in moderate/vigorous activity [$\beta = 0.16$, $t(152) = 1.92$, $P = 0.06$], but not with sedentary activity [$\beta = -0.06$, $t(152) = -0.73$, $P = 0.47$] (Fig. 3*B*). Activity in the $VMPFC_{behavior\ change}$ during the health messages task predicted subsequent increases in moderate/vigorous activity [$\beta = 0.16$, $t(152) = 2.04$, $P = 0.04$], as well as greater decreases in sedentary behavior [$\beta = -0.19$, $t(152) = -2.43$, $P = 0.02$] (Fig. 3*C*). This triangulates the effects of different forms of self-transcendence manipulations, and replicates prior work demonstrating that VMPFC activation during persuasive messages can predict later behavior change.

We did not observe any interactions between condition and activity within our ROIs in predicting behavior change (Ps > 0.20) (*SI Appendix*, Fig. S7), and observed largely parallel results to the models above when controlling for participants' self-reports of attitudes, intentions, self-efficacy, and mood (*SI Appendix*). Additionally, we ran models with ROIs in brain regions chosen for their role in counterarguing and positive valuation, and found positive associations between brain activity associated with valuation and behavior change (*SI Appendix*). We also explored the overlap between ROIs chosen for their roles in self-related processing and value during the health messages task (*SI Appendix*), given mounting evidence for the importance of message value to self in promoting behavior change (25). Furthermore, path analyses revealed that neural activity during the priming task influenced activity during the messages task (*SI Appendix*, Fig. S5). Finally, whole-brain analyses of the health messages task identified areas associated with later behavior change, including the VMPFC (*SI Appendix*, Fig. S6).

Discussion

The current study presents an integrative model of self-transcendence by testing its effects on brain activity, neural receptivity to subsequent health messages, and objectively logged subsequent behavior change. We experimentally manipulated exposure to two

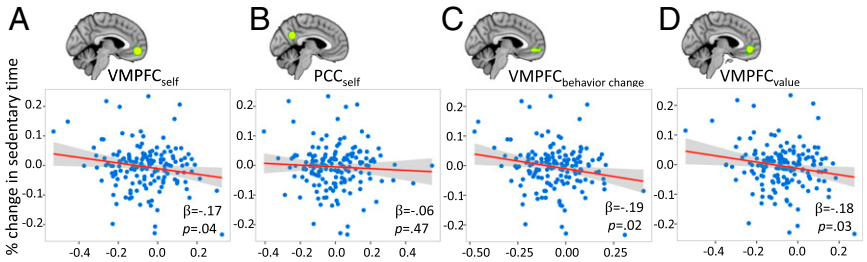

Fig. 3. Changes in sedentary behavior from baseline to endpoint visit predicted by activity during health message exposure in the primary ROIs, including (*A*) VMPFC$_{self}$, (*B*) PCC$_{self}$, (*C*) VMPFC$_{behavior\ change}$, and (*D*) VMPFC$_{value}$.

interventions designed to prime a self-transcendent mindset, including a self-transcendent value affirmation manipulation and a compassion intervention that is independent of personal values. Affirmation and compassion practice, compared with a control activity, led to message-consistent changes in physical activity among sedentary adults throughout the month following the health messages intervention. The affirmation and compassion tasks, compared with the control task, produced similarly robust patterns of activation within neural regions previously associated with positive valuation/reward, consistent with the idea that self-transcendence involves positive value/reward-related processes. During the subsequent health messages intervention, participants in both the affirmation and compassion conditions produced comparably greater activity in the VMPFC$_{self}$, relative to controls, identified by our localizer as engaging in self-related processes, and VMPFC$_{behavior\ change}$, which predicted message-consistent changes in physical activity a month later. Despite the reduced power due to a smaller sample size, the compassion manipulation produced similar effects to affirmation, indicating the robustness of the self-transcendence effect.

The present findings replicate and substantially extend previous findings on the effect of self-affirmation on increased receptivity and behavior change (14). Furthermore, the present data offer initial evidence that compassion practice, an intervention that focuses on self-transcendence, may also promote openness to potentially threatening yet beneficial health information. Indeed, compassion training has been associated with various health benefits (32), and the effect of self-transcendence processing on receptivity to health behavior change may underlie some of these effects.

The common engagement of activity within regions associated with reward/positive value across affirmation and compassion priming offers a window into one key component of success across two different ways of accessing self-transcendence. A growing body of research suggests that some reward-related regions are responsive to safety, and dampen threat-related neural activity in response to detecting safety signals (33, 34). Reward and safety signals can in turn motivate more exploration, learning, and memory formation (7). Thus, it is possible that self-transcendence primes openness to new information by activating such a positive reward stance, which allows for a nondefensive, open-hypothesis testing mindset. In this way, messages that might otherwise pose a threat to self-worth can be received and retained more effectively. However, manipulations of reward processing alone tend to not produce the same effects as self-affirmation (35) or compassion (36) tasks, suggesting that self-transcendence likely involves additional critical components, such as reduced focus on the threatened aspects of the self (4), increased other-focus (29), or decreased self/other distinctions (37). As such, the combination of other focus and reward may be particularly effective in reducing subsequent self-focused defensiveness and promoting message receptivity.

To this end, in an exploratory whole-brain analysis, we observed increased activity during the self-transcendence (affirmation and compassion) vs. control tasks in the bilateral TPJ, and this effect was further associated with behavior change (*SI Appendix*, Fig. S2). Given the TPJ's role in other-focused social cognition, especially during mentalizing (38), these results suggest that self-transcendence priming may increase other-focused processing (in addition to reward) during the priming, which subsequently allows people to experience otherwise threatening messages as more self-relevant and hence valuable. Notably, although activation in the bilateral TPJ was greater for both self-transcendence tasks compared with the control condition, TJP activity was even stronger for compassion, with a whole-brain search for regions differentiating affirmation and compassion tasks showing greater activity in the RTPJ for compassion compared with affirmation (Fig. 2*F*). Greater engagement of the RTPJ activity during compassion compared with affirmation is consistent with explanations for the putative psychological processes underlying compassion practice, which is explicitly other-focused, versus affirmation, which is not necessarily explicitly focused on the well-being of others.

During subsequent message exposure, self-transcendence priming also resulted in significantly greater activity in a subregion of the VMPFC associated with self-relevance, as defined by our functional localizer. Building on past results that have suggested links between the VMPFC and behavior change (5, 22, 23), the present investigation offers more confidence in this link by providing a substantially larger (and hence better powered), preregistered test of this link, using a targeted, independent functional localizer task. Of the two functionally localized self-relevance ROIs, the link between PCC$_{self}$ activity and behavior change was weaker than that of the VMPFC$_{self}$ following both affirmation and compassion priming. This finding of weaker links with the PCC is consistent with past research connecting brain activity in the VMPFC, and less robustly in the PCC, to health behavior change (23). One possibility is that the VMPFC may be responsible for evaluating self-relevance of specific contexts (e.g., a specific health behavior), whereas the PCC may be involved with more general and abstract evaluation of the self (39).

Another possibility is that the VMPFC in this context is more centrally involved in computing the value to oneself (or possibly self/value integration). In line with this view, across the two types of self-transcendence priming we observed consistency such that the affirmation and compassion priming both increased subsequent neural activity in a region associated with positive valuation (i.e., VMPFC$_{value}$) during message exposure (*SI Appendix*). This may suggest that seeing value in a message can be primed by different forms of self-transcendence manipulations. Supporting this view, an exploratory whole-brain analysis revealed that neural regions associated with later behavior change included other positive value/reward-related brain regions (VMPFC, VS, ventral tegmental area) (*SI Appendix*, Fig. S6), and the region of the VMPFC at the intersection of our self and value ROIs was robustly associated with behavior change (*SI Appendix*). Moreover, although the present study was not designed to disambiguate the potential role of self-relevance and positive valuation/reward in predicting behavior change, both processes are likely involved in perception of subjective value in health messages (e.g., "This message is *valuable* to *me*."). Consistent with this idea, we found that the overlapping neural region between functionally defined self and value ROIs during message exposure was significantly associated with behavior change, and that the effects of activity defined using purely the self-task or purely the value tasks become nonsignificant when controlling for activity in the self/value

overlapping region (*SI Appendix*). Furthermore, the region of the $VMPFC_{behavior\ change}$ most commonly associated with behavior change in past studies (5, 22, 23, 31) is at the border of brain regions implicated in self-related and value processing. This highlights the importance of considering not only self-relevance but also self and value integration in the effectiveness of health messaging.

The control task used in the present study involved reflecting on the lowest ranked values. This approach is extensively used in the affirmation literature (5, 21), and is particularly advantageous in a neuroimaging environment as it provides a tight between-subjects control for features unrelated to core interests. However, even reflecting on the lowest ranked values may have been affirming for some participants, which may explain the whole-brain activation in reward-related regions observed during the control task (although this was still significantly less, on average, than in the self-transcendent groups). Similarly, to the extent that participants in the control condition did show heightened activity in brain regions chosen for their role in self-relevance and message receptivity during message exposure, they showed greater behavior change (*SI Appendix*). As such, this control condition represents a conservative test of our hypotheses. Finally, because individual differences in the VMPFC across conditions predicted behavior change, differences in neural receptivity may have utility in designing individually tailored health interventions. For example, future research might establish whether measuring neural responses to health messages following affirmation, compassion, or other interventions, may indicate which is most likely to produce behavior change for specific individuals.

The current study extends previous research linking brain activity to health behavior change and elucidates core mechanisms associated with self-transcendence and subsequent receptivity to persuasive messaging. Our results highlight significant activations within the VMPFC, particularly at the intersection of regions identified based on their roles in processing self-relevance and value of stimuli during health messaging as key links to behavior change.

Methods

Hypothesis Preregistration, and Data Availability. Before data collection, we preregistered study hypotheses and analysis plans (https://osf.io/7whpz) relevant to ROIs implicated in positive value/reward processing (VMPFC, VS) during affirmation and compassion priming, and in brain regions localized using a self-related processing task (VMPFC, PCC) during subsequent health messaging (*SI Appendix*).

Participants. We recruited sedentary and obese/overweight adults who are most likely to be defensive in response to health messages (n = 220; mean age = 33.75 y, SD = 11.62; 144 females; 96 Black, 86 White, 16 Asian, 9 Hispanic, 13 Other) (*SI Appendix*, Table S1). Participants with usable data were included in final behavioral outcome analyses (n = 184), neural outcome analyses (n = 175), and analyses linking neural and behavioral outcomes (n = 159) (*SI Appendix*). The study was approved by the University of Pennsylvania Institutional Review Board. All participants provided informed consent.

Procedure. Participants visited the laboratory for the baseline appointment (T1), an fMRI intervention appointment (T2) ∼10 d later (mean = 9.60 d, SD = 5.00), and an endpoint appointment (T3) ∼1 mo after T2 (mean = 34.91 d, SD = 2.79) (Fig. 4).

At T1, all participants provided informed consent, completed value ranking for the affirmation task, and performed the baseline accelerometer calibration (*SI Appendix*). Participants continued to wear the accelerometers for the baseline period between T1 and T2, and for the postintervention period between T2 and T3. At the T2 fMRI appointment, participants were randomly assigned to one of three conditions: (*i*) affirmation (n = 88), (*ii*) compassion (n = 44), or (*iii*) control (n = 88). Depending on their condition, participants completed one of three priming tasks (affirmation, compassion, or control task), followed by completing a health messages intervention task in the fMRI scanner. From T2 to T3, the priming and health messages were reinforced via daily mobile text messages. Each day, participants received two messages one after another, consisting of an affirmation/compassion/control priming and a health message, drawn from the corresponding fMRI tasks. At T3, participants returned accelerometers and were debriefed, paid, and thanked for their participation. Self-report measures were embedded among other surveys not reported here using an online survey tool (Qualtrics). Scanner tasks were presented using PsychoPy2 (40). In-scanner responses were collected using a four-button response device attached to each participant's right wrist.

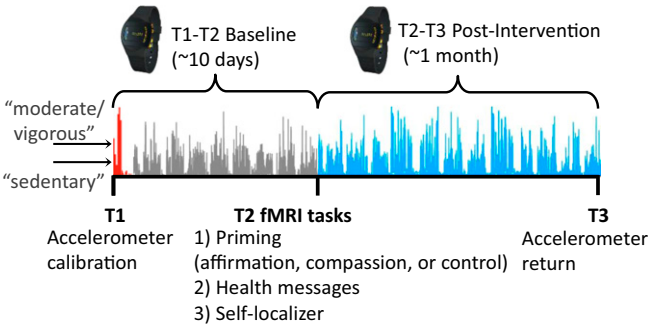

Fig. 4. A schematic illustration of the study timeline.

Measures.

Physical activity. The primary behavioral outcome was change in objectively measured levels of physical activity as recorded by wrist-worn triaxial accelerometers (*SI Appendix*). Accelerometer data were collected throughout the entire duration of the study using an accelerometer worn on the left wrist. Following the procedure from Falk et al. (5), we defined sedentary and moderate/vigorous cut points according to measurements taken during the T1 laboratory baseline calibration (*SI Appendix*).

Demographics and self-report measures. At the end of T1, participants reported their age, sex, ethnicity, and years of education. The ethnicity variable was converted into a binary variable indicating black (the majority of the current sample) vs. nonblack status. Participants in the affirmation, compassion, and control conditions did not significantly differ with respect to age, sex, ethnicity, or education (Ps > 0.15). Participants also completed self-reports assessing individual differences in health behavior and mood (*SI Appendix*).

fMRI Scanner Tasks. At the T2 fMRI appointment, participants were randomly assigned to complete one of three priming tasks: affirmation, compassion, or control (Fig. 4) (task timing identical between conditions). During the affirmation (control) task, participants reflected on their highest (lowest) ranked values determined at T1. During the compassion task, participants made positive well-wishes for others. Following the priming task, all participants completed the health messages intervention task that presented messages encouraging physical activity and discouraging sedentary behavior. Finally, participants completed an independent self-localizer task designed to functionally locate brain ROIs associated with self-relevance processing, and a counterarguing localizer. See *SI Appendix* for the full descriptions of fMRI tasks.

Analysis Plan. A series of models tested the hypothesized effects of self-transcendence on neural activity during health message exposure and behavior change. All analyses controlled for demographic variables, and models predicting behavior change controlled for baseline activity levels.

fMRI data acquisition, preprocessing, and modeling. Fixed-effects models of the priming tasks (affirmation, compassion, control) were constructed using a single boxcar function for each block with two block types (value/wish, control). For the affirmation/control task, a contrast between blocks in which people were affirmed with the highest (affirmation condition) or lowest (control condition) values vs. thinking about value-neutral everyday activities was used. For the compassion task, a contrast between blocks in which people made wishes for people (well-wishes) vs. wishes for everyday activities was used.

The health messages task was modeled including regressors for each message type (why to be less sedentary and more active, how to be less sedentary and more active, risk messages about health, why to perform other daily activities, how to perform other daily activities, risk messages about other daily activities) and the corresponding response periods. A contrast was computed for each participant by averaging across the 30 health messages of different types, and comparing parameter estimates of activity during those messages to rest. For all tasks, second-level random-effects models were constructed by averaging across participants and were submitted to a further ROI analysis described below.

ROI analyses. During the priming tasks, we examined ROIs associated with positive valuation (denoted as $VMPFC_{value}$, VS_{value}) (19). During the health

messages task, we examined ROIs associated with self-relevance processing (denoted as $VMPFC_{self}$, PCC_{self}; defined using a self-localizer task as part of the present study) and an additional $VMPFC_{behavior\ change}$ subregion of interest implicated in health behavior change across multiple prior studies (5, 22, 23). We also preregistered hypotheses related to a counterarguing localizer, and present these along with exploratory results of ROIs implicated in positive valuation during the health messages task in *SI Appendix*.

Affirmation and compassion task ROIs. $VMPFC_{value}$ and VS_{value} masks were taken from a metaanalysis of 206 studies that reported neural signals associated with reward/positive value processing (19). Activity during the priming tasks (affirmation, compassion, control) within each mask was compared across the between-subjects conditions in R (e.g., affirmation vs. control, compassion vs. control, and so forth).

Health messages intervention ROIs. We drew $VMPFC_{self}$ and PCC_{self} fROIs using results from the self-localizer task (*SI Appendix*). We also tested an ROI within the VMPFC subregion during health messages by drawing the same $VMPFC_{behavior\ change}$ ROI used in a prior investigation that identified a robust link between VMPFC activity and later changes in sedentary behavior (5). In addition, although not preregistered, given a large body of research implicating positive valuation in persuasion and behavior change (25), we also explored activity in brain regions implicated in positive valuation and the intersection between these ROIs and those defined by our self-related processing localizer (*SI Appendix*).

Whole-brain analyses. Exploratory whole-brain searches were performed to test for regions associated with self-transcendence during the affirmation and compassion tasks, and for brain regions activated during exposure to health messages that were associated with later changes in the average proportion of daily physical activity (*SI Appendix*). Six separate contrasts were created: (*i*) a within-subjects contrast in the affirmation task when people reflected on their highest value situations vs. everyday activities (n = 73); (*ii*) a within-subjects contrast in the compassion task when people made well-wishes for others vs. wishes for everyday activities (n = 32); (*iii*) a within-subjects contrast in the control task when people reflected on their lowest value situations vs. everyday activities (n = 70); (*iv*) a between-subjects contrast of affirmation vs. control conditions (n = 143); (*v*) a between-subjects contrast of compassion vs. control conditions (n = 102); and (*vi*) a between-subjects contrast of compassion vs. affirmation conditions (n = 105). These analyses were thresholded at $P < 0.005$, $k = 243$, corresponding to $P < 0.05$, corrected (*SI Appendix*). An additional whole-brain search exploring regions associated with self-transcendence tasks (affirmation + compassion) > control was also examined at $P < 0.001$, uncorrected.

Neural activity predicting behavior change. We examined activity in each of the ROIs during the messages task as predictors of subsequent changes in physical activity. A regression model included changes in the average proportion of daily sedentary or moderate/vigorous activities during the postintervention period (T2–T3) as an outcome variable and the activity in each ROI separately during the messages task as a predictor variable controlling for the respective activity levels during the baseline (T1–T2).

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