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Original article

Neurological evidence for the role of construal level in future-directed thought

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Abstract

The ability to mentally represent future events is a significant human psychological achievement. A challenge that people encounter is that they often lack detailed specifics about distant relative to near future events. Construal level theory proposes that people represent distant future events by their abstract and essential features—a process referred to as high-level construal. As events become temporally proximal, people represent events by their increasingly available and reliable concrete and idiosyncratic features—a process referred to as low-level construal. The present fMRI experiment provides direct neural evidence for these assertions. Using the why–how localizer as a measure of construal level, results revealed brain regions associated with both temporal distance and high-level construal (medial prefrontal cortex), as well as temporal proximity and low-level construal (precuneus). We discuss the implications of these findings for the neuroscience of mental time travel and cognitive representation.

Key words: construal level theory; temporal distance; mental time travel; prospection; abstraction

Prospection—the ability to think about and anticipate future events—is an important psychological achievement and serves a number of critical functions (Atance and O'Neill, 2001; Schacter and Addis, 2007; Suddendorf and Corballis, 2007). It enables people to respond not only to reward contingencies in the present, but also to those anticipated in the future (Suddendorf and Corballis, 2007). Prospection improves self-control (Peters and Büchel, 2010; Daniel *et al.*, 2013), and promotes goal-directed planning (Gollwitzer, 1999). Prospection may also help people regulate their affective and motivational states (Brown *et al.*, 2002; Peetz and Wilson, 2008). Although functional, prospection is also prone to systematic biases (e.g. Gilbert and Wilson, 2007). To understand the benefits and limits of future-directed thinking, researchers have sought to illuminate its cognitive and neurological mechanisms (Atance and O'Neill, 2001; Okuda *et al.*, 2003; Gilbert and Wilson, 2007; Schacter and Addis, 2007; Packer and Cunningham, 2009; Spreng and Grady, 2010; Tamir and Mitchell, 2011; Liberman and Trope, 2014).

Construal level theory

One theoretical framework that describes the cognitive mechanisms of prospection is construal level theory (CLT; Trope and Liberman, 2003, 2010; Liberman and Trope, 2014). CLT treats

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prospection as an instance of mental distance travel. A key concept in CLT is psychological distance—the degree to which events are removed from direct experience. People can use their perceptual systems to create event representations of the here-and-now. Events that extend beyond these perceptual capacities, such as those that will occur in the distant future, require people to construct representations from information stored in memory.

A challenge that people face when representing psychologically distant events is the absence of reliable detailed specifics. In response, CLT proposes that people engage in high-level construal—a process that extracts the abstract and essential features that are common and invariant to all possible instances of those events. In contrast, as events become psychologically proximal, CLT suggests that people engage in low-level construal—a process that incorporates the specific details that are increasingly available and reliable to construct more concrete and idiosyncratic representations. Whereas a focus on abstract essences allows people to transcend the immediate context, the focus on concrete specifics facilitates immersion into the here-and-now. This relationship between psychological distance and construal level is over-generalized, evident even when people have access to equivalent information about psychologically distant *vs* near events (Bar-Anan *et al.*, 2006).

Extensive behavioral research supports CLT's proposition that people engage in high-level (*vs* low-level) construal to represent distant (*vs* near) future events (Trope and Liberman, 2003, 2010; Liberman and Trope, 2014). People are more likely to sort objects associated with distant *vs* near future events into fewer, broader groups—suggesting more abstract categorization (Liberman *et al.*, 2002). People also tend to identify actions (e.g. 'locking a door') by the abstract ends they promote (e.g. 'securing a house') rather than the concrete means used to achieve those actions (e.g. 'turning a key') when those events will occur in the distant rather than near future (Liberman and Trope, 1998).

Differences in construal level can be directly induced by having people rehearse mental processes characteristic of high- or low-level construal (Freitas *et al.*, 2004; Fujita *et al.*, 2006). One task, the category–exemplar task (Fujita *et al.*, 2006), presents participants with objects (e.g. 'dog') and has participants generate superordinate categories to which that objects belong (e.g. 'animal') *vs* subordinate examples of the objects (e.g. 'poodle'). Another task, the why–how task (Freitas *et al.*, 2004), presents participant with an action (e.g. 'watching TV') and asks them to generate superordinate ends that action serves (e.g. 'why do people watch TV?') *vs* subordinate means with which to accomplish this action (e.g. 'how do people watch TV?'). These manipulations reliably induce the tendency to engage in high- *vs* low-level construal, even in subsequent semantically unrelated contexts (for review, see Fujita and Trope, 2014).

Providing neural evidence for the construal-distance link

Tests of CLT's assertion that people construe distant *vs* near future events in high- *vs* low-level terms, respectively, have been limited to behavioral research. We hope to advance the literature by first extending the existing literature beyond behavioral methods. Second, we attempt to highlight the generativity of CLT by demonstrating it can make testable neuroscientific predictions. Third, we hope to bring insights from CLT—namely, the role of construal level in the representation of psychologically distant *vs* proximal stimuli—to inform theory on the neuroscience of cognitive representation.

Neuroscience research on temporal distance and construal level

Although no neuroscience work has directly tested the link between temporal distance and construal level, work has investigated these phenomena independently. For example, research reveals regions of medial prefrontal cortex (mPFC), precuneus and posterior cingulate cortex (PCC) associated with retrospection are also active when engaged in prospection (e.g. Okuda *et al.*, 2003; Addis *et al.*, 2007; Szpunar *et al.*, 2007; Spreng and Grady, 2010; see also Schacter and Addis, 2007). Notably, Okuda et al. (2003) found that, irrespective of direction (past *vs* future), regions of mPFC were more active when thinking about temporally distant *vs* near events. Packer and Cunningham (2009) further found that thinking about distant future goals activated regions of orbitofrontal cortex (OFC) and ventrolateral prefrontal cortex, whereas thinking about near future goals activated regions in posterior cortex such as the precuneus and the calcarine sulcus. In contrast, Mitchell *et al.* (2011) and Tamir and Mitchell (2011) failed to find any regions preferentially active when evaluating temporally distant relative to near events, but did find greater activation of ventromedial prefrontal cortex (vmPFC) and PCC when evaluating temporally near *vs* distant events. The region of vmPFC, however, appears more posterior or dorsal than the regions that respond to distant stimuli reported by Packer and Cunningham (2009) and Okuda *et al.* (2003). Thus, there is some inconsistency in the literature about the neural representation of temporal distance.

Examining brain regions involved in high- and low-level construal, Spunt and colleagues (Spunt *et al.*, 2011, 2016; Spunt and Adolphs, 2014) have optimized a localizer task based on the why–how construal level manipulation described earlier. Across multiple studies, high-level why (relative to low-level how) trials recruited regions of the mPFC, precuneus and PCC (for review, see Spunt and Adolphs, 2014). In contrast, low-level how (relative to high-level why) trials recruited regions of the lateral parietal cortex such as the intraparietal sulcus, supramarginal gyrus and dorsal precuneus. Note that those regions involved in high-level construal are also implicated in the processing of abstract mental states (e.g. Spunt *et al.*, 2016), whereas those involved in low-level construal support the execution and perception of actions (e.g. Utevsky *et al.*, 2014)—findings further consistent with behavioral CLT research (Trope and Liberman, 2010). One might further observe some overlap between those areas associated with temporal distance *vs* proximity and high- *vs* low-level construal (Packer and Cunningham, 2009).

There are, however, notable inconsistencies in this literature. Gilead *et al.* (2014) scanned participants while they completed versions of the category–exemplar and why–how construal level manipulations. The why (high-level) trials of the why–how task recruited similar regions of mPFC and precuneus as found by Spunt and Adolphs (2014). Unexpectedly, these same regions were active in the 'mismatching' exemplar (low-level) trials of the category–exemplar task. Research by Baetens *et al.* (2014) suggests this surprising 'backward' effect may be due in part to methodology. They instantiated a version of the category–exemplar task in which participants generated features of objects in the low-level trials *vs* categories to which the object belonged to in the high-level trials. The regions activated in low- and high-level trials were consistent with those identified by Spunt and Adolphs (2014). Nevertheless, as

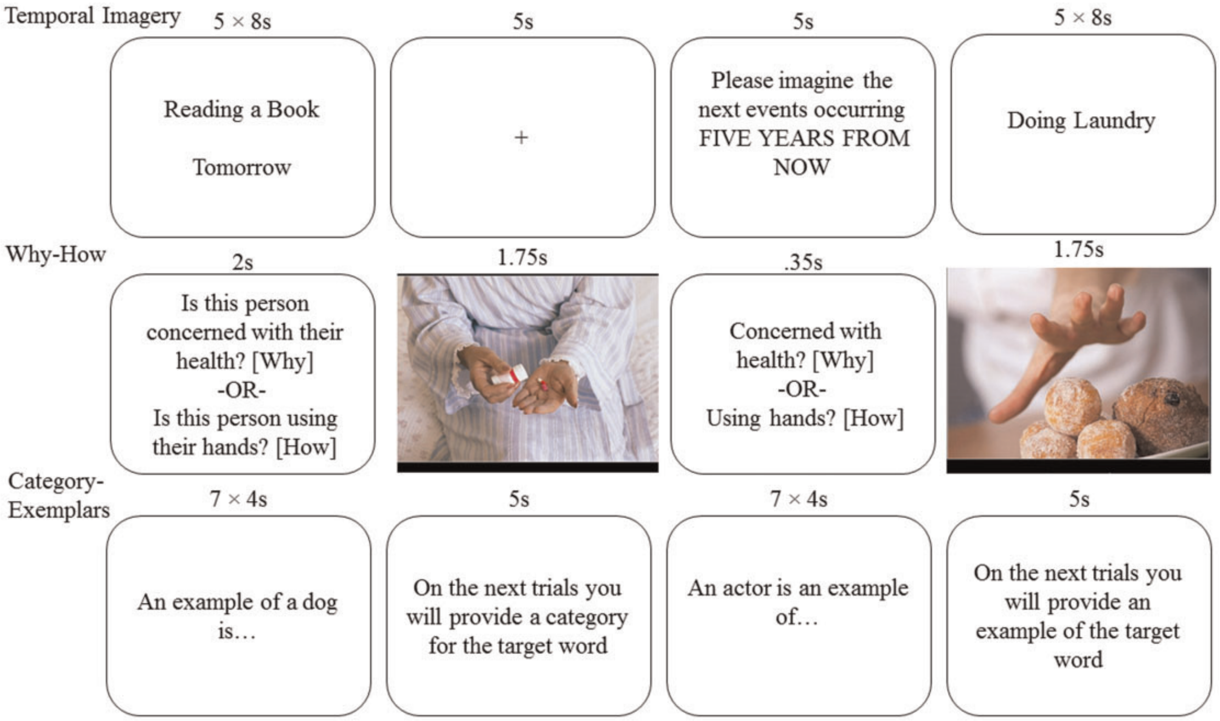

Fig. 1. Schematic of the three tasks of temporal imagery (top), why/how (middle) and category/exemplars (bottom). Each task followed a block design with the following total number of blocks per condition: temporal imagery, 3; why–how, 8; category–exemplar, 4.

this apparent discrepancy has yet to be resolved empirically within the same study, questions remain about the neural representation of high- *vs* low-level construal and how best to implement these processes in the scanner.

The present study

Together, some inconsistencies notwithstanding, the existing literature suggests that the mPFC may be involved in both the neural representation of temporally distant events and high-level construal. Similarly, dorsal precuneus and vmPFC may be involved in both the representation of temporally proximal events and low-level construal. No research, however, has yet examined both in the same study. We seek to provide the first direct test of these hypotheses.

Methods

Participants

Thirty right-handed participants (21 female, ages 18–30) were paid $25 for participation. Participants reported no abnormal neurological history and had normal or corrected-to-normal vision. All provided informed consent and were debriefed at the conclusion of the study.

Temporal imagery and construal level tasks

We presented participants with three tasks (Figure 1)—one manipulation of temporal imagery (temporal proximity *vs* distance) and two direct manipulations of construal level (low- *vs* high-level). The tasks, each lasting the entire functional run of ∼6 m, used the same general form: participants completed trials of both conditions of each task, manipulated within-subject. In each task, participants completed several trials of one condition (i.e. a block), and then completed several trials of the opposing condition in an alternating fashion. Condition order was counterbalanced across participants.

Temporal imagery. Participants imagined engaging in an activity (e.g. going to a party) either tomorrow (temporal proximity) *vs* 5 years from now (temporal distance). As imagining temporally distant relative to proximal events may be more difficult, we asked participants to take a minute to imagine their lives in 5 years both prior to entering the scanner and again before the start of the run. This should equate the accessibility and availability of distant *vs* near future thoughts. Participants then completed alternating blocks in which they imagined near and distant future actions. Each block consisted of five trials, and each trial lasted for 8 s. Following each block was 5 s of fixation followed by 5 s of a prompt that read ‘please imagine the next events occurring TOMORROW [FIVE YEARS FROM NOW]’. Participants completed six blocks total, three of each trial type.

Direct inductions of construal level. We used two direct manipulations of construal level: why–how and category–exemplar tasks. We used the why–how localizer developed by Spunt and Adolphs (2014). Participants responded yes/no to image/question pairs that required participants to consider either the superordinate (high-level) goal that the action in the image served (e.g. ‘Is this person protecting themselves?’) or the subordinate (low-level) means used to accomplish that action (e.g. ‘Is this person using both hands?’). The task consisted of 16 blocks of 8 images each, evenly divided into why *vs* how. At the beginning of each block, participants were presented with a question for 2 s (e.g. ‘Is this person protecting themselves?’), and asked to respond ‘yes’ or ‘no’ via a button box during the presentation of each of 8 subsequent images (pressing a button did not advance to the next screen). Each image was displayed for 1.75 s, followed by a reminder of the question prompt for 0.35 s. Of the eight images, ‘yes’ was the correct answer for five and ‘no’ was the correct answer for three. Each block was followed by 2 s of fixation. Each image was repeated twice so that the same image was presented in each condition. We selected one randomized presentation order for all participants, which Spunt and Adolphs (2014) optimized to maximize efficiency.

The second construal level induction was Gilead *et al.* (2014) category–exemplar task.[1] Participants completed alternating blocks of category (high-level) and exemplar (low-level) trials. Each block consisted of seven trials, with each trial lasting 4 s. Each trial presented participants with a target word and a prompt asking them to generate either a category (‘A DOG is an example of…’) or exemplar (‘An example of a DOG is…’). At the conclusion of each block, participants were informed what the next block’s prompt would be [e.g. ‘On the next trials, you will provide a category (example) for the target word’]. Participants completed a total of 8 blocks (56 trials). Whether a target word was presented in one condition *vs* the other was randomized between participants.

Participants also completed several scanner tasks that are not relevant to this article (including the visualization of events in black-and-white *vs* color and intertemporal choices) and are not discussed further. Following scanning, participants completed an Implicit Association Test (IAT) designed to provide a behavioral assessment of to what degree participants tend to construe temporally distant *vs* proximal events in high-level *vs* low-level terms (Bar-Anan *et al.*, 2006). Analyses involving the IAT are described in the Supplementary Data.

Procedure

Participants first completed the intertemporal choice task, and then completed the other tasks in random order, with the exception that the two direct construal level manipulations were always completed one after the other (order randomized between subjects). We chose this randomization strategy to minimize noise that may be introduced from switching between temporal imagery and construal level tasks. Following scanning, participants completed the behavioral and reaction-time measures.

fMRI parameters

We conducted the neuroimaging using a Siemens 3T Trio scanner equipped with a 12-channel head coil. Functional images were acquired using a single-shot gradient echo-planar pulse sequence (echo time = 28 ms, repetition time = 2.1 s, in-plane resolution = 2.5 × 2.5 × 3.2 mm, field of view = 250 mm, 40 axial slices per whole brain volume). For each task, data were collected during a single functional run lasting ~5–6 min (why–how task: 162 whole-brain volumes; category–exemplar: 131 whole-brain volumes; temporal imagery: 146 whole-brain volumes).

fMRI pre-processing

We prepared the data using FSL (FMRIB Software Library, www.fmrib.ox.ac.uk/fsl). Data pre-processing were carried out using FEAT (FMRI Expert Analysis Tool) Version 6.00. The following pre-processing transformations were applied: motion correction using MCFLIRT (Jenkinson and Smith, 2001), non-brain removal using BET (Smith, 2002), spatial smoothing using a Gaussian kernel of FWHM 5 mm, grand-mean intensity normalization of the entire 4D dataset by a single multiplicative factor, and high-pass temporal filtering (Gaussian-weighted least-squares straight line fitting, with sigma = 45 s). Following this, non-linear registration to high-resolution structural and Montreal-Neurological Institute (MNI) standard space images was performed using FNIRT (Jenkinson and Smith, 2001; Jenkinson *et al.*, 2002).

General Linear Model

For each task, we modeled BOLD activity in response to our conditions of interest (temporal distance/proximity for the temporal imagery task and high-/low-level construal for the direct inductions) by convolving block timings with a double-gamma HRF, yielding two regressors of interest per task. Six motion parameters were also included in the model. We then performed six contrast analyses, each corresponding to one of our conditions of interest (e.g. why > how, temporal proximity > distance). We thresholded these contrast maps at $P < 0.001$. Following this, we estimated smoothness of our data using the autocorrelation function option of the 3dFWHMx tool from AFNI on the residuals of our GLM output, and used this as input to 3dClustSim, yielding cluster sizes of at least 60 contiguous voxels to be significant at the $P < 0.05$ level.

Conjunction analyses

We conducted conjunction analyses to gauge overlap between conditions of interest. These analyses examine the intersection of two contrast maps (contrast A ∩ contrast B), leaving only the voxels that are significantly active for both. We conducted all six pairwise cross-task conjunction analyses (e.g. temporal distance > temporal proximity ∩ why > how). We note that this is a conservative analysis, as it takes as input two maps thresholded at $P < 0.05$ corrected, resulting in a map that is effectively thresholded at $P < 0.0025$. We finally apply a cluster correction of 25 voxels to remove trivially small conjunction clusters (see Supplementary Data for further details and analyses using more liberal correction criteria).

We further report the results of an omnibus 2 (construal level: high- *vs* low-level) × 3 (task: temporal imagery *vs* why–how *vs* category–exemplar) ANOVA on the parameter estimates derived from the GLM in the Supplementary Data.

Results

We first examined regions activated in response to different conditions of the temporal imagery, why–how, and category–exemplar tasks. Results are displayed in Figure 2.

Temporal imagery

Temporal distance and proximity trials both produced significant differences in activation relative to the other (Table 1). Replicating past work, temporal distance activated regions of both OFC and mPFC. Temporal proximity preferentially activated bilateral precuneus.[2]

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[1] One might ask why we chose not to implement the Baetens *et al.* (2014) category-exemplar task, given the difficulties Gilead *et al.* (2014) had in using this particular version to differentiate high- and low-level construal—particularly across construal level manipulations (why–how *vs* category–exemplar). Although in retrospect it may have been better to use the Baetens *et al.* (2014) version, we were more comfortable with the Gilead *et al.* (2014) version as it more closely paralleled the behavioral version that we have repeatedly used in our lab (Fujita *et al.*, 2006; Fujita and Han, 2008; see Fujita and Trope, 2014).

[2] There was also non-significant activation of vmPFC, consistent with Tamir and Mitchell (2011).

Why–how

Why *vs* how trials produced significant differences in activation (Table 2) that mirror past work (Spunt and Adolphs, 2014). Why relative to how trials activated large areas of both medial prefrontal as well as PCC. How relative to why trials activated lateral-parietal cortex.

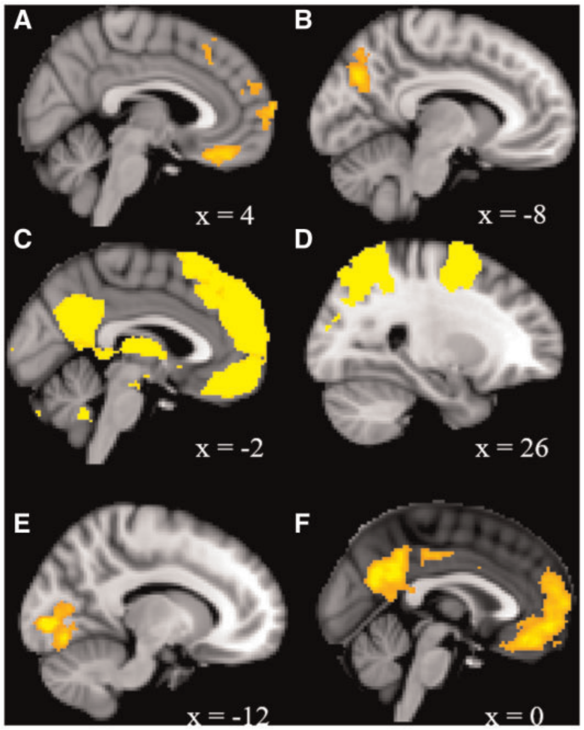

Fig. 2. Regions that preferentially activated to (A) temporal distance relative to temporal proximity, (B) temporal proximity relative to temporal distance, (C) why relative to how trials, (D) how relative to why trials, (E) category relative to exemplar trials and (F) exemplar relative to category trials. All maps were thresholded at $P < .001$ and cluster corrected at 60 contiguous voxels, yielding a significance threshold of $P < 0.05$, corrected.

Category–exemplar

Category and exemplar trials (Table 3) replicated previous work (Gilead *et al.*, 2014). Category relative to exemplar trials activated frontal pole as well as visual cortex. Exemplar relative to category trials activated large regions of mPFC as well as PCC and precuneus. This latter finding appears to contradict the results of the previous two tasks, an issue we explore in depth below.

Conjunction analyses

Why–how and category–exemplar. We first examined the conjunction analyses between why–how and category–exemplar tasks, which should produce similar neural signatures as two direct manipulations of construal level. We found significant conjunction in the corresponding high-level trials (why > how ∩ category > exemplar), as well as the corresponding low-level trials (how > why ∩ exemplar > category; Table 4). Specifically, high-level trials (i.e. why and category) both activated a single region of the left frontal pole, whereas low-level trials (i.e. how and exemplar) both activated a region in lateral parietal cortex (Figure 3). However, these were overshadowed by more pervasive overlap between 'mismatching' trials: 'low-level' exemplar trials looked very similar to 'high-level' why trials. These data are consistent with Gilead et al. (2014). Given this, we subsequently investigated the overlaps between temporal imagery and construal level separately for each construal level induction.

Temporal imagery and why–how. Consistent with hypotheses, regions in mPFC, as well as dlPFC, angular gyrus and bilateral middle temporal gyrus (Figure 4) survived the conjunction analysis between temporal distance and why trials (Table 4). Two regions in the precuneus (Figure 5) survived the conjunction analysis between temporal proximity and how trials. Importantly, no clusters survived correction for the conjunction analyses

Table 1. Clusters that survived correction for the temporal imagery task, corrected whole brain at $P < 0.001$ and cluster corrected at a threshold of 60 contiguous voxels, yielding an overall correction of $P < 0.05$

Contrast	Voxels	Max t	X	Y	Z	Region
Temporal Distance > Temporal Proximity	895	8.1	18	38	42	dlPFC
	676	6.97	−28	−78	−32	Cerebellum
	513	6.08	52	−62	30	Angular gyrus/lateral occipital cortex
	310	6.5	2	40	−20	OFC
	268	5.91	−18	32	48	dlPFC
	248	7.42	64	−6	−22	Middle temporal gyrus
	202	5.46	38	34	−12	OFC
	168	6.79	8	70	12	mPFC
	126	6.75	−64	−4	−18	Middle temporal gyrus
	113	5.08	−16	−96	14	Occipital cortex
	105	5.75	42	28	22	Inferior frontal gyrus
	91	4.92	8	60	38	mPFC
Temporal Proximity > Temporal Distance	494	7.82	−12	−66	32	Precuneus
	109	6.07	16	−68	36	Precuneus
	66	5.38	2	38	8	Cingulate gyrus
Nonsignificant clusters—Temporal Proximity > Temporal Distance	35	4.45	−56	−46	50	vmPFC

Notes: Coordinates are in MNI space. The region listed in the bottom of the table did not survive stringent cluster correction, yet is consistent with past work (Tamir and Mitchell, 2011) and is included for meta-analytic purposes.

Table 2. Clusters that survived correction for the why–how task, corrected whole brain at $P < 0.001$ and cluster corrected at a threshold of 60 contiguous voxels, yielding an overall correction of $P < 0.05$. Coordinates are in MNI space

Contrast	Voxels	Max t	X	Y	Z	Region
Why > How	8495	15.9	−14	58	26	mPFC
	7926	13.3	−60	−12	−10	Middle temporal gyrus
	2945	10.6	−2	−56	32	PCC
	2665	8.63	52	−10	−14	Middle temporal gyrus
	1130	13	36	−78	−34	Cerebellum
	871	8.84	−54	−62	32	Angular gyrus/lateral occipital cortex
	312	8.2	−30	−78	−34	Cerebellum
	310	6.44	56	−64	28	Angular gyrus/lateral occipital cortex
	238	6.81	52	24	14	Inferior frontal gyrus
	234	7.65	6	−52	−38	Cerebellum
	214	5.01	−10	−100	22	Occipital cortex
How > Why	14 995	14.3	−62	−32	34	Precuneus
	1102	9.52	−26	−2	58	Superior frontal gyrus
	929	8.9	28	2	56	Superior frontal gyrus
	472	8.2	56	−54	−2	Middle temporal gyrus
	468	7.56	−38	40	34	Frontal pole
	429	8.26	−50	6	12	Precentral gyrus
	323	5.83	36	46	30	Frontal pole
	307	6.88	52	8	24	precentral gyrus
	171	6.4	−34	−38	−40	Cerebellum
	117	6.51	36	−40	−46	Cerebellum
	95	6.1	−12	−32	38	PCC
	74	5.72	−38	−16	0	Insula

Table 3. Clusters that survived correction for the category–exemplar task, corrected whole brain at $P < 0.001$ and cluster corrected at a threshold of 60 contiguous voxels, yielding an overall correction of $P < 0.05$ Coordinates are in MNI space

Contrast	Voxels	Max t	X	Y	Z	Region
Category > Exemplar	664	7.93	−12	−88	0	Occipital cortex
	399	6	−52	32	4	Inferior frontal gyrus
	85	6	−34	−52	40	Angular gyrus
	60	5.04	−46	4	46	Middle frontal gyrus
Exemplar > Category	3050	8.3	−4	44	−6	mPFC
	2384	8.28	−4	−62	30	PCC
	750	7.9	−30	−36	−12	Parahippocampal gyrus
	569	7.06	−20	34	42	dlPFC
	535	5.96	64	−46	30	Angular gyrus
	454	6.72	−60	−12	−16	Middle temporal gyrus
	242	6.08	56	−20	−12	Middle temporal gyrus
	188	5.99	8	14	68	Superior frontal gyrus
	161	5.43	−38	−72	28	Lateral occipital cortex
	105	5.82	−50	−58	36	Angular gyrus
	77	6.14	34	32	−34	Temporal pole
	68	4.51	28	−18	−16	Parahippocampal gyrus
	60	4.69	16	−32	−4	Thalamus

between ‘mismatching’ trials (proximity/why; distance/how). This suggests that high- (*vs* low-level) construal and temporal distance (*vs* proximity, respectively) share overlapping neural regions.

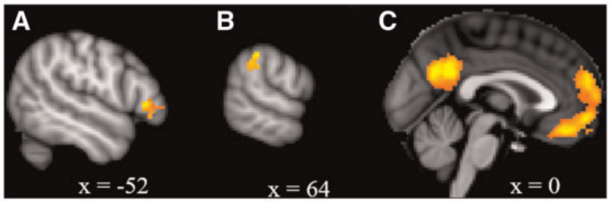

Fig. 3. Results of the conjunction analyses between (A) category and why trials, (B) exemplar and how trials and (C) exemplar and why trials. Conjunction maps were attained by multiplying the two contrast maps together (each significant at $P < 0.05$, corrected), yielding an effective correction rate of $P < 0.0025$.

Temporal imagery and category–exemplar. There was a single significant cluster of overlap between temporal distance and category trials in the occipital pole (Table 4), as well as a single significant cluster between temporal proximity and exemplar trials in the precuneus (Figure 6). These clusters, however, were overshadowed by a large degree of overlap between ‘mismatching’ temporal distance and exemplar trials in the medial frontal cortex and PCC. There was no significant overlap between temporal proximity and category trials. These results, although counter to our hypotheses, appear to reflect the significant overlap between ‘mismatching’ why and exemplar trials reported earlier. Overall, although we find strong support for our hypotheses using the why–how task as a manipulation of construal level, we do not find the same support using the category–exemplar task.

General discussion

This study provides evidence for CLT’s assertion that people engage in high- *vs* low-level construal to represent distant *vs* near future events, respectively. Our results indicate that, with the why–how task as a manipulation of construal level, high- *vs* low-level construal and the representation of distant future *vs* near future events share overlapping neural regions, respectively. We did not, however, find the same effects with the

Table 4. Clusters that survived correction for the conjunction analyses

Overlap	Voxels	X	Y	Z	Max	Region
Why ∩ Category	128	−54	28	2	47.2	Inferior frontal gyrus
How ∩ Exemplar	113	62	−34	40	30.1	Supramarginal gyrus
Why ∩ Exemplar	1865	−2	54	−10	59.1	mPFC
	1351	−4	−60	32	81.9	PCC
	413	−62	−10	−14	69	Middle temporal gyrus
	296	−18	34	44	39.7	dlPFC
	108	−24	−14	−12	31.6	Amygdala
	80	64	−2	−24	31.2	Middle temporal gyrus
	73	12	46	46	36.9	dlPFC
	63	−34	30	−16	30.6	OFC
	47	6	16	66	26.5	Superior frontal gyrus
	45	−52	−60	32	32.6	Lateral occipital cortex
	35	34	30	−34	28.6	Temporal pole
Why ∩ Temporal Distance	268	−12	40	48	41.8	dlPFC
	255	2	40	−20	56	OFC
	249	54	−62	30	35.9	Angular gyrus
	239	12	46	48	46.1	dlPFC
	208	−30	−78	−32	50.9	Cerebellum
	181	64	−4	−22	40.3	Middle temporal gyrus
	125	−66	−6	−16	61.2	Middle temporal gyrus
	95	38	34	−12	34.1	OFC
	87	4	56	22	38.8	mPFC
	76	6	66	8	30.7	mPFC
	32	54	28	22	22.7	Inferior frontal gyrus
How ∩ Temporal Proximity	47	−12	−68	48	35	Precuneus
	28	−16	−66	32	23.3	Precuneus
Temporal Distance ∩ Category	31	−10	−88	0	37.2	Occipital pole
Temporal Proximity ∩ Exemplar	31	−16	−58	20	21.9	Precuneus
Temporal Distance ∩ Exemplar	167	2	36	−20	34.7	OFC
	123	20	42	40	35.3	dlPFC
	97	−66	−8	−16	31.7	Middle temporal gyrus
	76	64	−6	−20	36.9	Middle temporal gyrus
	52	8	64	30	26.1	mPFC
	49	−18	32	44	33.5	Superior frontal gyrus
	41	4	64	8	22.9	mPFC

Notes: Clusters are the conjunction of two contrasts corrected at $P < 0.05$, yielding an effective correction of $P < 0.0025$, following which a 25 voxel cluster correction was applied. Conjunctions not shown had no significant clusters.

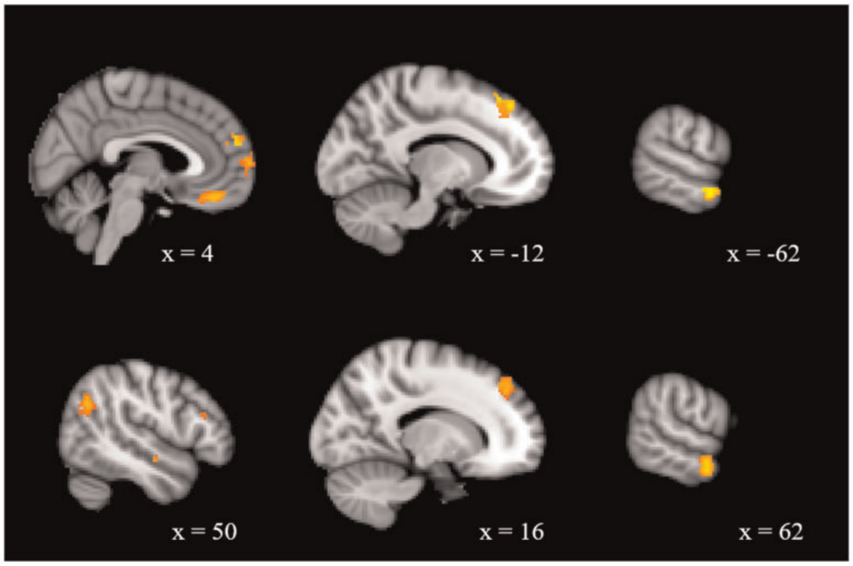

Fig. 4. Results of the conjunction analyses between why trials and temporal distance. Conjunction maps were attained by multiplying the two contrast maps together (each significant at $P < 0.05$, corrected), yielding an effective correction rate of $P < 0.0025$.

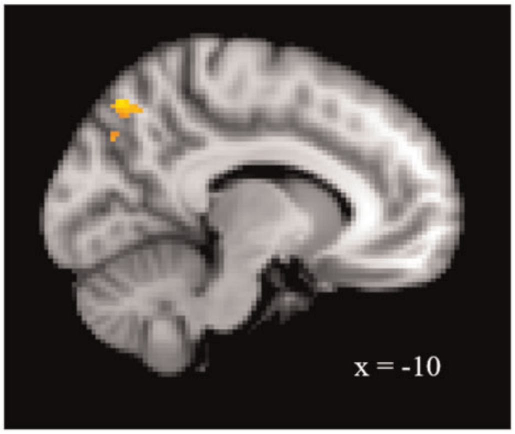

Fig. 5. Results of the conjunction analyses between how trials and temporal proximity. Conjunction maps were attained by multiplying the two contrast maps together (each significant at $P < 0.05$, corrected), yielding an effective correction rate of $P < 0.0025$.

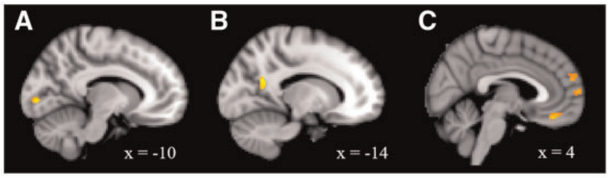

Fig. 6. Results of the conjunction analyses between (A) category and distance trials, (B) exemplar and proximity trials and (C) exemplar and distance trials. Conjunction maps were attained by multiplying the two contrast maps together (each significant at $P < 0.05$, corrected), yielding an effective correction rate of $P < 0025$.

category–exemplar task as a manipulation of construal level. We might note that that the psychological context of the why–how and temporal imagery tasks—considering actions—are more analogous to one another than with the category–exemplar task—generating words. A task in which individuals consider categories *vs* exemplars in the context of understanding actions may produce more consistent results.

The lack of neural correspondence, moreover, between the two construal level manipulations replicates past research (Gilead *et al.*, 2014). To explain this, we might highlight the distinction between representation (or construal) as a process *vs* output. Both why–how and category–exemplar tasks were originally developed as procedural priming manipulations that evoke the tendency to construe subsequent unrelated events in high- *vs* low-level terms (Freitas *et al.*, 2004; Fujita *et al.*, 2006; for review, see Fujita and Trope, 2014). These tasks were intended to activate similar cognitive processes, even when the semantic content across the two tasks was distinct. These two manipulations produce similar behavioral results, even on subsequent tasks that are semantically unrelated (Fujita and Han, 2009; Fujita *et al.*, 2006; see also Fujita and Trope, 2014). In contrast, Spunt *et al.* (2016) have suggested that the why–how localizer task assesses differences in content rather than process. They independently manipulated content (abstract *vs* concrete stimuli) and process (engaging in abstraction via why *vs* concretization via how), and found that the localizer was sensitive to the former. One reason for the lack of neural correspondence between the two manipulations may therefore be that they have been optimized to detect differences in content rather than similarities in process.

Why then did exemplar (low-level) trials activate similar neural regions to those activated by ‘mismatching’ why (high-level) trials? This may be due to the stimuli that we presented in the category–exemplar task (e.g. ‘dog’, ‘fruit’), which tended to represent basic level categories (Rosch *et al.*, 1976). Basic level categories are the most inclusive level of categorization that maximizes similarity between constituents (Corter and Gluck, 1992). One consequence is an asymmetry in the similarity of the basic level category to any subordinate exemplar relative to superordinate category. The basic level category ‘dog’, for example, has more in common with the exemplar ‘poodle’ than the superordinate category ‘pet’. Given this, both exemplar and basic level representations may be highly similar or co-activate when generating exemplars—two assertions consistent with past research (Kosslyn *et al.*, 1995; Gauthier *et al.*, 1997). Thus, although exemplar generation is designed to promote concretization as a cognitive process, the resulting output may appear ‘high-level’ due to representational similarities between exemplars and basic level categories. In contrast, the category generation may activate more diffuse and heterogeneous representations, leading to more varied and less consistent neural activation.

As noted earlier, Baetens *et al.* (2014) adapted the category–exemplar task with several important differences. Perhaps most critically, although their category condition was similar to ours, their exemplar condition required the listing of target objects’ features. Their results were more consistent with Spunt and Adolphs’s (2014) why/how localizer. It is possible that we would have obtained greater correspondence between construal level inductions had we used the Baetens *et al.* (2014) procedure instead. Future work should address this possibility.

Neural representation of near and distant future events

Our work largely replicates previous work by Okuda *et al.* (2003) and Packer and Cunningham (2009), documenting distinct networks for the representation of distant *vs* near future events. We also generally replicated findings by Mitchell *et al.* (2011) and Tamir and Mitchell (2011): vmPFC (to a limited extent) and posterior cortex activation (although in regions of precuneus rather than PCC) in response to near relative to future events. However, in contrast to Mitchell *et al.* (2011) and Tamir and Mitchell (2011)—who reported no regions that increased in activity as temporal distance increased, we found robust differences in line with others (Okuda *et al.*, 2003; Packer and Cunningham, 2009). Methodological differences may account for these discrepancies. In particular, to control for any potential differences in cognitive accessibility and availability of temporally distant *vs* near future events, we had participants imagine the distant future prior to scanning. Future work should examine the effects of these different methodological details.

The function of the default mode network

These data may promote new cumulative neurocognitive models of how people represent future events. Although a fully elaborated model is beyond the scope of this article, that temporal distance and construal level both activate similar neural regions may help to shed light on the functions of these regions. Of note is the activation of three regions: mPFC and middle temporal gyrus for temporal distance/high-level construal and precuneus for temporal proximity/low-level construal. These regions are heavily implicated in the default mode network (DMN, Raichle *et al.*, 2001; Greicius *et al.*, 2003), which plays an important role in prospection (Buckner and Carroll, 2007), navigation (Iaria *et al.*, 2007), theory of mind (or 'mentalizing', Spunt *et al.*, 2011) and counterfactual thought (Spreng *et al.*, 2009; Van Hoeck *et al.*, 2013). Although others have noted that the DMN is involved in internally generated cognition (Schacter *et al.*, 2012; Andrews-Hanna *et al.*, 2014; Raichle, 2015), we suggest that another common element that underlies these phenomena is the traversal of psychological distance. Indeed, each of the four examples above refers to traversing a different dimension of psychological distance: temporal distance, social distance, spatial distance and hypotheticality, respectively. The present data further suggest that the DMN may be partially separable—with some regions specialized for proximity (i.e. precuneus) *vs* distance (i.e. mPFC, middle temporal gyrus).

CLT proposes that psychological distance travel is made possible by high-level construal (i.e. abstraction). Our findings are consistent with theorizing that abstraction entails more anterior rather than posterior regions of the prefrontal cortex (Amodio and Frith, 2006; Bunge and Zelazo, 2006; Badre and D'Esposito, 2007; Badre, 2008). CLT further proposes that the function of low-level construal is to immerse people into the idiosyncratics of proximal events, tailoring thoughts, feelings, and actions to the demands at-hand. This immersion viewpoint is supported by findings that the precuneus serves as an integral hub region, integrating inputs from the DMN and fronto-parietal control network to balance internal and external cognition in goal-pursuit (Smallwood *et al.*, 2012; Spreng *et al.*, 2013; Utevsky *et al.*, 2014). The precuneus also appears to integrate sensory/motor inputs with internally generated information (Cavanna and Trimble, 2006; Cavanna, 2007)—functions that are critical for the execution of immediate behavior. This region also responds to self-referential thought and first-person perspective taking (Cavanna and Trimble, 2006)—a finding consistent with behavioral research that first-person relative to third-person visual perspective prompts low- *vs* high-level construal (Libby and Eibach, 2011).

Beyond DMN, we find other regions of activity whose proposed functions are consistent with behavioral CLT research. For instance, people tend to weight desirability (value) over feasibility (implementation) concerns when decisions are to be implemented in the distant *vs* near future (Liberman and Trope, 1998; Sagristano *et al.*, 2002) and when engaged in high- *vs* low-level construal (Fujita *et al.*, 2006). That the OFC is preferentially active in our data in these same conditions is consistent with theorizing that this region is involved in the representation of predicted reward value (Gottfried *et al.*, 2003).

The dorsolateral regions of PFC are associated with working memory (e.g. D'Esposito and Postle, 2015), and theorized to exert top-down influence on lower order networks to sustain goal-directed cognition (Cunningham and Zelazo, 2007; Cunningham *et al.*, 2007; O'Reilly, 2010; O'Reilly *et al.*, 2002). Our findings may link these proposed functions to behavioral findings that indicate that goal-directed behavior is enhanced with future-directed thought (Peters and Büchel, 2010; Daniel *et al.*, 2013) and when engaged in high-level relative to low-level construal (Fujita and Carnevale, 2012).

Future directions

Different modalities of distance. CLT suggests that psychological distance should evoke high-level construal regardless of modality—time, physical space, social distance and hypotheticality. Future research should substantiate this prediction. Parkinson *et al.* (2014) provide initial support for CLT's contention that all psychological distance traversal shares common neural representation. An important next step is to establish that construal level as the mediator for these commonalities. The present results suggest this may be the case. Some of the regions that Parkinson *et al.* (2014) identify as involved in the common representation of psychological distance overlap with hotspots identified by our conjunction analyses—in particular, the angular gyrus.

Further integrating CLT with neuroscience research. Behavioral research has documented numerous effects of construal level on judgment, decision-making and behavior. Future research should investigate whether neural activation—particularly within the DMN—mediates the effect of construal level on these tasks as this work suggests. Such work would not only reveal the neural mechanisms by which construal level impacts judgment and behavior, but may also help to integrate behavioral and neurocognitive research. Consider, for instance, behavioral research suggesting high-level (*vs* low-level) construal facilitates perspective-taking or 'mentalizing'—tasks that require inferring others' mental states (e.g. Eyal and Epley, 2010). One might test whether this construal-moderated increase in mentalizing accuracy is mediated through heightened activity within the DMN (e.g. Ruby and Decety, 2001; Frith and Frith, 2006; Spunt *et al.*, 2011). Behavioral research also suggests that high-level (*vs* low-level) construal promotes self-control (Fujita *et al.*, 2006; Fujita and Carnevale, 2012). This work may connect this work to the neuroscientific literature on self-control (e.g. Kelley *et al.*, 2015). We encourage and look forward to work bridging CLT with neuroscience research.

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Supplementary data

Supplementary data are available at *SCAN* online.

Conflict of interest. None declared.

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