The Default Network Distinguishes Construals of Proximal versus Distal Events

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Abstract

■ Humans enjoy a singular capacity to imagine events that differ from the "here-and-now." Recent cognitive neuroscience research has linked such simulation processes to the brain's "default network." However, extant cognitive theories suggest that perceivers reliably simulate only relatively proximal experiences —those that seem nearby, soon, likely to happen, or relevant to a close other. Here, we test these claims by examining spontaneous engagement of the default network while perceivers consider experiencing events from proximal and distal perspectives. Across manipulations of perspective in four dimensions, two regions of the default network—medial prefrontal cortex and retrosplenial cortex—were more active for proximal than distal events, supporting cognitive accounts that perceivers only richly simulate experiences that seem immediate and that perceivers represent different dimensions of distance similarly. Moreover, stable individual differences in default activity when thinking about distal events correlated with individual variability in an implicit measure of psychological distance, suggesting that perceivers naturally vary in their tendency to simulate far-off or unlikely experiences. ■

INTRODUCTION

Although our physical bodies exist only in the here-and-now, humans wander freely across time and space through the imaginative powers of our minds. We can envision ourselves in far-flung locations, during bygone times, in completely hypothetical situations, or even as other people (Liberman & Trope, 2008; Buckner & Carroll, 2007; Gilbert, 2005). This capacity to conjure up subjective experiences that are wholly divorced from the current perceptual environment is often referred to as *simulation* or *self-projection*—the power to imagine ourselves experiencing that which isn't but might be. By virtue of this cognitive faculty, humans enjoy a unique ability to preview the consequences of their decisions by "sneaking a peek" at the subjective experiences likely to result from a particular course of action.

However, as pointed out by recent commentators, individuals do not always simulate events by imagining them in rich, concrete detail. Instead, researchers distinguish *distal* simulations, which are removed from one's current experience, from *proximal* simulations, which are psychologically much more similar to one's own current experience. Specifically, Liberman, Trope, and colleagues have demonstrated that perceivers tend to simulate using rich, concrete detail only relatively proximal experiences —those that occur close in time or nearby, are likely to happen, or refer to the minds of close others (Liberman & Trope, 2008; Liberman, Trope, & Stephan, 2007; Trope & Liberman, 2003). In contrast, when events occur at a

spatial or temporal distance, are improbable, or refer to the minds of unusual others, perceivers often decline to imagine experiencing them firsthand and, instead, represent such events in an amorphous, abstract manner. This account, known as *construal level theory*, comprises two main hypotheses: (i) individuals spontaneously imagine proximal events in terms of rich, concrete details but construe distal events in terms of more general, simplified abstractions and (ii) these cognitive differences distinguish proximal from distal events regardless of whether they vary spatially (here vs. near vs. far), temporally (now vs. soon vs. later), socially (self vs. close others vs. strangers), or in terms of hypotheticality (actual vs. likely vs. improbable).

Data from cognitive neuroscience now permit a test of these predictions. Over the past few years, researchers have linked simulation and self-projection to a specific set of brain regions that include the medial prefrontal cortex (MPFC), medial parietal cortex, lateral parietal cortex, and regions within medial and lateral temporal cortex (Spreng, Mar, & Kim, 2009; Buckner & Carroll, 2007; Schacter & Addis, 2007). These regions—sometimes described as the brain's "default network" (Raichle et al., 2001)—have been identified consistently by neuroimaging studies in which individuals are asked to actively simulate an experience. For example, these regions have been observed regularly during tasks in which participants are asked to imagine (i) an event in the distant past or future (Botzung, Denkova, & Manning, 2008; Addis, Wong, & Schacter, 2007; Schacter, Addis, & Buckner, 2007; Szpunar, Watson, & McDermott, 2007; Okuda et al., 2003); (ii) fictitious, hypothetical events (Hassabis & Maguire,

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2009; Hassabis, Kumaran, & Maguire, 2007); or (iii) the goings-on of another person's mind (Mitchell, 2009a; Amodio & Frith, 2006; Frith & Frith, 2006; Gallagher & Frith, 2003). Such findings have been interpreted as evidence that attempting to imagine experiences removed from the here-and-now involves a common set of cognitive processes, regardless of whether doing so requires one to consider the distant past or future, hypothetical events, or others' mental states (Buckner & Carroll, 2007).

However, in most of these experiments, researchers explicitly asked participants to simulate an experience in rich, concrete detail (research on inferring others' mental states provides an exception; for a review of these issues, see Mitchell, 2009a). For example, in studies of autobiographical memory and future/hypothetical thinking, participants have been explicitly prompted by task instructions to reconstruct the sights, sounds, and subjective experiences that accompanied or might accompany an event (Addis et al., 2007; Hassabis et al., 2007; Szpunar et al., 2007). Little research has examined the hypothesized variation in *spontaneous* engagement of these processes as perceivers simulate experiences from differing perspectives. That is, although researchers have suggested that perceivers will naturally simulate proximal events in more concrete detail than distal ones (Trope & Liberman, 2003), studies have yet to test these predictions against what has recently become known about the neural basis of simulation and self-projection.

In the current study, we address these issues using a combination of functional neuroimaging and cognitive measures of implicit association. Participants were scanned while considering different experiences (e.g., snowboarding and public speaking) from both a proximal and distal perspective. In each of the four tasks, participants were asked to consider these events while transcending the here-and-now in one of the four different dimensions: spatially ("in this building" vs. "at Oxford"), temporally ("in the next 24 hours" vs. "this time next year"), socially ("self" vs. "Obama"), and hypothetically ("me as I am" vs. "me as a man" for female participants). On each trial, participants rated how likely they (or the distal social target) would be to enjoy the activity. This design allowed us to test two central hypotheses regarding how humans simulate experiences. First, to the extent that perceivers more regularly imagine the concrete details of immediate experiences than of experiences removed from the here-and-now, we anticipated that components of the default network associated with simulation and self-projection would be more active when considering proximal than distal experiences. Second, to the extent that perceivers are equally unlikely to simulate distal events regardless of how doing so requires transcending current experience, we anticipated that the same neural differences would be associated with manipulations of distance across all four dimensions of space, time, social distance, and hypotheticality. Finally, by examining neural responses that arise spontaneously, rather than as

the result of explicit task instructions to richly simulate the event, we assessed whether some individuals more regularly simulate distal experiences than others—that is, whether the tendency to consider events removed from the here-and-now by imagining them in concrete detail represents a stable individual difference (Vallacher & Wegner, 1989). We evaluated such putative individual neural differences against established measures of implicit association, a version of the Implicit Association Test (IAT) that measures the degree to which participants automatically associate proximal concepts in each dimension with proximal concepts in each other dimension (e.g., near and soon), and the degree to which participants automatically distinguished between proximal concepts and distal concepts across all four dimensions of distance (e.g., soon vs. hypothetical).

METHODS

Participants

Twenty-one (13 women) right-handed, native English speakers with no history of neurological problems participated in all four tasks (mean age = 21.3 years, range = 19–25 years). Data from five tasks (two spatial, two temporal, and one hypothetical) across three participants were excluded from all analyses because of the high rate of nonresponses (>15%). All participants provided consent in a manner approved by the Committee on the Use of Human Subjects at Harvard University.

Behavioral Procedure

Participants were scanned while completing the four tasks that required them to consider events from either a proximal or distal perspective. During each task, participants answered a series of questions about their opinions or preferences (e.g., "get nervous speaking in public" and "enjoy snowboarding"). In the *temporal* task, participants were asked how much they currently hold these opinions or enjoy these activities in the present ("in the next 24 hours") or how much they anticipate holding these opinions or enjoying these activities in the future ("this time next year"). In the *spatial* task, participants were asked how much they hold these opinions or enjoy these activities in their current location ("in this building") or at a distant location ("at Oxford"). In the *social* task, participants were asked how much they themselves hold these opinions or enjoy these activities ("self") or how much another person does ("Obama"); the choice of U.S. President Barack Obama was guided by earlier research (Symons & Johnson, 1997; Rogers, Kuiper, & Kirker, 1977), which has generally compared self-referential processing to inferences about the current head of state (a familiar, but not personally known, other). Finally, in the *hypotheticality* task, participants were asked how much they hold these opinions as the

person they actually are ("me as I am") or as they would if they had woken up that morning as a member of the opposite sex (e.g., "me as a man" for female participants). This manipulation of hypotheticality was selected because it (i) could be implemented without simultaneously manipulating the other three distances, (ii) was specific to the self and did not require imagining an alternative reality (e.g., what life would be like if the planet supported another form of intelligent life), and (iii) was sufficiently distant from the actual self. To acclimate to the hypotheticality manipulation, participants spent several minutes before this task, imagining themselves as a member of the opposite sex.

For each task, a trial began with a cue indicating whether a response should be given from a proximal or distal perspective. After 500 msec, a question appeared and participants had 3500 msec to indicate the extent to which they would enjoy the activity using a 5-point scale anchored at "extremely unlikely" to "extremely likely." During each task, participants responded to each of 50 statements twice, once from the proximal and once from the distal perspective, allowing us to assess differences between behavioral responses to proximal and distal trials for each statement.

Each task included a unique set of statements, selected to be irrelevant to the dimension of distance being manipulated. For example, the degree to which one would enjoy eating a banana might not be expected to differ between Cambridge, MA, and Oxford, England, although one's enjoyment of clam chowder or fish and chips might. Accordingly, in the spatial task, participants were only asked to consider activities that should not vary as a function of physical location; likewise, in the hypotheticality task, participants only considered activities or opinions that were pretested to be judged similarly by men and women, and so on (see Supplementary Materials for a full list of stimuli). In each task, trials were separated by a variable ISI between 0 and 10,000 msec ($M = 1362$ msec; Dale, 1999). Each of the four tasks was divided into two consecutive runs of 268 sec (134 TRs) each. Task order was randomized for each participant.

Imaging Procedure

Functional data were acquired using a gradient-echo echo-planar pulse sequence (repetition time [TR] = 2 sec; echo time [TE] = 35 msec) on a 3T Siemens Trio. Images were acquired using 31 axial, interleaved slices with a thickness of 5 mm (1 mm skip) and 3×3 in-plane resolution. Functional images were preprocessed and analyzed using SPM2 (Wellcome Department of Cognitive Neurology, London, United Kingdom). Data were first preprocessed to correct for slice time acquisition differences in each whole brain volume and spatially realigned to correct for head movement. Images were then normalized to a standard anatomical space (2-mm isotropic voxels) on the basis of the ICBM 152 brain template (Montreal Neurological Institute

[MNI]). Normalized images were then spatially smoothed using an 8-mm FWHM Gaussian kernel.

Preprocessed images were analyzed using a general linear model in which trials were modeled as an event with no duration that onset at the presentation of the cue. The events were modeled using a canonical hemodynamic response function, its temporal derivative, and covariates of no interest (session mean and linear trend, no response trials, and their temporal derivative). Analyses were performed individually for each participant, and contrast images were subsequently entered into a second-level analysis, treating participants as a random effect. Peak coordinates were identified at the group level using a statistical criterion of 85 or more contiguous voxels at a voxel-wise threshold of $p < .01$, providing an experiment-wise threshold of $p < .05$, corrected for multiple comparisons (S. Slotnick, Boston College, Boston, MA). Functional regions of interest were defined using an automated search algorithm (R. Poldrack, University of California-Los Angeles, Los Angeles, CA) that identified peak activations separated by a minimum of 8 mm.

Trials were conditionalized on the basis of task (spatial, temporal, social, and hypothetical) and perspective (proximal and distal), resulting in eight conditions of interest. Primary analyses identified voxels in which BOLD response differed between the proximal and distal conditions within each of the four tasks. Subsequently, conjunction analysis was performed using xjView statistical software (people.hnl.bcm.tmc.edu/cuixu/xjView). Whole-brain statistical maps were created from the proximal > distal contrast for each of the four tasks separately to identify voxels that were modulated by the distance manipulation (thresholded at $p < .025$). The intersection of suprathreshold voxels common to these four contrasts yielded a composite map that identified voxels that significantly differentiated between proximal > distal for each and all tasks at a probability of $p < 4 \times 10^{-7}$.

Network Analyses

Functional connectivity analyses were conducted over resting state data to confirm that the regions identified by whole-brain analyses were indeed embedded within the default network. Following all distance tasks, each participant completed one run in which they rested passively with their eyes open for 372 sec. Resting state data were collected using a gradient-echo echo-planar pulse sequence (TR = 3000 msec; TE = 30 msec). Images were acquired with 47 axial slices (0 skip) and 3-mm isotropic voxels. Images were preprocessed by first discarding the first four volumes of each run to allow for signal stabilization, correcting for slice time acquisition differences (Wellcome Department of Cognitive Neurology, London, United Kingdom) and correcting for head motion (FSL, FMRIB, Oxford, United Kingdom); volumes were registered to a T1 EPI template in MNI atlas space (SPM2), smoothed with a 6-mm FWHM Gaussian kernal, low-pass filtered to

remove frequencies above 0.08 Hz, and filtered to remove linear trends. Using partial regression, we then removed nuisance variables reflecting the six motion correction parameters, global signal, average signal within the lateral ventricles, and average signal within white matter, as well as the temporal derivatives of each nuisance variable.

Functional connectivity was computed as the correlation between the average time course within each seed ROI and the time course from each of the remaining voxels in the acquired volume. The ROIs used as seeds in this analysis were defined by the results of the conjunction analysis outlined above. Functional connectivity analyses were conducted individually for each participant and independently for each ROI seed. Resulting correlation maps from each individual analysis were then transformed to z maps. Group maps were computed as the average over all participants' correlation z maps, thresholded at $z = 0.2$, corresponding to a minimum rho of .2.

Moreover, to assess the extent to which the default network as a whole responded differentially to proximal and distal trials, we also conducted an ROI analysis on an independently defined default network. ROIs were created as a sphere with a radius of 8 mm centered around the coordinates identified by Andrews-Hanna, Reidler, Sepulcre, Poulin, and Buckner (2010), who defined the 11 default network regions using low-frequency intrinsic connectivity in a group of 28 adults. Parameter estimates for all eight conditions (proximal and distal trials in all four dimensions) were extracted from all 11 ROIs to examine how these regions respond during simulations of proximal and distal events, across all dimensions. This previous research separates these 11 regions into three functionally and anatomically separable subnetworks within the default network: (i) a medial-temporal lobe subsystem that comprises the hippocampal formation, parahippocampal cortex, retrosplenial cortex, posterior intraparietal lobe, and OFC; (ii) a dorsomedial PFC (dMPFC) subsystem that comprises the dMPFC, temporal pole, lateral temporal cortex, and temporal-parietal junction; and (iii) a "core" subsystem that comprises the posterior cingulate cortex (PCC) and ventromedial prefrontal cortex (vMPFC) and that is highly connected to both of the other two subsystems (Andrews-Hanna et al., 2010).

Implicit Association Test

After scanning, participants completed six versions of the IAT (Greenwald, McGhee, & Schwartz, 1998), designed to measure the strength of their automatic associations among the different dimensions of distance. The IAT assesses how strongly people associate two concepts on the basis of the speed with which they can make the same behavioral response to exemplars from each. During each version of the IAT, participants considered two different dimensions of distance. For example, one IAT measured how strongly participants associated spatially proximal with temporally proximal concepts and spatially

distal with temporally distal concepts. Specifically, during the *congruent* block of this IAT, participants were asked to make the same button press (the "d" key) to words that denoted spatially proximal (domestic, close, and near) or temporally proximal (today, present, and current) concepts and to make another button press (the "k" key) to words that denoted spatially distal (abroad, far, and away) or temporally distal (tomorrow, future, and after) concepts. During the *incongruent* block of this IAT, participants were asked to make the same button press to words that denoted spatially proximal or temporally distal concepts and to make another button press to words that denoted spatially distal or temporally proximal concepts. The extent to which participants responded to trials more quickly in the congruent than the incongruent block served as an index of the automatic association between spatial and temporal proximity and automatic dissociation between spatial proximity and temporal distance. Participants completed one IAT for each of the six possible pairings of distance perspectives (see Supplementary Materials for stimuli). Each IAT block comprised 20 practice followed by 40 critical trials, and each participant completed the IAT blocks in a random order. Data are presented as the mean RT difference between incongruent and congruent blocks, such that higher values indicate a stronger association between the same perspective (e.g., spatially proximal and temporally proximal) than opposing perspectives (e.g., spatially proximal and temporally distal).

RESULTS

Psychological Distance Tasks

Behavioral Results

Consistent with earlier research (Mitchell, Schirmer, Ames, & Gilbert, 2010; Zauberman & Lynch, 2005), participants' opinions differed between proximal and distal perspectives. Specifically, a two-tailed, one-sample t test showed that the absolute difference between responses on each statement for the proximal and distal perspectives was significantly different from zero in each of the four tasks (Table 1). Participants distinguished between proximal and distal perspectives even under conditions when doing so was a demonstrable error: although stimuli on the hypotheticality task were pretested such that female and male participants expressed similar opinions (mean difference = 0.1, $p > .40$), participants assumed that they would answer such questions differently if they were a member of the opposite sex (mean difference = 0.8, $SD = .45$). Importantly, response times did not significantly differ between proximal and distal perspectives in any of the four tasks (all p values > .15), and indeed, participants responded faster during the distal conditions for two of the dimensions, and faster for the proximal conditions for two dimensions, ruling out RT differences as a consistent source of any reported neural effects (Table 1).

Table 1. Behavioral Results Obtained from the Psychological Distance Tasks

|	Response			Reaction Time (msec)			
	Proximal (SD)	Distal (SD)	t (p)	Proximal (SD)	Distal (SD)	t (p)	Cohen's d
Spatial	2.96 (0.40)	3.08 (0.46)	8.9 ($\approx 10^{-7}$)	1854 (208)	1852 (181)	0.1 (.91)	0.02
Temporal	2.81 (0.56)	3.42 (0.45)	8.6 ($\approx 10^{-7}$)	2030 (211)	1991 (235)	1.3 (.21)	0.31
Social	3.33 (0.41)	2.96 (0.61)	20.5 ($\approx 10^{-14}$)	1913 (238)	1940 (195)	−0.9 (.37)	0.20
Hypothetical	2.84 (0.24)	3.00 (0.37)	8.8 ($\approx 10^{-7}$)	2053 (175)	2077 (204)	−1.4 (.19)	0.32

The leftmost three columns display the mean response to statements considered from a proximal and distal perspective (1–5 scale) and the t and p values associated with a one-sample t test on the absolute difference between responses to each statement under these two conditions. The rightmost four columns display the mean RT to statements considered from a proximal and distal perspective (in msec), the t and p values associated with a paired-sample t test of the difference between these two conditions (all values ns), and a measure of the magnitude of this difference (Cohen's d). Each row refers to one of the four dimensions of distance.

Imaging Results

To identify brain regions that responded differently as a function of perspective, we conducted four whole-brain random effects contrasts that compared proximal > distal trials separately for each of the four distance tasks (spatial, temporal, social, and hypothetical). Consistent with our predictions, BOLD response in two regions of the default network was significantly greater when participants considered proximal than distal perspectives in each of the four distance tasks: MPFC and the retrosplenial region of the posterior cingulate (Figure 1 and Table 2). To test formally whether the same region of MPFC and retrosplenial cortex was modulated across each dimension of distance, we conducted a conjunction analysis across the four tasks (see Methods). Considerable overlap was observed across

tasks in only two regions, MPFC and retrosplenial cortex (Figure 2), suggesting that the four manipulations of perspective were associated with modulations in the same set of voxels.

To examine whether these neural effects were consistently larger in some participants than others, we examined the correlation of BOLD differences within the MPFC and retrosplenial regions obtained from the conjunction analysis across the four tasks. For each distance task, we correlated the BOLD difference between proximal and distal trials across all subjects with the corresponding difference for each other distance task. For both the MPFC and retrosplenial regions, we then calculated the mean correlation of the BOLD difference between proximal > distal on each task with every other and tested whether the distribution of these six correlation values differed from zero using
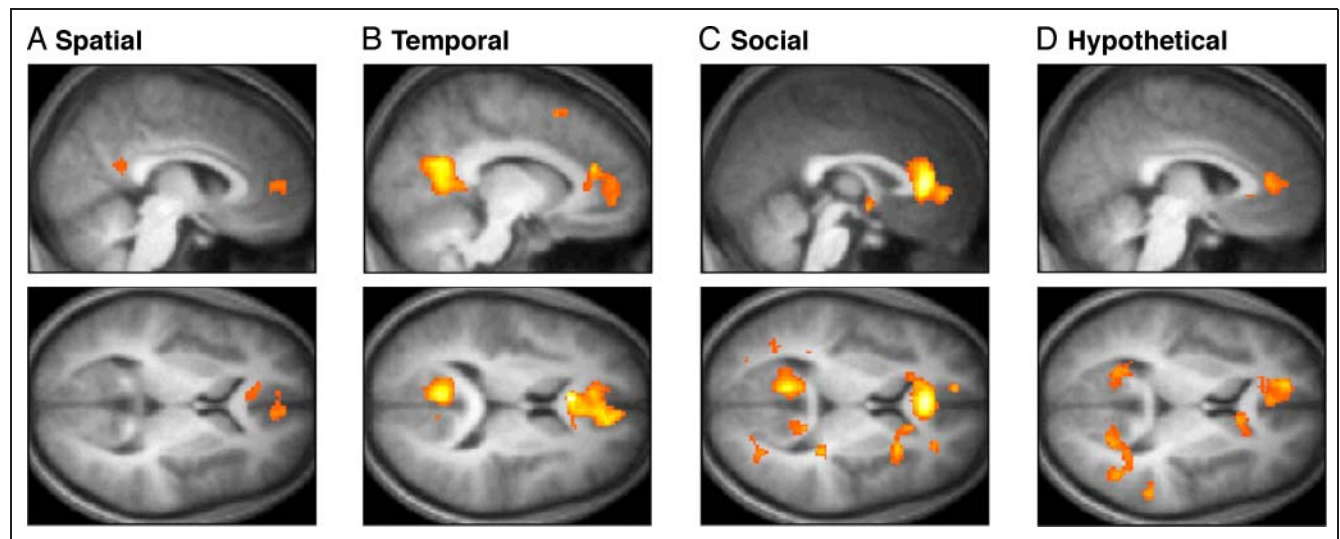
Figure 1. BOLD differences for main effect of proximal > distal. The results from four tasks ($p < .05$, corrected) identified regions of the medial prefrontal and medial parietal cortices as significantly more active for near events than far events in each of four dimensions. In all tasks, participants reported preferences in both a proximal and a distal perspective within one of four dimensions: (A) In the spatial task, participants responded about their own preferences in their current location and a distant location. (B) In the temporal task, they responded about present and future preferences. (C) In the social dimension task, they reported their own preferences and those of another person. (D) In the hypothetical task, they responded about their actual preferences or about the preferences of a hypothetical self.

Table 2. Peak Voxel and Cluster Size for All Regions Obtained from a Contrast of Proximal > Distal in Each of the Four Dimension Tasks ($p < .05$, Corrected)

Anatomic Label	x	y	z	Volume	Max t
Spatial					
Retrosplenial cortex	18	−52	14	514	4.02
	28	−38	26	125	3.57
MPFC	4	56	6	118	3.09
ACC	−4	32	−4	114	3.53
Temporal					
MPFC	−4	26	14	1895	6.71
Retrosplenial cortex	−8	−62	20	1317	5.94
Posterior orbital gyrus	26	42	−12	499	6.60
	−26	14	−24	349	4.68
Superior frontal gyrus	−14	16	56	488	4.31
Thalamus/ventral striatum	10	−14	10	241	3.79
Middle frontal gyrus	36	8	40	218	4.01
	38	28	44	212	4.54
	−26	30	44	177	3.82
Fusiform gyrus	34	−62	−16	137	3.56
Middle temporal gyrus	−48	−34	0	126	4.13
	−52	−6	−18	89	3.68
Cerebellum	−26	−66	−34	96	3.84
Social					
MPFC	18	12	50	5890	7.11
Retrosplenial cortex	−12	−64	18	1466	5.44
	20	−52	18	380	5.14
Postcentral gyrus	54	−14	56	975	6.09
	−18	−14	60	85	3.50
Midcingulate cortex	−14	−24	48	785	4.44
	22	−28	52	231	4.05
Middle occipital gyrus	−42	−66	0	417	3.99
	36	−74	2	291	4.16
Middle frontal gyrus	32	44	18	368	3.87
Parahippocampal gyrus	−22	−32	−6	251	3.58
Nucleus accumbens	−4	0	−6	148	4.07
Insula	30	−32	10	115	4.63
	34	−10	22	105	3.18

Table 2. (*continued*)

Anatomic Label	x	y	z	Volume	Max t
Hypothetical					
Posterior cingulate cortex	−24	−60	12	578	4.41
	26	−64	10	371	4.50
MPFC	−10	28	−2	569	5.61
	18	34	20	216	3.90
Cerebellum	16	−30	−26	257	4.99
Superior temporal gyrus	54	−36	6	256	3.77
Inferior frontal gyrus	−50	12	22	155	4.31
	28	16	−18	118	3.67
Middle frontal gyrus	−28	42	26	152	3.28
	−24	28	34	98	3.36
White matter	40	−24	−8	123	4.14
Middle temporal gyrus	−50	−26	−16	121	3.80
Superior parietal lobule	26	−54	58	107	3.55
Caudate	10	20	10	102	3.82
Insula	−32	4	−12	88	3.49
Temporal lobe	38	−4	−26	85	3.85

t Tests reflect the statistical difference between the two conditions, as computed by SPM2. Coordinates refer to the stereotaxic space of MNI.

a two-tailed, one-sample *t* test. This analysis revealed that the BOLD difference between proximal and distal trials was significantly correlated across tasks in the MPFC, $t(5) = 3.9$, $p = .01$, mean $r = .25$, $SD = .16$, indicating that participants in whom the MPFC most distinguished between proximal and distal perspectives for one dimension (e.g., temporal) were also those participants in whom the MPFC most distinguished between proximal and distal across the other three dimensions. The corresponding analysis for retrosplenial cortex did not reach significance, $t(5) = 1.5$, $p = .17$, mean $r = .12$, $SD = .18$.

No brain region was consistently more active for the distal than proximal perspective. A region of precuneus responded more strongly for distal > proximal trials in both the social and hypothetical tasks (Table 3), but this contrast did not reveal any regions for the other two tasks.

Network Analyses Results

To determine whether the regions identified by the conjunction analysis reflect activity within the default network, we examined the functional connectivity of the MPFC and retrosplenial clusters with the rest of cortex using resting state data from the participants in this study (see Methods). By assessing correlations among spontaneous fluctuations in BOLD activity during rest, such functional connectivity analyses can be used to show

Figure 2. Conjunction analysis across dimensions of distance. (A) Results of a conjunction of all four distance tasks at voxel-wise alpha level of .05 (yellow), .025 (red), and .01 (green). At a voxel-wise alpha level of .025, the conjunction included 150 contiguous voxels in the MPFC and 61 contiguous voxels in the PCC. (B) Mean distance IAT scores correlated with BOLD activity in the MPFC but not the PCC ROI identified in the conjunction analysis.
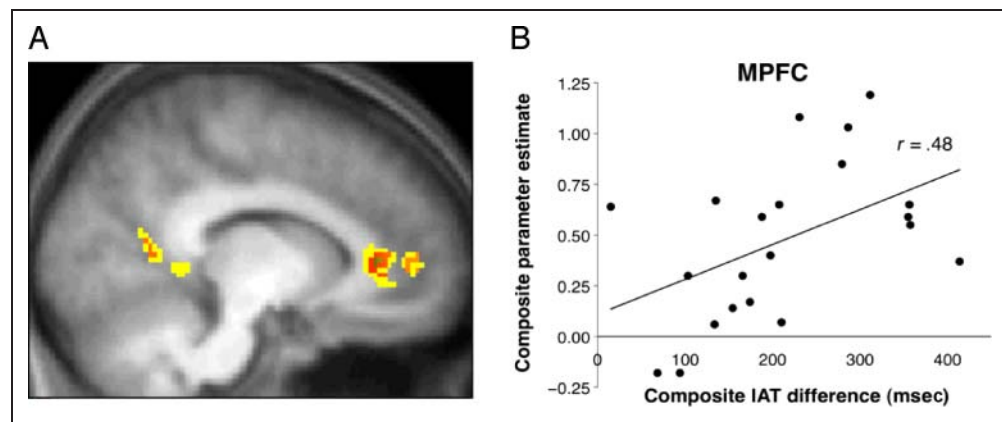
the intrinsic connectivity between a seed region and the rest of cortex and, thus, can identify the larger network within which specific clusters are embedded. Results revealed that our MPFC cluster was highly connected with all of the regions that constitute the default network: medial parietal cortex, lateral parietal cortex, medial and lateral temporal cortex, as well as other subregions of the MPFC. Similarly, the retrosplenial cluster was highly connected with the medial parietal cortex, MPFC, lateral parietal cortex, and the medial-temporal cortex (Supplementary Figure 1). These results replicate earlier findings from Andrews-Hanna et al. (2010) that the MPFC and retrosplenial cortices serve as nodes within the core and medial temporal lobe (MTL) subsystems of the default network, respectively.

Second, we interrogated 11 regions independently defined as the default network—inclusive of those regions not identified by our conjunction analysis above—to see if they show the predicted pattern of greater activity for proximal than distal trials. These regions, identified by Andrews-Hanna et al. (2010) as making up the default network, form three functionally and anatomically separable subnetworks within the default network. Results showed that activity in both the MTL and core subsystem of the default network, collapsed across all dimensions, was significantly greater for the proximal conditions than the distal conditions (both p values < .05; Supplementary Figure 2A). Activity within the dMPFC subsystem also largely conformed to this pattern, with one interesting exception: Within the social dimension, the dMPFC subsystem was significantly more active for the distal condition than the proximal one (Supplementary Figure 2B).

Implicit Association Test

On all six IAT tasks, participants responded more quickly when the two proximal concepts were paired together and the two distal concepts were paired together (congruent blocks) than when proximal and distal concepts all required the same response (incongruent blocks): all $t(20) > 5.4$, all $p < .001$ (Table 4). These data suggest that participants strongly associated proximal concepts

with other proximal concepts and distal concepts with other distal concepts, regardless of the particular dimension of distance tested, and did not associate proximal concepts in any dimension with distal concepts in any other dimension (Srinivasan & Carey, 2010; Stephan, Liberman, & Trope, 2010; Casasanto & Boroditsky, 2008).

Finally, we compared individual differences in the strength of these automatic associations to neural differences between proximal and distal perspectives. A composite IAT score was calculated for each participant as the mean difference between incongruent and congruent blocks across all six IAT tasks. This composite IAT value was significantly correlated with the mean BOLD difference across all four tasks between proximal > distal trials in the MPFC region obtained from the conjunction analysis, $r(19) = .48, p = .025$, 95% confidence interval = [.06, .76] (Figure 2B). In other words, the more difficult it was for a participant to associate proximal and distal concepts on the IAT, the more that participant's MPFC differentiated between proximal and distal trials during the preceding scanning task. The corresponding correlation in retrosplenial cortex region obtained from the conjunction analysis did not approach significance, $r(19) = .12$, $p = .61$, 95% confidence interval = $[−.33, .52]$.

DISCUSSION

Extant cognitive theories suggest that although perceivers can richly simulate a wide range of experiences removed from the current perceptual environment, they naturally tend to only imagine proximal events in such concrete detail and instead construe distal events as generalized abstractions (Stephan et al., 2010; Liberman & Trope, 2008; Bar-Anan, Liberman, Trope, & Algom, 2007; Liberman et al., 2007; Trope & Liberman, 2003). Such theories also suggest that this reluctance to simulate distal events is common across all the various dimensions along which perceivers can transcend the here-and-now. The current study evaluated these hypotheses against recent neuroscience findings that specific brain regions—corresponding to those described as "the default network"—are engaged

Table 3. Peak Voxel and Cluster Size for All Regions Obtained from the Contrast of Distal > Proximal in All Four Dimension Tasks ($p < .05$, Corrected)

Anatomic Label	x	y	z	Volume	Max t
Spatial					
No regions identified					
Temporal					
No regions identified					
Social					
dMPFC	−6	42	54	2197	5.53
Precuneus	6	−62	32	934	5.60
Inferior frontal gyrus	50	24	14	631	5.44
Superior temporal gyrus	58	−64	26	352	4.71
Inferior temporal gyrus	−60	−18	−22	330	5.13
Orbito-frontal gyrus	6	54	−16	187	6.23
Middle temporal gyrus	−48	−72	26	171	4.72
Inferior frontal gyrus	−48	26	2	135	4.12
Middle temporal gyrus	60	−4	−24	118	4.19
Cerebellum	14	−40	−46	95	3.15
Hypothetical					
Precuneus	4	−70	42	479	4.22
Midcingulate cortex	0	−16	26	181	4.35

when individuals engage in active simulation of experiences, such as those that might happen elsewhere, later, to someone else, or purely as a pigment of one's imagination. Participants were scanned while alternately considering events from a proximal perspective (nearby, soon, to oneself, or in reality) or from a distal perspective (far away, much later, to a distant other, or purely hypothetically). Across all four manipulations of perspective (spatial, temporal, social, and hypothetical), two regions of the default network—MPFC and retrosplenial cortex—were more active for thinking about proximal than distal events. Conjunction analyses confirmed that these differences were localized to the same subregions of MPFC and retrosplenial cortex. Thus, these findings support both hypotheses of construal theory: (i) perceivers are more likely to richly simulate proximal events than distal ones and (ii) distance affects simulations similarly regardless of the particular dimension along which these "what-ifs" differ from the current environment.

Network-based analyses revealed that the preferential MPFC and retrosplenial response to proximal events reflects a consistent pattern of activity throughout the default network. Functional connectivity analyses showed the MPFC cluster to be highly connected with all areas of the canonically defined default network and the retrosplenial cluster to be highly connected with two of the three subsystems of the default network, the MTL and core subsystems. Analyses of task-based activity showed greater neural response to proximal than distal events within an independently defined default network (Andrews-Hanna et al., 2010), most robustly in the same two subsystems. These convergent findings suggest that the effects of distance may be carried in particular by the MTL and core subsystems of the default network. Interestingly, these two subsystems have been associated consistently with the two factors specifically manipulated in this study: imagery-based processes of scene construction (MTL subsystem) and self-referential thought (core subsystem). In fact, all three subsystems actually conformed to this pattern of activity with one especially robust exception: the distal social condition activated the dMPFC subsystem significantly more than the proximal social condition. Previous research has consistently linked the regions within this subnetwork, including the dMPFC and TPJ, to thinking about the minds of other people, in particular, about those who are dissimilar to oneself (Mitchell, Macrae, & Banaji, 2006) or who hold conflicting beliefs to one's own (Sommer et al., 2007). The current findings, along with a growing body of literature on the divergence of social cognition from other forms of cognition (Mitchell, 2009a, 2009b), thus, suggest an interesting distinction associated with the social dimension.

Results further suggested that the tendency to simulate distal events—as indexed by activity within the MPFC—differs stably across individuals. Participants varied in the extent to which the MPFC was more active for proximal than distal trials, and this variability was consistent across different dimensions (spatial, temporal, social, and hypothetical). Those participants least likely to simulate any one type of distal event were also those participants least likely to simulate other types of distal events, as if all experiences considered outside the here-and-now were equally difficult to imagine in concrete detail. Moreover, the strength of these MPFC differences was correlated with a well-characterized cognitive measure of association,

Table 4. Reaction Time and Effect–Size Differences between Incongruent and Congruent IAT Blocks across All Six Dimension Pairings

Dimension	Spatial	Temporal	Social	Hypothetical
Spatial		355 (183)	179 (146)	178 (159)
Temporal	1.98		186 (113)	220 (186)
Social	1.25	1.68		160 (98)
Hypothetical	1.07	1.21	1.67	

Values in the top right display the mean RT difference (in msec) for incongruent minus congruent blocks, with standard deviation in parentheses. Values in the bottom left display the same differences as the effect–size (Cohen's *d*) associated with the difference between incongruent and congruent blocks.

the IAT, which indexed the degree to which participants automatically distinguished between proximal concepts and distal concepts across all four dimensions of distance. That is, the more a participant struggled to associate proximal and distal concepts on the IAT, the more their MPFC differentiated between proximal and distal experiences.

As such, these results extend and integrate four lines of extant research. First, this study complements earlier cognitive work that has similarly demonstrated that perceivers construe proximal and distal events differently. Perceivers routinely distinguish between proximal and distal events by imagining the former in low-level concrete detail and representing the latter as high-level, decontextualized abstractions (Trope & Liberman, 2010; Liberman et al., 2007). For example, people will identify actions (e.g., reading) in terms of their high-level goals or features (e.g., gaining knowledge) when considering them from a spatially distant perspective but will focus on low-level observable features (e.g., following lines of print) when considering an action from a proximal perspective (Fujita, Henderson, Eng, Trope, & Liberman, 2006). In addition, people will attribute their own actions to low-level, situational factors if taking a proximal perspective but will attribute their own (and others) actions to high-level, dispositional factors when considering them from a distant third person perspective (Frank & Gilovich, 1989; Nigro & Neisser, 1983). The current neural and IAT findings support these earlier findings by demonstrating that people represent proximal and distal events quite distinctly at both an implicit and neural level.

Second, these findings replicate and extend previous research that suggests an overlap in the way people relate distances across different dimensions. For example, researchers have consistently demonstrated strong interactions between the domains of time and space. Looking at long lines leads perceivers to overestimate the duration of events (Casasanto & Boroditsky, 2008) and watching forward spatial movement facilitates future thinking whereas backward spatial movement facilitates thinking about the past (Miles, Karpinska, Lumsden, & Macrae, 2010). Space and time also interact with social dimension, such that thinking about another person in a spatially distant location or in the future causes perceivers to think about the person as socially distant (Liberman et al., 2007); indeed, perceivers show strong implicit associations between proximal concepts in the spatial dimension with proximal concepts in the other three dimensions (i.e., social, temporal, and hypothetical; Bar-Anan et al., 2007). By examining the effects of distance in all four dimensions concurrently in the same set of subjects, the current study was able to show that (i) perceivers implicitly associate all four dimensions of distance with each other dimension, (ii) specific brain regions respond in an equivalent manner to differences in distance across four dimensions, and (iii) implicit measures of the dissociations between proximal and distal construals correlate with a neural measure of the difference between proximal and distal self-projections. These results,

thus, provide a comprehensive demonstration that people represent different forms of distance similarly.

Third, the current study complements a growing number of observations of the pervasive role of psychological distance in human decision-making. For example, our group has recently demonstrated that activity in regions of MPFC and retrosplenial cortex—highly similar to those observed here—distinguishes between thoughts about temporally proximal and temporally distal events and that the strength of this difference in MPFC reliably predicted monetary choices (such that participants who most differentiated neurally between temporally proximal and distal events were most likely to opt for a small financial reward immediately over a larger one in the future; Mitchell et al., 2010). Similar findings have also been reported recently by Ersner-Hershfield, Wimmer, and Knutson (2009). Modulations of MPFC also accompany manipulations of social distance that strongly influence interpersonal decisions, such as differences between "up close and personal" versus impersonal moral scenarios (Greene, Sommerville, Nystrom, Darley, & Cohen, 2001) or judgments of similar and dissimilar others (Mitchell et al., 2006). The current study suggests that these effects should generalize to decisions about events that vary in the spatial and hypothetical dimensions and that neural modulations should correlate with differences in the way perceivers make decisions about such faraway or improbable events.

Finally, the current study extends recent observations that both introspecting about the self and reporting one's attitudes draw on the default network (Mitchell, 2009b). A considerable number of studies have now observed greater response in MPFC during tasks in which participants introspect about their personality characteristics (Schmitz, Kawahara-Baccus, & Johnson, 2004; Fossati et al., 2003; Johnson et al., 2002; Kelley et al., 2002). In addition, this region has been implicated repeatedly in studies in which participants explicitly evaluate a stimulus as positive or negative (Cunningham, Raye, & Johnson, 2004; Paulus & Frank, 2003; Zysset, Huber, Ferstl, & von Cramon, 2002; Gusnard, Akbudak, Shulman, & Raichle, 2001) or—as in the current study—report on their personal preferences (Jenkins, Macrae, & Mitchell, 2008; Pfeifer, Lieberman, & Dapretto, 2007; Mitchell et al., 2006; Zysset et al., 2002). Consistent with such neuroimaging observations, damage to ventral aspects of the MPFC impairs the ability to report one's preferences (Fellows & Farah, 2007) and to appraise the value of different choices (Fellows, 2006; Bechara, Damasio, Damasio, & Anderson, 1994; Damasio, 1994).

The current study amends these observations by demonstrating that this region of the default network does not generally subserve introspecting about the self or evaluating and reporting one's attitudes but does so only under specific conditions. Although greater activity in MPFC accompanied trials on which perceivers considered their preferences in their current location and time or as the person they actually are, these regions did not as robustly contribute to the evaluation of one's attitudes when

perceivers were asked to do so from a distal perspective. That is, even when the requirement to introspect about one's attitudes was held constant across trials (e.g., in the spatial, temporal, and, to some extent, hypothetical tasks), the response of MPFC varied as a function of perspective. Despite its putative roles in introspection about the self and evaluation of attitudes, MPFC was not spontaneously engaged when introspecting about one's attitudes in the future, in another location, or as part of some fictitious scenario to the same extent as for those situations associated with construals of proximal events.

These results suggest an important overlap between self-referential thought and construals of distal events, such that perceivers might introspect less when considering themselves in the future, at another location, or in a hypothetical scenario. Consistent with this possibility, behavioral evidence suggests that the self is less embedded in thoughts of distal than in proximal experiences (Trope & Liberman, 2010), and neural evidence suggests that the core subsystem of the default network, which includes the MPFC, is especially responsive to the extent of self-referential thought in a simulation (Andrews-Hanna et al., 2010). Moreover, behavioral research suggests that psychological distance likely influences both self-relevance and representation complexity concurrently, as people represent their distal self in a less complex and more generalized manner than their proximal self (Wakslak, Nussbaum, Liberman, & Trope, 2008). Indeed, events or stimuli that are termed highly "self-relevant" may just be those that invoke especially rich simulations or associations. We look forward to future research investigating the intimate relationship between psychological distance, self-referential thought, and the richness of an imagined event.

Taken together, the current findings serve to demonstrate the limits of human imagination. Although individuals can preview experiences by simulating them in advance, they do not always avail themselves of such prognostic powers. Instead, only when events seem nearby, soon, likely to happen, or relevant to a close other do we reliably imagine them in concrete, rich detail. Only with reluctance do we likewise simulate distal events. Interestingly, perceivers treat distance in all dimensions similarly, and individuals differ in their natural willingness to use simulation as a strategy for understanding events removed from the here-and-now, an individual difference with demonstrable consequences for everyday life (Mitchell et al., 2010; Zauberman & Lynch, 2005). Together, these observations suggest the enormous advantages of, as well as the formidable constraints on, the human ability to transcend the here-and-now through mental simulation.

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