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Los Angeles

Investigating the Neural Correlates of Self-Affirmation

A dissertation submitted in partial satisfaction of the
requirements for the degree of Doctor of Philosophy
in Psychology

by

Janine Michele Dutcher

2016

ABSTRACT OF THE DISSERTATION

Investigating the Neural Correlates of Self-Affirmation

by

Janine Michele Dutcher

Doctor of Philosophy in Psychology

University of California, Los Angeles, 2016

Professor Naomi Ilana Eisenberger, Chair

Reflecting on important personal values or attributes has a host of benefits from reducing stress, to improving performance and enhancing well-being. This process, self-affirmation, has led to a rich literature establishing it as a strategy that could help the most distressed among us to be successful and thrive. Some work has shown that self-affirmation may lead to effects because it promotes feelings of social connection, or broadens one's perspective, or reminds one of their resources. However, each of these studies has fallen short in identifying the basic processes involved in self-affirmation. The present work sought to address this problem using a novel method for studying self-affirmation: neuroimaging. This dissertation posits a reward-related neural mechanism for self-affirmation. To do so, Paper 1 examined whether self-affirmation led to reward-related neural activity. Across two studies, one with college students and one with community adult women, we tested whether reflecting on important personal values led to greater reward-related neural activity compared to reflecting on less important personal values. In Study 1, we also compared self-affirmation to making value judgments about non-personally relevant information (attributes in toasters). In Study 2, we used a different values affirmation task with a different demographic population. Paper 1 demonstrated that self-affirmation led to greater reward-related neural activity, in the first set of studies to examine the neural correlates of self-affirmation. To follow up on this, Paper 2 investigated whether self-affirmation's reward-related neural activity was similar to other rewarding stimuli, social support and basic reward. Because these stimuli types have been shown to reduce stress, this examination aimed to determine if they all rely on the same mechanism, or if there are important differences. Results show that self-affirmation, social support and basic reward all led to reward- and caregiving-related neural activity. However, activity in these regions during self-affirmation and social support were associated, but not associated with activity during basic reward. This suggests self-affirmation and social support may be a category of 'social reward' and may therefore differ from basic reward in their mechanism. Collectively, these results advance self-affirmation theory by identifying the neurocognitive processes that occur during self- affirmation.

The dissertation of Janine Michele Dutcher is approved

Julienne Elizabeth Bower

Matthew D. Lieberman

Teresa Ellen Seeman

Naomi Ilana Eisenberger, Committee Chair

University of California, Los Angeles

2016

To Nanny, for reminding me what was important
in life, and for never forgetting to believe in me.

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As is apparent from the list of authors on Paper 1, this work was been a collaborative effort. Paper 1 is a version of a previously published article (Dutcher, J. M., Creswell, J. D., Pacilio, L. E., Harris, P. R., Klein, W. M., Levine, J. M., ... & Eisenberger, N. I. (2016). Self-affirmation activates the ventral striatum: A possible reward-related mechanism for self-affirmation. *Psychological Science*, *27*(4), 455-456). Paper 2 will be submitted for review at a later date. I would like to thank Jared Torre for statistical guidance with both papers, and Kate Byrne Haltom for assistance with data collection and troubleshooting. I would also like to thank

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I know it takes a whole village, and I had a good one.

VITA

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Muscatell, K.A., Moieni, M., Inagaki, T.K., Dutcher, J.M., Jevtic, I., Breen, E.C., Irwin, M.R., & Eisenberger, N.I. (In press). Inflammation Enhances Neural Sensitivity to Negative and Positive Social Feedback. *Brain, Behavior and Immunity.*

Tabak, B. A. Meyer, M.L., Dutcher, J.M., Castle, E., Irwin, M.R., Lieberman, M.D., & Eisenberger, N.I. (In press). Oxytocin, but not vasopressin, decreases social cognitive ability among individuals with higher levels of social anxiety: A randomized controlled trial. *Social, Cognitive and Affective Neuroscience.*

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Dutcher, J. M. & Eisenberger, N. I. *Self-Affirmation and Social Support: A Possible Shared Mechanism.* Poster presented at the 13th Annual American Psychosomatic Society Meeting, Miami, FL, 2013.

Dutcher, J. M. & Eisenberger, N. I. *Happy and Connected: Self-Affirmation and Social Support Lead to Similar Affective States.* Poster presented at the Emotion Preconference at the 14th Annual Society for Personality and Social Psychology Meeting, New Orleans, LA, 2013.

Dutcher, J. M.,_Creswell, J. D., Harris, P. R., & Klein, W. M. P. *Improving performance on a creativity task via self-affirmation.* Poster presented at the 13th Annual Society for Personality and Social Psychology Meeting, San Diego, CA, 2012.

Invited Talks and Colloquia

University of California, Los Angeles, Social Psychology Colloquium, 2012
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INTRODUCTION

People are motivated to maintain a positive global concept of themselves and their adequacy. Threats to this self-integrity result in stress, defensiveness and anxiety. While there are a number of ways that individuals boost their global self-concept, one such way is via self-affirmation. Self-affirmation can take many forms including receiving positive feedback, successfully accomplishing a goal, or reflecting on what is important to oneself. These events can strengthen the individual's identity as a person of worth, improving their self-concept and enabling them to face threats to the self. Some research indicates that this is due to self-affirmation resulting in a broader self-concept that identifies the resources the individual has to cope with a sometimes challenging world (Sherman & Hartson, 2011).

Self-affirmation research has most often focused on a simple intervention: reflecting on important personal values (e.g., art, politics, social issues). Participants in these studies typically receive a list of values and are asked to rank order them in the order of importance to their life. Subsequently, they will write about their top-ranked value and why it is important to them (Cohen, Aronson, & Steele, 2000) or make decisions about which values from that list are most important to them (Steele & Liu, 1983) to affirm their ranking choices. Individuals often rank friends and family, humor, or religion very highly; however, the list of values varies across studies, and most research indicates that which items are on the list is mostly irrelevant, as individuals are able to reflect on whichever value from the list is most important to them (for a systematic review see McQueen & Klein, 2006).

Self-affirmation research has become a very popular topic of study, with a wide range of studies showing many benefits for those who affirm. For example, self-affirmation has been shown to reduce various forms of threat (for a review see Sherman & Cohen, 2006 and Cohen &

Sherman, 2014). Self-affirmation (compared to a control condition) has been shown to reduce the negative educational consequences of chronic stress, stereotype threat and discrimination (Cohen, Garcia, Apfel, & Master, 2006; Cohen, Garcia, Purdie-Vaughns, Apfel, & Brzustoski, 2009; Creswell, Dutcher, Harris, Klein, & Levine, 2013), reduce defensiveness toward a targeted health messages (for reviews see Harris & Epton, 2009, 2010), and buffer against physiological stress responding (Creswell, Welch, Taylor, Sherman, Gruenewald, & Mann, 2005; Sherman, Bunyan, Creswell, & Jaremka, 2009). Self-affirmation has also been shown to have a wide range of effects on behavior following social stress including improving self-control following rejection (Burson, Crocker, & Mischkowski, 2012). However, despite the many benefits empirical studies have shown for self-affirmation, the mechanism is not known.

Human neuroimaging work has found that neural reward regions, such as the ventral striatum (VS), are activated when people disclose self-traits or beliefs *(*Tamir & Mitchell, 2012). The VS is also more active when participants think about positive, compared with neutral, autobiographical memories (Speer, Bhanji, & Delgado, 2014). These studies provide evidence that thinking about positive aspects of the self may activate neural reward pathways, and therefore, we hypothesized that self-affirmation may also activate neural reward pathways.

This reward account of self-affirmation also provides a possible explanation for how self-affirmation regulates threat responding. Neural reward regions have inhibitory connections to many regions that process threat (Schiller, Levy, Niv, LeDoux, & Phelps, 2008; Peters & Buchel, 2010). Indeed, in both animal and human behavioral research, various different types of reward have been shown to reduce physiological stress responding (Ulrich-Lai et al., 2010; Creswell, Pacilio, Denson & Satyshur, 2013). Thus, it is possible that self-affirmation activates reward-related neural regions, which regulate threat-related neural regions resulting in reduced threat experience and fewer negative outcomes.

In order to begin to address this gap in understanding, this dissertation presents two papers that address a possible neural mechanism for self-affirmation. Across three studies using neuroimaging techniques (functional magnetic resonance imaging, fMRI) with multiple samples (undergraduates and community adults), a reward account of self-affirmation is proposed and tested.

Paper 1: Self-Affirmation Activates the Ventral Striatum: A Possible Reward-Related Mechanism for Self-Affirmation

Paper 1 investigated what neural activity is associated with the process of affirming an important personal value across two fMRI studies. Inspired by work finding that disclosing self-beliefs and thinking about positive autobiographical memories lead to increased VS activity (Tamir & Mitchell, 2012; Speer et al., 2014), this paper had three aims. The first aim was to identify whether self-affirmation leads to increased VS activity compared to control. The second aim was to test whether this reward-related activity was different from making simple preference judgments. And finally, the third aim was to determine if this effect would replicate in a community sample, because self-affirmation has been shown to lead to benefits for a variety of different demographic groups. To create a scanner-friendly self-affirmation task, we could not use the commonly used writing paradigm, so we modified the self-affirmation personal values decision-making tasks used in early self-affirmation work (Steele & Liu, 1983). In Study 1, 38 undergraduate participants completed a neuroimaging session. One group of the participants completed the self-affirmation fMRI task. To test aim 2, that reward-related activity to self-affirmation was not just based on making preference judgments about valued items, the other group of subjects completed a decision-making task not based on important personal values, but rather based on attributes of toasters. Thus, we were able to assess whether self-affirmation leads to increased reward-related neural activity (VS activity) and if that was significantly different from making non-self-relevant judgments of value. In Study 2, a sample of 21 community adult women came in and did a slightly different version of the self-affirmation task to investigate whether the effects seen in Study 1 were due to specifics of the task, or to the process of self-affirmation. Identifying the neural correlates of self-affirmation can help further our understanding of the theory of self-affirmation. Moreover, by understanding the neural activity associated with self-affirmation, this study can begin to identify the mechanism by which self-affirmation has its many beneficial effects.

Paper 2: Examining the Neural Substrates of Self-Affirmation, Social Support and Basic Reward

Due to the fact that self-affirmation has been previously linked to feelings of social connection (Crocker et al., 2009; Dutcher & Eisenberger, 2013), and that social support and reward both involve VS and VMPFC activation (Strathearn, Fonagy, Amico, & Montague, 2009; Inagaki & Eisenberger, 2013; Eisenberger et al., 2011; Berns, McClure, Pagnoni & Montague, 2001; Knutson, Adams, Fong & Hommer, 2001) it is possible that self-affirmation, social support and basic reward rely on similar neural mechanisms. Paper 2 had two main aims: 1) to assess the possible overlap in neural activity for self-affirmation, social support and basic reward stimuli; and 2) to assess the possible differences between self-affirmation, social support and basic reward. Using a completely within-subjects design with 25 undergraduate participants, we used a paradigm similar to Paper 1 for manipulating self-affirmation, and then created social support and reward tasks with a similar format. From this, we were able to test the similarities and differences in neural activity across the three tasks. Results from this study help to further elucidate the neural mechanisms for self-affirmation. In addition, these results might inform future intervention work on which interventions strategies might work in certain situations for certain people.

General Approach

Together, these two papers seek to identify the neural mechanism for self-affirmation, and how similar self-affirmation, social support and basic reward are neurally. This work attempts to bridge a gap in the self-affirmation literature by using a previously unused method (fMRI) to further understand what is happening when an individual affirms. With greater understanding of the process of self-affirmation, future work can assess whether this reward-related activity leads to the many benefits of self-affirmation.

Paper 1: Self-Affirmation Activates the Ventral Striatum: A Possible Reward-Related Mechanism for Self-Affirmation

Janine M. Dutcher, J. David Creswell, Laura E. Pacilio, Peter R. Harris, William M. P. Klein,
John M. Levine, Julienne E. Bower, Keely A. Muscatell, and Naomi I. Eisenberger

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Abstract

Self-affirmation (reflecting on important personal values) has been shown to have a range of positive effects; however, the neural basis of self-affirmation is not known. Building on studies showing that thinking about self-preferences activates neural reward pathways, we hypothesized that self-affirmation would activate brain reward circuitry during functional MRI (fMRI) studies. In Study 1, with college students, making judgments about important personal values during self-affirmation activated neural reward regions (i.e., ventral striatum), whereas making preference judgments that were not self-relevant did not. Study 2 replicated these results in a community sample, again showing that self-affirmation activated the ventral striatum. These are among the first fMRI studies to identify neural processes during self-affirmation. The findings extend theory by showing that self-affirmation may be rewarding and may provide a first step toward identifying a neural mechanism by which self-affirmation may produce a wide range of beneficial effects.

Introduction

Self-affirmation—the process of reflecting on important personal values or personal characteristics and strengths—has been shown to have a broad range of benefits in hundreds of studies (for reviews: Sherman & Cohen, 2006; Cohen & Sherman, 2014). For example, self-affirmation has been shown to reduce defensiveness (Sherman, Nelson & Steele, 2000) and stress (Creswell et al., 2005), and improve academic outcomes (e.g., GPA, problem solving performance; Cohen, Garcia, Apfel, & Master, 2006; Creswell, Dutcher, Klein, Harris & Levine, 2013). Self-affirmation has also shown a range of positive effects on social and affective behavior, including improved self-control following rejection (Burson, Crocker, & Mischkowski, 2012), increased well-being (Nelson, Fuller, Choi, & Lyubomirksy, 2014), reduced rumination (Koole, Smeets, Van Knippenberg, & Dijksterhuis, 1999), and enhanced feelings of relational security (Stinson, Logel, Shepherd, & Zanna, 2011). However, we know little about the underlying neural mechanisms.

Recent research has focused on building mechanistic accounts of self-affirmation; studies have suggested that self-affirmation triggers a psychological cascade of effects, such as increasing attention to threat, broadening perspective, increasing feelings of social connection, and enhancing coping resources (e.g., Correll, Spencer & Zanna, 2004; Crocker, Niiya, & Mischkowski, 2008; Klein & Harris, 2009; Sherman & Hartson, 2011). In a recent review, Cohen and Sherman (2014) noted there could be multiple mechanisms for self-affirmation and using a variety of methods could illuminate these processes. However, most accounts have not identified the basic neural and cognitive processes leading to these psychological effects. In particular, no published research to date has considered which neural regions are involved during self-affirmation (although some work has examined the neural consequences of self-affirmation;

Falk et al., 2015; Legault, Al-Khindi, & Inzlicht, 2012). Using neuroimaging as a tool to investigate the self-affirmation process could help advance self-affirmation theory, given that neuroimaging does not rely on self-report.

In two studies, we proposed and tested a novel self-affirmation neural reward account. Specifically, we posited that engaging in self-affirmation activates not only self-related neural regions (medial prefrontal cortex, precuneus), but also neural reward pathways in the brain's mesolimbic dopamine system. Our proposed account was informed by studies showing that neural reward regions, such as the ventral striatum (VS) and ventral tegmental area (VTA), are activated when people disclose self-traits or beliefs *(*Tamir & Mitchell, 2012). The VS is also more active when participants think about positive, compared with neutral, autobiographical memories (Speer, Bhanji, & Delgado, 2014). These studies provide evidence that thinking about positive aspects of the self may activate neural reward pathways.

This reward account may provide a mechanistic explanation for self-affirmation's effects on threat and stress responding, given that previous research has found that rewarding stimuli (e.g., sexual stimuli, sucrose) decrease physiological stress responses in humans (Creswell, Pacilio, Denson & Satyshur, 2013) and rats (Ulrich-Lai et al., 2010). It is possible that, when participants perform a self-affirmation task, their reward-related neural activity increases, which diminishes their neural responses to threat, allowing them to be more resilient and open to self-related threats compared with nonaffirming participants.

We conducted two neuroimaging studies to explore neural activity specific to the process of self-affirmation; in particular, we examined whether self-affirmation led to increased activity in neural reward regions (VS and VTA) relative to nonaffirmation (in Study 1) or control (in Study 2).

In Study 1, college-age participants were randomly assigned to either a self-affirmation group, in which they made decisions about important personal values (experimental condition) and decisions about less important personal values (control condition), or a nonaffirmation group, in which they made decisions about attributes others might prefer in toasters (experimental condition) and decisions about less important toaster attributes (control condition). Thus, this study used a 2 x 2 mixed design, with group (self-affirmation, nonaffirmation) manipulated between subjects and ranking of value or attribute (high, low) manipulated within subjects. We included a nonaffirmation group to evaluate whether neural reward activity was due specifically to self-affirmation or to the difference in value between the experimental conditions (important personal values or toaster attributes) and control conditions (less important personal values or toaster attributes) conditions. In Study 2, we tested whether these effects extended to a community sample of older adult women.

Study 1

Methods

Participants

Forty university students (18 female; mean age=24.13 years, SD=5.72 years) completed study procedures. Data collection was stopped after each group reached a minimum of 20 participants, but data from two participants in the non-affirmation were not saved after the completion of the imaging session, so that group had 18 participants with usable data. All participants met fMRI study eligibility criteria (right-handed, not claustrophobic, free of implanted metal, not pregnant). Fifty-nine percent were White, 3% were Hispanic, 11% were Black, and 11% as Asian-American or Asian, and 16% were of “other” race. The Carnegie Mellon University Institutional Review Board approved all study procedures.

Procedure

Before the scanning session, participants were randomly assigned to either the self-affirmation group (*n* = 20) or the non-affirmation group (*n* = 18). We used a standard self-affirmation decision-making task (Steele & Liu, 1983; Steele, 1988); participants were given a series of paired personal value statements and were asked to indicate their relative preference (based on Vernon & Allport, 1931; see Figure 1). In the self-affirmation group, participants ranked five personal values (art, religion, science, social issues, politics) in order of importance. We used this list to create a scanner task that was specific to the participant's own values. In the nonaffirmation group, participants were asked to rank a list of five toaster attributes (e.g. slice capacity, color, size) in the order of the importance that they believed an average college student would rank them *(*for frequency tables reporting the personal values and toaster attributes selected by participants, see Supplementary Materials*).* We used this list to create a scanner task that was specific to the participant's beliefs about what other people prefer. Before the scanning session, participants were trained on the tasks assigned to them. In these training sessions, participants were familiarized with the pictures that represented each personal value or toaster attribute, so the pictures were not novel to participants at test.

Although many self-affirmation studies use a control condition in which participants focus on a value of lower personal relevance and why it might be important to someone else (Sherman & Cohen, 2006), the design for this study was slightly different to accommodate standard imaging techniques. Specifically, fMRI contrasts require a within-subjects design, using comparisons between two conditions to isolate neural activity to the specific psychological differences between the conditions. Therefore, both groups in the current study included an experimental condition (self-affirmation group: high personal value ratings; nonaffirmation group: high toaster attribute ratings) and a control condition (self-affirmation group: low personal value ratings; nonaffirmation group: low toaster attribute ratings).

Consequently, our within-subjects self-affirmation conditions differed only in how the personal values displayed had been previously ranked by the participant, which controlled for any self-related processes. The within-subject non-affirmation conditions also differed only in how the toaster attributes displayed had previously been ranked by the participant. Including both within- and between- subjects levels of comparison offered a more specific tests of whether self-affirmation relies on reward activity inherent in the self-affirmation process itself or just relies on self- or value-related reflection. This design also closely approximates the original paradigms used in behavioral self-affirmation studies, ensuring that we manipulated self-affirmation.

Imaging procedures for the self-affirmation and nonaffirmation tasks. During each task, participants viewed instructions, images and words via a high-resolution projector and were asked to make responses (when appropriate) using a 5-button data glove.

The self-affirmation task used a block design. Each block included three decision-making trials, and each trial lasted for 8 s, for a total of 24 s per block. In the self-affirmation trials, participants were shown pictures associated with two personal values, one of which was always the top-ranked value; the values' labels appeared beneath the pictures (Fig. 1a). Participants were asked to think about the role of these two personal values in their lives and then indicate which of the two displayed values was more important to them. Participants responded using a 5-point scale (1 = *strongly prefer* [the value on the left], 2 = *slightly prefer* [the value on the left], 3 = *no preference*, 4 = *slightly prefer* [the value on the right], 5 = *strongly prefer* [the value on the right]).

The control blocks had the same timing and instructions; however, participants were shown their fourth- and fifth-ranked personal values on each trial. Thus, the only difference between the experimental and control trials was whether subjects were able to affirm important values during the trials. Participants completed four experimental blocks in one run and four control blocks in another run. Run order was counterbalanced across participants. The two conditions were completed in separate runs to reduce carryover effects, given that self-affirmation has been shown to have sustained benefits over time (Cohen et al., 2006).

We wanted to have a comparison group to test whether the observed neural correlates of self-affirmation were due to the difference between making preference judgments regarding more important characteristics and making preference judgments regarding less important characteristics. To this end, we created a task that was similar to the self-affirmation task in design and demands but did not lead participants to self-affirm. As in the self-affirmation task, each nonaffirmation block included three 8-s decision-making trials, for a total of 24 s per block. In these trials, participants were shown pictures associated with toaster attributes with the attribute label beneath each picture (see Fig. 1b). Each experimental block contained three experimental trials. In the experimental trials, participants were asked to indicate which of the two displayed toaster attributes, one of which was always the top-ranked attribute, was more important to the average college student. Participants responded using a 5-point scale (1 = *strongly prefer* [the attribute on the left], 2 = *slightly prefer* [the attribute on the left], 3 = *no preference*, 4 = *slightly prefer* [the attribute on the right], 5 = *strongly prefer* [the attribute on the right]). Each control block included three trials. In the control trials, participants were given the same instructions, but were shown the fourth- and fifth-ranked attributes. Each of the trials and blocks was the same length as in the experimental condition. Participants completed four experimental blocks in one run and four control blocks in another run to match the self-affirmation group. Runs were counterbalanced.

Image acquisition. Data were acquired using a 3-T MRI scanner (Verio; Siemens Medical Solutions USA, Malvern, PA). Foam padding surrounded each participant's head to reduce head movement. For each participant, we first acquired a high-resolution structural magnetization-prepared rapid gradient-echo (MPRAGE) imaging volume—repetition time (TR) = 1,700 ms, echo time (TE) = 2.48, matrix size = 128 × 128, resolution = 1 × 1 × 1 mm, field of view (FOV) = 256 mm, 176 slices (1 mm thick), flip angle = 9°, and bandwidth = 170 Hz/pixel. For the tasks, two functional gradient-echo scans (3 min for self-affirmation/toasters and 3 min for control) were acquired—TR = 2,000 ms, TE = 29 ms, flip angle = 79°, matrix size = 64 × 64, resolution = 3 × 3 × 3 mm, FOV = 192 mm, 36 axial slices (3 mm thick), and bandwidth = 2232 Hz/pixel. These tasks were conducted in separate runs to give participants a break and to minimize carry-over effects.

fMRI data analysis. Imaging data were analyzed using Statistical Parametric Mapping software (SPM8; Wellcome Department of Cognitive Neurology, Institute of Neurology, London, England). For preprocessing, we first manually reoriented the echoplanar images to align brains along a horizontal anterior commissure-posterior commissure, with an image origin at the anterior commissure. For functional images, the first run's first-image parameters were applied to each subsequent volume in the respective run to correct for head motion. Structural MPRAGE images were normalized to Montreal Neurological Institute (MNI) space using diffeomorphic anatomical registration through exponentiated lie (DARTEL) algorithms and were then smoothed using an 8-mm Gaussian kernel, full-width at half maximum. Before first-level analyses, images were visually inspected for accurate normalization. The 24 s of trials for each condition (self-affirmation experimental condition, self-affirmation control condition, nonaffirmation experimental condition, nonaffirmation control condition) were modeled as blocks. Rest periods, when participants viewed a fixation cross between blocks, comprised the implicit baseline.

We computed linear contrasts for the self-affirmation experimental condition compared with its control condition (high-rated personal values vs. low-rated personal values) for each participant. These individual contrast images were then used in group-level analyses. For the nonaffirmation group, we computed linear contrasts for the experimental condition compared with its control condition (high-rated toaster attributes vs. low-rated toaster attributes) for each participant. These individual contrast images were then used in group-level analyses. In addition, to determine whether there were differences in neural activation between the two groups, an independent (two-sample) *t*-test was computed comparing the self-affirmation group (self-affirmation experimental minus yoked control contrast) to the nonaffirmation group (experimental minus yoked control contrast).

On the basis of a priori predictions that self-affirmation would activate reward-related regions, group-level results were examined using regions of interest (ROIs) of the left and right VS and the VTA. VS ROIs were structurally defined using the automated anatomical labeling atlas (Tzourio-Mazoyer et al., 2002); caudate nucleus and putamen from the atlas were combined and constrained at x between 0 and –24, y between 4 and 18, and z between 0 and –12 for the left ROI and x between 0 and 24, y between 4 and 18, and z between 0 and –12 for the right ROI (based on ROIs from Inagaki & Eisenberger, 2012). Thus, we constrained the ROI to the ventral parts of the caudate nucleus and putamen to create this VS ROI. The VTA ROI was created in the MarsBar Toolbox for SPM (http://marsbar.sourceforge.net; Brett, Anton, Valabregue, &

Poline, 2002) and centered at ($x = 2$, $y = -12$, $z = -8$) within a 3-mm radius on the basis of previous work investigating social reward (Aron et al., 2005). We examined activity within each of these ROIs for the self-affirmation and nonaffirmation conditions relative to their yoked control conditions. Parameter estimates representing the average activity across all voxels in the ROI were extracted and averaged. ROI analyses were run in MarsBar, which reports an fMRI standard statistical threshold of $p < .05$, one-tailed. Confidence intervals (CIs) for these tests were estimated using the bias-corrected and accelerated-percentile method (10,000 random samples with replacement), implemented using the BOOTCI function in MATLAB (The MathWorks, Natick, MA).

Because this was the first study to explore neural activity during self-affirmation, we also conducted exploratory whole-brain analyses to provide a complete picture of the neural regions involved in this process. Thus, we performed whole-brain analyses contrasting activity in the self-affirmation experimental trials (relative to activity in the yoked control trials) with activity in the nonaffirmation experimental trials (relative to activity in the yoked control trials). We used an exploratory threshold of $p < .005$ and 20 voxels (Lieberman & Cunningham, 2009). We then explored the post hoc simple effects. To do so, we created ROIs based on the clusters of activity in the whole-brain analysis and extracted and averaged parameter estimates for the contrast between experimental and yoked control trials in the self-affirmation group and for the contrast between experimental and yoked control trials in the nonaffirmation group. Analyses were run in MarsBar, which reports an fMRI standard statistical threshold of $p < .05$, one-tailed.

Results

ROI analyses. To examine differences in neural activity between the self-affirmation and nonaffirmation groups, we investigated whether activity in the self-affirmation experimental condition (measured as activity relative to its yoked control condition) was greater than activity in the nonaffirmation experimental condition (measured as activity relative to its yoked control condition). We then further examined these effects by examining neural activity in each group separately.

Results showed greater activity in the left VS in the self-affirmation group compared with the nonaffirmation group, $t(36) = 2.04$, $p = .025$ (Fig. 2). Consistent with our hypotheses, in the self-affirmation group, there was greater activity in the left VS during the experimental trials than in the control trials, $t(19) = 2.12$, $p = .024$, mean parameter estimate = 0.538, 95% CI = [0.022, 0.987], whereas within the nonaffirmation group, there was no difference in left VS activity during the experimental and control trials, $t(17) = -0.53$, $p > .250$, mean parameter estimate = −0.099, 95% CI = [−0.424, 0.280].

Results showed greater activity in the right VS in the self-affirmation group than in the nonaffirmation group, but the difference was not statistically significant, $t(36) = 1.02$, $p = .157$ (Fig. 2). As we found for the left VS, this effect was driven by the self-affirmation group; there was greater activity, albeit not significantly greater, in the right VS during the experimental trials than during the control trials, $t(19) = 1.06$, $p = .152$, mean parameter estimate = 0.306, 95% CI = [−0.257, 0.837], but there was no difference between the experimental and control trials in the nonaffirmation group, $t(17) = -0.32$, $p > .250$, mean parameter estimate = −0.072, 95% CI = [−0.483, 0.350].

Finally, there were no differences in VTA activity between the self-affirmation and nonaffirmation groups, $t(36) = 0.13$, $p > .250$ (Fig. 2). Specifically, in the self-affirmation group, there was marginally greater (albeit non-significant) VTA activity in the experimental trials than in the control trials, $t(19) = 1.34$, $p = .098$, mean parameter estimate = 0.731, 95% CI = [−0.054, 2.119], and the same pattern was seen in the nonaffirmation group, $t(17) = 1.22$, $p = .119$, mean parameter estimate = 0.632, 95% CI = [−.203, 1.806].

Whole-brain analyses. Like the ROI analyses, whole-brain analyses revealed significantly greater activation in the VS during the self-affirmation experimental trials (relative to activation in the yoked control) than in the nonaffirmation experimental trials (relative to activation in the yoked control; Table 1). There was also significant activation in clusters in the medial prefrontal cortex and precuneus/posterior cingulate cortex, regions previously shown to play a role in self-processing (Heatherton et al., 2006; for a full list of activations, see Table 1). To further investigate these findings, we used post hoc tests of simple effects to explore which trials drove the effect. As expected for the VS, these tests revealed that there was greater activity in the VS during self-affirmation experimental trials than during the yoked control trials, $t(19) = 2.26$, $p = .018$, but there was no difference in activity between the nonaffirmation experimental and yoked control trials, $t(17) = -2.90$, $p > .250$. The other clusters showed the same pattern: There was greater activity during the self-affirmation experimental trials than during the yoked control trials (ps < .024; medial prefrontal cortex: $p = .143$), but there was no difference in activity between the nonaffirmation experimental and yoked control trials (ps > .559).

On the other hand, whole brain analyses revealed no significant clusters of activity during the reverse contrast, which tested for greater activity in the experimental condition (relative to the yoked control condition) in the nonaffirmation group compared with the self-affirmation group. In addition, within the self-affirmation group, there were no clusters with significantly greater activity in the control condition than in the experimental condition.

Interim Summary

Results indicated that the self-affirmation group showed greater VS activity than did the nonaffirmation group. This effect was driven by increased VS activity specific to the self-affirmation condition. Whole-brain results revealed that neural regions implicated in self-processing (precuneus/posterior cingulate cortex) and reward processing (VS) were more active in the self-affirmation group than in the nonaffirmation group. Results from the VTA were inconclusive. Most self-affirmation paradigms do not include pictures, so we conducted a second study without pictures to rule out the possibility that the VS activity was due to viewing pictures. Moreover, to test the generalizability of our findings, we conducted this study with a community sample.

Study 2

Method

Participants

Twenty-one female participants (mean age = 55.5 years) completed the study procedures. All participants were deemed eligible for fMRI (i.e., right-handed, not claustrophobic, free of implanted metal, and not pregnant). Participants were recruited from a larger study investigating the neurobiological pathways linking psychological stress and inflammation in breast cancer survivors and healthy control participants; thus, 6 of the participants were breast-cancer survivors. Because there were no differences in neural activity between the healthy participants and breast cancer survivors in any of the analyses for any of the ROIs (*p*s > .20), we collapsed the data across participants for all analyses reported here. We aimed to collect data from a minimum of 20 participants, and data collection stopped at the targeted enrollment for the larger study. Data from 1 participant were excluded because she did not follow task instructions.

Seventy-six percent of participants were White, 14% were of "other" race, 5% were Hispanic, and 5% were Asian American. The University of California, Los Angeles, institutional review board approved all procedures.

Procedure

Imaging procedures. Before the scanning session, participants were emailed a survey in which they were asked to rank a list of 11 personal values (e.g., art, religion, friends and family) in order of importance (for a frequency table reporting the personal values selected by participants, see the Supplemental Materials). From this, we were able to create tasks that were specific to each participant's most important personal value for the scanning session. During the scan, participants viewed instructions and words through scanner-compatible goggles and were asked to make responses (when appropriate) using a four-button button box.

The self-affirmation task was similar to that used in Study 1; however, for this study, all participants completed the self-affirmation only (i.e., there was no nonaffirmation group). For this experiment, participants selected which of the two personal values shown on screen was most important to them on each trial. However, in this study, participants were shown only the personal-value label, without a picture; we hoped to ensure that the results observed in Study 1 were not being driven by participants' seeing pictures of important values. Each self-affirmation block included three trials, lasting 7 s each, separated by a 1-s fixation cross, for a total of 23 s per block. During the self-affirmation trials, participants were shown their top-ranked personal value and another highly ranked value. They were asked to indicate which of the two personal values displayed was more important using a 4-point scale (1 = *strongly prefer* [the value on the left], 2 = *slightly prefer* [the value on the left], 3 = *slightly prefer* [the value on the right], 4 = *strongly prefer* [the value on the right]). Each control block included three trials. During the control trials, participants were given the same instructions, but were shown two personal values that they had rated as being less important to them, with the same timing as the self-affirmation trials and blocks. Participants completed three self-affirmation blocks and three control blocks. Blocks were randomized once with the constraint that there were never three consecutive blocks of the same condition for any task.[1] The blocks could be ordered in seven different ways, but each participant saw only one order.

Image acquisition. Data were acquired on a Siemens Trio 3-T MRI scanner. Foam padding surrounded each participant's head to reduce head movement. For each participant, we acquired a high-resolution structural matched-bandwidth scan—TR = 5,000 ms, TE = 34, matrix size = 128 × 128, resolution = 1.6 × 1.6 × 3 mm, FOV = 200 mm, 36 slices (3 mm thick), flip angle = 90°, and bandwidth = 1302 Hz/pixel. The self-affirmation task was completed in one functional scan lasting 436 s (about 7 min, 16 s)—TR = 2,000 ms, TE = 25 ms, matrix size = 64 × 64, resolution = 3.1 × 3.1 × 4.0 mm, FOV = 200 mm, 33 axial slices (3 mm thick with 1-mm gap), flip angle = 90°, and bandwidth = 2604 Hz/pixel.

fMRI data analysis. Imaging data were analyzed using SPM8. For preprocessing, functional and anatomical images were realigned, coregistered to the structural scan, and normalized using the DARTEL procedure in SPM8. For each participant, the 23 s of self-affirmation decision-making trials were modeled as the self-affirmation blocks, and the 23 s of control trials were modeled as the control blocks. Implicit baseline consisted of the rest periods (viewing a fixation cross).

We computed linear contrasts comparing the self-affirmation trials with the control trials for each participant. These individual contrast images were then used in group-level analyses. We examined activity within each of the ROIs used in Study 1 for the self-affirmation trials compared with the control trials. Parameter estimates representing the average activity across all voxels in the ROI were extracted and averaged. Analyses were run in MarsBar. A standard statistical threshold of $p < .05$ was used for these ROI analyses. CIs for these tests were estimated using the bias-corrected and accelerated-percentile method (10,000 random samples with replacement; implemented using the BOOTCI function in MATLAB).

To supplement the ROI analyses, we performed whole brain analyses on the self-affirmation compared with control contrast. Whole-brain analyses used an exploratory threshold ($p < .005$, $k = 20$; Lieberman & Cunningham, 2009). All coordinates are reported in MNI space.

Results

ROI analyses. As in Study 1, compared with the control trials, the self-affirmation trials produced significantly more left VS activity, $t(19) = 1.84$, $p = .041$, mean parameter estimate = 0.261, 95% CI = [0.001, 0.548], and marginally more right VS activity, $t(19) = 1.62$, $p = .061$, mean parameter estimate = 0.263, 95% CI = [–0.046, 0.560] (Fig. 3). As in Study 1, there was no difference in VTA activity between the self-affirmation and control trials, $t(19) = .72$, $p = .240$, mean parameter estimate = 0.190, 95% CI = [–0.111, 0.597] (Fig. 3).

Whole-brain analyses. As in Study 1, results from the whole-brain analyses revealed a significant cluster in the VS (putamen) as well as in the medial prefrontal cortex (for a full list of activations, see Table 3). Results from the posterior cingulate cortex at this threshold did not reach statistical significance. The control condition > self-affirmation condition contrast revealed no significant clusters of activation.

Discussion

Reflecting on important personal values during self-affirmation activated neural reward pathways (VS) across two studies with different age groups, using either affirming personal value pictures and text or text only. VS activation was not due simply to making judgments about preferences or personal values; rather, it was specific to thinking about one's most important personal value. This is the first fMRI study to identify neural systems engaged during self-affirmation, which extends self-affirmation theory by suggesting that self-affirmation is rewarding. This is a first step toward identifying the neural mechanisms by which self-affirmation reduces threat and stress responding, improves performance, reduces defensiveness, and alters social and health behaviors.

The VS is a key region in the mesolimbic dopamine reward pathway, which suggests that affirming important personal values is rewarding and may lead to a cascade of effects associated with reward processing. Indeed, when we investigated the term "reward" using Neurosynth (http://neurosynth.org/), a large-scale database of neuroimaging studies that provides meta-analytic reverse-inference analyses, the z score identified in the VS by Neurosynth suggested that neural activity reliably indicated reward processing. In fact, the z score for inferring that activity in the VS is indicative of reward ($z = 26.11$) was higher than the z score for inferring that activity in the occipital cortex was indicative of vision ($z = 13.36$) or that activity in the amygdala was indicative of affect ($z = 6.41$), fear ($z = 13.10$), or emotion ($z = 18.01$). These findings from Neurosynth provide further support for our evidence that self-affirmation elicits reward-related processing.

These two studies used different populations, which suggests that the neural correlates of self-affirmation extend from undergraduates to community-dwelling adults. This is consistent with the wealth of previous research on self-affirmation, which has found benefits for a range of ages and ethnicities (Cohen & Sherman, 2014). Study 2's self-affirmation task differed from the one used in Study 1 in that it used a different list of personal values and no pictures, but it yielded similar effects. This provides converging evidence that increased VS activity during self-affirmation is not specific to viewing personal value pictures. Rather, the VS is sensitive to thinking about one's most important value. Although the difference in VS activity between self-affirmation and yoked control was statistically significant for the left VS but not quite significant for the right VS, the pattern was in the same direction for both regions.

Whole-brain results showed that, in addition to activating the VS, self-affirmation led to greater activity in regions typically associated with thinking about the self (the precuneus in Study 1; the medial prefrontal cortex in Studies 1 and 2). Indeed, self-affirmation requires participants to reflect on their preferences, which makes these findings unsurprising. However, self-affirmation also led to greater activity in self-processing regions compared with its yoked control, which still required participants to think about their own preferences. The difference was that the self-affirmation experimental condition had participants think about their top-ranked personal value. Self-affirmation may lead to a deeper processing of self-related information, which may also be a key ingredient in self-affirmation's effects on behavior.

The present studies employed stringent control conditions. For the self-affirmation task, participants received the same instructions for both conditions; the only difference was the participant's prior ratings of the personal values shown. This allowed us to conclude that it was not preference judgments about important values per se that activated reward circuitry; rather, it was about focusing on one's most important personal values. Whereas many standard self-affirmation manipulations use a control condition in which participants think about why a less important value might be important to someone else, our design provided a more specific test of the neural activity involved in the self-affirmation condition, providing insight into a possible mechanism for self-affirmation.

One important question for future studies is whether this neural-reward account of self-affirmation can explain the subsequent cascade of neural and psychological effects observed in previous studies (Creswell et al., 2005; Falk et al., 2015; Legault et al., 2012; Sherman et al., 2000). Falk et al. (2015) showed that activity in the ventromedial prefrontal cortex in response to health messages was greater in participants who performed a self-affirmation task than in participants who performed a control task, and their findings may be consistent with our findings. Specifically, the ventral striatum shows functional connectivity with the ventromedial prefrontal cortex (Di Martino et al., 2008). It is possible, then, that VS activity during self-affirmation activates a cascade of neural effects, including increased ventromedial prefrontal cortex activity, which in turn lead to psychological and behavioral changes. Our findings could also be consistent with the finding that self-affirmation led to greater neurophysiological error-related negativity during subsequent tasks (Legault et al., 2012). Specifically, there is evidence that reward and positive affect increase correlates of error-related negativity event-related potentials, which might relate to improved conflict adaptation (Larson, Perlstein, Stigge-Kaufman, Kelly, & Dotson, 2006; Sturmer, Nigbur, Schacht, & Sommer, 2011). Therefore, it is plausible that self-affirmation activates reward processing, which increases error-related negativity and causes a shift in strategy that leads to improved performance (Legault et al., 2012). Further research should investigate the subsequent neural and behavioral processes that follow self-affirmation's reward activity.

There are a few limitations to these studies. In Study 1, we chose to have participants think about the toaster attributes most important to an average college student to ensure this task was not inadvertently affirming. Future work should have participants make decisions that are important to them, but not in the values domain. In Study 1, the experimental and control conditions were in separate runs, which is nonstandard for fMRI studies. Because self-affirmation findings sometimes show lasting effects (Cohen et al., 2006), this design was selected to provide participants with a break to prevent carryover. Study 2 employed a more typical design with blocks of affirmation and control randomly ordered in one run. However, the results were the same for both studies. In these studies, self-affirmation was manipulated via values affirmation. Although this is the most common self-affirmation operationalization used, it is not the only one. Our results may be specific to this values-affirmation procedure, and future studies could determine whether all self-affirmation operationalizations rely on similar neural substrates.

These findings provide insight into the neural mechanism by which self-affirmation reduces threat responding. Recent work has found that rewarding stimuli (e.g., sweet foods, sweet drinks, or sexual stimuli) lead to reductions in stress responding (Creswell, Pacilio et al., 2013; Ulrich-Lai et al., 2010). This effect extends to social rewards also, given that social support activates reward regions, such as the VS (Inagaki & Eisenberger, 2012; Strathearn, Fonagy, Amico, & Montague, 2009), and has been shown to reduce threat-related neural activity (Eisenberger et al., 2011; Younger, Aron, Parke, Chatterjee, & Mackey, 2010). It is possible that self-affirmation relies on similar neural mechanisms to reduce threat responding. In the present article, self-affirmation (vs. control) led to greater VS activity, which could correspond with activation decreases in neural threat regions during subsequent tasks. In turn, this could contribute to the array of threat reduction benefits that self-affirmation has been shown to foster. Future studies should assess whether this proposed reward-system mechanism underlies the stress-buffering effects shown in previous self-affirmation studies. Although we suggest a reward-related mechanism, it is possible that the reward associated with self-affirmation may be distinct from non-self-related reward (e.g., food, winning money). Future studies could investigate the possible distinct and overlapping neural reward circuitry underlying different reward processes.

Footnotes

1. Participants also completed another self-affirmation task in which they were asked to think about important values for 23 seconds at a time (a task more similar to the self-affirmation manipulations involving writing; Cohen et al., 2000). However, because the neuroimaging results suggested that this manipulation was not successful, we do not focus on this task here. The blocks in this task were modeled separately from the blocks in the task of interest. Details of this task procedure and results are included in supplemental information.

Table 1. Brain Regions More Active During Self-Affirmation Minus Yoked Control Compared to Non-Affirmation Minus Yoked Control in Study 1

Anatomical Region	Brodmann Area	Hemisphere	x	y	z	t	k
Ventral Striatum		Left	-3	15	-6	3.48	29
Medial Prefrontal Cortex	10		0	54	-6	4.15	330
Occipital Cortex	18	Right	6	-78	-3	4.02	321
Subgenual Anterior Cingulate Cortex	24	Left	-18	24	-6	3.40	22
Thalamus		Right	3	-9	3	4.04	46
Middle Temporal Cortex	39	Left	-36	-63	12	3.45	36
Rostrolateral Prefrontal Cortex	9	Left	-24	30	36	4.41	40

Table 2. Brain Regions More Active During Self-Affirmation Compared to Control in Study 2

Anatomical Region	Brodmann Area	Hemisphere	x	y	z	t	k
Ventrolateral Prefrontal Cortex	47	Left	-51	27	-3	4.14	135
VS/Putamen		Left	-21	21	-6	3.63	
Ventrolateral Prefrontal Cortex	47	Right	33	27	-9	3.65	24
Medial Prefrontal Cortex	10	Right	9	60	18	3.74	27
Rostrolateral Prefrontal Cortex	10	Right	21	63	9	4.18	30
Dorsolateral Prefrontal Cortex	46	Right	45	30	21	3.82	62
Dorsomedial Prefrontal Cortex	9	Left	-12	51	21	3.36	24
Supplementary Motor Area	6		-6	24	54	4.13	276
Angular Gyrus	40	Left	-54	-66	39	3.74	24

Note: Activations were significant at $p<.005$, 20 voxels. Statistics in the *t* column show values at peak coordinates. Cluster voxel extent is shown in column *k.* The *x, y* and *z* coordinates are in Montreal Neurological Institute (MNI) space. An activation that does not include a *k* value extends from the larger cluster listed above that activation.

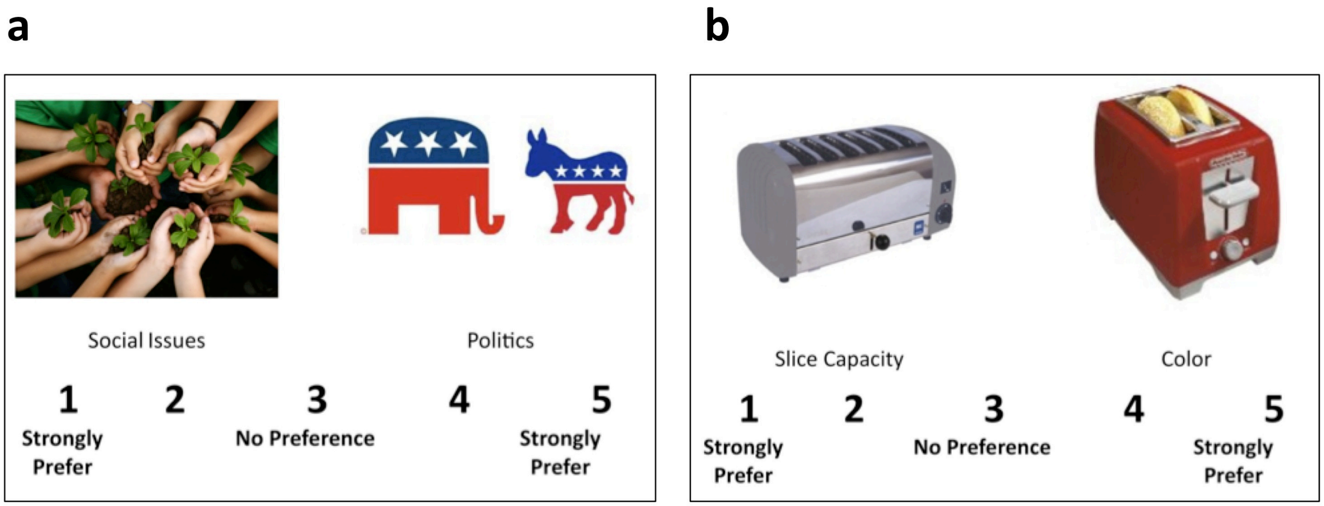

Fig. 1. Examples of trials for each condition. (a) Self-affirmation task trial example. In the self-affirmation condition, one of the value/image combinations included their top ranked value. The control condition included their lowest ranked value. (b) Non-affirmation task trial examples. In the non-affirmation experimental condition, one of the attribute/image combinations included their top ranked attribute. The control condition included their bottom ranked attributes.

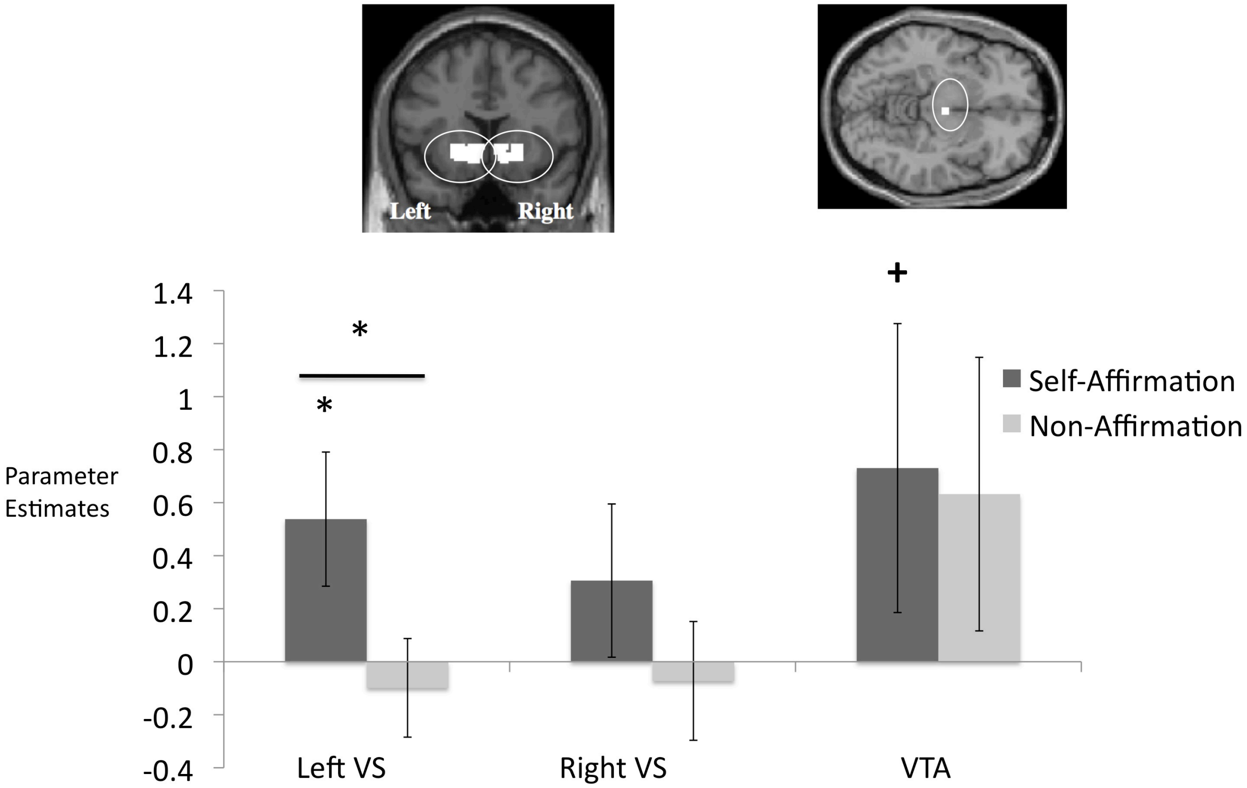

Fig. 2. Parameter estimates from left and right ventral striatum (VS) and ventral tegmental area (VTA) ROIs during each condition compared to its yoked control. Error bars represent standard errors. The asterisk indicates a significant result (p<.05) and the plus sign indicates a marginally significant result (p<.10).

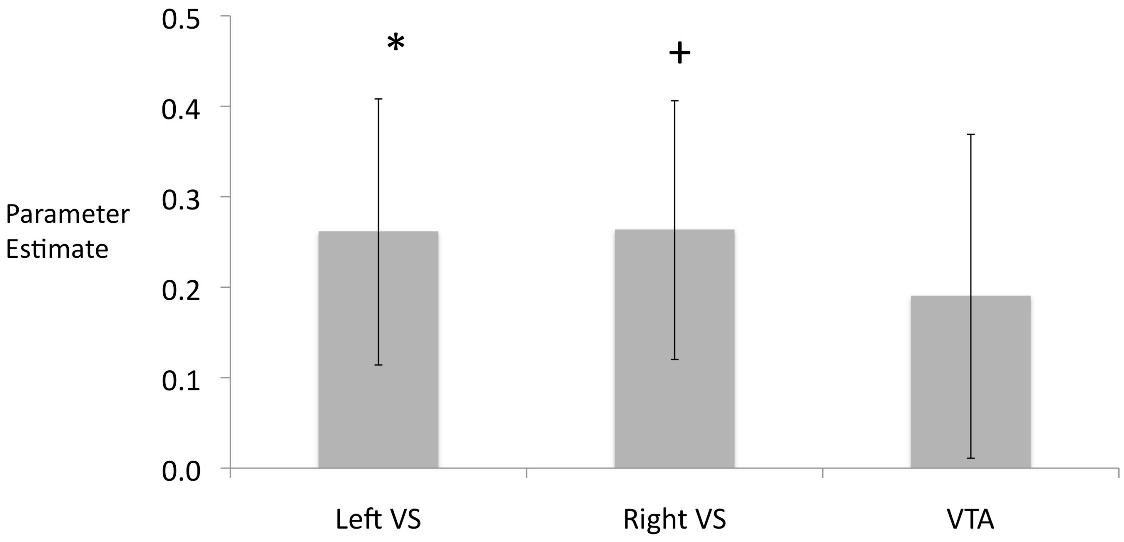

Fig. 3. Parameter estimates from left and right ventral striatum (VS) and ventral tegmental area (VTA) ROIs during self-affirmation versus control. Error bars represent standard errors. The asterisk indicates a significant result (p<.05) and the plus sign indicates a marginally significant result (p<.07).

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Supplemental Information

Values Chosen By Participants

Table 1. Frequency of Personal Values Chosen by Participants in Study 1

Value	Percentage who Chose It
Art	15%
Politics	0%
Religion	10%
Science/Theory	50%
Social Issues	25%

Table 2. Frequency of Toaster Attributes Chosen by Participants in Study 1

Attribute	Percentage who Chose It
Capacity	6%
Color	0%
Shape	6%
Size	55%
Versatility	33%

Table 3. Frequency of Personal Values Chosen by Participants in Study 2

Value	Percentage who Chose It
Art	5%
Friends and Family	60%
Independence	5%
Music	5%
Religion	15%
Spontaneity	10%

*all other values (Science, Creativity, Business, Sense of Humor, Athletics) were chosen 0 times

Self-Affirmation Free Thought Task, Study 2

Methods. In this task, participants were instructed to think about the value on screen in a block-design for the fMRI scanner. In the experimental condition blocks, participants were given the instruction "Important to You" and were asked to think about their top ranked value (shown on screen) and a time in which it was important to their life. In the control condition blocks, participants were given the instruction “Important to Others” and were asked to think about their 9^{th} ranked value (shown on screen) and why it could be important to the Average American. Participants were trained on these instructions before scanning. Each block was 23 seconds long, and there were 3 blocks of each condition.

fMRI data analysis. Imaging data were analyzed using Statistical Parametric Mapping (SPM) software (SPM8; Wellcome Department of Cognitive Neurology, Institute of Neurology, London, England). For preprocessing, functional and anatomical images were realigned, co-registered to the structural scan, and normalized using the DARTEL procedure in SPM8. For each participant, the 23 seconds of self-affirmation trials were modeled as the self-affirmation blocks, and the 23 seconds of control trials were modeled as the control blocks. Implicit baseline consisted of the rest periods (viewing a fixation cross, as in Study 1).

Linear contrasts for the self-affirmation condition compared to the control condition were computed for each participant. These individual contrast images were then used in group-level analyses. The approach for analyzing group level results in the VS and VTA ROIs was the same as in Study 1. Whole brain analyses were conducted in the same manner as in Study 1. One participant was excluded for not following task instructions. Data from the remaining 20 participants (14 healthy controls) are analyzed here.

Results. There were no significant differences in left VS activity ($t(19)=-1.47$, $p = .922$), right VS activity ($t(19) = -.73$, $p = .763$) or VTA activity ($t(19)= -1.15$, $p = .868$). In addition, whole brain analyses reveal no clusters of activation other than left (coordinates: -9, -75, -6) and right (coordinates: 18, -75, -6) occipital cortex.

Discussion. Due to these results, it looks like the design of this task was not effective, perhaps because the blocks were too long. Thus, it may be challenging for participants to think about one topic for 23 seconds in the scanner, and this may have led to mind-wandering in both conditions. Because we cannot determine what participants were thinking about during these trials, these results should be interpreted with caution.

Paper 2: Examining the Neural Substrates for Self-Affirmation, Social Support and Basic Reward

Abstract

Self-affirmation (reflecting on important personal values) has been shown to reduce stress responding and broaden one's perspective. Recent work has also found that self-affirmation leads to reward-related neural activity. Other stimuli that have been known to activate reward-related neural activity (social support and basic reward) also have been shown to be effective in reducing stress. Thus, we explored the extent to which these three tasks (self-affirmation, social support and basic reward) lead to similar neural activity. In an fMRI study with 25 college students, self-affirmation, social support and basic reward activated reward- and caregiving-related neural activity. However, neural activity during self-affirmation and social support correlated with each other, but not with neural activity during basic reward. In addition, neural activity during self-affirmation was correlated with a measure of prosocial behavior. These results suggest that self-affirmation and social support might be a slightly different category of rewarding stimuli than basic reward. The findings extend theory by showing that although all three strategies may reduce stress responding and led to increased reward- and caregiving-related neural activity, their mechanisms may differ.

Introduction

In stressful situations, humans turn to a variety of different coping strategies to manage their stress, including thinking about or communicating with loved ones, reflecting on their own accomplishments and skills, and, in some cases, eating comfort foods. Provided these strategies effectively reduce stress, they may have similar underlying mechanisms for their effects. However, they may also differ in key ways. Here we investigate the similarities and differences between the neural correlates of self-affirmation, social support, and basic reward, three strategies that have been shown to lead to reward-related neural activity as well as reduce stress responding.

Self-Affirmation. Self-affirmation, the process of affirming one's global self-concept, has been shown to have a wide range of benefits, including reducing various forms of threat and enhancing learning and social outcomes (for a review see Sherman & Cohen, 2006 and Cohen & Sherman, 2014). Self-affirmation can take many forms, but is experimentally induced most often by having individuals reflect on their important personal values. There are two main paradigms that have been used in the literature to lead people to affirm values, including making decisions about which values (from a given list) are most important to the individual as well as writing about one's most important personal value (for a review see McQueen & Klein, 2006). These experimental manipulations have been the basis of a flourishing line of research in self-affirmation.

Specifically, self-affirmation has been shown to reduce the negative educational consequences of stereotype threat and discrimination (Cohen, Garcia, Apfel, & Master, 2006; Cohen, Garcia, Purdie-Vaughns, Apfel, & Brzustoski, 2009; Cohen & Sherman, 2014), and reduce defensiveness toward targeted health messages (for reviews see Harris & Epton, 2009, 2010). In addition, participants who completed a self-affirmation task showed reduced cortisol responses to a stressful social evaluation task compared to control participants (Creswell, Welch, Taylor, Sherman, Gruenewald, & Mann, 2005). Similarly, another study found that self-affirmation also reduced epinephrine levels, a biological marker of distress (Steptoe, 1987), in university students during exam periods (Sherman, Bunyan, Creswell & Jaremka, 2009). The benefits of self-affirmation are not just limited to acute threats. For example, following self-affirmation, students with high levels of chronic stress performed better on a purported intelligence test than students who did a control task (Creswell, Dutcher, Harris, Klein & Levine, 2013). Self-affirmation has also been shown to have a wide range of effects on behavior following social stress; including improving self-control following rejection (Burson, Crocker, & Mischkowski, 2012), improved emotional recovery from ostracism (Hales, Wesselmann, & Williams, 2016), and enhancing secure social behavior weeks later for those most insecure socially (Stinson, Logel, Shepherd, & Zanna, 2011). These results suggest that self-affirmation can reduce various forms of threat, including psychological stress and the biological cascade that follows a stressor.

A newer line of work in self-affirmation has been investigating whether self-affirmation can lead to positive outcomes in the absence of stress. Indeed, self-affirmation (vs. a control task) has been shown to increase prosocial behavior (Lindsay & Creswell, 2014) and enhance eudaimonic well-being (Nelson, Fuller, Choi & Lyubomirsky, 2014). In addition, spontaneous self-affirmation, the tendency to self-affirm as a possible coping style, has been shown to be associated with more engagement in one’s own healthcare, including leading to more positive perceptions of communication with providers, and a greater likelihood to seek out health information for others as well as themselves (Taber, Howell, Emanual, Klein, Ferrer, & Harris, 2016), even in the absence of threat.

One possible mechanism underlying the beneficial effects of self-affirmation comes from a study that found that self-affirmation leads to increased feelings of social connection compared to control, and that this mediated the relationship between self-affirmation and reduced threat (Crocker, Niiya & Mischowski, 2009). Indeed, other studies have found that self-affirmation and social support similarly lead to increases in feelings of social connection and self-worth (Dutcher & Eisenberger, 2013). Taken in concert with findings of increased other focus (Taber et al., 2016) and prosocial behavior (Lindsay & Creswell, 2014), it is possible that self-affirmation is a process that broadens one's focus from themselves, to their place in a social world. Indeed, recent empirical work has consistently found that self-affirmation may benefit those under threat by enhancing feelings of social belonging (Shnabel, Purdie-Vaughns, Cook, Garcia & Cohen, 2013; Cook, Purdie-Vaughns, Garcia, & Cohen, 2012). Thus, self-affirmation may be a more social process than it was originally understood to be.

Recent work has focused on the neural correlates of self-affirmation, as well. This work has shown that self-affirmation led to enhanced ventral striatum (a key region in the reward network in the brain) activity compared to making other value judgments (Dutcher et al., 2016), and that reward-related neural activity to self-affirmation seems to be related to health behavior change (Cascio et al., 2016). Therefore, it is likely that self-affirmation leads to a multitude of benefits via a reward-related neural mechanism. However, it is unclear whether self-affirmation is more similar to a social reward, like social support, or a basic reward, like rich foods.

Social Support. Social support has been repeatedly shown to buffer individuals against the negative effects of stress (for a review see Cohen & Wills, 1985). Social support can be defined in a variety of ways including, the perception of the availability of support, being the recipient of actions of support (e.g., being emotionally comforted, having one's hand held during a painful medical procedure), and integration into a social network (i.e., having social ties and connections; Seeman, 1996). Research has identified two different ways of measuring social support: objective and subjective. Objective measures of social support are typically operationalized as the presence of certain social ties in the individual's network; whereas subjective measures of social support typically are evaluated based on how the individual perceives their availability or receipt of social support (McNally & Newman, 1999). Both objective and subjective measures of social support have been shown to buffer individuals against stress, as well as enhance well-being and health (Cohen & Wills, 1985).

Social support has been shown to reduce threat and stress responding. For example, the presence of a friend (compared to alone) reduced cardiovascular responding to a socially stressful task (Kamarack, Manuck, & Jennings, 1990). This effect is not limited to supportive friends, as even a supportive confederate can attenuate cardiovascular stress responding to a social stressor (Lepore, Allen & Evans, 1993). Self-reports of social support have also been linked to reduced cortisol responding to a social stressor and decreased distress-related responding in the brain to a social exclusion task (Eisenberger, Taylor, Gable, Hilmert, & Lieberman, 2007). This effect is not specific to laboratory stressors, as a great deal of work has identified how social support moderates life stressors as well (for a review see Cobb, 1976). Evidence consistently supports a stress buffering model of social support.

Across several studies, social support has been shown to activate the ventromedial prefrontal cortex (VMPFC) and the ventral striatum (VS), key regions in the reward network. Mothers viewing images of their babies show increased activation in VS compared to when they view unknown babies (Strathearn, Fonagy, Amico, & Montague, 2009). Reading warm, supportive messages from support figures leads to activation in the VS compared to neutral messages from support figures (Inagaki & Eisenberger, 2013). In addition, viewing pictures of romantic partners during a painful experience leads to increases in VMPFC (Eisenberger et al., 2011) and VS (Younger, Aron, Parke, Chatterjee, & Mackey, 2010) compared to viewing images of strangers during a painful experience. Furthermore, activations in these regions while viewing partner images lead to reductions in activation in threat-responding regions such as the dorsal anterior cingulate cortex (dACC) and anterior insula (AI) (Eisenberger et al., 2011; Younger et al., 2010) as well as reduced self-reports of pain (Master, Eisenberger, Taylor, Naliboff, Shirinyan, & Lieberman, 2009; Eisenberger et al., 2011; Younger et al., 2010).

An interesting area of research has begun to look at *providing* social support and the possible benefits that it may confer to the provider. Giving support to others has been linked with lower mortality rates (Brown, Nesse, Vinokur, & Smith, 2003) and reduced sympathetic stress responding to a social stressor (Inagaki & Eisenberger, 2015). Importantly, providing support relies on neural regions involved in reward and caregiving (VS, septal area; Inagaki & Eisenberger, 2012), which are known to reduce threat and stress responding (Eisenberger & Cole, 2012). Self-reports of giving support have been shown to be correlated with VS and septal area activity to affiliation and prosocial tasks (Inagaki et al., 2016), as well. Relatedly, another region associated with prosocial reward and affiliation is the subgenual anterior cingulate cortex (subACC). Work has found that this region is active when an individual is making a charitable donation compared to when they are receiving a monetary reward themselves (Moll, Krueger, Zahn, Pardini, de Oliveira-Souza, & Grafman, 2006) and when viewing a picture of their child (compared to a known non-kin child) (Bartels & Zeki, 2004). In summary, the septal area and subACC, key regions in the caregiving network, are associated with social reward and social support, in addition to reward-related regions.

Similar to self-affirmation, social support leads to enhanced reward-related neural activity, reduces stress, and is associated with prosocial behaviors. In addition, social support is associated with increases in activity in caregiving regions.

Basic Reward. We know anecdotally and empirically that individuals turn to drugs, rich foods, and other sources of reward in the face of stress (Tomiyama, Dallman, & Epel, 2011; Taylor, Sherman, Kim, Jarcho, Takagi, & Dunagan, 2004; Zellner et al., 2006), and recent work has sought to identify if this tendency results in effective reduction of stress responding. Reward is often defined as a stimulus or event that an animal will work to obtain (Murray, 2007). Classically, reward stimuli of interest have included reproduction and reproductive behaviors, food and drink, and drugs. These basic reward stimuli have been linked to VS and VMPFC activity, hence these regions being considered 'reward-related' regions. Specifically, in humans, the VMPFC and VS are implicated in reward processing for monetary incentives (Knutson, Adams, Fong & Hommer, 2001), drugs (Wise, 1996) and sweet-tasting solutions (Berns, McClure, Pagnoni & Montague, 2001). Unsurprisingly, rewarding stimuli are linked to increases in reward-related neural activity. However, it is less clear why rewards might be a way people cope and whether they are effective in doing so.

A few animal studies have investigated whether basic reward leads to stress- or threat-reduction. Early fear conditioning evidence suggested that rewarding stimuli might inhibit threat responding (Dickinson & Pearce, 1977). There is also evidence that a sucrose drink leads to reduced stress (as measured by HPA axis activity and autonomic nervous system activation) during a restraint stress paradigm in rats, as does saccharin-drink (Ulrich-Lai et al., 2010). This suggests that this effect is specifically driven by the pleasurable sweet-taste of the drink. Importantly, intragastric lavage of sucrose, in which the animal never actually tastes the drink but does receive the metabolic components, does not lead to this same decrease in threat (Ulrich-Lai et al., 2010). This supports the hypothesis that the effect of the sucrose drink on threat responding is not due to the caloric intake, but rather the pleasant sweetness. This implicates the role of the reward system in the relationship between sucrose drink and threat responding. Interestingly, when researchers allowed rats sexual contact, their physiological stress responses were dampened to a subsequent restraint stress experience (Ulrich-Lai et al., 2010). Moreover, chronic exposure to mild reward (sucrose drink) led to reduce HPA activation (corticosterone) to an acute stressor (Christiansen, DeKloet, Ulrich-Lai & Herman, 2011). While there is some animal evidence that reward dampens threat, less work has been done in human behavioral research. However, one experimental study to date found that showing erotic images (a basic reward) compared to neutral images to male participants, led to decreased HPA axis activity (cortisol) to a known social evaluative stressor, the Trier Social Stress Task (Creswell, Pacilio, Denson & Satyshur, 2013). This evidence suggests that there may be stress-inhibitory effects of different kinds of rewards.

Specific Aims. Self-affirmation, social support and basic reward all lead to reward-related neural activity and reduce stress responding. However, self-affirmation and social support tasks have been shown to be associated with more social and prosocial outcomes than are basic reward tasks. Therefore, it is possible that self-affirmation, social support and basic reward may all rely on reward-related neural activity, but differ in terms of the relationship between this activity and prosocial outcomes. In addition, if self-affirmation is a social reward like social support, it is possible, then, that they both lead to increased caregiving-related neural activity, whereas basic reward will not.

The present study aimed to explore the similarities and differences between self-affirmation, social support and basic reward by: 1) assessing if all three led to similar neural activity in reward- and caregiving-related regions, 2) assess the correlations among the three tasks to determine how much activations in these regions are associated, and 3) examining the extent of similarity between correlations with a measure of prosociality and neural activity in each of the three tasks. In order to directly compare the neural mechanism for each of these tasks, analyses must be conducted on the same group of subjects. Thus, each participant completed (in counterbalanced order): 1) a self-affirmation values task in which subjects made decisions about values that are important to them compared to a control task, 2) a social support task in which subjects made decisions about characteristics of their support figure that they appreciate compared to a control task, and 3) a basic reward task in which subjects made decisions about rich foods that they prefer compared to a control task.

We hypothesized that self-affirmation, social support, and basic reward would all activate reward-related regions in comparison to their respective control conditions. Moreover, we hypothesized that activation in reward-related regions during self-affirmation, social support, and basic reward would overlap, suggesting that these tasks might rely on a similar neural mechanism. However, as both self-affirmation and social support are more social in nature, we hypothesized that both self-affirmation and social support (compared to their respective controls) would lead to greater caregiving-related neural activity, whereas reward (compared to control) would not.

In addition, we examined the extent to which neural activity to self-affirmation, social support and basic reward were correlated across individuals. To determine whether these tasks shared a neural mechanism, we correlated activity in each task (compared to its control) to the other two tasks. We hypothesized that the neural activity during self-affirmation, social support, and basic reward (compared to control) within each participant would be highly correlated in reward-related regions. On the other hand, we hypothesized that while self-affirmation and social support would correlate in caregiving-related regions, activity in both tasks would not correlate with basic reward activity in caregiving-related regions.

Finally, because self-affirmation and social support are associated with greater prosociality, we were interested in investigating whether neural activity to these tasks was correlated with a measure of helping others, whereas neural activity during basic reward would not be correlated with helping others. Understanding the extent of similarities and differences among self-affirmation, social support, and basic reward may improve our understanding of these coping strategies. In particular, because so little is known about the mechanism for self-affirmation, the results from this study will push our understanding of self-affirmation theory, by identifying if self-affirmation is more similar to social reward or basic reward.

Method

Participants

Twenty-five participants (17 female, mean age = 20.7 years) completed the study procedures. All participants were deemed eligible for fMRI (i.e., right-handed, not claustrophobic, free of implanted metal, and not pregnant). We aimed to collect data from a minimum of 25 participants, and data collection stopped at the targeted enrollment. Thirty-six percent of participants were White, 20% were Latino/Chicano, 16% were East Asian, 16% were

South Asian, 8% were Filipino, and 4% were Black/African American. The University of California, Los Angeles, institutional review board approved all procedures.

Procedure

Task procedures

Before the scanning session, participants were emailed a survey link in which they were asked to rank 3 lists in order of their preferences (with 1 being most preferred, 11 being least preferred): 11 personal values, 11 tasty foods, and 11 characteristics in their support figure (for a frequency table reporting the items selected by participants and pilot testing results, see the Supplemental Materials). From this, we were able to create tasks that were specific to each participant's preferences for the scanning session. During the scan, participants viewed instructions and words through scanner-compatible goggles and were asked to make responses (when appropriate) using a four-button button box. Each of the three tasks included a matched control condition for comparison.

Self-affirmation task. The self-affirmation task utilized a block design. Each block included three decision-making trials, and each trial lasted for 8 seconds, for a total of 24 seconds per block. In the self-affirmation trials, participants were shown pictures of two values with the value label beneath each image. In the majority of trials, one of the values shown was their top ranked value (See Figure 1). They were asked to think about these two values and the role the values play in their lives and then indicate which of the two displayed values was more important to them on a 4-point scale (1=strongly prefer [value on left], 2=slightly prefer [value on left], 3=slightly prefer [value on right], 4=strongly prefer [value on right]). In the control trials, participants were shown pictures of two values, but the value label beneath each image was scrambled. Participants were asked to indicate which of the two labels was scrambled such that the letters were in alphabetical order (1=label on left, 4=label on right). The images shown were taken directly from the self-affirmation trials, thus participants saw their top rated value image on most trials. Participants completed 3 blocks of each type interleaved together in each of two runs.

Social Support task. The social support task utilized a block design. Each block included three decision-making trials, and each trial lasted for 8 seconds, for a total of 24 seconds per block. In the social support trials, participants were shown the pictures of their chosen support figure, with two characteristic labels beneath the image. In the majority of trials, one of the characteristics shown was their top ranked characteristics (See Figure 1). They were asked to think about these two characteristics and ways in which their support figure might display those characteristics and then indicate which of the two displayed characteristics they appreciated most in their support figure on a 4-point scale (1=strongly prefer [characteristic on left], 2=slightly prefer [characteristic on left], 3=slightly prefer [characteristic on right], 4=strongly prefer [characteristic on right]). In the control trials, participants were shown the same image, but the characteristic label beneath the image was scrambled. Participants were asked to indicate which of the two labels was scrambled such that the letters were in alphabetical order (1=label on left, 4=label on right). The images shown were taken directly from the social trials, thus participants saw their top rated characteristic label scrambled on most trials. Participants completed 3 blocks of each type interleaved together in each of two runs.

Basic Reward task. The reward task utilized a block design. Each block included three decision-making trials, and each trial lasted for 8 seconds, for a total of 24 seconds per block. In the reward trials, participants were shown pictures of two rich foods with the food label beneath each image. In the majority of trials, one of the foods shown was their top ranked food (See

Figure 1). They were asked to think about these two foods and how much they would like to consume them and then indicate which of the two displayed foods was more important to them on a 4-point scale (1=strongly prefer [food on left], 2=slightly prefer [food on left], 3=slightly prefer [food on right], 4=strongly prefer [food on right]). In the control trials, participants were shown pictures of two foods, but the food label beneath each image was scrambled. Participants were asked to indicate which of the two labels was scrambled such that the letters were in alphabetical order (1=label on left, 4=label on right). The images shown were taken directly from the reward trials, thus participants saw their top rated food image on most trials. Participants completed 3 blocks of each type interleaved together in each of two runs.

All three of the tasks were presented in each of the two runs. The two runs did not display the tasks in the same order, and the order of the tasks in each run was randomly assigned.

Measure of Helping Others

Following the completion of the scan, participants filled out the Social Provisions Scale (Cutrona & Russell, 1987), including the Opportunities for Nurturance subscale. Opportunities for Nurturance assesses how individuals provide assistance for others on a 1 (strongly disagree) to 4 (strongly agree) scale. Items from this subscale had a high degree of reliability (alpha = .738). Items were averaged. In addition, participants completed a survey in which they indicated how many hours they would be willing to volunteer for six different charities (Doctors without Borders, United Animal Nations, St. Jude's Children's Hospital, Red Cross, Alzheimer's Association, UNICEF). Each charity was presented with a brief description of the charity's aim, and participants were asked to indicate how many hours they would be willing to volunteer to the charity from 0 to 6 hours. The items had a high degree of reliability (alpha = .941), and items were converted to match the Opportunities for Nurturance scale using a linear transformation.

Transformed Hours Willing to Volunteer items and Opportunities for Nurturance items were highly reliable (alpha = .910). The sum of the average of Opportunities for Nurturance and the average of Hours Willing to Volunteer formed the measure of Helping Others.

Follow-up questionnaire

After all participants had completed the study procedures, participants were emailed a survey link in which they were asked to think back to the tasks and report on their experiences. Participants were asked to report on how much they enjoyed the task, how good they felt about themselves during the task, and how socially connected they felt during the task on a 7-point Likert scale (1=not at all, 7=a great deal). 18 of the 25 participants filled out the follow-up questionnaire. For each of the three items, the average score across all participants was calculated.

Image acquisition

Data were acquired on a Siemens Prisma 3-T MRI scanner. Foam padding surrounded each participant's head to reduce head movement. For each participant, we acquired a high-resolution structural MPRAGE scan—TR = 2300 ms, TE = 2.32ms, matrix size = 256 × 256, FOV = 240 mm, 192 slices (0.9 mm thick), flip angle = 8°, and bandwidth = 200 Hz/pixel . The preferences tasks were completed in two equal functional scans lasting 610 s (about 10 min, 10 s)— TR = 2,000 ms, TE = 24 ms, matrix size = 64 × 64, FOV = 200 mm, 36 axial slices (3 mm thick), flip angle = 90°, and bandwidth = 2604 Hz/pixel.

fMRI data analysis

Imaging data were analyzed using SPM8 (Wellcome Department of Cognitive Neurology, Institute of Neurology, London, England). For preprocessing, we first manually reoriented to align brains along a horizontal AC-PC line with an image origin at the anterior commissure. For functional images, the run's first image parameters were applied to each subsequent volume in the respective run to correct for head motion. Structural MPRAGE images were normalized to Montreal Neurological Institute space (MNI space) using DARTEL algorithms. The DARTEL procedure then smoothed using an 8mm Gaussian kernel, full-width at half maximum. Prior to first level analyses, images were visually inspected for accurate normalization.

A general linear model was used to estimate the effects of interest for each of the three tasks. We defined three models per task: experimental trials compared to baseline, control trials compared to baseline, and experimental compared to control trials. All models use the canonical hemodynamic response function for convolution and modeled serial correlations as an AR(1) process. In addition, all models included covariates of no interest. These included the six motion parameters from image realignment and regressors that modeled time points where the in-brain global signal change exceeded 2.5 SDs of the mean global signal change or where the estimated motion was greater than a .5mm translation or .5-degree rotation. Then we applied a 128s high pass filter.

For each participant, the 24 seconds of self-affirmation decision-making trials were modeled as the self-affirmation blocks, and the 24 seconds of self-affirmation control trials were modeled as the self-affirmation control blocks. This procedure was repeated for the social support and basic reward tasks, as well. Implicit baseline consisted of the rest periods (viewing a fixation cross). Thus, our contrasts of interest include: self-affirmation > baseline, self-affirmation control > baseline, social support > baseline, social support control > baseline, basic reward > baseline, and basic reward control > baseline. In addition, for the correlation analyses, contrasts comparing each experimental condition to its matched control were created (self-affirmation > self-affirmation control, social support > social support control, and basic reward > basic reward control. These individual contrast images were then used in group-level analyses in one-sample t-tests.

Region of interest analyses. Based on a priori predictions that self-affirmation, social support and reward would activate reward-related regions, we examined activity within relevant ROI networks, Reward and Caregiving. Parameter estimates representing the average activity across all voxels in the ROI were extracted and averaged, and estimates were entered into SPSS for further analysis. We ran two repeated measures ANOVAs with task (self-affirmation, social support and basic reward) and condition (experimental and control) as independent variables and each of the two ROI networks as dependent variables. Significant effects were followed up with t-tests. A standard statistical threshold of $p < .05$, one-tailed was used for these ROI analyses.

The Reward ROI network was defined by combining VS and VMPFC ROIs. VS ROIs were structurally defined using the automated anatomic labeling (AAL; Tzourio-Mazoyer et al, 2002) atlas by combining the caudate and putamen from the atlas and constraining at $-24 < x < 0$, $4 < y < 18$, and $-12 < z < 0$ for the left ROI, and $0 < x < 24$, $4 < y < 18$, and $-12 < z < 0$ for the right ROI (based on ROIs from Inagaki & Eisenberger 2012 and Dutcher et al., 2016). The VMPFC ROI was created in the MarsBar Toolbox (http://marsbar.sourceforge.net; Brett et al., 2002) and centered at (-6, 51, -15) within a 8mm radius based on previous work investigating social support in the brain (Eisenberger et al., 2011).

The Caregiving ROI network was defined by combining the septal area and subACC. The septal area ROI used was based on previous work investigating prosocial emotions in the brain (Zahn et al., 2009) and constrained between $y = 0$ and $y = 14$. The subACC ROI was created in the MarsBar Toolbox and centered at (0, 26, -5) within a 10mm radius based on previous work investigating charitable donation in the brain (Moll et al., 2006).

Conjunction analyses. To examine shared neural activity to self-affirmation, social support and reward, we tested all three tasks (each relative to its control condition) against the conjunction null, which identifies neural regions that were active during all three tasks. To follow up, we completed conjunctions comparing each task to each of the two other tasks (self-affirmation and reward, self-affirmation and social support, and social support and reward). A voxel extent threshold of 46 voxels, $p < .001$ was used to identify significant clusters of activation.

Correlation analyses. To examine associations between neural activity and psychosocial variables, we ran bivariate correlation analyses. A standard statistical threshold of $p < .05$, one-tailed was used for all correlation analyses.

Results

Self-reports of enjoyment and social connection. To understand the psychological experiences of the participants, we investigated differences in self-reported enjoyment and feelings of social connection during each of the tasks. A repeated-measures ANOVA revealed no significant differences in levels of enjoyment across the three tasks, $F(2, 34) = .62$, $p = .273$. Self-affirmation ($M = 4.39$, $SD = 1.29$), social support ($M = 4.61$, $SD = 1.20$) and basic reward ($M = 4.50$, $SD = 1.10$) all led to similar reports of enjoyment for participants. There were also no significant differences in how good participants felt about themselves during the task, $F(2, 34) = .10$, $p = .452$, with self-affirmation ($M = 4.33$, $SD = 1.53$), social support ($M = 4.39$, $SD = 1.14$), and basic reward ($M = 4.44$, $SD = 1.42$) all leading to similar levels of feeling good. However, a repeated-measures ANOVA revealed significant differences in feelings of social connection across the three tasks, *F*(2, 34) = 8.67, *p* < .001. Self-affirmation (*M* = 3.61, *SD* = 1.33) and social support (*M* = 3.94, *SD* = 1.73) led to greater feelings of social connection than basic reward (*M* = 2.83, *SD* = 1.47). Indeed, post-hoc paired samples t-tests a marginal difference in levels of social connection between self-affirmation and social support, *t*(17) = -1.46, *p* = .082, but significant differences between self-affirmation and basic reward, *t*(17) = 3.11, *p* = .003, and social support and basic reward, *t*(17) = 3.34, *p* = .002.

Reward Network. To investigate the main effects of task and condition and the interaction between them, we ran a task (self-affirmation, social support, and basic reward) by condition (experimental and control) repeated measure ANOVA with Reward Network activity as the dependent measure. Results revealed a significant main effect of condition, *F*(1, 24) = 55.47, *p* < .001 (Figure 2) and a significant main effect of task (collapsing across condition), as well, *F*(2, 48) = 3.25, *p* = .048 (Figure 2). We were also interested in assessing whether activity in this ROI would differ between the tasks by investigating the interaction between task and condition. Results revealed no significant interaction in the Reward network ROI, *F*(2, 48) = .94, *p* = .396.

We then followed up on the significant main effect of condition with t-tests to assess whether each task's experimental condition was different from its control condition. Consistent with our hypothesis, self-affirmation (compared to control) led to greater Reward network activity, *t*(24) =5.51, *p*<.001, mean parameter estimate = .190, 95% CI = [.119, .261]; social support (compared to control) led to greater Reward network activity, *t*(24) = 4.39, *p*<.001 mean parameter estimate = .142, 95% CI = [.075, .209]; and basic reward (compared to control) led to greater Reward network activity, *t*(24) = 3.96, *p*<.001, mean parameter estimate = .132, 95% CI = [.063, .200].

In addition, we ran pairwise t-tests to follow up on the main effect of task. Results revealed that there was greater activity in the Reward network ROI during the social support task (*M* = .080, *SD* = .169) compared to the self-affirmation task (*M* = -.003, *SD* = .152), *t*(24) = 2.66, *p* = .007, as well as the basic reward task (*M* = -.007, *SD* = .142), *t*(24) = 1.85, *p* = .039. There was no difference in neural activity in the Reward network ROI between the self-affirmation and basic reward tasks, *t*(24) = -.29, *p* = .389.

Caregiving Network. We then repeated this repeated measures ANOVA with the Caregiving network ROI. Results revealed a significant main effect of condition, *F*(1, 24) = 35.42, *p* < .001 (Figure 3) and a significant main effect of task (collapsing across condition), *F*(2, 48) = 3.08, *p* = .028 (Figure 3). We were also interested in assessing whether activity in this ROI would differ between the tasks by investigating the interaction between task and condition. Results revealed no significant interaction in the Caregiving network, *F*(2, 48) = 1.07, *p* = .176.

We then followed up on the significant main effect of condition with t-tests to assess whether each task's experimental condition was different from its control condition. Consistent with our hypotheses, self-affirmation led to greater Caregiving network activity than the control condition, *t*(24) = 4.16, *p*<.001, mean parameter estimate = .192, 95% CI = [.097, .287], and social support led to greater Caregiving network activity compared to control, *t*(24) = 5.24, *p*<.001, mean parameter estimate = .191, 95% CI = [.115, .265]. However, inconsistent with our hypotheses, basic reward (compared to control) also led to greater Caregiving activity, *t*(24) = 4.42, *p*<.001, mean parameter estimate = .137, 95% CI = [.073, .200].

Finally, we followed up on the main effect of task with pairwise t-tests. Results showed that neural activity in the Caregiving network ROI was greater in the social support task (*M* = -.099, *SD* = .131) compared to the self-affirmation task (*M* = -.193, *SD* = .200), *t*(24) = 2.13, *p* =

.022, as well as the basic reward task (*M* = -.196, *SD* = .199), *t*(24) = 2.16, *p* = .021. There was no difference in neural activity in the Caregiving network ROI between the self-affirmation and basic reward tasks, *t*(24) = .76, *p* = .470.

Conjunction. To investigate the degree of overlap in neural activity during the self-affirmation, social support and basic reward tasks, we ran a conjunction investigating the voxels that were active for all three tasks (compared to their respective controls). Results showed significant overlapping activation with peak activity in clusters in cuneus, middle temporal gyrus and MPFC extending into VMPFC, VS and subACC, but not septal area (Figure 4; see Table 1 for full list). Consistent with the ROI results, self-affirmation, social support and basic reward all led to significant Reward-related neural activity. We also investigated the degree of overlap between each of the tasks. For each of the pairwise conjunction analyses (self-affirmation and social support, self-affirmation and basic reward, social support and basic reward) there was overlapping activity in VMPFC, VS and subACC, but not septal area (See supplemental information for table listing all activations).

Correlations of Neural Activity Between Tasks. In order to assess the degree to which self-affirmation, social support, and reward similarly activate the Reward network we conducted a series of bivariate correlations (See Figure 5). Results suggest that Reward network activity during the self-affirmation and social support tasks were marginally positively correlated, *r* = .328, *p* = .055. Reward network activity during the self-affirmation and basic reward tasks were marginally negatively correlated, *r* = -.301, *p* = .072. However, this correlation seemed to be driven by one participant; removing this participant from the analyses changed the correlation to non-significant, *r* = -.081, *p* = .353. Finally, Reward network activity during the support and basic reward tasks were not correlated, *r* = .229, *p* = .135.

In order to assess the degree to which the self-affirmation, social support, and reward tasks led to correlated patterns of neural activity in the Caregiving network, we conducted bivariate correlations as we did for the Reward network (See Figure 5). Consistent with our hypotheses, in the Caregiving ROI, neural activity to the self-affirmation and social support tasks were fairly highly correlated, $r = .515$, $p = .004$, whereas neural activity to the self-affirmation and basic reward tasks were not correlated, $r = .180$, $p = .195$. Finally, neural activity to the social support and basic reward tasks were also significantly correlated, $r = .428$, $p = .017$.

Correlations Between Neural Activity and Prosocial Tendencies. To further understand the possible differences between the self-affirmation, social support, and basic reward tasks, we investigated whether activity in the pre-specified regions during the tasks correlated with a measure of prosociality, Helping Others.

We examined whether neural activity during the self-affirmation, social support, and basic reward tasks in the Reward network would correlate significantly with Helping Others. Activity in the Reward network during self-affirmation (compared to control) was significantly correlated with Helping Others, $r = .349$, $p = .044$ (Figure 6). However, activity in the Reward network during social support (compared to control) was not correlated with Helping Others, $r = .205$, $p = .164$, nor was activity in the Reward network during basic reward (compared to control), $r = -.130$, $p = .268$.

We repeated these same correlations with activity in the Caregiving network. Activity in this network during self-affirmation (compared to control) was correlated with Helping Others, $r = .415$, $p = .019$; however, activity in this network was not correlated with Helping Others during the social support task, $r = .175$, $p = .202$, or basic reward task, $r = .005$, $p = .490$.

Discussion

Self-affirmation, social support and basic reward all led to increased Reward and Caregiving-related neural activity. Indeed, a conjunction analysis revealed that there were clusters of activity for each of the three tasks that overlapped in VS, VMPFC, and MPFC, among other regions. This suggests that the three psychological processes are similar, to an extent. However, when investigating the correlations amongst the neural activity across the three tasks, some differences emerged. Specifically, Reward and Caregiving activity during social support and self-affirmation were correlated. Activity during basic reward and self-affirmation were not correlated in the Reward or Caregiving networks. Social support and basic reward activity were correlated in the Caregiving network. This suggests that although these three tasks lead to similar neural activity, neural activity across tasks is not perfectly correlated, indicating a possible difference in the mechanisms by which self-affirmation, social support, and basic reward reduce stress. Specifically, it is possible that self-affirmation and social support could be considered 'social rewards' as they both lead to Reward activity, and activity in this network is correlated across the two tasks, but not with basic reward. Perhaps this special category of 'social reward' could lead to different outcomes than basic reward, and further research could investigate this possibility.

As greater evidence that self-affirmation and social support are 'social rewards' that differ from basic reward, participants reported remembering greater feelings of social connection during self-affirmation and social support compared to basic reward. There was no significant difference in enjoyment of the tasks, though. These findings are consistent with previous work suggesting that self-affirmation leads to feelings of social connection and that self-affirmation is not so much about the 'self', but rather about transcending the self and connecting with the world around us (Lindsay & Creswell, 2014; Crocker et al., 2009). A social reward neural mechanism could provide the foundation for connecting with the surrounding world, and subsequently lead to fewer consequences of relevant threats and stressors.

Due to previous research suggesting that self-affirmation and social support may lead to enhanced prosocial behavior, we investigated whether neural activity during these tasks was correlated with a measure of Helping Others, hypothesizing that basic reward would not show this same pattern. In partial support of this hypothesis, neural activity in Reward and Caregiving ROIs during self-affirmation was correlated with Helping Others. However, neural activity in both networks during basic reward was not significantly correlated with Helping Others. This suggests that self-affirmation may also be associated with enhanced social outcomes, in addition to personally relevant stress reduction outcomes. It, therefore, may be an advantage for individuals to turn to self-affirmation to cope with stress as these strategies could lead to greater helping behaviors, which might cyclically reduce stress as well (Inagaki & Eisenberger, 2015). It is also possible that those individuals who help others more show greater reward or caregiving activity to engaging in self-affirmation. The direction of this association is unclear, but studies could explore this association further. Understanding the direction of the relationship could shed light on how individuals benefit from social rewards.

One surprising finding was that activity during each task, collapsed across condition, was significantly higher for social support than for self-affirmation or basic reward in both ROI networks. Because the control conditions also displayed the same images as the experimental conditions, it is possible the social support images led to greater neural activity in both Reward and Caregiving networks than did the images in the self-affirmation and basic reward tasks. The tasks do differ in that the social support and social support control trials only display one image, the other tasks and respective control conditions showed two images. Therefore, it is possible that the difference in features of the tasks could be contributing to this observed difference in neural activity.

The participants for this study were university students with high ratings of closeness with the support figures they chose. It is possible that more lonely or isolated populations would show different patterns of neural activity to the social support task. Along these lines, recent work has found that people with higher levels of loneliness show *greater* VS activity to viewing an image of a support figure, suggesting a yearning for support and closeness (Inagaki et al., 2015). Consistent with this idea of yearning, self-affirmation has been shown to be most effective, or exclusively effective, for those most in need of the intervention, such as stereotyped minority middle school students struggling in school, or those with the highest levels of chronic stress (Cohen et al., 2009; Creswell, Dutcher et al., 2013). Future studies could discover whether vulnerable populations show stronger reward- or caregiving-related neural activity to self-affirmation and social support, and if this is different from their sensitivity to basic reward stimuli. It will be important for future research to understand what makes individuals more and less sensitive to these strategies. In particular, understanding the individual differences could lead to a greater understanding of what will work, for whom and when, to reduce threat responding.

This work has a couple important limitations to note. First, while these tasks are based on manipulations for social support and basic reward, they were built to have a similar format to the self-affirmation task for comparison purposes. It is possible that other differences (or similarities) would emerge if we repeated this work with other sorts of social support and basic reward tasks. Moreover, future research should investigate if these are similar to other ways of manipulating social support and basic reward. Second, it will be important to probe deeper to discover what psychological similarities and differences these tasks lead to. Although self-affirmation, social support and basic reward all lead to reward- and caregiving-related neural activity, the experience of these manipulations may differ in critical ways that could help lead to improvements in future stress-reduction interventions.

This study provides a first step in identifying the neural similarities and differences across three distinct rewarding tasks. Results suggest that self-affirmation, social support, and basic reward all lead to increased activity in two neural networks (reward, caregiving), but that activity in these regions is similar for self-affirmation and social support, but not reward. As further evidence of self-affirmation being a category of social reward, neural activity during this task is associated with a measure of helping others. Thus, while there is evidence that self-affirmation, social support, and basic reward all reduce threat responding, and all show similar neural activity in reward- and caregiving-related networks, the associations between them suggest a possible different mechanism by which these strategies have their effects. Future research should investigate further whether self-affirmation and social support, or social rewards, lead to decreased threat responding via the same mechanism, and if this mechanism differs from that of basic reward.

Table 1. Brain Regions Active in Conjunction of Self-Affirmation, Social Support and Basic Reward

Anatomical Region	Brodmann Area	Hemisphere	x	y	z	t	k
Cerebellum		Left	-18	-90	-36	5.02	61
Cuneus			0	-96	15	12.18	4124
Middle Temporal Gyrus	21	Right	60	0	-18	6.99	113
Medial Prefrontal Cortex	10	Left	-12	45	42	9.31	2569
Posterior Cingulate Cortex/Angular Gyrus	39/40	Right	51	-57	33	5.59	101

Note: Activations were significant at $p<.001$, 46 voxels. Statistics in the *t* column show values at peak coordinates. Cluster voxel extent is shown in column *k.* The *x, y* and *z* coordinates are in Montreal Neurological Institute (MNI) space.

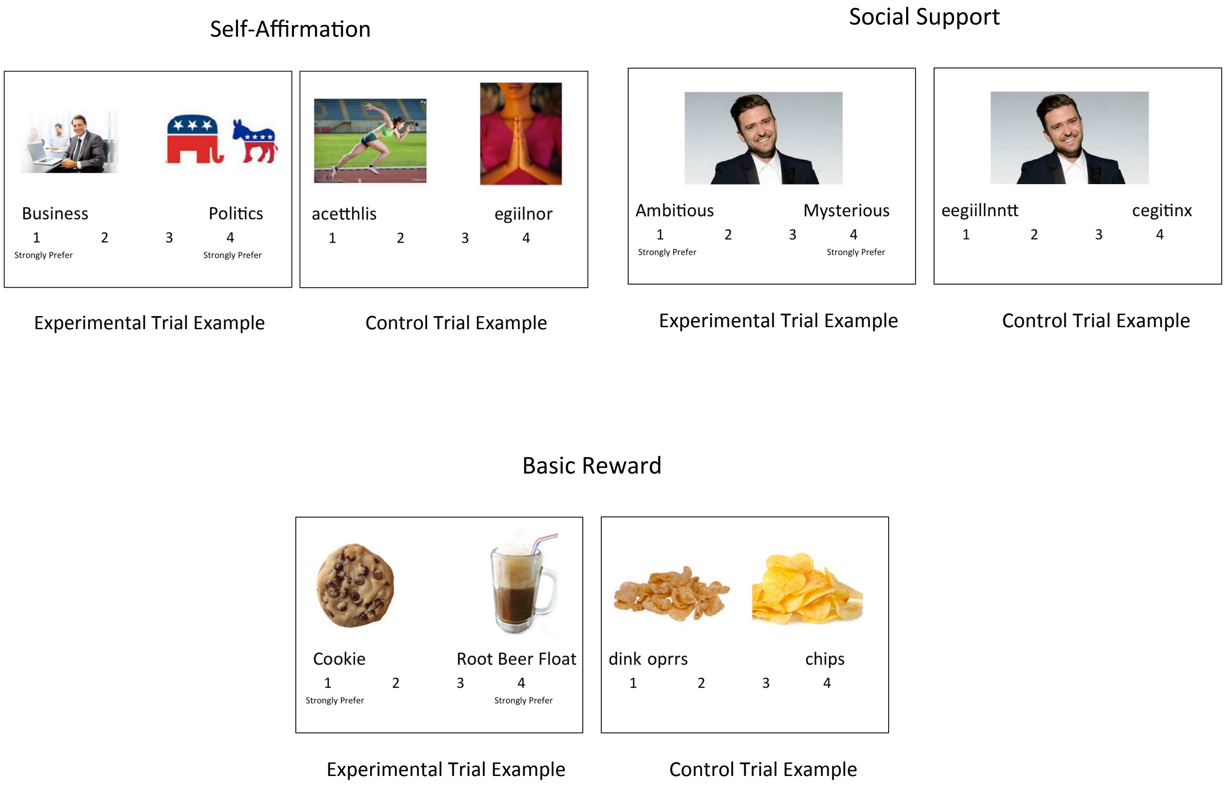
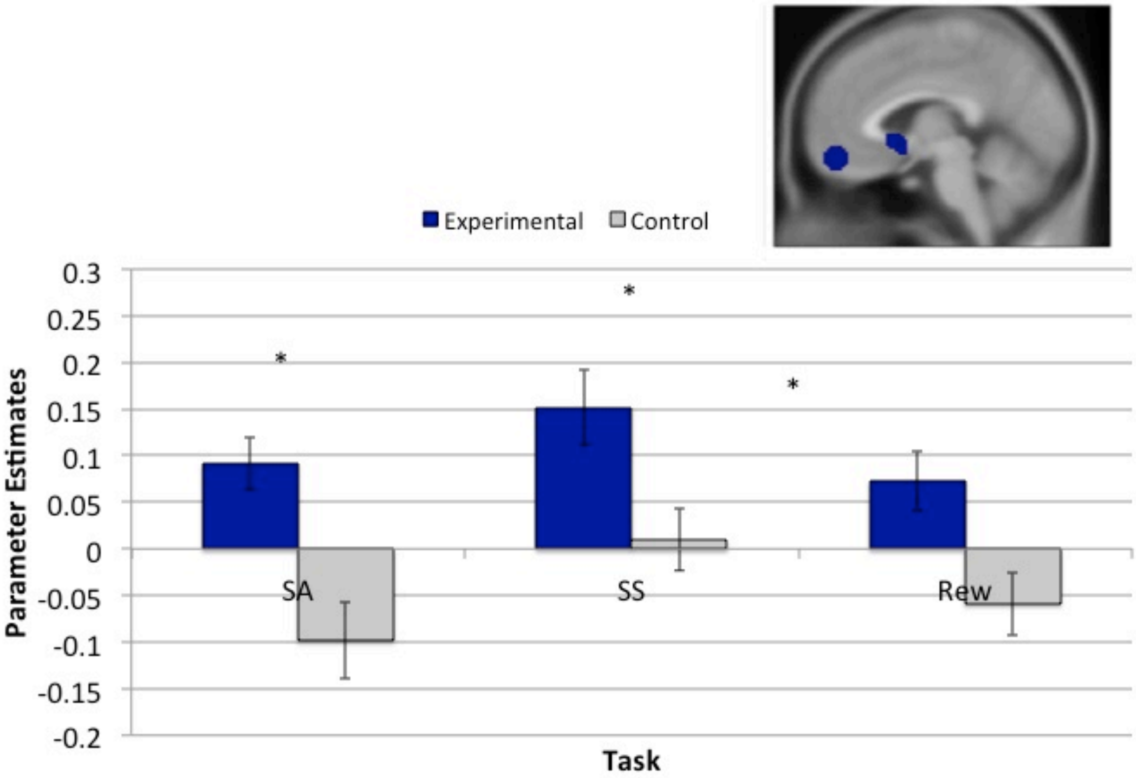


Figure 1. Examples of Trails from the self-affirmation, social support and basic reward trials.



** p = <.001

Figure 2. Activity in the Reward Network during self-affirmation, social support and basic reward and the respective control conditions.

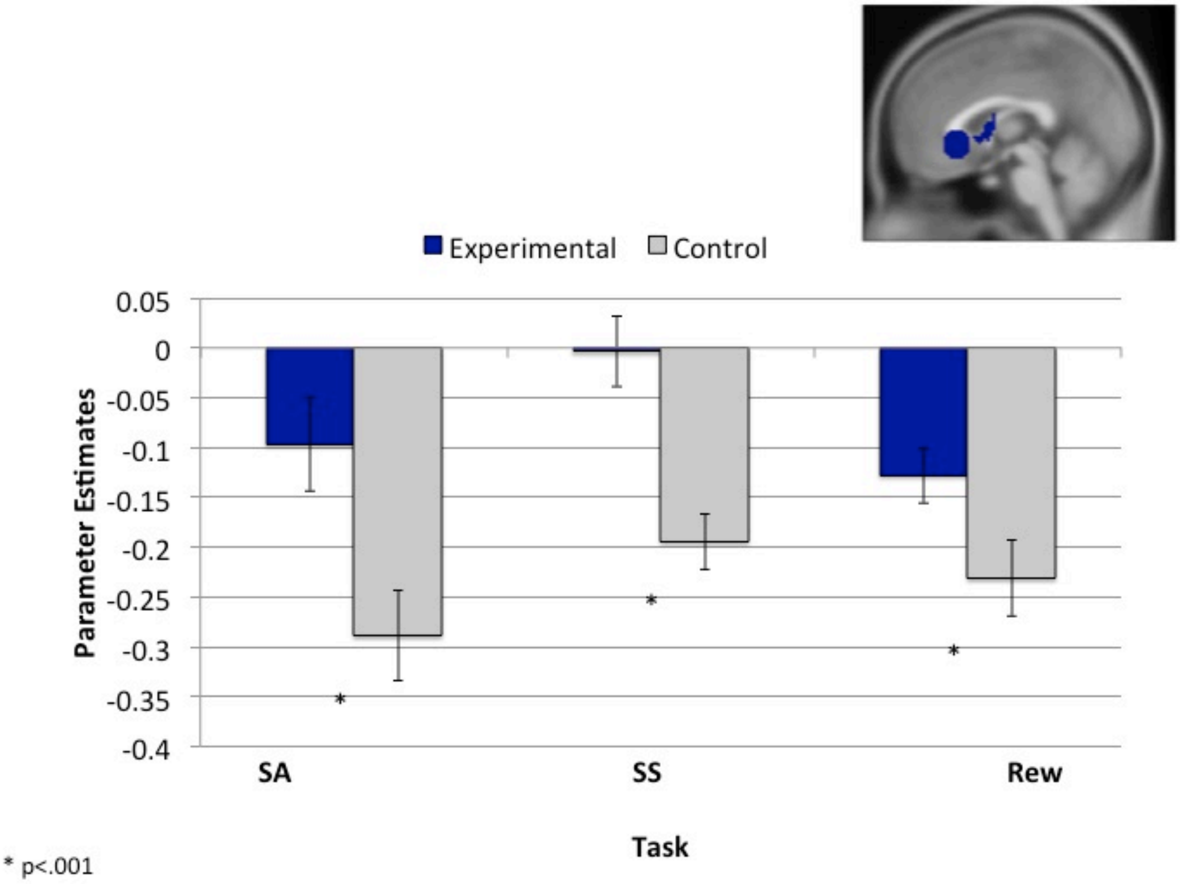


Figure 3. Activity in the Caregiving Network during self-affirmation, social support and basic reward and the respective control conditions.

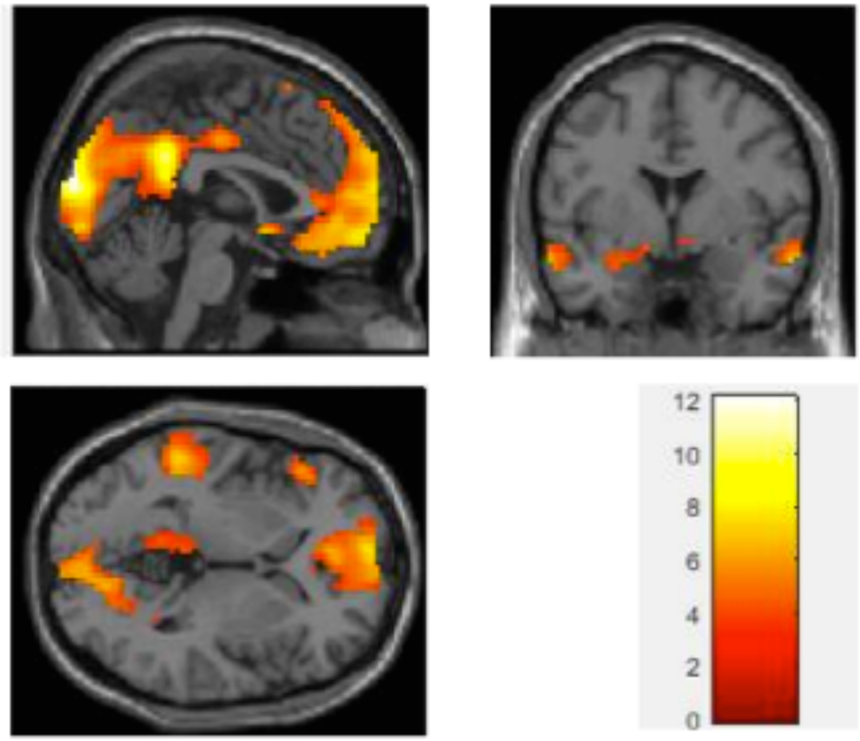


Figure 4. Image displaying significant clusters of activation from conjunction of self-affirmation (vs. control), social support (vs. control) and basic reward (vs. control). Legend shows heat map of t-values. [images at x=0, y=0, z=0]

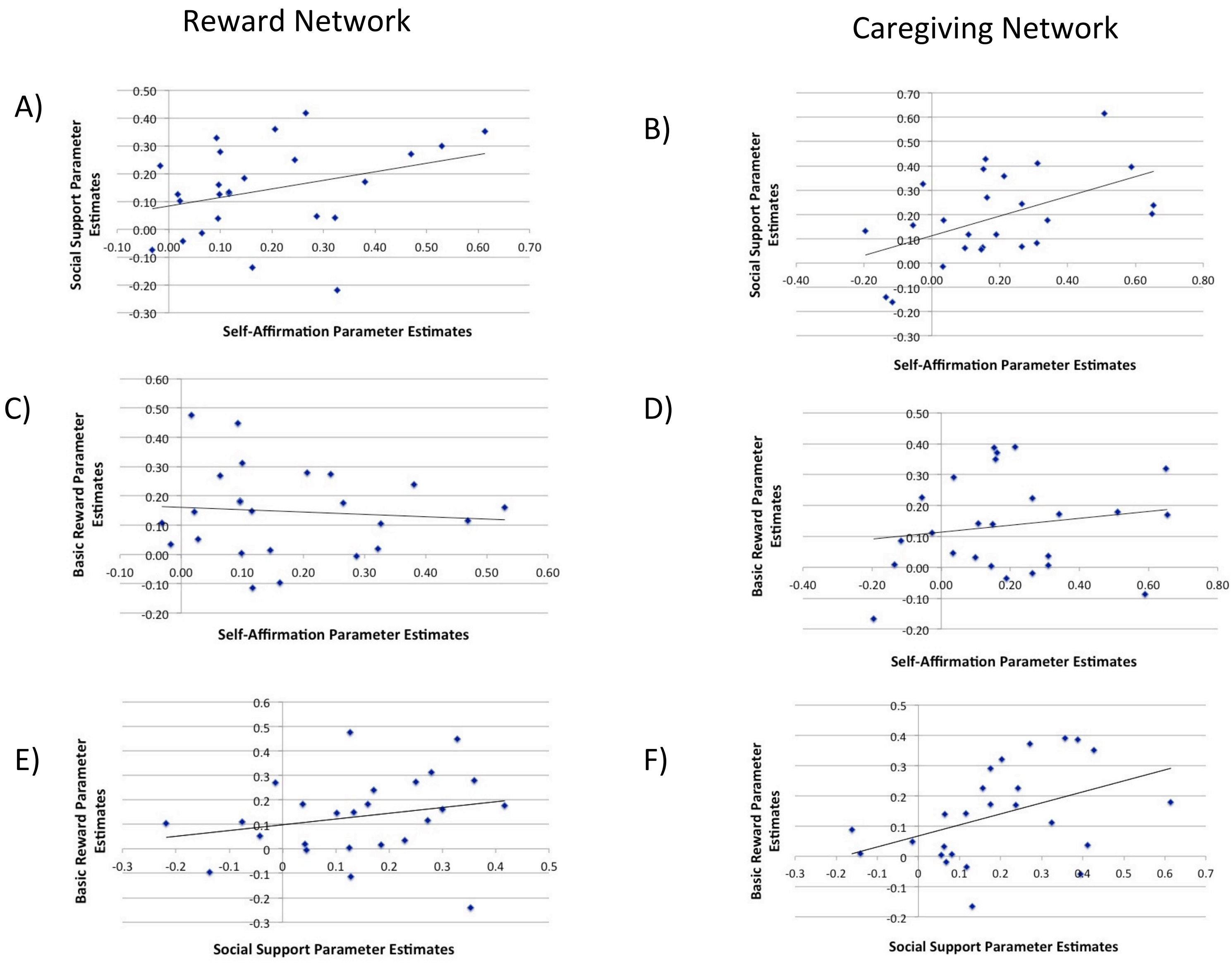


Figure 5. Correlations between neural activity in self-affirmation, social support and basic reward. Correlations based on activity in the Reward network ROI are in the left column, correlations based on activity in the Caregiving network ROI are in the right column. * indicates p<.05. A) Correlation between self-affirmation and social Support in Reward Network, *r* = .328*. B) Correlation between self-affirmation and social support in Caregiving Network, *r* = .515*. C) Correlation between self-affirmation and basic reward in Reward Network, *r* = .-.087, excluding multivariate outlier. D) Correlation between self-affirmation and basic reward in Caregiving Network, *r* = .180. E) Correlation between social support and basic reward in Reward Network, *r* = .229. F) Correlation between social support and basic reward in Caregiving Network, *r* = .428.

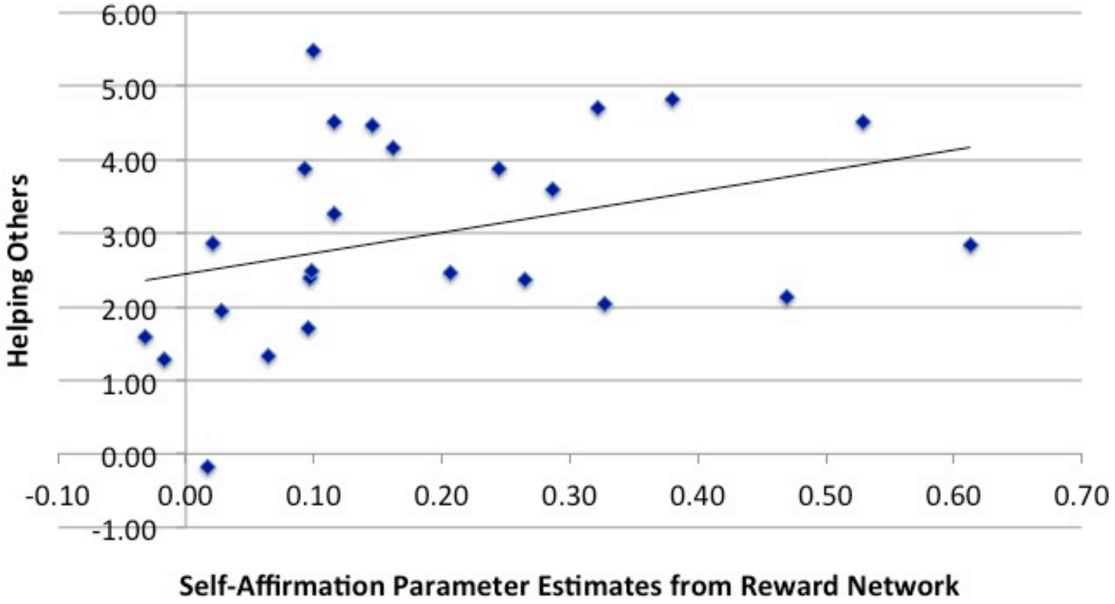


Figure 6. Correlation between Helping Others and Reward Network activity to self-affirmation.

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Supplemental Information

Table 1. Frequency of Personal Values Chosen by Participants for Self-Affirmation Task

Value	Percentage Who Chose It
Humor	28%
Creativity	12%
Music	12%
Science	12%
Social Issues	12%
Art	0%
Business	0%
Leadership	0%
Athletics	0%
Politics	0%
Religion	24%

Table 2. Frequency of Foods Chosen by Participants for Basic Reward Task

Food	Percentage Who Chose It
Pizza	16%
Tacos	12%
French Fries	16%
Hamburger	20%
Brownies	8%
Cookies	12%
Chips	0%
Donuts	4%
Root Beer Float	0%
Gummy Bears	4%
Pork Rinds	8%

Table 3. Frequency of Traits Chosen by Participants for Social Support Task

Traits	Mean Rating of Importance (*SD*)
Supportive	28%
Honest	24%
Understanding	12%
Loyal	32%
Intelligent	0%
Interesting	4%
Ambitious	0%
Exciting	0%
Outgoing	0%
Mysterious	0%
Edgy	0%

Pairwise Task Conjunction Results

Table 4. Brain Regions Active in Conjunction of Self-Affirmation and Social Support

Anatomical Region	Brodmann Area	Hemisphere	x	y	z	t	k
Cerebellum		Left	-27	-84	-33	7.23	158
Cerebellum		Right	24	-87	-33	13.96	7799
Inferior Temporal Gyrus	21	Right	63	-6	-18	7.48	170
Hippocampus		Right	27	-15	-15	5.44	46
Middle Temporal Gyrus		Right	51	-39	0	4.99	57
Angular Gyrus	39/40	Right	48	-54	30	5.80	190

Note: Activations were significant at p<.001, 46 voxels. Statistics in the *t* column show values at peak coordinates. Cluster voxel extent is shown in column *k.* The *x, y* and *z* coordinates are in Montreal Neurological Institute (MNI) space.

Figure 1. Self-Affirmation and Social Support Conjunction Image

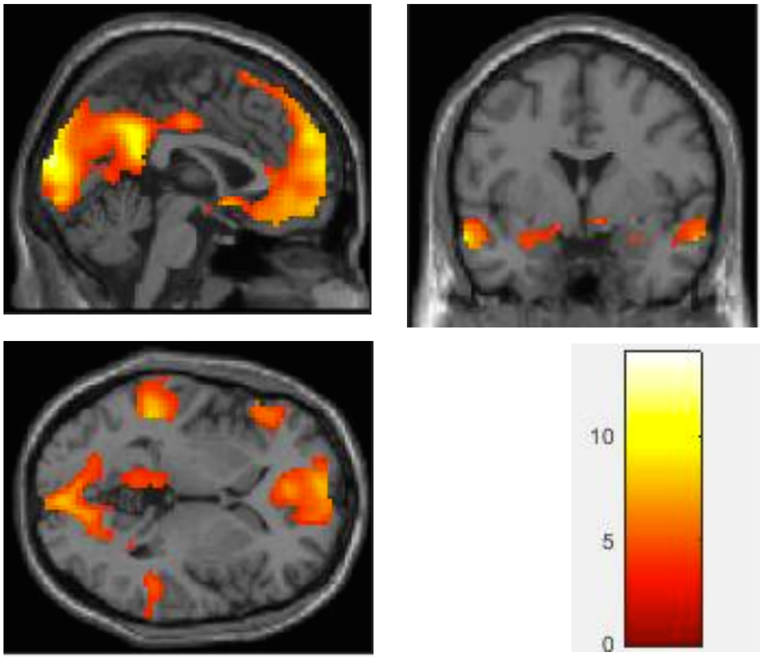


Table 5. Brain Regions Active in Conjunction of Self-Affirmation and Basic Reward

Anatomical Region	Brodmann Area	Hemisphere	x	y	z	t	k
Cerebellum		Left	-18	90	-36	5.02	61
Cuneus			3	-93	18	15.04	8419
Middle Temporal Gyrus	21	Right	60	0	-18	6.99	119
Angular Gyrus	39/40	Right	51	-57	33	5.59	101

Note: Activations were significant at p<.001, 46 voxels. Statistics in the *t* column show values at peak coordinates. Cluster voxel extent is shown in column *k.* The *x, y* and *z* coordinates are in Montreal Neurological Institute (MNI) space.

Figure 2. Self-Affirmation and Basic Reward Conjunction Image

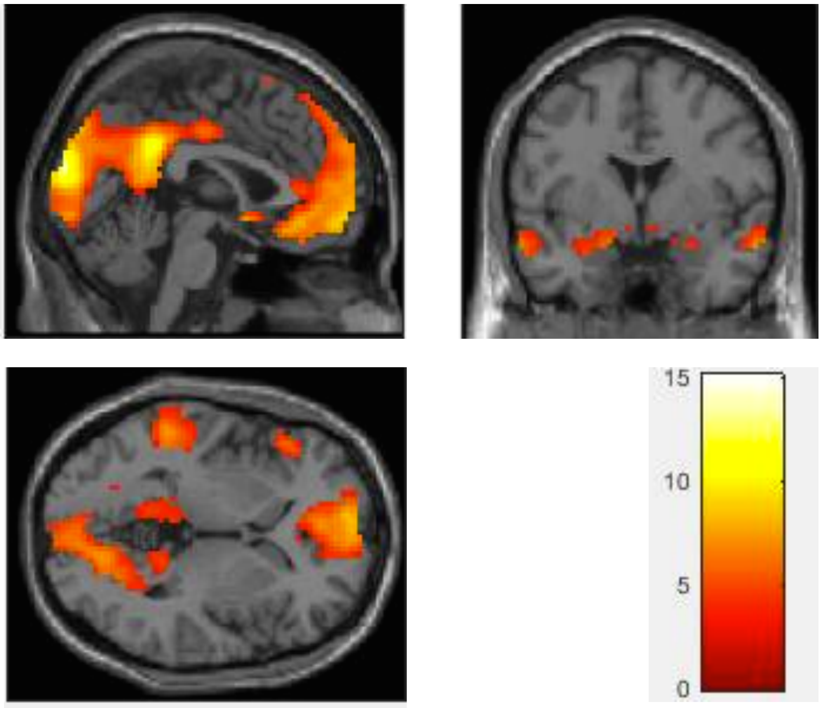
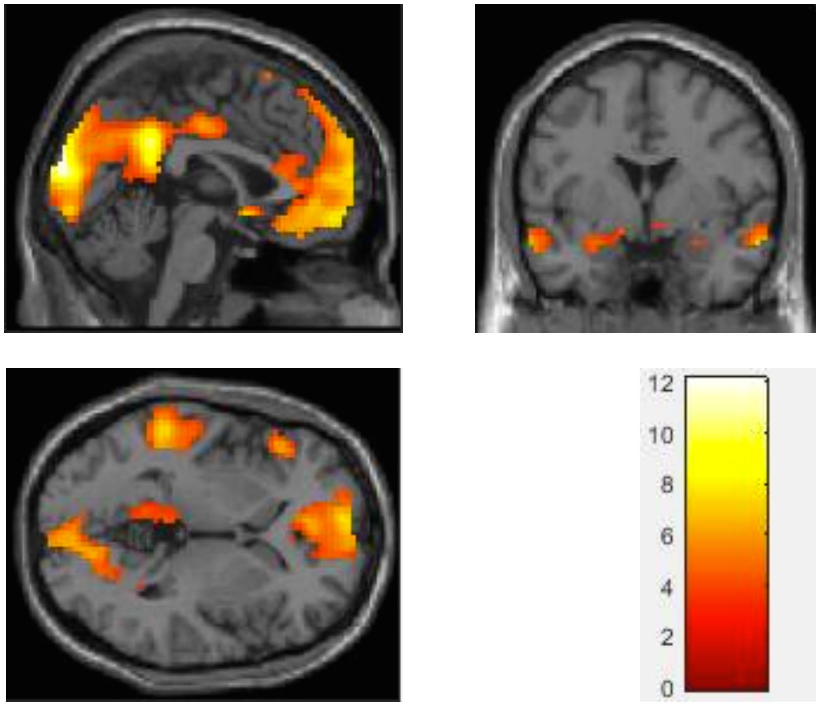


Table 6. Brain Regions Active in Conjunction of Social Support and Basic Reward

Anatomical Region	Brodmann Area	Hemisphere	x	y	z	t	k
Cerebellum		Left	-18	-90	-36	5.02	61
Cuneus			0	-96	15	12.18	4238
Right Temporal Pole	21	Right	51	18	-27	7.59	114
Medial Prefrontal Cortex		Left	-12	48	45	9.69	2676
Hippocampus		Right	27	-15	-15	5.01	66
Angular Gyrus	40	Right	57	-60	39	5.92	106

Note: Activations were significant at p<.001, 46 voxels. Statistics in the *t* column show values at peak coordinates. Cluster voxel extent is shown in column *k.* The *x, y* and *z* coordinates are in Montreal Neurological Institute (MNI) space.

Figure 3. Social Support and Basic Reward Conjunction Image



Pilot Studies

Pilot Study 1a

Participants

61 participants (41 males, *mean age* = 34.72 (*SD* = 11.00)) were recruited from Amazon's Mechanical Turk database of workers to participate in an online-based survey to rate how important different values, foods and traits in a support figure were to them. All participants

were residents of the United States of America. The University of California, Los Angeles, institutional review board approved all procedures.

Procedure

Participants were directed to an online survey link, in which they were asked to rate items in three different categories (personal values, foods, and traits in a supportive other). For personal values, participants were asked to rate how important the value listed was to them on a Likert scale (1= not at all important, 7 = extremely important). For foods, participants were asked to rate how much they liked the food listed on a Likert scale (1 = dislike extremely, 7 = like extremely). For traits in a supportive other, participants were asked to rate how important it was to them that this support figure had this trait on a Likert scale (1 = not at all important, 7 = extremely important).

Results

Value	Mean Rating of Importance (*SD*)
Humor	5.87 (1.13)
Creativity	5.33 (1.29)
Music	5.26 (1.41)
Science	5.25 (1.29)
Social Issues	4.95 (1.31)
Art	4.77 (1.41)
Business	4.46 (1.26)
Leadership	4.41 (1.53)
Athletics	4.33 (1.64)
Politics	4.25 (1.53)
Religion	2.66 (1.93)

Food	Mean Rating of Liking (*SD*)
Pizza	6.43 (0.69)
Tacos	6.20 (0.89)
French Fries	6.02 (1.15)
Hamburger	5.90 (1.34)
Brownies	5.66 (1.40)
Cookies	5.56 (1.26)
Chips	5.48 (1.15)
Donuts	5.34 (1.57)
Root Beer Float	4.21 (1.95)
Gummy Bears	4.20 (1.89)
Pork Rinds	3.56 (1.77)

Traits	Mean Rating of Importance (*SD*)
Supportive	6.28 (0.76)
Honesty	6.23 (0.86)
Understanding	6.23 (0.78)
Loyal	6.05 (1.09)
Intelligent	5.77 (1.19)
Interesting	5.72 (0.82)
Ambitious	5.28 (1.10)
Exciting	4.84 (1.27)
Outgoing	4.67 (1.50)
Mysterious	3.16 (1.44)
Edgy	2.57 (1.38)

The ratings for all three categories have a similar spread from the most important to least important on their respective lists.

Pilot Study 1b

Participants
75 participants (45 males, *mean age* = 38.35 (*SD* = 13.24)) were recruited from Amazon's Mechanical Turk database of workers to participate in an online-based survey to rate images that represented personal values and foods. Participants were residents of the United States of America. The University of California, Los Angeles, institutional review board approved all procedures.

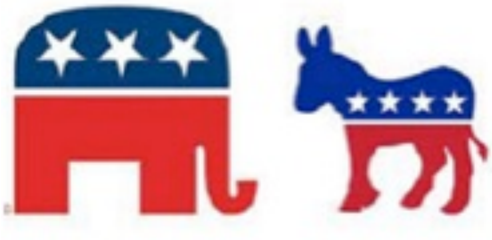
Procedure
Participants were directed to an online survey link, in which they were asked to images that represented different personal values and foods. For personal values, participants were asked to rate how much a variety of images were representative of the value listed (1= not at all representative, 5 = perfectly representative). For food images, participants were asked to rate how much a variety of images were representative of the food listed (1= not at all representative, 5 = perfectly representative).

Results
Of the shown images, the highest rated image for each value and food was selected for the larger study. The highest rated images for each value and food are shown below.

Values:

Art

Politics



Religion

Science

Business

Athletics

Humor

Music

Leadership

Social Issues

Creativity

Foods:

Pizza

French Fries

Tacos

Chips

Brownies

Donuts

Gummy Bears

Root Beer Float

Pork Rinds

Cookies

Hamburger

Pilot Study 1c

Participants

45 participants (23 males, *mean age* = 33.33 (*SD* = 8.73)) were recruited from Amazon's Mechanical Turk database of workers to participate in an online-based survey to rank order a list of personal values, tasty foods, and traits in a support figure. Participants were residents of the United States of America. The University of California, Los Angeles, institutional review board approved all procedures.

Procedure

Participants were directed to an online survey link, in which they were asked to rate items on three lists in order of importance to them. Participants rated lists of personal values, tasty foods and traits in a support figure. After they ranked the items on each list in order of importance to them, they were then asked to report on how hard was it for to decide how to select the order of their preferences on a 7-point Likert scale (1= very difficult, 7 = very easy).

Results

Participants found deciding how to select their order of preference for the personal values list ($M = 3.51$, $SD = 1.49$), tasty foods ($M = 3.36$, $SD = 1.61$), and traits in a support figure ($M = 3.78$, $SD = 1.78$) equally challenging, $F(2, 88) = 1.83$, $p = .166$.

CONCLUSION

Reflecting on important personal values can reduce stress, help us to play a more engaged role in our healthcare, improve performance, help us connect socially with the world around us and improve our sense of well-being (Creswell, et al., 2005; Taber, Howell, Emanual, Klein, Ferrer, & Harris, 2016; Crocker, Niiya, & Mischowski, 2009; Nelson, Fuller, Choi, & Lyubomirsky, 2014). The two papers in this dissertation used neuroimaging to identify what is happening neurally when we think about our values, or the process of self-affirmation. Investigating these neural correlates of self-affirmation is an important and novel contribution to self-affirmation theory, because self-affirmation's mechanism is yet unknown. To conclude this work, I will summarize each paper and the contribution they make to self-affirmation and reward theory.

Paper 1 proposed a possible neural reward account of self-affirmation, and tested it across two different fMRI studies. This reward account was informed by work suggesting that disclosing information about the self and thinking about positive autobiographical memories lead to activity in a key region in the neural reward network, the ventral striatum (Tamir & Mitchell, 2102; Speer, Bhanji, & Delgado, 2014). In addition, because self-affirmation has been shown to reduce physiological stress responding, and reward has been shown to reduce physiological stress responding as well, we proposed that the reward network could be a mechanism by which self-affirmation reduces stress. In Study 1, we modified an existing values-based, decision-making self-affirmation task to be used in the scanner environment and have a within-subjects control condition, and created a separate non-affirmation task that also required individuals to make judgments of items' values, specifically what attributes college students prefer most in toasters. This allowed for two comparisons: 1) within the self-affirmation subjects, we could compare neural regions that were active for thinking about one’s *most* important personal values, regions active for thinking about less important personal values, and 2) between subjects, to compare making personally-relevant value judgments to other-relevant value judgments. Results indicate that self-affirmation leads to greater VS activity than non-affirmation, and making preference judgments about one’s most important values leads to greater VS activity than making preference judgments about less important values. However, we wanted to ensure that these results were generalizable and not just due to features of the task.

Paper 1 also sought to replicate these results in a slightly different version of the values-based, decision-making task with a community adult population. Self-affirmation research has been conducted on a wide range of demographic groups, with many studies showing benefits regardless of the population studied (for a review see Cohen & Sherman, 2014). Study 2 investigated whether the proposed neural reward account was replicated in a non-university sample. In addition, the self-affirmation task was modified such that it did not have images, to rule out that the reward-related activation as due to viewing images of important personal values, and we used a different list of values for participants to select from. This is an important addition to the research because there is no standardized manipulation for self-affirmation and results indicate that the exact format of the decision-making task does not matter, as self-affirmation (compared to control) led to greater VS activity for this version of the task as well. Together, the two studies from Paper 1 provide support for a neural reward account of self-affirmation, which suggests a possible mechanism for self-affirmation’s benefits. These findings advance self-affirmation theory by using a method that had not yet been used to study self-affirmation, fMRI, to investigate what is happening in the brain during self-affirmation without relying on self-reports. This reward account serves as a catalyst for further research as it offers a line of testable hypotheses to investigate the neural mechanism of self-affirmation's threat buffering effects.

Paper 2 is a follow-up to the findings from the studies in Paper 1, and had three goals. First, because Paper 1 demonstrated that self-affirmation increases reward-related activity, we aimed to identify whether this reward-related activity was similar to other stimuli known to activate the reward network: social support and basic reward. Because self-affirmation and social support lead to changes in social behavior and reward has not been shown to do so, the second aim was to evaluate the differences among self-affirmation, social support and basic reward in terms of neural activity. The third aim was to determine if self-affirmation could be considered a 'social reward' by investigating its convergence with social support, a social reward, and its divergence from basic reward. Results suggest that although self-affirmation, social support and basic reward all led to increased reward- and caregiving-related neural activity, neural activity to self-affirmation (vs. control) in both networks was correlated with neural activity during social support but not basic reward. In addition, self-affirmation and social support both led participants to report greater feelings of social connection than did basic reward. In combination, these results suggest that self-affirmation and social support might be a separate category of reward from basic reward, 'social reward'. This study has implications for understanding how these three strategies, which are known to activate reward-related neural activity and decrease stress responding, could be used as interventions. While many people turn to basic rewards, such as rich foods, to cope with stress, social rewards might have other benefits that could be important for vulnerable populations.

Collectively, Papers 1 and 2 identified a neural reward account for self-affirmation and assessed how similar and different it was from other types of rewarding stimuli. This advances self-affirmation theory by applying a novel method to explore a long-standing question in self-affirmation work—namely, what is the mechanism of which self-affirmation? By using fMRI, we were able to look at a measure that did not exclusively rely on self-report, and thus shed light on the very basic processes in the brain during self-affirmation. With the knowledge that self-affirmation is possibly a social reward, this work opens a new line of research that can investigate how these neural mechanisms lead to downstream benefits and consequences, with the end goal of helping reduce stress effectively for the most vulnerable among us.

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