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From mind to matter: neural correlates of abstract and concrete mindsets

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Much work in the field of social cognition shows that adopting an abstract (*vs* concrete) mindset alters the way people construe the world, thereby exerting substantial effects across innumerable aspects of human behavior. In order to investigate the cognitive and neural basis of these effects, we scanned participants as they performed two widely used tasks that induce an abstracting *vs* concretizing mindsets. Specifically, participants: (i) indicated 'why' perform certain activities (a task that involves abstraction) or 'how' the same activities are performed (a task that involves concretization) and (ii) generated superordinate categories for certain objects (a task that involves abstraction) or subordinate exemplars for the same objects (a task that involves concretization). We conducted a conjunction analysis of the two tasks, in order to uncover the neural activity associated with abstraction and concretization. The results showed that concretization was associated with activation in fronto-parietal regions implicated in goal-directed action; abstraction was associated with activity within posterior regions implicated in visual perception. We discuss these findings in light of construal-level theory's notion of abstraction.

Keywords: construal level; abstraction; functional magnetic resonance imaging; default network; mirror neuron system; action identification

INTRODUCTION

For hundreds of millions of years, animals developed exceedingly more intricate nervous systems, for the main purpose of achieving mastery over concrete objects in their surroundings. Then, the human brain came along. To use the words of Arthur Koestler—'in creating it, evolution has wildly overshot its mark'. Abstract ideas such as 'Democracy', 'Derivatives' and 'Qualia' emerged, as humans became less confined to particular worldly objects and more concerned with the universal essence of things. And yet, despite our anomalous nature, we have not completely divorced our ancestral past; a pervasive view of human cognition sees it as a chimeric entity: one part of which remains true to our evolutionary origins and deals with concrete objects that occupy a specific point in space and time, the other is concerned with those objects that lack such a referent—i.e. abstractions. The present article investigates how abstraction and concretization are processed in the brain.

Reflecting the widely held view that abstraction is of utmost importance to humans' intellectual abilities and behavior (e.g. Inhelder and Piaget, 1964) much extant research within psychology has addressed its various manifestations. To give just a few examples—research on concept formation (e.g. Medin and Schaffer, 1978) focused on the process in which abstract categories are derived from concrete exemplars; research on relational thinking investigated how the extraction of abstract properties facilitates analogical thought (e.g. Gentner and Markman, 1997); and research on action identification (e.g. Vallacher and Wegner, 1987) focused on the causes and consequences of representing human action concretely *vs* abstractly.

Despite the different approaches to the study of abstraction, it has been argued that there is consistency between various notions of this construct, which can be most broadly defined as a process in which a perceiver: 'makes a distinction between primary, defining features, which are relatively stable and invariant, and secondary features, which may change with changes in context and hence are omitted' (Shapira *et al.*, 2012, 236). In this article, we investigate the commonalities between the neural activity that is associated with two important types of abstraction: level of action identification and width of object categories.

Action-identification theory (e.g. Vallacher and Wegner, 1987) contends that the representation of goal-directed action is organized within a hierarchy of abstraction, wherein moving to a higher level is achieved by answering the question of 'why' the action is performed and moving to a lower level is achieved by answering the question of 'how' the same action is performed. For example, 'going jogging' could be represented at a higher level as 'maintaining health,' and at a lower level as 'putting on running shorts.' Lower levels of action identification are context-specific and tend to involve concrete objects. Higher levels of action identification are more context invariant and capture the perceived essence of the action.

Within the domain of object categorization, a similar representational hierarchy could be described. Objects (e.g. pants) can be construed in more abstract terms, by referring to a superordinate, more inclusive category (e.g. clothes), or may be exemplified by referring to a specific example (e.g. jeans). As with action hierarchies, whereas the most particular exemplars are limited to specific spatio-temporal contexts (i.e. 'the dirty blue jeans I put yesterday in the laundry'), thinking of the superordinate category to which a particular exemplar belongs is more invariant in that it applies to innumerable specific contexts and captures the perceived essence of that object.

Much research shows that the degree of abstraction exerts significant effects across many aspects of human behavior (to give just a few examples: social perception—Semin and Fiedler, 1988; creativity—e.g. Ward *et al.*, 2004 and affect—Watkins *et al.*, 2008). Furthermore, research shows that giving participants a task that requires abstraction (or concretization) can induce a temporary inclination to approach subsequent tasks in a concrete or abstract 'mindset'; using such techniques, researchers can alter people's subjective construal of objective information. Two of the most commonly used procedures to induce abstract *vs* concrete mindsets are based on the aforementioned conceptions of level of action identification and category width.

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In the Why-How paradigm (WH; Freitas *et al.*, 2004), participants in the abstract condition are given a description of an activity and are asked to answer *why* they would engage in it (e.g. why do you maintain your health?); participants in the concrete condition are asked *how* they would engage in the same activity (e.g. how do you maintain your health?). Focusing on the means required to achieve a specific goal ultimately entails transforming an abstract idea into a concrete action and thus primes a concretizing mindset; likewise, focusing on the purpose of an action primes an abstracting mindset.

To date, at least 50 studies have employed this manipulation or a variant of it and have shown that adopting an abstract (*vs* concrete) mindset exerts considerable effects across many aspects of behavior, ranging from estimates of one's distance to a goal (Maglio and Trope, 2012) and the prediction of task duration (Kanten, 2011) to stereotyping (McCrea *et al.*, 2012). For example, Torelli and Kaikati (2009) have used the WH task to show that an abstract mindset can cause people to behave in a manner more consistent with their values.

A second widely used mindset priming task is the Categories-Exemplars paradigm (CE; Fujita *et al.*, 2006). In this task, participants in the abstract condition are given a list of objects and they are asked to generate superordinate category labels for them (e.g. a singer is an example of ____); participants in the concrete condition are asked to generate a subordinate exemplar of the same object (e.g. ____is an example of a singer). Focusing on the category to which an object belongs entails transforming a concrete object into an abstraction and thus primes an abstracting mindset; likewise, focusing on the object rather than the category primes a concretizing mindset.

The CE task was used to induce abstract/concrete mindsets in approximately 20 studies dealing with topics ranging from self-construal (Mok and Morris, 2012) and trait inference (Rim *et al.*, 2009) to consumer behavior (Pham *et al.*, 2011). For example, Shah and Oppenheimer (2011) have used a variant of the CE task and showed that priming participants to an abstract mindset can cause them to group several associated (yet separate) units of information into a single category, diminishing their overall effect on judgment.

At least 11 studies manipulated mindset using both the WH and CE tasks (e.g. Epstude and Foerster, 2011; Tsai and Thomas, 2011; Vess *et al.*, 2011) and found convergent effects. To give a few examples: Wakslak and Trope (2009) have used both manipulations to show that concrete mindsets cause people to believe that future events are more likely to occur; Mccrea *et al.* (2008) have shown that adopting a concrete mindset lowers the likelihood of procrastination; Fujita *et al.* (2006) found that a concrete mindset hinders self-control. Importantly, in all cases, priming had the same effect on behavior regardless of whether it was done with the WH or CE paradigm. In view of the convergent behavioral findings of the effects of the WH and the CE procedures, we thought that examining the neural convergence of these procedures would shed light on the nature and the mechanism of abstraction and concretization.

Previous studies (e.g. Spunt *et al.*, 2010; Spunt and Lieberman, 2012) have employed variants of WH task to discover the neural systems that are responsible for the 'why' and 'how' of action identification. These studies revealed that thinking 'how' an action is performed activates a network of regions involved in action execution and observation, which primarily includes the fronto-parietal mirror-neuron system (Rizzolatti *et al.*, 2001); contrastingly, thinking 'why' an action is performed activated the 'mentazling network'—a widespread network of regions associated with theory-of mind reasoning including the temporal lobe, the medial prefrontal cortex, the precuneus and the right temporo-parietal junction (van Overwalle and Baetens, 2009).

Although this seminal work (e.g. Spunt *et al.*, 2010) furthered our understanding of the neural mechanisms that subserve social cognition and action identification, our aim is to identify the neural correlates of the task-invariant process of abstraction and concretization. To that end, we conducted an functional magnetic resonance imaging study in which participants performed a variant of both the WH and CE tasks. We contrasted the neural activity associated with abstraction and concretization in each task, and then looked for the conjunction of the abstraction- and concretization-related activity. We predicted that concretization will be associated with a subset of the fronto-parietal network which was activated in previous studies when participants contemplated 'how' actions are performed; similarly, we predicted that abstraction will be associated with a subset of the mentalizing network which was activated when participants contemplated 'why' actions are performed (e.g. Spunt *et al.*, 2010; Spunt and Lieberman, 2012).

METHODS

Participants

Twenty-four right-handed participants (12 women, average age 23.6 years, range 18–27 years) from Tel-Aviv University participated in the experiment. They were all native speakers of Hebrew, none had a history of neurological or psychiatric disorders, and all had normal or corrected-to-normal vision. They gave written consent prior to taking part in the experiment. The study was approved by the Institutional Review Board of the Sourasky Medical Center, Tel-Aviv.

Materials

Why-How task

The experimental stimuli were 36 various everyday activities adapted from the Behavior Identification Form (Vallacher and Wegner, 1989). Each of these activities was embedded within a question regarding 'why' or 'how' it is performed (e.g. 'why do people watch TV?'/'how do people watch TV?,' 'why do people take aspirin?'/'how do people take aspirin?'). Two counterbalanced stimuli lists were created so that each participant saw each activity either in the Why or How conditions. The complete list of stimuli is provided in Appendix, Table 1A.

Categories-Exemplars task

The experimental stimuli were 36 objects taken from Fujita *et al.* (2006). Each of these objects were embedded within a question that probed for an example of it, or for a superordinate category (e.g. 'a singer is an example of ____)'/'____is an example of a singer,' 'a university is an example of ____)'/'____is an example of a university'). Two counterbalanced stimuli lists were created so that each participant saw each object either in the Categories or the Exemplars conditions. The complete list of stimuli is provided in Appendix, Table 1A.

Behavioral procedure

Participants were carefully instructed and trained on the task prior to entering the scanner. The training was repeated verbatim inside the scanner. The items used for the training session were taken from a different pool of sentences than the main task. Participants were instructed to silently read the questions displayed, give a specific answer to them in their head and press a button once they finished answering.[1] Stimuli were presented with Presentation version 14.9 (Neurobehavioral Systems, CA, USA). Each question was presented on screen for 4000 ms. Participants indicated that they responded by a pressing key on a response box with their index and middle left-hand fingers.

[1]In order to minimize motion artifacts participants did not provide overt answers to the questions, but rather responded 'in their head'. In light of this, a limitation of this study is that we do not have a record of participants' responses on the task (other than their RT).

The experiment had one session lasting 528 s. Stimuli were presented in a blocked design. There were a total of eight experimental blocks, four from the WH task and four from the CE task. Within each task (WH/CE), two blocks were from the abstract condition (Why/Categories) and two blocks from the concrete condition (How/Exemplar). Each block contained a series of nine questions of the same type and was succeeded by a 30 s fixation. For each participant, the order of experimental blocks was determined in a pseudo-random fashion with the limitation that there were no two consecutive Concrete/Abstract blocks, and no two consecutive WH/CE blocks. Stimuli within each block were presented in random order. In total, each participant answered 72 questions (18 questions from each of the four block types).

Imaging procedure

Whole-brain T2*-weighted EPI functional images were acquired with a GE 3-T Signa Horizon LX 9.1 echo speed scanner (Milwaukee, WI, USA). The experiment consisted of one scanning session in which 264 volumes were acquired (TR = 2000 ms, 200 mm FOV, 64×64 matrix, TE = 35, 35 pure axial slices, $3.15 \times 3.15 \times 3.5$ mm voxel size, no gap). Slices were collected in an interleaved order. At the beginning of each scanning session, 5 additional volumes were acquired, to allow for T1 equilibration (they were not included in the analysis). Before the experiment, high-resolution anatomical images (SPGR; 1 mm sagittal slices) were obtained. Head motion was minimized by using cushions arranged around each participant's head and by explicitly guiding the participants prior to entering the scanner. Imaging data were preprocessed and analyzed using SPM5 (Wellcome Department of Cognitive Neurology, London). A slice-timing correction to the first slice was performed followed by realignment of the images to the first image. Next, data were spatially normalized to an EPI template based on the MNI305 stereotactic space. The images were then resampled into 2 mm cubic voxels and finally smoothed with an 8 mm FWHM isotropic Gaussian kernel. The general linear model was used for statistical analyses. Four regressors (one for each stimulus condition) were used to model the effects of interest; each consisted of a boxcar function convolved with a standard hemodynamic response function. We then computed the second-level analyses (in which subjects were treated as random effects) using one-sample *t*-tests. Significant regions of activation were identified using a threshold of $P < 0.001$ with a cluster size threshold of 74 voxels, corresponding to a threshold of $P < 0.05$, corrected for multiple comparison, as assessed through Monte Carlo simulations implemented in Matlab (Slotnick *et al.*, 2003). We ran 1000 iterations of the simulation using the pre-defined parameters of our design, and the smoothness parameter as estimated in SPM.

The concretization conjunction analysis *{(How > Why) ∩ (Exemplars > Categories)}* was implemented by running the contrast of How > Why (at a threshold of 0.031) inclusively masked with the contrast of Exemplars > Categories (at a threshold of 0.031). Since both contrasts are orthogonal, with a cluster size of 74 voxels, this analysis tests against the conjunction null at $P < 0.05$, corrected. Similarly, the abstraction conjunction analysis was implemented by running the contrast of Why > How inclusively masked with the contrast of Categories > Exemplars.

RESULTS

Behavioral results

Response Time

We conducted a Task (CE/WH) × Mindset (Concrete/Abstract) ANOVA on response time data. There was no effect of task, $F(1, 23) = 1.05$, $P = 0.31$, no significant effect of Mindset, $F(1, 23) = 3.27$, $P = 0.08$, or an interaction $F(1, 23) < 1$. There were also no response time (RT) differences within the CE task, $t(23) = 1.69$, $P = 0.10$, or within the WH task, $t(23) = 0.77$, $P = 0.44$ (Table 1).

Table 1 Response time (ms) by task (WH, CE) and mindset (Concrete, Abstract)

Mindset/Task	Why/How	Categories/Exemplars
Concrete	2317	2244
	(453)	(376)
Abstract	2353	2347
	(475)	(426)

Imaging data

How > Why contrast

Thinking 'how' (compared with 'why') an action is performed, recruited a left-lateralized fronto-parietal network implicated in motor behavior (i.e. the 'Mirror Neuron System', Rizzolatti *et al.*, 2001) and in goal-directed action (Corbetta and Shulman, 2002). This result replicates previous studies (e.g. Spunt *et al.*, 2010; Spunt and Lieberman, 2012) (Figure 1 and Table 2).

Exemplars > Categories contrast

Thinking of exemplars (compared with thinking of categories) resulted in activation within parts of the fronto-parietal action network and of the 'default-mode network' (Raichle *et al.*, 2001). Action-related activations consisted of the right middle frontal gyrus and the left superior frontal gyrus (BA 8), the pre-Supplementary Motor Area (pre-SMA), and the inferior parietal lobule (IPL) (which is also considered as part of the default-network). The default-network activations consisted of the dorsomedial prefrontal cortex and the posterior cingulate cortex. The remaining regions of the default network (the lateral temporal cortex, ventromedial prefrontal cortex and parahippocampal gyrus) were observed at a lower statistical threshold ($P < 0.005$, uncorrected) (Figure 1 and Table 2).

Neural activity associated with concretization {(How > Why) ∩ (Exemplars > Categories)}

In order to find the neural correlates associated with a concretizing mindset, we searched for the conjunction of neural activity associated with the How > Why and the Exemplars > Categories contrasts. The results showed that a concretizing mindset recruits parts of the fronto-parietal action network: the IPL, the left precentral gyrus and the pre-SMA (Figure 1 and Table 2).

Why > How contrast

Thinking 'why' (compared with 'how') an action is performed did not reveal significant activation at a threshold of $P < 0.05$ (corrected). However, at a lower statistical threshold ($P < 0.005$, uncorrected), we observed the 'mentalizing-network' which is a sub-set of the 'default-mode network' and consists of the medial prefrontal cortex, the posterior cingulated and the right temporo-parietal junction (Van Overwalle, 2009) (Figure 1 and Table 2). Thus, despite the smaller effect size, this result basically replicates previous studies which examined the same contrast (e.g. Spunt *et al.*, 2010; Spunt and Lieberman, 2012).

Categories > Exemplars contrast

Thinking of categories (compared with thinking of exemplars) did not reveal significant activation at a threshold of $P < 0.05$ (corrected) (Figure 1 and Table 2).

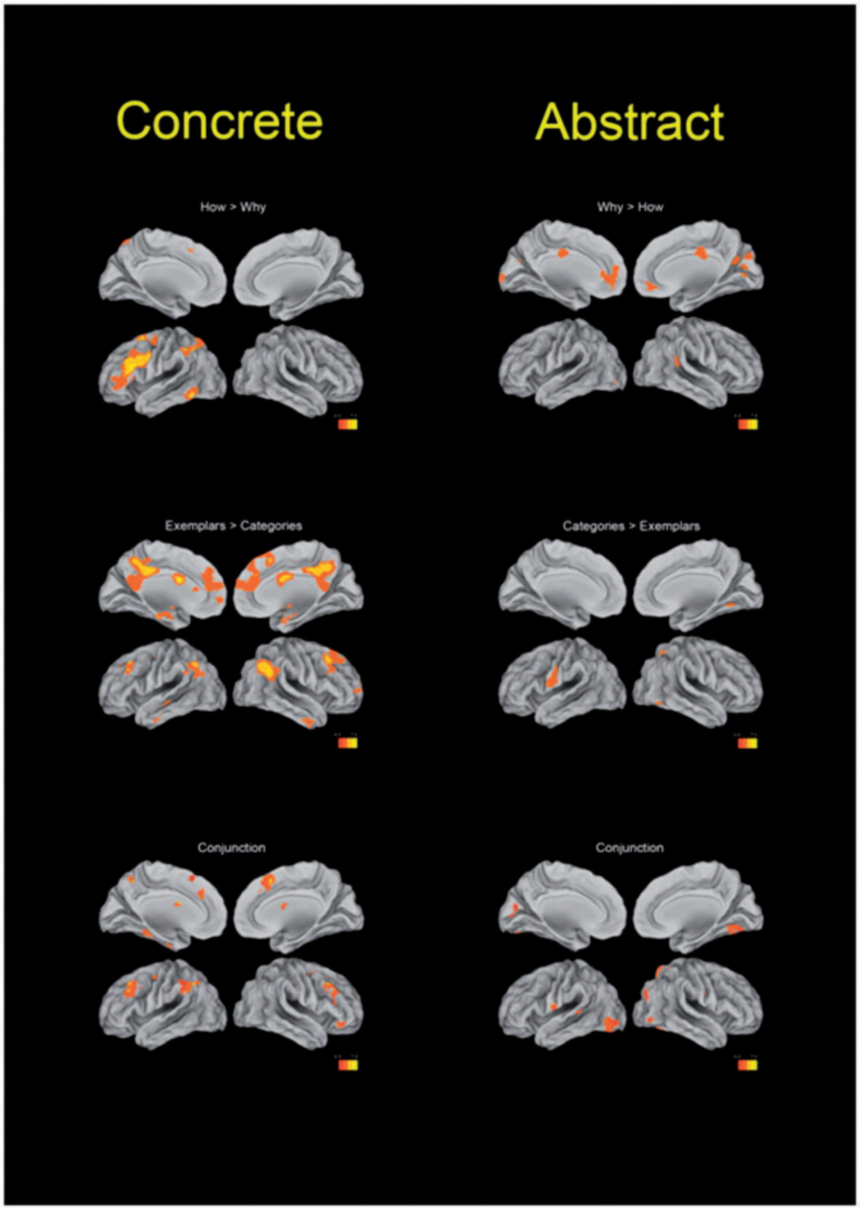

Fig. 1 Neural activity associated with concretization and abstraction. Activations are shown at an uncorrected threshold of $P < 0.01$, to show spatial extent. Legend displays *t*-values.

Neural activity associated with abstraction {(Why > How) ∩ (Categories > Exemplars)}

In order to find the neural correlates associated with the abstracting mindset, we searched for the conjunction of neural activity associated with the Why > How and the Categories > Exemplars contrasts. The results showed activation within a single region of the left primary visual cortex (Figure 1 and Table 2).

Task × Concreteness interaction

To provide a full exposition of the data, we also examined the regions which showed a differential association with abstraction across tasks (the interaction of Task and Concreteness). The results show that the medial 'default network' regions—the precuneus, cingulate gyrus and medial prefrontal cortex showed greater activation in the Concrete condition of the CE task, and in the Abstract condition of the WH task (Table 2).

DISCUSSION

We scanned participants as they: (i) indicated 'why' perform certain activities (which entails abstraction) *vs* 'how' they are performed (which entails concretization); (ii) generated superordinate categories (abstraction) *vs* subordinate exemplars (concretization). We conducted a conjunction analysis of the neural activity associated with concretization (How > Why ∩ Exemplars > Categories) and abstraction (Why > How ∩ Categories > Exemplars).

What are the neural substrates of concretization?

The results showed that the left IPL, left precentral gyrus and the pre-SMA were involved in concretizing. Extant neuroimaging (Grezes and Decety, 2001), lesion (e.g. Halsband *et al.*, 1993) and animal (e.g. Hanes and Schall, 1996) studies show that these regions are a central part of the motor system and are involved in the voluntary control of action; furthermore, overlapping areas are implicated in the voluntary control of outwards-oriented attention (Corbetta and

Table 2 Regions identified in the whole-brain analysis at significance level $P < 0.05$ (corrected)

Contrast	Region	Coordinates			Significance level	Voxels
		x	*y*	*z*	*Z*-score	
Concrete conjunction						
	Frontal					
	L Precentral gyrus	−44	30	32	5.96	580
	R Superior frontal gyrus	10	24	48	3.31	93
	L Precentral gyrus	−28	−6	60	2.96	91
	Parietal					
	L Inferior parietal lobule	−52	−54	52	4.04	248
Abstract conjunction						
	Occipital					
	L Inferior occipital gyrus	−38	−72	−2	2.89	119
Exemplars > Categories						
	Temporal					
	R Superior temporal gyrus	58	−54	30	5.99	660
	Frontal					
	R Middle frontal gyrus	30	22	44	5.89	354
	L Superior frontal gyrus	−32	32	50	4.64	211
	Superior frontal gyrus	6	38	62	4.3	83
	Medial frontal gyrus	2	38	32	3.95	86
	Parietal					
	Precuneus	4	−48	44	5.76	1078
	L Inferior parietal lobule	−54	−62	44	4.97	261
	Limbic					
	Cingulate gyrus	−4	6	24	5.7	154
	Sub-lobar					
	Hypothalamus	8	−8	−16	5.64	142
Categories > Exemplars						
	Non-identified					
How > Why						
	Frontal					
	L Precentral gyrus	−44	32	34	6.27	1611
	L Middle frontal gyrus	−22	8	44	4.47	99
	Parietal					
	L Angular gyrus	−32	−54	42	5.01	277
	L Inferior parietal lobule	−46	−52	60	4.16	100
	Temporal					
	L Fusiform gyrus	−52	−54	−14	4.54	115
Why > How						
	Non-identified					
Task × Concreteness						
	Frontal					
	Medial frontal gyrus	−4	56	0	4.17	621
	Limbic					
	Cingulate gyrus	4	10	26	4.09	122
	Sub-lobar					
	Hypothalamus	6	−6	−18	3.99	80
	Parietal					
	Precuneus	0	−40	34	3.97	628

Shulman, 2002), which is also an important aspect of goal-directed action. Our results indicate that these regions are additionally recruited when people mentally concretize an idea, even when this concretization does not entail performing actual actions on real-world objects.

The finding that thinking 'how' actions are performed (compared with 'why' they are performed) activates fronto-parietal motor regions is not surprising and provides a replication of previous work (e.g. Spunt *et al*., 2010; Spunt and Lieberman, 2012). Much evidence within cognitive neuroscience suggests that the retrieval of sensory and motor knowledge is associated with the activation of the neural systems involved in action and perception (e.g. Wheeler *et al*., 2000; Nyberg *et al*., 2001). A more surprising finding of this study is that thinking of exemplars of an object (when compared with thinking of a category to which this object belongs) also activated this fronto-parietal system. This result is perhaps best explained in terms of the embodied cognition framework (e.g. Barsalou, 1999; Glenberg and Kaschak, 2002).

Embodiment theory argues that cognition did not evolve in order to allow us to safely store and organize mental representations inside a library-like conceptual system. Instead, it stresses the point that our cognitive system evolved in order to accommodate action. When one goes to his or her 'mental library' and looks up the title on 'ketchup' s/he will not discover a yellowing encyclopedia page, which defines this concept by reference to various other titles on 'tomato,' 'sauces,' 'French fries,' etc.; rather, according to the embodiment view, retrieving the concept of ketchup will 'bring to life' experiences pertaining to ketchup: it's sight, smell and taste and the actions associated with it.

Indeed, much evidence in recent years supports the view that the semantic processing of objects can automatically activate action representations. For example, Grezes *et al*. (2003) presented participants with images of objects and asked them to perform a semantic judgment task (decide whether these objects are man-made or natural) on which they responded by performing a precision grip or a power grip. When the object afforded a power grip (e.g. a hammer) and participants responded with a precision grip, response latencies increased. Furthermore, the same effect occurs when the object stimulus is verbal rather than pictorial (i.e. the word 'hammer' or 'grape'; Bub and Masson, 2012).

Our results suggest that the claim that 'cognition is for action' (James, 1983) is especially true when participants apply a concretizing mindset. Relatively concrete exemplars (e.g. jeans) appear to be more closely tied to motor action than more abstract categories (e.g. clothes), since they elicited greater activity within the fronto-parietal action network. This result is also consistent with a previous study (van Dam *et al*., 2010) that showed that reading sentences that described specific motor action (e.g. 'to wipe') elicited more motor activity than sentences that described these actions more abstractly (e.g. 'to clean').

The strength of abstractions lies in the fact that they are applicable in multiple contexts and instances. For example, upon hearing a rattle in the woods, a hunter can prepare for an encounter with a specific exemplar such as a wild *boar*, by automatically activating an action schema associated with approaching and chasing the prey. However, if his prediction is incorrect, and the rattle was caused by a wild *bear*, then committing to a specific course of action could be fatal. Therefore, an adaptive response is to activate the more abstract category *animal*, which does not entail a specific, automatic motor response. The current results, as well as previous findings (van Dam *et al*., 2010), suggest that our brains abide this normative prescription, and that the strength of the link between thought and action is modulated by abstractness.

What are the neural substrates of abstraction?

Our results show that abstraction was not associated with much specific and robust neural activity. Only a small cluster within the early visual cortex was implicated in both the Why > How and in the Categories > Exemplars contrasts.

Despite the relative weakness of this finding, it might still reflect an interesting process associated with abstraction. Research within Construal-Level Theory (CLT; Liberman and Trope, 2008; Trope and Liberman, 2010) shows that adopting an abstract mindset can cause objects to seem physically more distal and that adopting a concretizing mindset makes object appear physically closer (Liberman and Forster, 2009). While proximal objects afford motor actions such as grasping and touching, distant objects can only be engaged via the so-called 'distal senses', and particularly with the sense of sight. And so, while we find it highly unlikely that activity within the early visual cortex subserves the higher cognitive functions which abstraction entails, it is possible that this activation captures an epiphenomenal experience associated with psychological distance and abstraction.

The very limited extent of abstraction-related (compared with concretization-related) activations might also be informative. It is possible that the process of abstraction (at least as it is operationalized in the CE and WH tasks) is more heterogeneous than the process of concretization, and this fact might have been reflected in the difficulty to localize it into specific regions of the brain. While the road from an abstract thought to concrete action appears paved and organized across the fronto-parietal cortex, the opposite direction (turning a particular object into an abstraction) goes through multiple sporadic, less-charted paths. In other words, our findings insinuate that the different manifestations of abstraction might be logically similar (in that they reflect the extraction of essential, context independent features), but their physical realization could be context-specific. Thus, the abstraction of visual information could occur along the brain's ventral stream (e.g. Quiroga *et al.*, 2005), the abstraction of social information in the medial prefrontal cortex (e.g. Mitchell *et al.*, 2006), the abstraction of mathematical knowledge in the parietal lobe (Cohen *et al.*, 2000) and so forth.

This result raises the (speculative) possibility that the previous behavioral effects associated with 'mindset priming' using the CE and WH tasks were caused by the 'de-concretization' which abstraction entrails, rather than the 'de-abstraction' which concretization entails.

The role of the 'default network' in abstraction and psychological distancing

Replicating previous studies (e.g. Spunt *et al.*, 2010; Spunt and Lieberman, 2012), our results show that thinking 'why' an action is performed (when compared with 'how' it is performed) recruited the default mode network (although at a slightly lower statistical significance). This finding is consistent with the notion that the default network also subserves the ability to 'mentalize' (i.e. ascribe intentions, goals and beliefs to other social agents; Van Overwalle, 2009).

Based on this previous evidence, some have assumed (e.g. Trope and Liberman, 2010) that the abstracting mindset is associated with the activity of the default mode network. At face value, this assumption seemed consistent with previous literature on abstraction. Specifically, much work within CLT (Liberman and Trope, 2008; Trope and Liberman, 2010) showed that as people contemplate events that increasingly diverge from the experience of the self, here and now (i.e. if they are more distant in time, occur at more distant places, pertain to distant people or are more hypothetical in nature) then these events are construed in a more abstract manner. For example, people describe the activity of 'reading a book' more abstractly when the activity is set to occur in the distant future (e.g. as 'broadening one's horizons') and more concretely when the activity is temporally proximal (e.g. as 'flipping pages').

Since the default mode network is activated whenever people 'transcend the here and now' (i.e. when they take the perspective of others, navigate to distant locations, think about the future or consider hypothetical scenarios; see Buckner and Carroll, 2007 for a review), it was suggested that it might be best defined as the neural seat of humans' abstraction capabilities (Trope and Liberman, 2008).

And yet, recent evidence (Tamir and Mitchell, 2011) showed the opposite to be true: thinking of *proximal* (*vs* distant) times, people, places and of more likely events causes increased default mode activity. It seems that both of these seemingly conflicting predictions were confirmed in our results: the default network emerged in Why > How contrast (replicating Spunt *et al.*, 2010; Spunt and Lieberman, 2012) and in the Exemplars > Categories contrast (conceptually replicating Tamir and Mitchell, 2011).

Ample research shows that the default mode network (also) subserves the retrieval of episodic memories and specific contextual details (e.g. Addis *et al.*, 2007). In light of this, it is perhaps not surprising that it emerged in the Exemplars > Categories contrast; thinking of concrete exemplars (when compared with thinking of categories) narrows the scope of retrieval and can bring to mind more specific episodic memories and contextual details. For example, when completing the item 'an example of sports is BASKETBALL,' one might have retrieved from memory an instance of watching or participating in a basketball game. Similarly, when people think of proximal and familiar events, they can construe such situations with greater specificity and contextual detail.

In light of this, our results paint a complicated picture, in which the default mode network (unlike the fronto-parietal action network) is not exclusively associated with either proximal/concrete processing or with distal/abstract processing.

Implication and future directions

The finding that a concretizing mindset is associated with embodied representation and motor activity may shed new light on the extant literature that utilized WH and CE tasks as their manipulation. For example, Fujita *et al.* (2006) have shown (using both the WH and CE tasks) that participants primed to an abstracting mindset showed greater restraint and self-control in front of tempting stimuli in comparison to participants primed with a concretizing mindset (an effect replicated many times, e.g. Malkoc *et al.*, 2010; Fujita and Sasota, 2011). Our results suggest that one possible mechanism behind the detrimental effect of concretization on self-control is in the activation of the tendency for motor action in the concretizing mindset condition. Indeed, self-control often requires restraint or inhibition of automatic responses; an abstracting mindset might help self-control by attenuating the automatic association between stimulus and response.

Furthermore, based on our result, one could predict that interventions that were found to diminish activity within the fronto-parietal action network might also serve to increase people's self-control abilities. Such a pattern of decreased fronto-parietal activity occurs when people attempt to relinquish the control of the self over behavior—e.g. during Jazz music improvisation (Limb and Braun, 2008) and Yoga Nidra mediation (Lou *et al.*, 1999). These findings might suggest that contrary to intuition, interventions that teach people how to 'let go' could actually facilitate self-control. Similarly, various other tasks that recruit the fronto-parietal action network could prime a concretizing mindset and thus prove useful in cases where abstraction is less appropriate (e.g. in reducing procrastination, Mccrea *et al.*, 2008). We believe that such a research agenda, in which behavioral and neural studies are closely intertwined, holds the promise of refining current conceptualizations in both the cognitive and neural domains.

SUPPLEMENTARY DATA

Supplementary data are available at *SCAN* online.

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APPENDIX

Table 1A List of stimuli

How/Why	Exemplars/Categories
Fill out a personality test	Singer
Listen to music	Queen
Lift weights	Pasta
Do laundry	Bag
Drive a car	Soap
Watch TV	Airplane
Clean the house	Mineral water
Diet	Lawyer
Chop wood	Newspaper
Join the Army	Movie theatre
Resist temptation	Bird
Read newspaper	Television
Eat ice-cream	A scooter
Paint room	E-mail
Sharpen pencil	University lecturer
Brush teeth	Clothing store
Fill a cavity	Writer
Grow a vegetable garden	Dog
Pick an apple	Chocolate
Eat	Running contest
Press doorbell	Table
Measure room	Guitar
Climb tree	Movie actor
Lock door	Tree
Talk to a child	Headache pill
Make a list	Beer
Read	Prime minister
Take an aspirin	Blanket
Greet someone	Sign post
Take care of plants	Traffic sign
Take an exam	Lake
Drink coffee	Car
Vote in election	Pub
Write in diary	City
Pay rent	University
Surf Internet	Planet