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Not my future? Core values and the neural representation of future events

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Abstract
Individuals with pronounced self-transcendence values have been shown to put greater weight on the long-term consequences of their actions when making decisions. Using functional magnetic resonance imaging, we investigated the neural mechanisms underlying the evaluation of events occurring several decades in the future as well as the role of core values in these processes. Thirty-six participants viewed a series of events, consisting of potential consequences of climate change, which could occur in the near future (around 2030), and thus would be experienced by the participants themselves, or in the far future (around 2080). We observed increased activation in anterior VMPFC (BA11), a region involved in encoding the personal significance of future events, when participants were envisioning far future events, demonstrating for the first time that the role of the VMPFC in future projection extends to the time scale of decades. Importantly, this activation increase was observed only in participants with pronounced self-transcendence values measured by self-report questionnaire, as shown by a statistically significant interaction of temporal distance and value structure. These findings suggest that future projection mechanisms are modulated by self-transcendence values to allow for a more extensive simulation of far future events. Consistent with this, these participants reported similar concern ratings for near and far future events, whereas participants with pronounced self-enhancement values were more concerned about near future events. Our findings provide a neural substrate for the tendency of individuals with pronounced self-transcendence values to consider the long-term consequences of their actions.

Keywords Core values · Future projection · Temporal distance · VMPFC

Introduction

In our everyday life, we are frequently confronted with situations in which we need to choose between following our egoistic impulses and taking into account the needs of others. Do I spend my money on yet another treat for myself, or do I give it to the beggar sitting on the street corner? Do I buy a powerful SUV car, which is a lot of fun but also quite the polluter, or rather do I invest in an electric vehicle, which is maybe not as much fun, but helps to preserve the environment for future generations? Whether the consequences of our choices for ourselves and others are visible immediately or will only materialize in the future, we need to integrate them into our considerations when deciding.

People differ in the degree to which they consider these aspects in their decision-making. When asked about the principles guiding their decisions, people often refer to their core values. Core values are abstract cognitive-affective-motivational structures that provide meaning and continuity in a constantly changing environment (Brosch & Sander, 2016). They represent beliefs about desirable end states. They shape our perception of the world, guide the selection and evaluation of behaviors and events, and act as a moral compass to which we refer when justifying preferences, decisions, or behaviors (Rohan, 2000). They provide an organizational principle for the self-schema (Roccas & Brewer, 2002), forming the core of our identity (Hitlin, 2003).

Cross-cultural research has shown that the structure of human core values is universal and that people in many different cultures use and recognize the same set of values, while prioritizing them differently in their individual value hierarchy (Schwartz, 1992). One central dimension used to describe differences in individual core value hierarchies spans the

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continuum from the maximization of self-interest (*self-enhancement*) to the consideration of the needs and concerns of others (*self-transcendence*; Schwartz, 1992). A person with pronounced self-transcendence values is more likely to cooperate with others in a laboratory game (Schwartz, 1996) and to devote their free time to volunteering (Shantz, Saksida, & Alfes, 2014) than a person who emphasizes self-enhancement values. Similarly, a person with pronounced self-transcendence values is more likely to consider the long-term consequences of their actions when making decisions, whereas a person who emphasizes self-enhancement values is more likely to focus on the immediate, short-term consequences. For instance, in an experimental study investigating preferences for different fuel types, participants with pronounced self-transcendence values were more willing to invest in expensive fuels causing a relatively low amount of environmental pollution, whereas participants with pronounced self-enhancement values preferred cheap, conveniently accessible fuels causing a high amount of pollution (Khachatryan, Joireman, & Casavant, 2013, see also Bardi & Schwartz, 2003).

The core value concept has emerged as a powerful construct that describes why different people choose differently in the same situation, prioritize different goals, and differentially weigh immediate versus future consequences in their choices.

Neuroscientific research has begun to investigate how core values affect decision processes at the neural level, illuminating how differences in core value hierarchies are associated with activation differences in neural decision systems related to reward processing and social cognition (Brosch & Sander, 2013; Moll, Zahn, & Oliveira-Souza, 2016, for reviews). For example, in a monetary donation task where participants were able to gain money for themselves and also donate some of their money to charity, participants with pronounced self-enhancement values made more egoistic decisions, donating less money to charity. At the neural level, this behavior was accompanied by increased activation of striatal reward regions and the amygdala when they were claiming money for themselves, suggesting that selfish choices are more salient and more rewarding for participants with pronounced self-enhancement values compared with participants with pronounced self-transcendence values (Brosch, Coppin, Scherer, Schwartz, & Sander, 2011).

Conversely, more altruistic behavior was related to increased activation in dorsomedial prefrontal cortex (DMPFC), which along with the temporoparietal junction (TPJ) and precuneus forms a social cognition network involved in impression formation and thinking about the needs, goals, and beliefs of others (Van Overwalle, 2009). In a similar study, activation in TPJ was correlated with the participants' willingness to donate money to a charitable organization (Hare, Camerer, Knoepfle, & Rangel, 2010), and neuroanatomical differences in gray matter volume in TPJ have been shown to be strongly associated with altruistic behavior (Morishima, Schunk, Bruhin, Ruff, & Fehr, 2012). These studies indicate that behavior driven by self-transcendence values may be preceded by a more thorough evaluation of the needs and goals of others via an increased activation of neural social cognition regions.

So far, neuroimaging work on core values has mainly focused on actions with immediately visible financial consequences. Because core values also determine to what extent people take into account potential future consequences (Khachatryan et al., 2013), we investigated the relationship of core values and the neural mechanisms underlying the consideration of outcomes that may occur in the future. In the context of the conflict between self-enhancement and self-transcendence core values, it seems especially interesting to contrast events occurring in a "near future," i.e., occurring during the lifetime of the concerned person, and events occurring in a "far future," i.e., occurring at a time by which the person will most likely no longer be around to experience these consequences. People with pronounced self-enhancement values may be more concerned about events in the near future compared with the far future, because they mainly care about consequences concerning themselves. Conversely, people with pronounced self-enhancement values may be equally concerned about consequences for themselves and for (future) others.

Previous neuroimaging research has exhaustively mapped the neural regions involved in the mental simulation of future states and episodes. Converging evidence indicates that mental simulations of future states rely on neural systems that also are involved in processes related to episodic memory. Neuroimaging studies have highlighted the activation of a common neural network, including ventromedial prefrontal cortex (VMPFC), medial temporal lobe, and medial posterior regions when remembering past events and imagining future events (Schacter, Addis, & Buckner, 2007; Schacter et al., 2012, for reviews). When thinking about potential future events, individuals are thought to recombine details from past events into novel scenarios and to project themselves mentally into a simulation of another time, place, or perspective (Buckner & Carroll, 2007).

When comparing the mental simulation of events occurring in the near and far future, respectively, studies have highlighted the importance of the anterior VMPFC for the mental simulation of the far future. For example, thinking about the far future led to stronger activation of the anterior VMPFC (BA 10, 11) compared with thinking of the near future (Okuda et al., 2003). Similarly, when participants were asked to think about potential future events with either positive or negative valence, thinking about the far future led to stronger activation of the ventral part of the anterior VMPFC (BA 11) than thinking of the near future (D'Argembeau, Xue, Lu, Van der Linden, & Bechara, 2008). VMPFC furthermore has been

linked to the representation of the personal relevance of simulated future events. For instance, D'Argembeau and colleagues (D'Argembeau et al., 2010) demonstrated increased anterior VMPFC (BA 10, 11) activation when participants were envisioning future events that were related to their personal goals compared with future events not related to their personal goals (see also Stawarczyk & D'Argembeau, 2015). These studies indicate that the anterior VMPFC is involved in simulating and encoding the personal relevance of future events, and especially of far future events.

In the present work, we were interested in investigating the neural mechanisms underlying the impact of core values on the perception of future events that occur either in the near future (and thus will be experienced by participants themselves) and events that occur in the far future (and will thus not be experienced by the participants themselves). Following previous research, which demonstrated the role of core values when considering future outcomes in the environmental domain (Khachatryan et al., 2013), we designed a judgment task in which participants were asked to evaluate future consequences of climate change—one of the most urgent challenges facing our planet. While some negative effects of climate change are already experienced today, future consequences are expected to be much more severe, including extreme weather events, resource shortages, increased social tensions, and extinction of species (IPCC, 2014). To mitigate these developments, behavioral changes, efforts, and investments are required today, but the impact of these actions will mainly benefit future generations (Schelling, 1995). Such an intergenerational conflict is highly likely to discriminate between individuals with pronounced self-enhancement values, who are mainly preoccupied by outcomes that concern themselves, and individuals with pronounced self-transcendence values, who also consider outcomes that concern others.

Given previous demonstrations in the neuroimaging literature that the ventral part of the anterior VMPFC (BA 11) is involved in simulating and encoding the personal relevance of future events, and especially of far future events, we were interested in investigating the link between individual core values and activation in this region of interest. To this end, we measured changes in our participants' BOLD response while they were reading and evaluating a series of potential consequences of climate change, which were labeled as occurring either in the near or in the far future. Participants were asked to read each consequence and to indicate to what extent they perceive each consequence as a serious problem and to what extent they are worried by it. Approximately 3 months before the scanning session, we measured our participants' core value hierarchy.

With this design, we addressed the following hypotheses:

H_1: Participants with pronounced self-enhancement values are especially concerned about events occurring in the near future compared with the far future, whereas participants with pronounced self-transcendence values are equally concerned about events occurring in the near and the far future.

H_2: Reflecting the increased relevance of far future events for participants with pronounced self-transcendence values, these participants are expected to show enhanced activation increases in anterior VMPFC when construing events in the far future.

Methods

Participants Thirty-six student volunteers (9 men, mean age: 21.4 [range: 19-37] years) participated in the study after giving informed consent according to the ethics regulation of the Geneva University Hospitals. All participants were right-handed, had normal or corrected-to-normal vision, and had no history of neurological or psychiatric disease.

Materials Approximately 3 months before their participation in the fMRI study, participants' core values were measured with an abbreviated version of the Schwartz Value Scale (de Groot & Steg, 2008; Schwartz, 1992; Stern, Dietz, & Guagnano, 1998), which is based on theoretical considerations as well as cross-cultural validation work on the universality of the factors that describe differences between individual value systems. Participants rated the importance of 12 different value items (e.g., wealth, authority, equality, social justice), as guiding principles in their life on a 9-point scale from "opposed to my principles" (−1) through "not important" (0) to "of supreme importance" (7). Individual indices for self-enhancement ($M_{self\text{-}enhancement}$) and self-transcendence ($M_{self\text{-}transcendence}$) value types were computed by averaging the importance ratings of the specific values representative of that type. To be able to combine the two value items into one score—consistent with the theoretically predicted value dimension spanning the space between self-enhancement values and self-transcendence values—we then computed a value score reflecting the relative weight of the two core values, which represent the two poles of the value dimension. To this end, we used the formula $V_i = (M_{self\text{-}transcendence} - M_{self\text{-}enhancement})/(M_{self\text{-}transcendence} + M_{self\text{-}enhancement})$, which standardizes the difference between the individual weights given to self-transcendence values and self-enhancement values into a numerical space from −1 to +1. Given the properties of the formula, positive scores reflect a higher relative weight of self-transcendence values compared with self-enhancement values, whereas negative scores reflect a higher relative weight of self-enhancement compared with self-transcendence values. While theoretically individual scores can range from −1 (reflecting exclusive emphasis on self-enhancement values) to +1

(reflecting exclusive emphasis on self-transcendence values), in our sample scores ranged from −0.11 to +0.93, with a median of +0.35.

Experimental procedure Participants were informed that their task was to read a series of potential consequences of climate change and to indicate to what extent each consequence (i) is a serious problem and (ii) worries them. Participants were presented with a series of 36 potential consequences of climate change, which had been compiled from the 2014 report of the Intergovernmental Panel for Climate Change (IPCC, 2014) and other sources. These consequences were presented as occurring either in the near future (in the year 2025, 2030, or 2035) or in the far future (in the year 2075, 2080, or 2085, e.g., "reduction of water reserves by the year 2030"; "mass disappearance of coral banks by the year 2035"; "increase of border conflicts by the year 2075"; "spreading of tropical diseases by the year 2080"). Importantly, to avoid confounds with stimulus content, the temporal occurrences of each individual event were counterbalanced between participants, i.e., one consequence was presented as occurring in the near future to half of the participants and as occurring in the far future to the other half of the participants.

Stimuli were back-projected on a screen that participants viewed through a mirror system attached to the head coil. At the beginning of each trial, participants were presented with a scenario for 10 seconds, followed by a fixation cross that was also presented for 10 seconds. Afterwards, participants were asked to rate the consequence, regarding "How serious is this consequence?" and "How worried does it make you feel?" each time on a scale from 1 to 8 using an MRI-compatible response box. Each question was presented for 5 seconds (after participants provided their answer, a feedback of their response appeared for the remainder of the time interval [e.g., "Response recorded. You have answered 6."]). The two rating questions were presented in randomized order and separated by a jitter ranging from 3.5 to 6.5 seconds. Experimental trials were separated from each other by a fixation cross presented for 10 seconds. To verify that participants perceived the presented scenarios as realistic, after the fMRI session, participants were again presented with the consequences as they had encountered them in the scanner, and were asked to indicate for each event how likely they found its predicted occurrence on a scale from one to eight. Participants then were debriefed and thanked for their participation.

fMRI acquisition and analysis A 3-T Siemens TIM TRIO scanner with a 12-channel head coil was used for data acquisition. Anatomical images were acquired using a T1-weighted protocol (256 × 256 matrix, 256 1-mm sagittal slices). Functional images were acquired using a single-shot gradient-echo echo-planar-imaging (EPI) sequence (repetition time = 2.1 s, echo time = 30 ms, field of view = 205 mm, flip angle = 80°). We obtained 36 contiguous oblique-axial slices (3.2 × 3.2 × 3.2-mm voxels) parallel to the anterior commissure–posterior commissure line. Data were preprocessed using SPM8 (Wellcome Trust Center for Neuroimaging, http://www.fil.ion.ucl.ac.uk/spm/). All images were realigned, corrected for slice timing, normalized to an EPI template (resampled voxel size of 3 mm), spatially smoothed (8-mm full-width/half-maximum Gaussian kernel), and high-pass-filtered (cutoff = 120 s). Experimental epochs were modeled by a standard synthetic hemodynamic response function (HRF).

Four event types were defined: SCENARIO NEAR FUTURE, SCENARIO FAR FUTURE, SERIOUSNESS RATING, and WORRY RATING. To account for residual movement artifacts after realignment, we entered movement parameters derived from realignment corrections (3 translations, 3 rotations) as covariates of no interest. The generalized linear model was then used to generate parameter estimates of activity at each voxel, for each condition and each participant. Given our a priori predictions regarding anterior VMPFC, we extracted average beta parameters for each event type from an 8-mm region of interest centered on the peak anterior VMPFC coordinates reported by D'Argembeau et al. (2008; peak coordinates: x = −3, y = 51, z = −18). Furthermore, to explore whether additional neural regions are involved at the whole brain level, we performed a series of exploratory random-effects group analyses on the contrast images from the individual analyses using one-sample *t* tests. To identify regions that respond more strongly to consequences occurring in the far future than the near future, we computed the contrast SCENARIO FAR FUTURE > SCENARIO NEAR FUTURE. Similarly, to identify regions that respond more strongly to consequences occurring in the near future than the far future, we computed the contrast SCENARIO NEAR FUTURE > SCENARIO FAR FUTURE. Exploratory whole-brain analyses were thresholded at $p < 0.001$, k = 20 (uncorrected).

Results

Behavioral results Given the high correlation between the *seriousness* and *worry* ratings ($r = 0.69$, $p < 0.001$), the two scores were combined into a single *concern* score. This score was analyzed using a general linear model (GLM) with the discrete factor *temporal distance* (near future/far future) and the continuous variable *value structure* (higher scores indicating higher relative weight of self-transcendence values as compared to self-enhancement values).

Confirming our initial hypotheses, we observed a statistically significant interaction of *temporal distance* and *value structure*, $F(1, 34) = 9.17$, $p = 0.005$, *partial* $\eta^2 = 0.21$. Simple slopes revealed that participants with a value structure centered on self-enhancement values (−1 SD below the mean)

expressed more concern for events occurring in the near future ($M = 5.34$) compared with the far future ($M = 5.08$), $F(1, 34) = 7.46$, $p = 0.01$, *partial* $\eta^2 = 0.18$, whereas no statistically significant difference was observed for participants with a value structure centered on self-transcendence (+1 SD above the mean), who appeared equally concerned with regard to events occurring in the near future ($M = 4.98$) and the far future ($M = 5.13$), respectively, $F(1, 34) = 2.50$, $p = 0.123$ (Fig. 1).

To control for the perceived plausibility of our scenarios, we submitted the participants' plausibility ratings to the same GLM. On average, participants judged all presented events as quite likely ($M = 5.49$). Consistent with the literature on the temporal pessimism bias (Gifford et al., 2009), events in the far future were judged as more likely ($M = 5.82$, $SD = 0.82$) than events in the near future ($M = 5.17$, $SD = 1.04$), as indicated by a main effect of *temporal distance*, $F(1, 34) = 19.34$, $p < 0.001$, *partial* $\eta^2 = 0.36$. Important for the interpretation of our main result, this effect did not differ as a function of participants' value structures, as indicated by the nonsignificant interaction of *temporal distance* and *value structure*, $F(1, 34) = 0.24$, $p = 0.88$.

Neuroimaging results For our main analysis, we submitted individual parameter estimates extracted from the region of interest in anterior VMPFC (sphere of 8-mm diameter centered on peak coordinates x = −3, y = 51, z = −18), to a GLM with the discrete factor *temporal distance* (near future/far future) and the continuous variable *value structure.*

Confirming previous observations in the literature that this region is more activated when thinking about the far future compared with the near future, we observed a significant main effect of *temporal distance*, $F(1, 34) = 7.72$, $p = 0.009$, *partial* $\eta^2 = 0.19$. Importantly, however, this effect was qualified by a significant interaction of *temporal distance* and *value structure*, $F(1, 34) = 9.82$, $p = 0.004$, *partial* $\eta^2 = 0.22$. Simple slopes revealed that the effect of temporal distance was driven by participants with a value structure centered on self-transcendence values, who showed stronger activation when considering the far future compared with the near future, $F(1, 34) = 17.49$, $p < 0.001$, *partial* $\eta^2 = 0.34$, whereas no such activation increase was observed in participants with a value structure centered on self-enhancement values, $F(1, 34) = 0.79$, $p = 0.78$ (Fig. 2B).

In an exploratory analysis designed to extend our findings beyond the region of interest in the anterior VMPFC, we then computed whole brain contrasts comparing the near future and the far future conditions (Table 1). Regions showing increased activation to the far future compared with the near future condition included anterior VMPFC (peak coordinates x = 3, y = 38, z = −17; Fig. 2A), left anterior cingulate cortex (ACC; x = −9, y = 41, z = −2), and left precuneus (x = −12, y = −52, z = 70). No region showed increased activation for the near future compared with the far future. For each of these regions, we extracted individual activation parameters for an 8-mm sphere, centered on the peak coordinates and computed general linear models with the discrete factor *temporal distance* (near future/far future) and the continuous variable *value structure.*

Corroborating the results of our ROI analysis, analysis of the extracted BOLD signal in the anterior VMPFC revealed both a main effect of *temporal distance*, $F(1, 34) = 10.75$, $p = 0.002$, *partial* $\eta^2 = 0.24$, and an interaction of *temporal distance* and *value structure*, $F(1, 34) = 5.59$, $p = 0.024$, *partial* $\eta^2 = 0.14$, illustrating that the activation increase to far future events was driven by participants with pronounced self-transcendence values. In contrast, while the ANOVAs for the other regions confirmed the effect of *temporal distance*, $F_{ACC}(1, 34) = 12.31$, $p = 0.001$, *partial* $\eta^2 = 0.27$, $F_{Precuneus}(1, 34) = 19.67$, $p < 0.001$, *partial* $\eta^2 = 0.37$, no further interactions of *temporal distance* and *value structure* were observed, $F_{ACC}(1, 34) = 0.003$, $p = 0.96$, $F_{Precuneus}(1, 34) = 0.52$, $p = 0.48$.

Discussion

We investigated the neural mechanisms underlying the impact of core values on the perception of future events that occur either in the near future (and thus will be experienced by participants themselves) and events that occur in the far future (and thus will not be experienced by the participants themselves).

Replicating previous work (D'Argembeau et al., 2008), we observed increased activation to events occurring in the far future compared with the near future in our region of interest in the ventral part of the anterior VMPFC (BA 11). Importantly, this is the first empirical demonstration that the role of the anterior VMPFC in future projection extends to the time scale of decades. Previous research has mainly compared the processing of two timepoints relatively close to the present (e.g., "the next few days" vs. "the next few years"; Okuda et al., 2003). We observed a similar neural effect for scenarios where both time points are several years or even decades away. This extends previous research on the neural basis of future projection and suggests that the temporal gradient represented in VMPFC can extend far into the future, even beyond the expected lifetime of the individual, suggesting a unitary neural mechanism for future projection independent of temporal scale.

Most important for our hypotheses, we observed an interaction of the temporal distance effect in anterior VMPFC with the core value structure of our participants. The observed activation increase towards events occurring in the far future was driven by participants with pronounced self-transcendence values, i.e., individuals who are not mainly driven by self-

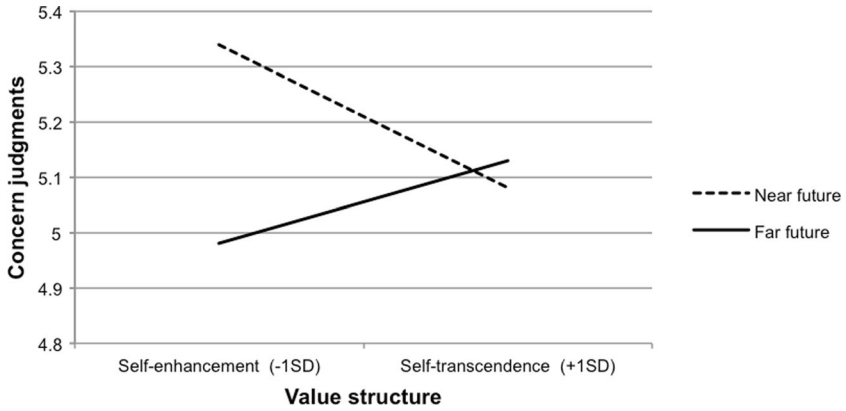

Fig. 1 Individual concern judgments for events occurring in the near future (2025-2035) and the far future (2075-2085), respectively, as a function of value structure. Participants with pronounced self-enhancement values (−1 SD, dashed line) showed significantly less concern for events in the far future compared with the near future, whereas participants with pronounced self-transcendence values (+1 SD, solid line) appear equally concerned with regards to events occurring in the near and far future

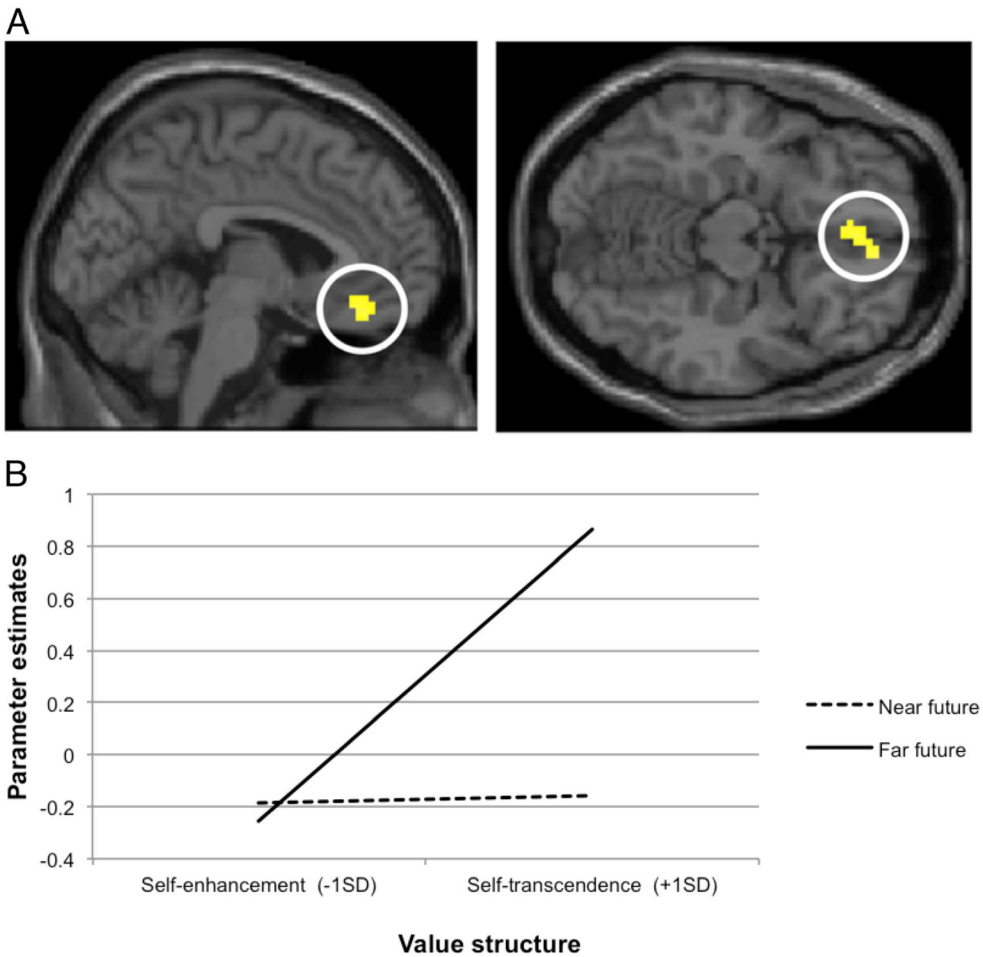

Fig. 2 (**A**) Activation in anterior VMPFC when considering events in the far future (2075-2085) relative to events in the near future (2025-2035), displayed at $p < 0.001$ with an extent threshold of 20 voxels. Brain map based on the exploratory whole-brain analysis. (**B**) Parameter estimates for region of interest in anterior VMPFC (peak coordinates: x = −3, y = 51, z = −18, based on D'Argembeau et al., 2008) for the near (dashed line) and far (solid line) future scenarios as a function of participants' value structure. While participants with pronounced self-transcendence values (+1 SD) showed increased BOLD responses when considering consequences in the far future relative to consequences in the near future, participants with pronounced self-enhancement values (−1 SD) did not show this increase

Table 1 Peak coordinates and Z values for brain regions associated with the effect of temporal distance

Brain region	Hemisphere	Peak coordinates			Z
		x	*y*	*z*	
Far future > Near future					
Anterior VMPFC*		3	38	-17	3.39
ACC	L	-9	41	-2	3.35
Precuneus	L	-12	-52	70	3.82
Near future > far future					
No activations observed					

*Analysis of beta estimates extracted from this region revealed an interaction of temporal distance and value structure. Activations are threshold at $p < 0.001$ with an extent threshold of 20 voxels

interest but also take the needs, goals, and the well-being of other people into consideration (Schwartz, 1992). This finding dovetails nicely with the results by D'Argembeau and colleagues, who observed increased anterior VMPFC activation to future events that were relevant to the personal goals of the participants (D'Argembeau et al., 2010). We can thus speculate that the anterior VMPFC activation observed in participants with pronounced self-transcendence values reflects the fact that they perceive these consequences to be more relevant compared with participant with pronounced self-enhancement values, given that their "personal sphere of concern" extends to other people and future generations.

The behavioral responses obtained during the task are consistent with this interpretation, as participants with pronounced self-enhancement values were especially concerned about events occurring in the near future—that is, during their lifetime—whereas participants with pronounced self-transcendence values perceived events occurring in the near and the far future as equally concerning. These results parallel previous behavioral research indicating that people with pronounced self-enhancement core values tend to be focused on short-term consequences concerning themselves in their choices (preferring, for example, cheap, convenient, but polluting fuel types), whereas people with pronounced self-transcendence core values take into account long-term consequences of their behavior (preferring more expensive, less convenient, but less polluting fuel types), even if they themselves may not be around to benefit from the positive consequences of their actions in the future (Khachatryan et al., 2013).

What can the observed modulation of anterior VMPFC activation as a function of participants' core values tell us about the psychological mechanisms involved in the differential weighting of future consequences by people with pronounced self-enhancement values and self-transcendence values, respectively? The capacity to mentally simulate the future as implemented in the neural network centered on VMPFC conveys an enormous advantage to mankind: it allows to anticipate future developments and to act flexibly in the present to increase future chances of survival (Suddendorf & Corballis, 2007). It has been argued that the main function of this ability is to represent affectively the costs and benefits of future situations to promote more far-sighted decision-making that serves one's long-term goals (Boyer, 2008). Research by Damasio and colleagues (1996) has demonstrated that lesions in VMPFC lead to poor decision-making, because patients tend to neglect the future consequences of their choices, resulting in a "myopia for the future" (Bechara, Damasio, Damasio, & Anderson, 1994). Moreover, patients with lesions in this region show a shorter time extension when projecting themselves into the future: when asked to elaborate their goals for the future, these elaborations are constrained to a time window that extends much less far into the future than projections by healthy control groups and patient control groups with lesions in other areas (Fellows & Farah, 2005). In our experiment, participants with pronounced self-transcendence values may have been able to simulate and represent the affective quality of future events more than participants with pronounced self-enhancement values. Conversely, participants with pronounced self-enhancement values may have been affected by a "myopia for the future" similar to the VMPFC patients, perceiving the distant events as occurring in a future that was "not their own" future.

Our findings add to the previous literature investigating the neural mechanisms by which core values exert their impact on our choices and behaviors. The observation that individuals with more pronounced self-transcendence values tend to show more altruistic behaviors in direct interactions with people has been previously linked to increased activation of social cognition regions, such as DMPFC and TPJ (Brosch et al., 2011; Hare et al., 2010). We show how self-transcendence core values modulate the processing of consequences occurring in the future by allowing for a more extensive simulation of far future events.

A few qualifications of the results are necessary. At the methodological level, our task included a certain amount of misrepresentation of the facts about climate change, which was made necessary by the experimental manipulation. While all the consequences of climate change that were presented during the task were taken from reliable sources and have been predicted to occur in the future by climate change experts, the timestamps we added to indicate whether the events would occur in the near or the far future were attributed randomly and were counterbalanced between participants. This was made necessary by the need to have an experimental manipulation of temporal distance that was not influenced by the details of the individual scenarios. Thus, at the experimental level, this measure was necessary to avoid confounds of temporal distance with stimulus content. However, the stimulus design also introduces an ethical dimension, because the

statements used during the task can be argued to be incorrect, at least in what concerns the date at which a specific consequence is predicted to occur. Thus, it is possible that by labeling a predicted consequence of climate change with a "near future" timestamp, additional discomfort may have been caused our participants, because they were led to believe that a specific scenario would occur relatively soon. Nevertheless, given that all events are actually predicted to occur by climate change experts (and that concern about these consequences is justified), we considered this experimental manipulation to be ethically justifiable.

Moreover, the statistical threshold for performing the exploratory whole brain analysis is relatively liberal, which can be considered a weakness of the current analyses. Even though it has been argued that this threshold is acceptable for exploratory research in social neuroscience (Lieberman & Cunningham, 2009), the results of this analysis should be considered exploratory and be replicated in future work. Note, however, that the main finding of the present manuscript is based on a predefined ROI analysis and has independently been confirmed by the whole brain analysis.

Based on previous work on the impact of core values on the perception of future events in the environmental domain (Khachatryan et al., 2013), we constructed our task around the topic of climate change, which, due to its intergenerational nature was able to discriminate between individuals with pronounced self-enhancement values and pronounced self-transcendence values, respectively. We do not assume that our findings are specific to the domain of climate change. To the contrary, it is very likely that similar results would be obtained when asking participants to contemplate future events from other domains (e.g., "first human colony on Mars in 2085"). However, the solution to many of mankind's current problems, including climate change, resource overconsumption, and overpopulation, is based on the need to overcome selfish impulses today to make efforts and sacrifices that may benefit future generations (Schelling, 1995). It is crucial to better understand the underlying psychological mechanisms that make such behavior possible. If a more detailed simulation of events in the far future is related to increased personal concern about this future—as suggested by our neuroimaging results—intervention strategies for the individual improvement of such simulations (e.g., by teaching visualization strategies) may be a promising tool to increase concern for the far future (see Bain et al., 2016, for a similar approach).

Conclusions

We investigated the neural mechanisms underlying the impact of core values on the perception of future events. Participants with pronounced self-transcendence values showed increased activation of the ventral part of anterior VMPFC (BA 11) when considering events in the far future. These findings provide a neural substrate for their tendency to take into account long-term consequences of their actions and expand our knowledge about the neural mechanisms underlying the impact of core values on our decisions and behaviors.

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