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The language of future-thought: An fMRI study of embodiment and tense processing ☆,☆☆

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ABSTRACT

The ability to comprehend and represent the temporal properties of an occurrence is a crucial aspect of human language and cognition. Despite advances in neurolinguistic research into semantic processing, surprisingly little is known regarding the mechanisms which support the comprehension of temporal semantics. We used fMRI to investigate neural activity associated with processing of concrete and abstract sentences across the three temporal categories: past, present, and future. Theories of embodied cognition predict that concreteness-related activity would be evident in sensory and motor areas regardless of tense. Contrastingly, relying upon construal level theory we hypothesized that: (1) the neural markers associated with concrete language processing would appear for past and present tense sentences, but not for future sentences; (2) future tense sentences would activate intention-processing areas. Consistent with our first prediction, the results showed that activation in the parahippocampal gyrus differentiated between concrete and abstract sentences for past and present tense sentences, but not for future sentences. Not consistent with our second prediction, future tense sentences did not activate most of the regions that are implicated in the processing of intentions, but only activated the vmPFC. We discuss the implications of the current results to theories of embodied cognition and tense semantics.

Introduction

Human cognition has long sought to understand the roots of its exceptionality in the natural world. Two notable answers to the question of human uniqueness have frequently emerged: one focuses on our ability to consider hypothetical future worlds (e.g., Kohler, 1927; Suddendorf and Corballis, 1997) and the other highlights our use of language (e.g., Davidson, 1975; Pinker, 1994). Most of the research into these faculties has been conducted separately, yet the two functions might be highly intertwined; some even suggest that the ability to use and comprehend language that refers to temporally displaced events was a critical component in the evolution of human foresight (Suddendorf and Corballis, 2007).

Temporal conception appears in all human societies and is considered a “cultural universal” of humankind (Brown, 1991). Be it when we set up a savings account for a rainy day, or when we promise our children ice-cream once they finish eating all their greens— linguistic reference to temporally displaced events is a major tenant of human relations and goal directed behavior. Most likely, such a major aspect of human language and cognition evolved to serve an important function. Consider, for example, how the ability to refer to future actions improved ancient humans' hunting skills: while a group of prehistoric hunters could have improved their odds of catching an elusive prey by saying to each other— “Throw your spears now!”, an even more successful group could have conveyed a plan such as “We first circle the prey, and only then attack”. Importantly, such sophisticated cooperative action, which is believed to have been pivotal in human evolution, entails both a comprehension of the action itself (knowing *who does what to whom*) and its location upon the temporal axis (knowing *when*) (Pinker, 2010).

In recent years, much investigation has begun to elucidate the mechanism that allows us to comprehend those aspects of a linguistic message that convey “*who did what to whom*”, that is, the cognitive and neurobiological apparatus through which we process concrete action and object concepts. For example, research conducted within the framework of embodied cognition theory (Barsalou, 1999), suggests that comprehension of a concrete concept is achieved by a reinstatement of the sensory-motor experiences associated with it. Indeed, as predicted by embodied cognition theory, studies have shown that comprehending language denoting motor actions activates motor cortex areas (Hauk et al., 2004; Tettamanti et al., 2005) or middle temporal areas associated with visual motion perception (e.g., Davis et al.,

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2004; but see Bedny et al., 2008, 2012) . Furthermore, when participants verify if an object possesses a property (e.g., “Can apples be green?”, “Can apples be salty?”), the appropriate modality-specific cortical areas (e.g., visual, gustatory, etc.) are activated (Goldberg et al., 2006). Lastly, a recent meta-analysis of concrete and abstract language processing revealed that processing concrete language recruits medial parietal and ventral temporal lobe areas, which are associated with visual/spatial imagery (Wang et al., 2010). It is important to note that the strong version of embodiment theory does not assume that our mental representations *can* be sensorimotor but rather that they are *necessarily* sensorimotor. According to this theory, sensorimotor representations are part and parcel of the process of sematic processing, rather than being a mere epiphenomenon. This view would predict that sensorimotor activity would be evident regardless of specific linguistic parameters, such as tense.

Although it is possible that concrete sentence comprehension strictly relies upon sensorimotor representations regardless of tense, the present study brings forth and investigates alternative predictions, which are based upon Construal Level Theory (CLT; for reviews see Liberman and Trope, 2008; Trope and Liberman, 2010). CLT is a theory of higher-order cognition which adopts a pluralistic perspective on mental representation; it argues that efficient goal-directed behavior requires making use of a variety of mental representations, ranging from the concrete and sensorimotor to the abstract and general. With regards to temporal conceptualization, much behavioral work within the framework of CLT shows that the processing of future occurrences is associated with a diminished concreteness of mental representation. For example, people describe the activity of reading a book in terms of intangible goals (e.g., “becoming intelligent”) rather than the more concrete, physical means (e.g., “flipping pages”) — when this activity is to occur in the distant future (Liberman and Trope, 1998), or when it is more hypothetical (i.e., less likely- Wakslak et al., 2006).

Alongside the empirical evidence showing that futurity is associated with a less concrete mental representation, a strictly sensorimotor account of mental representation also poses a theoretical difficulty, as it might obscure the discrimination between mental representations of real and imagined experiences. Evidence from the reality-monitoring framework (Johnson and Raye, 1981) suggests that people use the degree of sensorimotor vividness of mental images as a cue to distinguish between factual and imaginary events (Goff and Roediger, 1998; Slotnick and Schacter, 2004). For example, when trying to decide whether they only planned to send a letter or actually sent it, people tend to conclude the latter to the extent that the image of this action is rich in sensorimotor details. The recruitment of the neural systems used for the processing of factual reality (i.e., events that have occurred or are occurring right now) might be problematic when thinking of future events, which are non-factual in nature, since it could lead to confusion between actual action and intention. In light of this, we recently proposed that future-thought might require a mental segregation of factual from hypothetical representations by means of reducing the extent of sensorimotor details (Gilead et al., 2012). Consequently, our first prediction was that the processing of factual (past and present) sentences would differ from that of hypothetical (future) sentences, with regards to the degree of concreteness-related processes that they evoke. Alternatively, if the strong version of the embodiment view is correct, then the degree of concreteness-related activity should be impervious to tense.

But how do people represent future actions and events? According to Pinker's (2007) analysis of the conceptual semantics of tense “Many languages don't express the future in the tense system at all, but in a distinction between events that have actually taken place or are now taking place (*realis*) and events that are hypothetical, generic, or in the future (*irrealis*)” (Pinker, 2007, pp. 195). Most relevantly, Pinker (2007, pp. 196) notes the “muddling of volition and futurity” which is evident in the English language's ambiguity of the word *will* (which denotes both future action and intention). Importantly, it appears that across different cultures, the markers used to denote future tense stem from verbs that describe volition (Bybee et al., 1994). Thus, due to the association between linguistic futurity and volition, our second prediction was that the processing of sentences in the future tense would be associated with activation of the neural systems involved in processing of intentions.

To test these predictions, we examined the neural activity associated with comprehension of concrete and abstract Hebrew sentences in the three temporal categories: past, present, and future. Native Hebrew speakers underwent functional magnetic resonance imaging (fMRI) while performing a language comprehension task, and we examined how the neural activity associated with concrete manual action language processing differed for factual (past and present) versus hypothetical (future) sentences. Furthermore, we examined the neural systems that are associated with the comprehension of future tense sentences, regardless of concreteness.

Our first set of hypotheses concerns the modulation of concreteness-related activity by tense. We predicted that comprehension of concrete motor-action (as opposed to abstract) sentences would be associated with increased activity within the Para-Hippocampal Cortex (PHC; e.g., Wallentin et al., 2005; Mestres-Misse et al., 2008) and in fronto-parietal motor regions (e.g., Hauk et al., 2004; Tettamanti et al., 2005). The PHC is implicated in visual/spatial processing (e.g., Epstein and Kanwisher, 1998), and is the locus of concrete language processing according to a recent meta-analysis (Wang et al., 2010). Furthermore, since the concrete action sentences in our experiment described manual motor actions, we expected that they would recruit fronto-parietal regions involved in the observation and execution of manual actions, as reported in Tettamanti et al. (2005). Most critically, we predicted that the neural markers associated with concrete language processing would be apparent only for factual (past and present tense) sentences, and not for hypothetical (future tense) sentences. In other words, we predicted an interaction of tense and concreteness, such that there would be a reduced concreteness effect for hypothetical (vs. factual) sentences.

Our second hypothesis concerned the association between processing of future sentences and processing of intentions. We predicted that future-tense sentences would activate a network of regions consisting of the ventral and dorsal medial prefrontal cortex, the posterior cingulate cortex, and the left temporo-parietal junction. This network was defined based on a quantitative meta-analysis, which we describe in more detail in Appendix A. These regions have been implicated in studies in which people processed the intentions and goals of others (the “mentalizing” function; e.g., Jenkins et al., 2008; Hirao et al., 2008; Lewis et al., 2011; Lombardo et al., 2010; Van Overwalle, 2009; Young and Saxe, 2009); and in studies which investigated people's ability to contemplate their own intentions and goals (the “prospection” function; e.g., D'Argembeau et al., 2010; Okuda et al., 2003; Szpunar et al., 2007). We predicted that this network would be recruited to a greater extent when processing future tense sentences (rather than past and present sentences).

Method

Participants

Twenty-one right-handed participants (12 women, average age 24.7 years, range 21–28 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. One participant was excluded from the data analysis due to failure to comply with task demands. Participants were paid or received course credit for their participation. 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

The experimental stimuli were 312 Hebrew sentences consisting of a transitive verb in the third-person male singular form, the word "the", and an object complement. The sentences were either abstract or concrete, and were either in the past-, present-, or future tense (52 sentences in each condition × 6 conditions). The abstract sentences included a verb and an object that did not denote a specific physical entity (e.g., "respected the decision"); the concrete sentences included a manual action verb and a specific physical object (e.g., "wiping the table"). Concrete and abstract verb and object frequencies were matched on the basis of available frequency norms in Hebrew (Frost and Plaut, 2005). This database is based on Hebrew newspapers and counts average word occurrence per million. For both abstract and concrete sentences, average verb frequency was 8.8 and average object frequency was 39.6 occurrences per million. Sentence lengths significantly differed between abstract ($M=14.36$ characters) and concrete ($M=13.40$ characters) sentences ($p<0.01$). None of the sentences were idiomatic, and none of the verbs had less than two possible object complements. In Hebrew, tense is conveyed by inflecting the verb into the past, present, or future form; thus, each concrete and abstract sentence rotated across the 3 tense conditions, resulting in 3 stimuli lists, counterbalanced across participants. The number of characters significantly differed between past ($M=13.58$), present ($M=13.93$), and future ($M=14.12$) sentences ($p<0.01$).[1] Appendix B presents the complete list of sentences. Additional 36 sentences (6 in each condition) of similar length and frequency were used in catch trials, and were immediately followed by a reading comprehension question. Half of the catch questions referred to a temporal aspect of the sentence (e.g., "Is the table currently being cleaned?") and half referred to a non-temporal aspect (e.g., "Did the sentence refer to a piece of furniture?"). The catch sentences and questions were introduced in order to make sure that participants were engaged in the reading comprehension task, and were modeled as events of no interest in the imaging data analysis.

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. Participants were instructed to silently read the sentences displayed, and press a button once they felt that they understood their meaning. They were told that occasionally a Yes/No question pertaining to the previous sentence will appear, and were asked to answer it. Stimuli were presented with Presentation version 14.9 (Neurobehavioral Systems, CA, USA). Each sentence was presented on screen for 3500 ms, followed by a 500 ms fixation cross. On catch trials, a reading comprehension question appeared instead of a fixation cross immediately after the sentence, and two possible answers (Yes/No) appeared on the bottom of the screen. The catch questions were displayed for 4000 ms followed by a 500 ms fixation cross. Participants responded to the target sentences and catch questions by pressing a response box with their index and middle left hand fingers. They did not know which sentence would be followed by a comprehension question, and therefore had to read all the sentences attentively.

The experiment had four sessions of 500 s each. Each session contained 13 items from each of the 6 experimental conditions (totaling 78 sentences) and 9 catch trials. Experimental and catch trials were intermixed with baseline trials in which a fixation cross was presented. The duration of the baseline trials randomly varied between 2 and 8 s (mean ITI = 3.22 s), totaling about one quarter of overall session duration. The sentences were randomly presented, and the order of the stimulus trials and baseline trials was determined by a sequencing algorithm designed to maximize the efficiency of the event-related design (Dale, 1999).

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). The experiment consisted of 4 sequential scanning sessions in each of which 250 volumes were acquired (TR = 2000 ms, 200 mm FOV, 64 × 64 matrix, TE = 35, 36 pure axial slices, 3.15 × 3.15 × 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 upon 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.

In order to model task-related activity in each of the relevant conditions, the canonical hemodynamic response was convolved with the onset of each trial. The general linear model was used for statistical analyses. For each subject, a fixed-effect model was implemented to linearly contrast brain activity for the effects of interest. 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 conservative threshold of $p<0.0005$ with a cluster size threshold of 20 voxels. Monte-Carlo simulations using the AlphaSim program indicated that this threshold sets the family-wise error rate at $p<0.05$ (Forman et al., 1995). To explore the interactive effects of tense and concreteness, regions of interest (ROIs) were identified using the same statistical thresholds employed in the whole-brain analysis. The parameter estimates were extracted from each ROI on a subject-by-subject basis using MarsBaR v.042 (Brett et al., 2002). The data from these ROIs were then used to observe the activation levels that were associated with each effect of interest in these regions. For visualization purposes, thresholded statistical parametric maps were overlaid on fiducial surface atlas images using Caret 5 (Van Essen et al., 2001).

Results

Behavioral results

Accuracy

Participants responded within the 4000 ms time limit on 94.88% of the catch trials, and their accuracy was 92.53%.

RT

We conducted a 2 (Concreteness) × 3 (Tense) ANOVA on response time data. Responses were slower for abstract sentences ($M=1311$ ms, $SD=473$) than for concrete sentences ($M=1251$ ms, $SD=448$), $F(1, 19)=24.15$, $p<0.01$. There was also an effect of tense, $F(2, 38)=3.77$, $p<0.05$, such that responses for sentences in the future tense were faster ($M=1263$, $SD=441$) than responses for sentences in the

[1] Due to properties of the inflectional morphology in Hebrew, small yet significant differences in sentence length were evident between the different tense conditions, with future sentences being longer by an average of 0.54 letters than past tense sentences. While low-level differences in stimuli might reflect themselves somehow in early visual areas or areas sensitive to language morphology, we find it highly unlikely that the frontal activation found in our study to be associated with future could be influenced by this difference.

present tense ($M = 1296$ ms, $SD = 477$), as revealed by a post-hoc Tukey's test.[2] A significant interaction, $F(2, 38) = 3.67$, $p < 0.05$, indicated a larger difference between concrete and abstract sentences in the past tense ($M = 95$ ms) than in the present tense ($M = 44$ ms) and the future tense ($M = 37$ ms), which did not differ from each other (see Table 2).[3]

Imaging data

Concreteness-related activations

We identified concreteness-related activations based upon the Concrete > Abstract contrast. Consistent with our hypothesis, processing concrete (as opposed to abstract) sentences, irrespective of tense, resulted in activation within the concreteness-related network of brain regions, previously identified in a meta-analysis of concrete language processing (Wang et al., 2010). The activation consisted of regions within the parahippocampal and fusiform gyri, retrosplenial complex, and a left superior occipital region (Table 3). These activations were then subject to a ROI analysis (see below). Contrary to our prediction, despite the fact that all concrete sentences in our design described manual actions, we did not observe fronto-parietal activations, as reported in Tettamanti et al. (2005) even at a much lower statistical threshold of $p < 0.05$ (uncorrected).

Modulation of concreteness-related activity by tense

We identified concreteness-related ROIs based upon the Concrete > Abstract contrast. This resulted in 5 activation foci: a left parahippocampal/fusiform gyrus cluster of 353 voxels, with a peak activation at MNI coordinates ($x = -22$, $y = -26$, $z = -30$), and which extends to include the peak parahippoampal coordinates reported in a recent meta-analysis of concrete language processing (Wang et al., 2010) ($x = -32$, $y = -32$, $z = -20$; $x = -28$, $y = -34$, $z = -20$); a right parahippocampal cluster of 166 voxels at MNI coordinates ($x = 26$, $y = -24$, $z = -28$); a right anterior parahippocampus/amygdala cluster of 73 voxels ($x = 22$, $y = -8$, $z = -30$); a left superior occipital cluster of 51 voxels ($x = -38$, $y = -86$, $z = 36$); and a right retrosplenial cluster of 45 voxels ($x = 22$, $y = -42$, $z = 2$). We extracted beta-values from these 5 ROIs using MarsBar toolbox (Brett et al., 2002) and conducted a 2 (Concreteness) × 3 (Tense) ANOVA with planned comparisons based on our prior hypothesis. Consistent with our hypothesis (and inconsistent with the embodiment view), while factual (past and present) sentences elicited greater parahippocamal activity for concrete- rather than abstract sentences, this was not the case for hypothetical (future) sentences, which did not exhibit increased concreteness-related activity (left PHC: $F(1, 19) = 3.22$, $p < 0.05$; right PHC: $F(1, 19) = 5.92$, $p < 0.05$) (Figs. 1 and 2). The same pattern of results emerged for the 3 smaller clusters, yet only the anterior parahippocamapal gyrus/amygdala cluster reached significance ($F(1, 19) = 3.31$, $p < 0.05$); the retrosplenial cluster neared significance ($F = 1.92$, $p < 0.1$); the superior occipital region displayed the same observed trend but failed to reach significance ($F = 1.47$, n.s.).

Activations associated with processing of abstract sentences

We identified abstractness-related activations based upon the Abstract > Concrete contrast. Consistent with previous literature (e.g., Pexman et al., 2007), comprehension of abstract sentences evoked widespread activation across 15 foci. The abstract sentences in our experiment served mainly as a baseline from which concreteness-related activation could be assessed, and therefore abstract-specific activation will not be discussed here. The complete list of abstraction-related activations is specified in Table 3 for future reference.

Table 1
Studies included in the prospection meta-analysis.

Study	n	Baseline task
D'Argembeau et al., 2008	12	Thinking of routine activities
Botzung et al., 2008	10	Episodic recollection
Abraham et al., 2008	20	Episodic or semantic recollection
D'Argembeau et al., 2010	20	Thinking of routine activities
Weiler et al., 2010	17	Episodic recollection
Addis et al., 2011	15	Episodic recollection or thinking of routine activities
Viard et al., 2011	12	Episodic recollection
Benoit et al., 2011	15	Monetary estimation
Martin et al., 2011	25	Sentence production

Our hypothesis was that the modulation of concreteness-related activity by tense reflects that fact that concreteness-related imagery/simulation processes are attenuated for hypothetical (future) sentences. Indeed, our results show that concreteness-related activations are substantially diminished in the future tense. An alternative interpretation of our result could argue that some unpredictable low-level property of future tense sentences caused this effect (e.g., to give an extreme example, by somehow causing future tense sentences not to be processed at all). Thus, In order to rule out the possibility that the Concreteness × Tense interactions observed in concreteness-related regions were unrelated to differential sensorimotor imagery/simulation, we repeated the ROI analysis described in the previous section for all 15 abstractness-related activation foci. None of the abstractness-related regions displayed a diminished abstractness effect for future sentences, (maximal F statistic value across all 15 comparisons = 1.16, $p = 0.29$), lending strong support to the claim that the modulation of concreteness-related activity is related to attenuation of imagery/simulation processes.

Processing future sentences

We identified activations associated with processing future sentences based upon the Future > Past + Present contrast. Processing future (as opposed to present- or past-) sentences was associated with an activation of the ventromedial prefrontal cortex (vmPFC), with peak activation at MNI coordinates ($x = 0$, $y = 42$, $z = -26$) (Fig. 3). A 2 (Concreteness) × 3 (Tense) ANOVA conducted on beta values extracted from this cluster revealed that the vmPFC is more responsive to future than present or past sentences $F(1, 19) = 19.09$, $p < 0.0005$. The vmPFC displayed an unexpected effect of Concreteness where concrete sentences activated this region more than abstract sentences, $F(1, 19) = 7.09$, $p < 0.05$. No Concreteness by Tense interaction was observed, $F(2, 38) < 1$ (Fig. 2).

Activations within the “intention network”

We identified the network of regions involved in processing of intentions based upon a quantitative meta-analysis we conducted of previous prospection studies and upon previously published meta-analyses of mentalizing studies (see Appendix A).

Table 2
Response time (milliseconds) by tense (past, present, future) and sentence concreteness.

Concreteness/Tense	Past	Present	Future
Concrete	1236 (446)	1274 (485)	1242 (435)
Abstract	1331 (506)	1318 (480)	1284 (457)

[2] There was no RT difference between future and past sentences, and thus this difference is highly unlikely to account for future-specific activations.

[3] The interaction between concreteness and tense on RT does not follow the pattern of brain activation, for which the same result emerged for present and past tense sentences.

Table 3
Regions identified in the whole brain analysis at significance level $p<0.0005$ uncorrected, k = 20.

Contrast	Region		Coordinates			Significance level	Voxels
			x	y	z	Z-score	
Concrete > Abstract							
	Temporal						
		L parahippocampal gyrus	−22	−26	−30	4.84	353
		R parahippocampal gyrus	26	−24	−28	4.51	166
	Occipital						
		L superior occipital	−38	−86	36	4.16	51
	Limbic						
		R retrosplenium	22	−42	−2	4.01	45
		R amygdala	22	−8	−30	3.86	73
Abstract > Concrete							
	Frontal						
		L Precentral gyrus	−50	−2	54	5.57	1380
		L Inferior frontal gyrus	−42	24	−8	4.74	1770
		R Precentral gyrus	40	18	30	4.49	513
		R Middle frontal gyrus	28	38	24	4.03	142
		R medial cortex	24	50	−8	3.67	20
	Cerebellum						
		L Cerebellar tonsil	−46	−42	−48	5.46	4094
		R Uvula	26	−84	−24	5.16	1098
	Parietal						
		L Superior parietal lobule	−24	−56	50	4.57	577
		R Superior parietal lobule	24	−64	60	4.27	915
		R Postcentral gyrus	36	−26	64	3.58	275
	Sub − lobar						
		R Claustrum	28	24	−4	4.56	337
	Temporal						
		L Middle temporal gyrus	−58	−8	−20	4.42	115
		R Middle temporal gyrus	56	0	−22	3.78	49
	Occipital						
		R Lingual gyrus	20	−102	−6	3.9	84
		L Cuneus	−8	−84	22	3.8	178
Future > Past + Present							
	Frontal						
		ventromedial	0	42	−12	3.57	21
Present > Past + Future							
	Insula						
		R Insula	36	24	12	4.44	84
	Cerebellum						
		R Culmen	34	−66	−28	3.55	26
Past > Present + Future							
	Non identified						

We extracted average beta-values from the "intention network" ROI using MarsBar toolbox (Brett et al., 2002) and conducted a 2 (Concreteness) × 3 (Tense) ANOVA with planned comparisons based on our prior hypothesis. Inconsistent with our second hypothesis, the results did not show significantly greater activation in the "intention network" when reading future compared to past and present tense sentences, $F(1,19)=2.31$, $p=0.07$. We extracted beta values from each of the 5 "intention-network" foci by drawing a sphere centered at the activation maxima of each cluster of its appropriate volume. Only the 2 ventral mPFC clusters reached significance: BA 10 ($F(1, 19)=5.42$, $p<0.05$); BA 11 ($F(1, 19)=4.21$, $p<0.05$). BA 9 displayed the same observed trend, yet did not reach significance ($F=1.21$, n.s.). Within the left TPJ and the PCC the observed trend was opposite to that of the mPFC regions, yet it did not near significance (both $Fs<1$).

Processing present and past sentences. Both the insular cortex and the cerebellum were selectively active when processing present tense sentences (compared to future and past). We did not have any a-priori prediction regarding these activations. They are reported in Table 3 for future reference.

No regions were selectively active for past tense sentences; furthermore, no regions were selectively active for the Past + Present > Future contrast or the Past + Future > Present contrasts, even at a more liberal threshold of $p<0.001$, uncorrected.

Discussion

We presented participants with concrete and abstract sentences in the past, present, and future tenses, and measured their neural activity with fMRI while they performed a reading comprehension task. Consistent with our first prediction, the neural markers associated with concrete language processing were apparent only for factual (past and present) sentences, but were absent for hypothetical (future) sentences. Inconsistent with our second prediction, processing future tense sentences, irrespective of concreteness, did not recruit the neural network associated with the processing of intentions.

Modulation of concreteness-related activity by tense

Comprehension of concrete (as opposed to abstract) sentences was associated with activation in the parahippocampal cortex (PHC) and fusiform gyrus, and to a lesser extent in a left superior occipital region and a bilateral retro-splenial region. This pattern of activation replicates previous experiments (e.g., Mestres-Misse et al., 2008; Wallentin et al., 2005) and is consistent with the meta-analysis of neuroimaging studies that compared concrete and

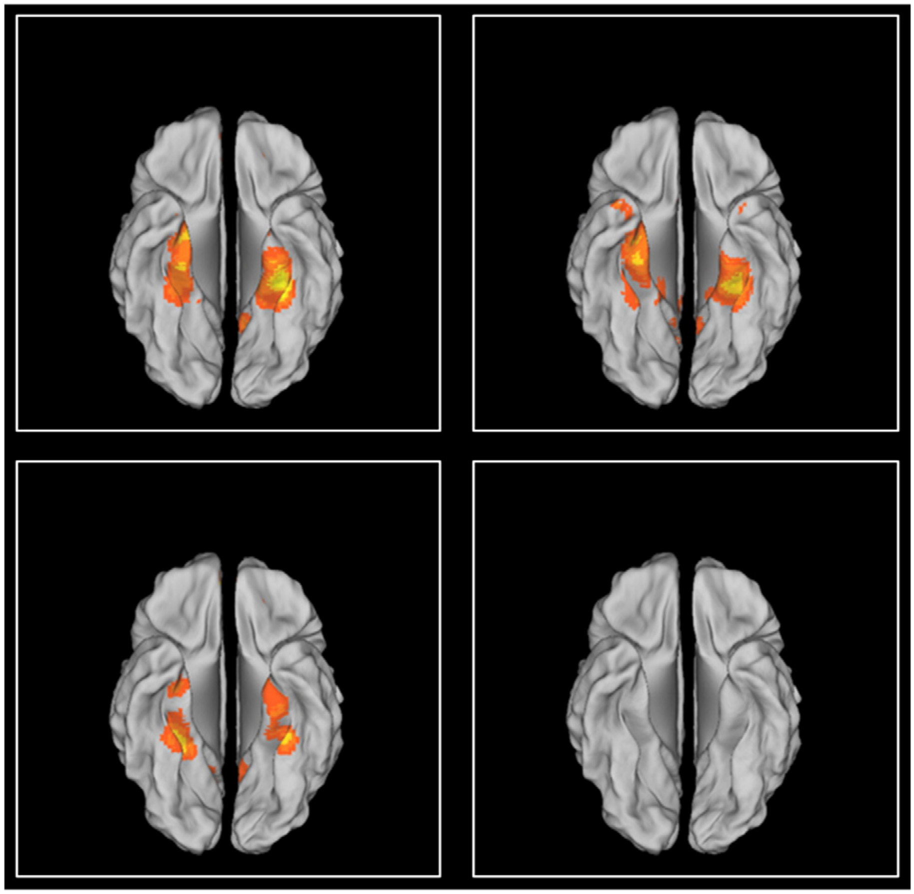

Fig. 1. Modulation of concreteness-related activity by tense, shown on an inflated cortical surface. Upper left panel: ventral temporal activation elicited by the concrete-abstract contrast, irrespective of tense; upper right panel: concrete-abstract contrast for past tense; lower left panel: concrete-abstract contrast for present tense; lower right panel: concrete-abstract contrast for future tense. Activations are shown at an uncorrected threshold of $p<0.01$ to show spatial extent. Activations in yellow survive a threshold of $p<0.0005$. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

abstract sentence processing (Wang et al., 2010). The PHC had been traditionally implicated in spatial scene processing (Epstein and Kanwisher, 1998), visual-spatial imagery (Ganis et al., 2004), and memory for contextual episodic details (Wagner et al., 1998). Since concrete language refers to physical objects and actions that are typically associated with well-defined spatial relations and sensory details (Schwanenflugel and Shoben, 1983), it is not surprising that the processing of concrete language involved PHC activation. Most importantly, our results revealed that the neural markers previously associated with concrete language processing were apparent only for past and present sentences, but were absent for future sentences.

This result is consistent with our prediction, which relied upon Construal-Level theory (Liberman and Trope, 2008; Trope and Liberman, 2010), and is not consistent with the predictions of the embodiment account (e.g., Barsalou, 1999). We employed a similar procedure to that used in the studies that provided support to the embodiment view (e.g., Tettamanti et al., 2005), and like these studies, we observed sensorimotor cortex activations associated with semantic processing. According to the embodiment view, the recruitment of modality-specific sensorimotor areas is a necessary part of semantic processing, and should be impervious to specific linguistic parameters such as tense. The fact that the neural markers of embodiment were eliminated in the future tense speaks against the idea of a necessary sensorimotor involvement in semantic processing.

While the experience of non-human animals is probably limited to events occurring in the "here-and-now," human beings can produce and comprehend language that refers to distant times and places as well as to hypothetical, non-existing states. This remarkable ability to conjure up imagined worlds requires us to somehow segregate representations of the factual and the hypothetical (Gilead et al., 2012); because our neural perceptual modules are primarily concerned with the task of accurately discovering factual reality, the reactivation of concrete sensorial images might be ill-suited when construing the meaning of hypothetical (rather than factual) actions.

Our finding is in line with previous behavioral studies that have indicated that concrete sensory-motor representations might be invoked to a lesser extent when processing hypothetical, counterfactual, and future events. For example, it has been shown that the well established phenomenon (Glenberg and Kaschak, 2002; Zwaan and Taylor, 2006), whereby reading an action sentence (e.g., "unlocked the door") primes an actual, concrete motor response (e.g., hand rotation) is eliminated when subjects read sentences describing counterfactual situations (e.g., "wanted to unlock the door") (Zwaan et al., 2010). Further evidence shows that imagination of future events (in comparison to remembrance of past events) is associated with fewer perceptual details (Anderson and Dewhurst, 2009). Similarly, perceptual detail tends to be omitted (D'Argembeau and Van der Linden, 2004) and the effect of perceptual cues on judgment is attenuated (Maglio and Trope, 2012) when thinking of temporally distant (vs. proximal) events. Finally, much behavioral evidence within construal level theory shows that processing of the distant- vs. proximal future, and of hypothetical- vs. certain events, is associated with a diminished reliance upon concrete mental representations (for reviews, see Liberman and Trope, 2008; Trope and Liberman, 2010).

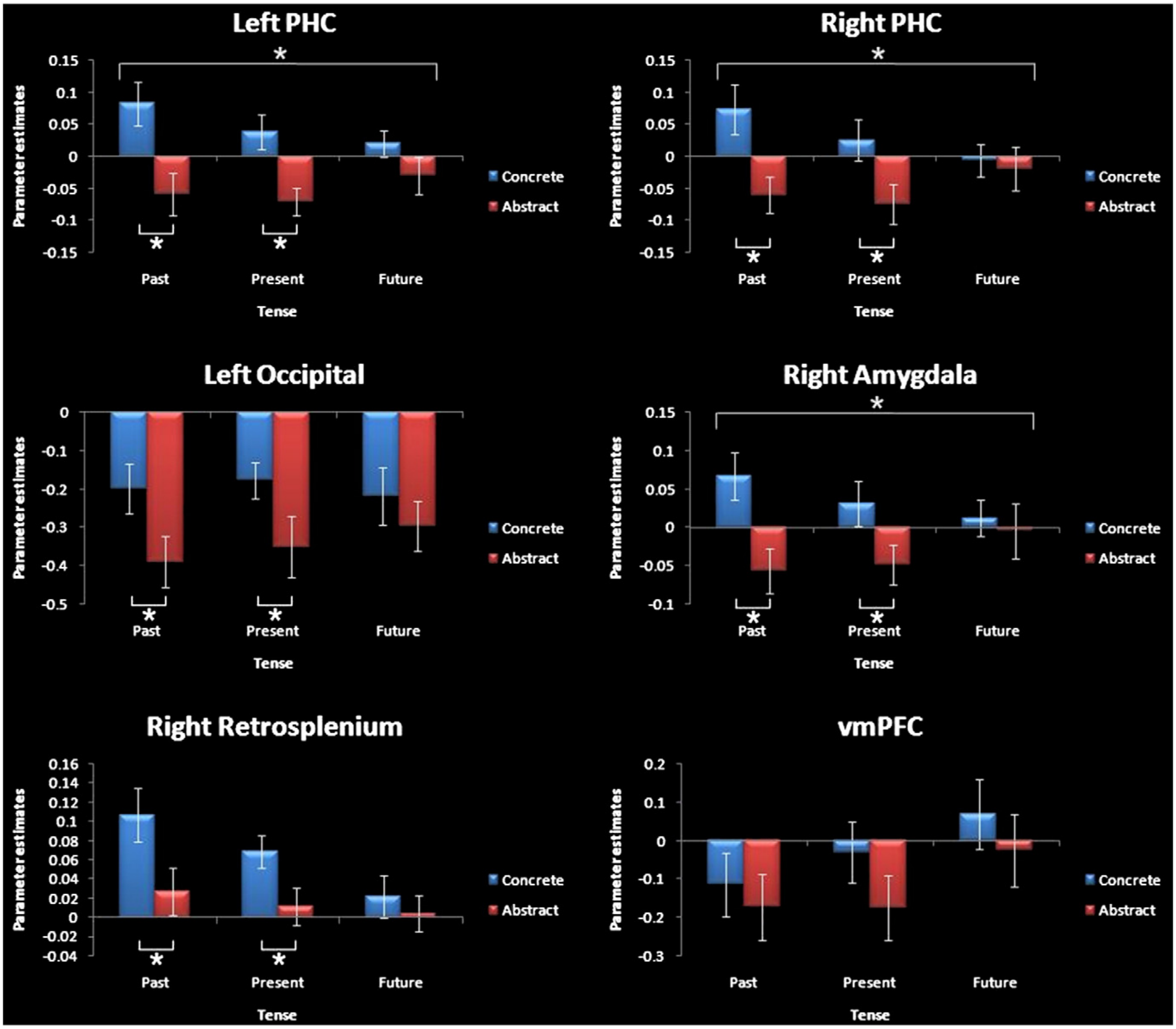

Fig. 2. *Parameter estimates.* An asterisk above the graph bars denotes a significant Tense × Concreteness interaction; an asterisk below graph bars denotes a significant difference between Concrete and Abstract within the tense condition.

We think that our study extends these behavioral results in an important way. Embodiment theory is an account of mental representation that commits itself to the view that activity in sensory-motor regions is a necessary part of the mechanism of processing semantic meaning. In that respect, examining neural activity is the most direct test of the theory's predictions. The previous findings that behavioral markers of embodiment were attenuated in processing of (the more distant) future could, in principle, be due to downstream processes, that occur after embodied representations have been invoked. In other words, past behavioral findings allowed for the possibility that embodied representations were activated in the brain in processing of the future, yet were not revealed behaviorally due to additional processes.

Our findings are also consistent with previous psycho-linguistic fMRI studies that investigated the effect of negation on language processing (Tettamanti et al., 2008; Tomasino et al., 2010). These experiments have shown that reading sentences describing a motor action (e.g., "push the button") was associated with motor cortex activity. However, when these actions were negated (e.g., "do not push the button"), motor activation decreased. Negated events, like future ones, describe non-factual world-states and thus should not call upon the same sensory-motor systems with which we encounter reality (Gilead et al., 2012). The present results join this previous work (e.g., Tettamanti et al., 2008; Tomasino et al., 2010) in suggesting that the invocation of concrete/embodied representations is not mandatory, as initially suggested (Hauk et al., 2004), but rather that it is part of a more intricate process by which meaning is construed.

There is an inconsistency between the current report and the results of the seminal study by Tettamanti et al. (2005), which was the first to examine the neural correlates associated with processing concrete manual-action sentences. Based upon this previous study, we hypothesized that the concrete sentences in our study, which described manual actions, would activate fronto-parietal motor areas, which are typically active when performing such actions. Surprisingly, the comparison of concrete and abstract sentences did not reveal activations in motor-specific regions, and instead recruited areas associated with processing of concrete language at large. A closer look

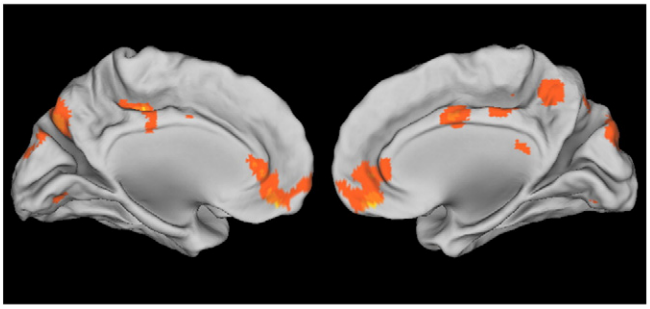

Fig. 3. Activations associated with processing of future-tense sentences, shown on an inflated cortical surface. Activations shown in orange are at an uncorrected threshold of $p<0.01$ to show spatial extent. Activations in yellow survive a threshold of $p<0.0005$. Activation maxima are also shown in Fig. 4. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

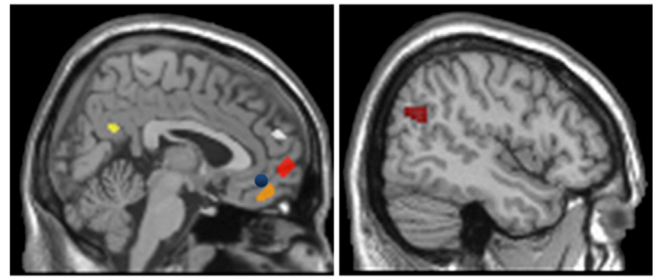

Fig. 4. The "intention network" identified by the ALE meta-analysis (Appendix A). Dark red (rightmost panel): Left TPJ; yellow: posterior cingulate cortex; white: mPFC (BA 9); light red: mPFC (BA 10); orange: mPFC (BA 11). The blue circle represents the activation maxima for Future>Past+Present contrast. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

at the action-sentence literature since Tettamanti's et al., (2005) study reveals that reported activation foci are subject to much variability and inconsistency. Specifically, to date five studies report activations associated with manual action sentences compared to abstract or non-manual action sentences: Tettamanti et al. (2005) reports activation within the precentral gyrus, insula, posterior inferior parietal sulcus, posterior inferior temporal gyrus extending to the fusiform gyrus, and the middle temporal gyrus; Willems et al. (2010) report activation of the superior frontal sulcus; Moody and Gennari (2010) report the middle frontal gyrus, anterior inferior frontal gyrus, and the inferior parietal lobule; Desai et al. (2010) report the posterior central sulcus and inferior temporal sulcus extending to the fusiform gyrus; finally, Tremblay and Small (2011) find the superior temporal gyrus. This variability in reported foci suggests that motor activation is not mandatory, but rather hinges upon the specifics of the sentential context.

Unlike most previous research, which made use of sentences in the imperative form or second and first person perspective (e.g., "I/You am/are cutting the paper"), the stimuli in our experiment were in a third person perspective (e.g., "He is cutting the paper"). It is possible that the comprehension of sentences in the third person is accompanied by visual imagery/simulation, while that of a first person perspective evokes a motor component. Indeed, a recent article by Papeo et al. (2011) used TMS to show that motor simulation occurs for sentences in the first, but not in the third person perspective; we are currently examining this question in our lab using behavioral and functional imaging techniques.

Processing future sentences

Our study was the first to examine the neural correlates associated with processing sentences in the three canonical temporal categories. We reasoned that processing sentences in the future tense (vs. the past and present tenses) would be associated with activation in regions implicated in processing of intentions. In the same way that when considering whether apples are salty, one might retrieve concrete memories of biting an apple; it is possible that when considering the sentence "Danny will kick the ball", one might retrieve memories of intending to kick a ball, or of someone else having that intention.

We performed a meta-analysis in order to identify the neural network that is involved in processing of intentions. This analysis yielded a network of regions consisting of the medial prefrontal cortex, the posterior cingulate cortex and the left temporo-parietal junction. We examined whether activation within this network would be greater for future tense sentences compared to past and present tense sentences. Our results showed the predicted trend, however this effect was not significant. Furthermore, a closer analysis of various components of the network revealed that that the trend towards significance was solely due to activation of the vmPFC.

The evidence that ascribes a role to the vmPFC in prospection (e.g., Okuda et al., 2003) and mentalizing (e.g., Van Overwalle, 2009) is ample. In light of this, it remains possible that its association with linguistic futurity is related to its role in intention processing. However, much evidence links this region to numerous other cognitive functions such as valuation (Hare et al., 2009) and self-referential processing (D'Argembeau et al., 2005). Thus, the current results do not permit us to draw a reverse-inference based upon its activation, and further research will be needed to delineate the nature of the futurity-related vmPFC activation.

Further effects of abstractness and concreteness

It is important to make clear that we do not adhere to a simplistic equation in which the neural correlates of abstract language processing are to be paralleled with those of future tense processing. One must keep in mind that while concrete sentences are defined positively (i.e., by a property they possess— a reference to tangible objects), abstract sentences, at least in our study, are defined by the properties they lack (they *do not* refer to tangible objects). Thus, the application of the subtractive method to the concrete-abstract contrast should result in the neural markers of imagery or sensorimotor simulation processes; conversely, the outcome of subtracting concrete from abstract sentences is (a-priori) less informative and should reflect various factors such as processing difficulty and age of acquisition, which were not the focus of the current study. In light of this, we did not predict that activation within abstractness related regions would increase in the future tense. Indeed, consistent with previous research (e.g., Pexman et al., 2007), our results show a rather non-specific, widespread activation for the Abstract-Concrete contrast. For the purpose of the current investigation, we believe that the most important observation was that none of these widespread abstractness-related activations displayed the same modulation by tense obtained with concreteness-related regions.

An unexpected finding from our study is that the region associated with future tense processing (vmPFC) was more active in concrete than in abstract sentence processing (although at liberal statistical threshold of $p<0.05$, relative to the threshold of $p<0.0005$ which was used to reliably identify the concreteness-related network). If it were the case that the vmPFC activation reflected sensorimotor simulation/mental imagery processes, this result would have been at odds with our prediction. However, based upon much previous

Table 4
The "intention processing network" identified by the ALE meta-analysis.

Region		Coordinates			ALE	Volume (mm^3)
		x	y	z		
Temporal						
	L temporo-parietal junction	−48	−62	26	0.02091	672
Frontal						
	vmPFC (BA 10)	−4	58	−2	0.02554	656
	mPFC (BA 11)	−4	44	−20	0.01844	432
	dmPFC (BA 9)	−2	52	22	0.01792	224
Parietal						
	Posterior cingulate	−6	−58	26	0.02143	384

literature, it is unequivocally accepted that the vmPFC is *not* part of the human sensorimotor cortex, and hence its activation is highly unlikely to reflect mental imagery processes; instead, as noted earlier, extant neuroimaging and neuropsychological evidence suggest that the vmPFC is involved in higher-order cognitive functions such as prospection and mentalizing (e.g., Okuda et al., 2003; Van Overwalle, 2009). What could explain the greater activation of the vmPFC for concrete rather than abstract sentences in our study? It is possible that concrete sentences are more easily interpreted in terms of the actor's intentions than abstract sentences. For example the sentences "slammed the door" or "opened the fridge" convey the actor's state of mind and intention, more than "focused the energy" or "quantified the odds". It is possible that this inherent difference is the reason why concrete language engages the vmPFC to a greater extent. We intend to further investigate this interesting possibility in future studies.

Similarities and differences between past and future

Our ability to "transcend the here and now" requires access to a reservoir of mental content upon which we can build imaginary scenarios. Indeed, much previous research has suggested an overlap between the neural systems which allow us to imagine future worlds and those with which we recollect the past (e.g., Schacter et al., 2007; Buckner and Carroll, 2007). This important branch of research also highlighted the phenomenological similarities between thinking of tomorrow and yesterday, which differ from the today in terms of the immediacy of experience.

This phenomenological difference might have been reflected in our study by diminished insular activation for present and future tense sentences (compared to present tense). The insular cortex is involved in the experience of agency (Farrer and Frith, 2002) and awareness (Craig, 2009). It is possible that a reduced insular involvement captures the lacking immediacy the past and future entail. It should be noted that we did not predict insular activation effect a-priori, and thus, this interpretation is no more than a post-hoc speculation.[4]

Despite the similarities between past- and future-thought, it is self-evident that they are not one of the same. It is an absolute necessity for cognitive agents to sharply distinguish between factual (past and present) and hypothetical (future) events (Gilead et al., 2012). It appears that due to the grave importance of this distinction, the factual/hypoethical (or realis/irrealis) dimension permeates the inner-substrates of our language (Pinker, 2007) and as the current study shows, is reflected in the way our brains process meaning.

Acknowledgments

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Appendix A. Defining the "intention network"

In order to accurately compare the future-related activations found in our study with past research on processing of intentions (i.e., mentalizing and prospection), we conducted a meta-analysis of the fMRI literature on prospection using the activation likelihood estimation (ALE) method (Laird et al., 2005) and the GingerALE 2.1.1 program (http://www.brainmap.org). We subsequently compared the results of this meta-analysis with previous meta-analyses of mentalizing studies (Van Overwalle, 2009; Van Overwalle and Baetens, 2009).

We searched (June, 2012) the Web of Science database (http://apps.webofknowledge.com) using the keywords "prospection" or "future" in the title field, and then searched within these results with the key word 'fMRI'. This yielded a total of 121 papers. We further incorporated 6 studies reported in a previous meta-analysis of prospection and self-projection (Spreng et al., 2009) and then added all studies which cited one of the 3 most prominent papers on prospection (Okuda et al., 2003; Szpunar et al., 2007; Addis et al., 2007) to our pool (a total of 631 papers). For our final analysis we selected fMRI studies which contrasted the envisioning or planning of events with various control tasks which are not prospection-related. The final list included 9 studies reported in Table 1.

ALE maps were created using a full-width half-maximum (FWHM) of 10 mm. The 3D Gaussian distributions were then summed to create an ALE map estimating each voxel's activation likelihood across the entire set of studies. Statistical significance was determined by a permutation test of randomly generated foci using the default GingerALE 2.1.1 parameters. Five thousand permutations were computed using the same FWHM value, and the same number of foci was used in computing the ALE values. All permutation tests were thresholded by a false discovery rate (FDR) value of $p<0.05$ and by clusters of suprathreshold voxels exceeding 200 mm^3.

We wished to restrict our results to only include clusters which are also consistently active during the processing of other people's intentions, beliefs and goals ("mentalizing"). To that purpose, we compared the location of foci from the prospection meta-analysis to those reported in previously published meta-analyses of mentalizing tasks (Van Overwalle, 2009; Van Overwalle and Baetens, 2009).

The prospection meta-analysis resulted in 5 activation foci: three clusters covering the ventral and dorsal aspect of the mPFC, a cluster within the posterior cingulate cortex, and a cluster near the *left* temporo-parietal junction (Table 4). Upon comparison with previously published mentalizing meta-analyses (Van Overwalle, 2009; Van Overwalle and Baetens, 2009) it was revealed that the prospection network found in our meta-analysis is a sub-set of the larger mentalizing network (which additionally includes the *right* temporo-parietal junction); hence, the conjunction of the two networks remained identical to the prospection network in itself.

[4] Furthermore, insular activation is frequent in neuroimaging studies, and is associated with many diverse cognitive functions (Chang et al., 2012). In light of this, it is especially difficult to draw reverse-inferences based upon insular activation.

Appendix B

Concrete			
English past	Future Hebrew	Present Hebrew	Past Hebrew
Pulled the string	ימתח את המיתר	מותח את המיתר	מתח את המיתר
Vacuumed the rug	ישאב את השטיח	שואב את השטיח	שאב את השטיח
Polished the trophy	ימרק את הגביע	ממרק את הגביע	מירק את הגביע
Seasoned the fish	יתבל את הדג	מתבל את הדג	תיבל את הדג
Inserted the needle	יחדיר את המחט	מחדיר את המחט	החדיר את המחט
Blew up the balloon	יפוצץ את הבלון	מפוצץ את הבלון	פוצץ את הבלון
Took off the coat	יפשוט את המעיל	פושט את המעיל	פשט את המעיל
Crushed the can	ימעך את הפחית	מועך את הפחית	מעך את הפחית
Plucked the hair	ימרוט את השערה	מורט את השערה	מרט את השערה
Absorbed the water	יספוג את המים	סופג את המים	ספג את המים
Punched the ticket	ינקב את הכרטיסייה	מנקב את הכרטיסייה	ניקב את הכרטיסייה
Put the book	יניח את הספר	מניח את הספר	הניח את הספר
Knitted the scarf	יסרוג את הצעיף	סורג את הצעיף	סרג את הצעיף
Turned the plate	יהפוך את הצלחת	הופך את הצלחת	הפך את הצלחת
Sealed the hole	יאטום את החור	אוטם את החור	אטם את החור
Closed the shutter	יסגור את התריס	סוגר את התריס	סגר את התריס
Planted the seedling	ייטע את השתיל	נוטע את השתיל	נטע את השתיל
Changed the tire	יחליף את הגלגל	מחליף את הגלגל	החליף את הגלגל
Ripped the cable	יתלוש את הכבל	תולש את הכבל	תלש את הכבל
Stirred the soup	יבחוש את המרק	בוחש את המרק	בחש את המרק
Mowed the lawn	יכסח את הדשא	מכסח את הדשא	כיסח את הדשא
Sipped the drink	ילגום את המשקה	לוגם את המשקה	לגם את המשקה
Shortened the dress	יקצר את השמלה	מקצר את השמלה	קיצר את השמלה
Unloaded the boxes	יפרוק את הארגזים	פורק את הארגזים	פרק את הארגזים
Slammed the door	יטרוק את הדלת	טורק את הדלת	טרק את הדלת
Filled the pot	ימלא את הסיר	ממלא את הסיר	מילא את הסיר
Cut the cloth	יחתוך את הבד	חותך את הבד	חתך את הבד
Rolled up the sleeve	יפשיל את השרוול	מפשיל את השרוול	הפשיל את השרוול
Dusted the CD's	יאבק את הדיסקים	מאבק את הדיסקים	איבק את הדיסקים
Licked the ice cream	ילקק את הגלידה	מלקק את הגלידה	ליקק את הגלידה
Loosened the knot	יתיר את הקשר	מתיר את הקשר	התיר את הקשר
Framed the picture	ימסגר את התמונה	ממסגר את התמונה	מיסגר את התמונה
Drew the map	ימשוך את המפה	מושך את המפה	משך את המפה
Crumbled the cookie	יפורר את העוגייה	מפורר את העוגייה	פורר את העוגייה
Fried the omelet	יטגן את החביתה	מטגן את החביתה	טיגן את החביתה
Lit the fire	ידליק את האש	מדליק את האש	הדליק את האש
Nailed the plank	ימסמר את הקרש	ממסמר את הקרש	מיסמר את הקרש
Smoked the pipe	יעשן את המקטרת	מעשן את המקטרת	עישן את המקטרת
Cut the ribbon	יגזור את הסרט	גוזר את הסרט	גזר את הסרט
Covered the matzos	יכסה את המצות	מכסה את המצות	כיסה את המצות
Turned off the air conditioner	יכבה את המזגן	מכבה את המזגן	כיבה את המזגן
Floured the baking dish	יקמח את התבנית	מקמח את התבנית	קימח את התבנית
Chased away the pigeons	יסלק את היונים	מסלק את היונים	סילק את היונים
Washed the undershirt	יכבס את הגופייה	מכבס את הגופייה	כיבס את הגופייה
Shaked the bottle	ינער את הבקבוק	מנער את הבקבוק	ניער את הבקבוק
Emptied the bucket	ירוקן את הדלי	מרוקן את הדלי	רוקן את הדלי
Wore the sweatshirt	ילבש את הסווטשירט	לובש את הסווטשירט	לבש את הסווטשירט
Erased the picture	ימחק את הציור	מוחק את הציור	מחק את הציור
Washed the apple	ירחץ את התפוח	רוחץ את התפוח	רחץ את התפוח
Salted the roast	ימליח את הצלי	ממליח את הצלי	המליח את הצלי
Wrapped the rope	ילפף את החבל	מלפף את החבל	ליפף את החבל
Drew near the chair	יקרב את הכיסא	מקרב את הכיסא	קירב את הכיסא
Crumpled the handkerchief	יקמט את המטפחת	מקמט את המטפחת	קימט את המטפחת
Opened the refrigerator	יפתח את המקרר	פותח את המקרר	פתח את המקרר
Dropped the key	ישמוט את המפתח	שומט את המפתח	שמט את המפתח
Held the candle	יאחוז את הנר	אוחז את הנר	אחז את הנר
Extinguished the cigarette	יאפר את הסיגרייה	מאפר את הסיגרייה	איפר את הסיגרייה
Shut the windows	יגיף את החלונות	מגיף את החלונות	הגיף את החלונות
Crushed the garlic	יכתוש את השום	כותש את השום	כתש את השום
Threaded the bead	ישחיל את החרוז	משחיל את החרוז	השחיל את החרוז
Tied the laces	יקשור את השרוכים	קושר את השרוכים	קשר את השרוכים
Smashed the mug	ינתץ את הספל	מנתץ את הספל	ניתץ את הספל
Ate the sandwich	יזלול את הכריך	זולל את הכריך	זלל את הכריך
Paved the sidewalk	ירצף את המדרכה	מרצף את המדרכה	ריצף את המדרכה
Locked the locker	ינעל את הלוקר	נועל את הלוקר	נעל את הלוקר
Drew away the fan	ירחיק את המאוורר	מרחיק את המאוורר	הרחיק את המאוורר
Cracked the nut	יפצח את האגוז	מפצח את האגוז	פיצח את האגוז
Sawed the tree	ינסר את העץ	מנסר את העץ	ניסר את העץ
Brushed the hair	יבריש את השיער	מבריש את השיער	הבריש את השיער

Appendix B (*continued*)

Concrete			
English past	Future Hebrew	Present Hebrew	Past Hebrew
Loaded the gun	יטען את האקדח	טוען את האקדח	טען את האקדח
Shook the test tube	יטלטל את המבחנה	מטלטל את המבחנה	טלטל את המבחנה
Put on the bracelet	יענוד את הצמיד	עונד את הצמיד	ענד את הצמיד
Tarred the roof	יזפת את הגג	מזפת את הגג	זיפת את הגג
Rubbed the oil	ימשח את השמן	מושח את השמן	משח את השמן
Carved the statue	יגלף את הפסל	מגלף את הפסל	גילף את הפסל
Stirred the cream	יערבל את השמנת	מערבל את השמנת	עירבל את השמנת
Wrapped the gift	יעטוף את המתנה	עוטף את המתנה	עטף את המתנה
Scattered the coins	יפזר את המטבעות	מפזר את המטבעות	פיזר את המטבעות
Crushed the fly	ימחץ את הזבוב	מוחץ את הזבוב	מחץ את הזבוב
Tucked the handkerchief	יתחב את הממחטה	תוחב את הממחטה	תחב את הממחטה
Set up the tent	יקים את האוהל	מקים את האוהל	הקים את האוהל
Squirted the syrup	יזליף את הסירופ	מזליף את הסירופ	הזליף את הסירופ
Stapeled the pages	ישדך את הדפים	משדך את הדפים	שידך את הדפים
Soaped the leg	יסבן את הרגל	מסבן את הרגל	סיבן את הרגל
Ripped the sock	יקרע את הגרב	קורע את הגרב	קרע את הגרב
Threw the gum	ישליך את המסטיק	משליך את המסטיק	השליך את המסטיק
Raked the leaves	יגרוף את העלים	גורף את העלים	גרף את העלים
Took off the glasses	יוריד את המשקפיים	מוריד את המשקפיים	הוריד את המשקפיים
Served the cake	יגיש את העוגה	מגיש את העוגה	הגיש את העוגה
Ironed the tie	יגהץ את העניבה	מגהץ את העניבה	גיהץ את העניבה
Picked up the mess	יאסוף את הלכלוך	אוסף את הלכלוך	אסף את הלכלוך
Shaved off the mustache	יגלח את השפם	מגלח את השפם	גילח את השפם
Crushed the tomatoes	ירסק את העגבניות	מרסק את העגבניות	ריסק את העגבניות
Scraped the tray	יקרצף את המגש	מקרצף את המגש	קירצף את המגש
Sharpened the pencil	יחדד את העפרון	מחדד את העפרון	חידד את העפרון
Took out the wallet	ישלוף את הארנק	שולף את הארנק	שלף את הארנק
Hoisted up the closet	יעלה את הארון	מעלה את הארון	העלה את הארון
Foamed the milk	יקציף את החלב	מקציף את החלב	הקציף את החלב
Bent the spoon	יכופף את הכפית	מכופף את הכפית	כופף את הכפית
Ate the salad	יאכל את הסלט	אוכל את הסלט	אכל את הסלט
Unraveled the sweater	יפרום את הסוודר	פורם את הסוודר	פרם את הסוודר
Sliced the bread	יפרוס את הלחם	פורס את הלחם	פרס את הלחם
Glued the stamp	ידביק את הבול	מדביק את הבול	הדביק את הבול
Twisted the rod	יעקם את המוט	מעקם את המוט	עיקם את המוט
Passed the package	יעביר את החבילה	מעביר את החבילה	העביר את החבילה
Removed the bandage	יסיר את הפלסטר	מסיר את הפלסטר	הסיר את הפלסטר
Copied the page	ישכפל את הדף	משכפל את הדף	שיכפל את הדף
Rolled down the cart	ידרדר את העגלה	מדרדר את העגלה	דירדר את העגלה
Cut the watermelon	יחצה את האבטיח	חוצה את האבטיח	חצה את האבטיח
Peeled the cucumber	יקלף את המלפפון	מקלף את המלפפון	קילף את המלפפון
Rotated the wheel	יסובב את ההגה	מסובב את ההגה	סובב את ההגה
Sprayed the paint	ירסס את הצבע	מרסס את הצבע	ריסס את הצבע
Planted the flower	ישתול את הפרח	שותל את הפרח	שתל את הפרח
Buttoned the shirt	יכפתר את החולצה	מכפתר את החולצה	כיפתר את החולצה
Poured the beer	ישפוך את הבירה	שופך את הבירה	שפך את הבירה
Wiped the dust	ינגב את האבק	מנגב את האבק	ניגב את האבק
Broke the sign	ישבור את השלט	שובר את השלט	שבר את השלט
Scratched the ticket	יגרד את הכרטיס	מגרד את הכרטיס	גירד את הכרטיס
Inflated the mattress	ינפח את המזרון	מנפח את המזרון	ניפח את המזרון
Colored the doorstep	יצבע את המשקוף	צובע את המשקוף	צבע את המשקוף
Oiled the pan	ישמן את המחבת	משמן את המחבת	שימן את המחבת
Wiped away the tears	ימחה את הדמעות	מוחה את הדמעות	מחה את הדמעות
Dropped the pen	יפיל את העט	מפיל את העט	הפיל את העט
Stacked the books	יערום את הספרים	עורם את הספרים	ערם את הספרים
Scraped the floor	ישפשף את הרצפה	משפשף את הרצפה	שיפשף את הרצפה
Picked the orange	יקטוף את התפוז	קוטף את התפוז	קטף את התפוז
Hung the towel	יתלה את המגבת	תולה את המגבת	תלה את המגבת
Flew the plane	יעיף את האווירון	מעיף את האווירון	העיף את האווירון
Lit up the fireplace	יבעיר את האח	מבעיר את האח	הבעיר את האח
Embedded the diamond	ישבץ את היהלום	משבץ את היהלום	שיבץ את היהלום
Tasted the pie	יטעם את הפשטידה	טועם את הפשטידה	טעם את הפשטידה
Filed the nail	ישייף את הציפורניים	משייף את הציפורניים	שייף את הציפורניים
Mixed the notes	יערבב את הפתקים	מערבב את הפתקים	עירבב את הפתקים
Distributed the forms	יחלק את הטפסים	מחלק את הטפסים	חילק את הטפסים
Stitched the button	יתפור את הכפתור	תופר את הכפתור	תפר את הכפתור
Dug the fork	ינעץ את המזלג	נועץ את המזלג	נעץ את המזלג
Blew the bubble	יפריח את הבועה	מפריח את הבועה	הפריח את הבועה
Folded the underwear	יקפל את התחתונים	מקפל את התחתונים	קיפל את התחתונים
Welded the metal	ילחים את המתכת	מלחים את המתכת	הלחים את המתכת
Painted the wall	יסייד את הקיר	מסייד את הקיר	סייד את הקיר
Sealed the envelope	יחתום את המעטפה	חותם את המעטפה	חתם את המעטפה
Rolled the threads	יגלגל את החוטים	מגלגל את החוטים	גילגל את החוטים
Threw the clothes	יזרוק את הבגדים	זורק את הבגדים	זרק את הבגדים

Appendix B (*continued*)

Concrete			
English past	Future Hebrew	Present Hebrew	Past Hebrew
Took the football	יקח את הכדורגל	לוקח את הכדורגל	לקח את הכדורגל
Loosened the screws	ירופף את הברגים	מרופף את הברגים	רופף את הברגים
Burned the papers	ישרוף את הניירות	שורף את הניירות	שרף את הניירות
Wrote the letter	יכתוב את המכתב	כותב את המכתב	כתב את המכתב
Cleared the dishes	יפנה את הכלים	מפנה את הכלים	פינה את הכלים
Washed the bowl	ישטוף את הקערה	שוטף את הקערה	שטף את הקערה
Watered the plant	ישקה את העציץ	משקה את העציץ	השקה את העציץ
Wore the robe	יעטה את הגלימה	עוטה את הגלימה	עטה את הגלימה
Grilled the steak	יצלה את הסטייק	צולה את הסטייק	צלה את הסטייק
Adjusted the mirror	יכוון את המראה	מכוון את המראה	כיוון את המראה
Drew the curtain	יסיט את הוילון	מסיט את הוילון	הסיט את הוילון
Packed the suitcase	יארוז את המזוודה	אורז את המזוודה	ארז את המזוודה
Squeezed the juice	יסחט את המיץ	סוחט את המיץ	סחט את המיץ

Abstract			
English past	Future Hebrew	Present Hebrew	Past Hebrew
Conceived the invention	יהגה את ההמצאה	הוגה את ההמצאה	הגה את ההמצאה
Prevented the embarrassment	ימנע את המבוכה	מונע את המבוכה	מנע את המבוכה
Fulfilled the wish	יגשים את המשאלה	מגשים את המשאלה	הגשים את המשאלה
Defiled the memory	יחלל את הזיכרון	מחלל את הזיכרון	חילל את הזיכרון
Expressed the feelings	יביע את הרגשות	מביע את הרגשות	הביע את הרגשות
Missed the deadline	יפספס את המועד	מפספס את המועד	פיספס את המועד
Stopped the execution	יעצור את הביצוע	עוצר את הביצוע	עצר את הביצוע
Quantified the odds	יכמת את הסיכויים	מכמת את הסיכויים	כימת את הסיכויים
Contradicted the testimony	יסתור את העדות	סותר את העדות	סתר את העדות
Hated the summer	ישנא את הקיץ	שונא את הקיץ	שנא את הקיץ
Recognized the limitations	יכיר את המגבלות	מכיר את המגבלות	הכיר את המגבלות
Earned the amount	ירוויח את הסכום	מרוויח את הסכום	הרוויח את הסכום
Formulated the concept	יגבש את הרעיון	מגבש את הרעיון	גיבש את הרעיון
Encoded the message	יצפין את המסר	מצפין את המסר	הצפין את המסר
Acknowledged the contribution	יוקיר את התרומה	מוקיר את התרומה	הוקיר את התרומה
Demonstrated the determination	ימחיש את הנחישות	ממחיש את הנחישות	המחיש את הנחישות
Used up the savings	יכלה את החסכונות	מכלה את החסכונות	כילה את החסכונות
Enforced the discipline	יאכוף את המשמעת	אוכף את המשמעת	אכף את המשמעת
Marketed the product	ישווק את המוצר	משווק את המוצר	שיווק את המוצר
Ruined the meeting	יהרוס את המפגש	הורס את המפגש	הרס את המפגש
Gained the experience	יצבור את הניסיון	צובר את הניסיון	צבר את הניסיון
Focused the energy	יתעל את האנרגיה	מתעל את האנרגיה	תיעל את האנרגיה
Spared the disappointment	יחסוך את האכזבה	חוסך את האכזבה	חסך את האכזבה
Withdrew the forces	יסיג את הכוחות	מסיג את הכוחות	הסיג את הכוחות
Eradicated the phenomenon	ימגר את התופעה	ממגר את התופעה	מיגר את התופעה
Formed the view	יעצב את ההשקפה	מעצב את ההשקפה	עיצב את ההשקפה
Unraveled the crime	יפענח את הפשע	מפענח את הפשע	פיענח את הפשע
Explained the Scripture	יבאר את הכתוב	מבאר את הכתוב	ביאר את הכתוב
Estimated the amount	יאמוד את הכמות	אומד את הכמות	אמד את הכמות
Called the meeting	יזמן את הפגישה	מזמן את הפגישה	זימן את הפגישה
Turned up the volume	יגביר את העוצמה	מגביר את העוצמה	הגביר את העוצמה
Took the opportunity	ינצל את ההזדמנות	מנצל את ההזדמנות	ניצל את ההזדמנות
Shelved the piece	יגנוז את היצירה	גונז את היצירה	גנז את היצירה
Practiced the skill	יתרגל את המיומנות	מתרגל את המיומנות	תירגל את המיומנות
Confirmed the suspicion	יאושש את החשד	מאשש את החשד	אושש את החשד
Fulfilled the promise	יקיים את ההבטחה	מקיים את ההבטחה	קיים את ההבטחה
Examined the feasibility	יבדוק את ההיתכנות	בודק את ההיתכנות	בדק את ההיתכנות
Repressed the thought	ידחיק את המחשבה	מדחיק את המחשבה	הדחיק את המחשבה
Spoiled the atmosphere	יעכור את האווירה	עוכר את האווירה	עכר את האווירה
Denounced the behavior	יוקיע את ההתנהגות	מוקיע את ההתנהגות	הוקיע את ההתנהגות
Kept the facility	יתחזק את המתקן	מתחזק את המתקן	תיחזק את המתקן
Assimilated the expression	יטמיע את הביטוי	מטמיע את הביטוי	הטמיע את הביטוי
Brought up the complaint	יציף את התלונות	מציף את התלונות	הציף את התלונות
Tried the recommendation	ינסה את ההמלצה	מנסה את ההמלצה	ניסה את ההמלצה
Applied the regulation	יחיל את התקנה	מחיל את התקנה	החיל את התקנה
Separated the discussion	יפריד את הדיון	מפריד את הדיון	הפריד את הדיון
Enabled the failure	יאפשר את המחדל	מאפשר את המחדל	איפשר את המחדל
Discovered the truth	יגלה את האמת	מגלה את האמת	גילה את האמת
Won the battle	יכריע את המערכה	מכריע את המערכה	הכריע את המערכה

Appendix B (*continued*)

Abstract			
English past	Future Hebrew	Present Hebrew	Past Hebrew
Took the credit	יגזול את הקרדיט	גוזל את הקרדיט	גזל את הקרדיט
Lost the title	יפסיד את התואר	מפסיד את התואר	הפסיד את התואר
Completed the task	יגמור את המלאכה	גומר את המלאכה	גמר את המלאכה
Asked for the approval	יבקש את האישור	מבקש את האישור	ביקש את האישור
Divided the property	יחלק את הרכוש	מחלק את הרכוש	חילק את הרכוש
Concealed the income	יעלים את ההכנסה	מעלים את ההכנסה	העלים את ההכנסה
Focused the energy	ימקד את המרץ	ממקד את המרץ	מיקד את המרץ
Loved the sonnet	יאהב את הסונטה	אוהב את הסונטה	אהב את הסונטה
Recounted the incident	ישחזר את המקרה	משחזר את המקרה	שיחזר את המקרה
Split the efforts	יפצל את המאמצים	מפצל את המאמצים	פיצל את המאמצים
Defined the requirements	יגדיר את הדרישה	מגדיר את הדרישה	הגדיר את הדרישה
Distorted the reality	יסלף את המציאות	מסלף את המציאות	סילף את המציאות
Suspended the activity	ישעה את הפעילות	משעה את הפעילות	השעה את הפעילות
Solved the riddle	יפתור את החידה	פותר את החידה	פתר את החידה
Renewed the license	יחדש את הרשיון	מחדש את הרשיון	חידש את הרשיון
Deducted the votes	יקזז את הקולות	מקזז את הקולות	קיזז את הקולות
Disrupted the reception	ישבש את הקליטה	משבש את הקליטה	שיבש את הקליטה
Cataloged the items	יקטלג את הפריטים	מקטלג את הפריטים	קיטלג את הפריטים
Abandoned the task	יזנח את המשימה	זונח את המשימה	זנח את המשימה
Brought about the change	יחולל את השינוי	מחולל את השינוי	חולל את השינוי
Reduced the interest	יפחית את הריבית	מפחית את הריבית	הפחית את הריבית
Enabled the state	יכשיר את ההתנהלות	מכשיר את ההתנהלות	הכשיר את ההתנהלות
Organized the event	יארגן את האירוע	מארגן את האירוע	אירגן את האירוע
Diverted the focus	יסיח את הדעת	מסיח את הדעת	הסיח את הדעת
Suspend the sanctions	ישהה את העיצומים	משהה את העיצומים	השהה את העיצומים
Minimized the impact	ימזער את ההשפעה	ממזער את ההשפעה	מיזער את ההשפעה
Justified the injustice	יצדיק את העוול	מצדיק את העוול	הצדיק את העוול
Ranked the preferences	ידרג את ההעדפות	מדרג את ההעדפות	דירג את ההעדפות
Demanded the rights	ידרוש את הזכויות	דורש את הזכויות	דרש את הזכויות
Worsened the situation	ירע את המצב	מרע את המצב	הרע את המצב
Limited the use	יגביל את השימוש	מגביל את השימוש	הגביל את השימוש
Complicated the matters	יסבך את העניינים	מסבך את העניינים	סיבך את העניינים
Denied the citizenship	ישלול את האזרחות	שולל את האזרחות	שלל את האזרחות
Portrayed the character	יגלם את הדמות	מגלם את הדמות	גילם את הדמות
Broke the engagement	יפר את ההתחייבות	מפר את ההתחייבות	הפר את ההתחייבות
Intensified the concern	יעצים את החשש	מעצים את החשש	העצים את החשש
Canceled the reservation	יבטל את ההזמנה	מבטל את ההזמנה	ביטל את ההזמנה
Nationalized the capital	ילאים את ההון	מלאים את ההון	הלאים את ההון
Adopted the habit	יסגל את ההרגל	מסגל את ההרגל	סיגל את ההרגל
Limited the assistance	יצמצם את הסיוע	מצמצם את הסיוע	צימצם את הסיוע
Justified the failure	יתרץ את הכישלון	מתרץ את הכישלון	תירץ את הכישלון
Reinforced the view	יחזק את הדעה	מחזק את הדעה	חיזק את הדעה
Predicted the outcome	ינבא את התוצאה	מנבא את התוצאה	ניבא את התוצאה
Planned the strategy	יתכנן את האסטרטגיה	מתכנן את האסטרטגיה	תיכנן את האסטרטגיה
Improved the approach	ישכלל את הגישה	משכלל את הגישה	שכלל את הגישה
Proved the loyalty	יוכיח את הנאמנות	מוכיח את הנאמנות	הוכיח את הנאמנות
Eliminated the debt	יחסל את החוב	מחסל את החוב	חיסל את החוב
Validated the procedure	יאמת את הנוהל	מאמת את הנוהל	אימת את הנוהל
Endangered the achievement	יסכן את ההישג	מסכן את ההישג	סיכן את ההישג
Studed the field	יחקור את התחום	חוקר את התחום	חקר את התחום
Achieved the goal	ישיג את המטרה	משיג את המטרה	השיג את המטרה
Subsidized the acquisition	יסבסד את הרכישה	מסבסד את הרכישה	סיבסד את הרכישה
Recorded the era	יתעד את התקופה	מתעד את התקופה	תיעד את התקופה
Conjured up the lie	יבדה את השקר	בודה את השקר	בדה את השקר
Privatized the institutions	יפריט את המוסדות	מפריט את המוסדות	הפריט את המוסדות
Compared the cases	ישווה את המקרים	משווה את המקרים	השווה את המקרים
Expressed the view	יבטא את התפיסה	מבטא את התפיסה	ביטא את התפיסה
Understood the criticism	יפנים את הביקורת	מפנים את הביקורת	הפנים את הביקורת
Modified the position	ימתן את העמדה	ממתן את העמדה	מיתן את העמדה
Transmitted the call	ישדר את הקריאה	משדר את הקריאה	שידר את הקריאה
Deepened the understanding	יעמיק את ההבנה	מעמיק את ההבנה	העמיק את ההבנה
Converted the measurements	ימיר את המידות	ממיר את המידות	המיר את המידות
Imagined the event	ידמיין את המאורע	מדמיין את המאורע	דמיין את המאורע
Financed the operation	יממן את המבצע	מממן את המבצע	מימן את המבצע
Celebrated the promotion	יחגוג את הקידום	חוגג את הקידום	חגג את הקידום

(continued on next page)

Appendix B (*continued*)

Concrete			
English past	Future Hebrew	Present Hebrew	Past Hebrew
Coordinated the timing	יתאם את התזמונים	מתאם את התזמונים	תיאם את התזמונים
Extended the visa	יאריך את האשרה	מאריך את האשרה	האריך את האשרה
Defined the software	יאפיין את התוכנה	מאפיין את התוכנה	אפיין את התוכנה
Delayed the progress	יעכב את ההתקדמות	מעכב את ההתקדמות	עיכב את ההתקדמות
Budgeted the department	יתקצב את המחלקה	מתקצב את המחלקה	תיקצב את המחלקה
Expressed the resistance	יצרף את ההתנגדות	מצרף את ההתנגדות	צירף את ההתנגדות
Leaked the news	ידליף את הידיעה	מדליף את הידיעה	הדליף את הידיעה
Launched the campaign	ישיק את הקמפיין	משיק את הקמפיין	השיק את הקמפיין
Manned the role	יאייש את התפקיד	מאייש את התפקיד	אייש את התפקיד
Mediated the transaction	יתווך את העסקה	מתווך את העסקה	תיווך את העסקה
Mortgaged the property	ימשכן את הנכס	ממשכן את הנכס	מישכן את הנכס
Disrespected the occasion	יבזה את המעמד	מבזה את המעמד	ביזה את המעמד
Caught the attention	ילכוד את הקשב	לוכד את הקשב	לכד את הקשב
Subtracted the numbers	יחסיר את המספרים	מחסיר את המספרים	החסיר את המספרים
Demonstrated the capabilities	ידגים את היכולות	מדגים את היכולות	הדגים את היכולות
Condemned the act	יגנה את המעשה	מגנה את המעשה	גינה את המעשה
Processed the information	יעבד את האינפורמציה	מעבד את האינפורמציה	עיבד את האינפורמציה
Respected the decision	יכבד את ההחלטה	מכבד את ההחלטה	כיבד את ההחלטה
Ruined the trip	יקלקל את הטיול	מקלקל את הטיול	קלקל את הטיול
Composed the music	ילחין את המנגינה	מלחין את המנגינה	הלחין את המנגינה
Selected the option	יבחר את האפשרות	בוחר את האפשרות	בחר את האפשרות
Performed the task	יבצע את המטלה	מבצע את המטלה	ביצע את המטלה
Exhausted the sources	ימצה את המקורות	ממצה את המקורות	מיצה את המקורות
Demanded the compensation	יתבע את הפיצוי	תובע את הפיצוי	תבע את הפיצוי
Missed the registration	יאחר את ההרשמה	מאחר את ההרשמה	איחר את ההרשמה
Calculated the factors	ישקלל את הגורמים	משקלל את הגורמים	שיקלל את הגורמים
Approved the request	יאשר את הבקשה	מאשר את הבקשה	אישר את הבקשה
Detested the treachery	יתעב את הבוגדנות	מתעב את הבוגדנות	תיעב את הבוגדנות
Extended the gaps	יקצין את הפערים	מקצין את הפערים	הקצין את הפערים
Reinforced the security	יתגבר את האבטחה	מתגבר את האבטחה	תיגבר את האבטחה
Reset the score	יאפס את הניקוד	מאפס את הניקוד	איפס את הניקוד
Provided the commentary	יספק את הפרשנות	מספק את הפרשנות	סיפק את הפרשנות
Censored the report	יצנזר את הדיווח	מצנזר את הדיווח	צינזר את הדיווח
Sold the shares	ימכור את המניות	מוכר את המניות	מכר את המניות
Determined the facts	יקבע את העובדות	קובע את העובדות	קבע את העובדות
Forgot the trauma	ישכח את הטראומה	שוכח את הטראומה	שכח את הטראומה
Symbolized the hope	יסמל את התקווה	מסמל את התקווה	סימל את התקווה
Prepared the example	יכין את הדוגמא	מכין את הדוגמא	הכין את הדוגמא
Exacerbated the conflict	יחריף את העימות	מחריף את העימות	החריף את העימות
Realized the potential	יממש את הפוטנציאל	מממש את הפוטנציאל	מימש את הפוטנציאל
Foiled the plot	יסכל את המזימה	מסכל את המזימה	סיכל את המזימה
Made the most	יפיק את המירב	מפיק את המירב	הפיק את המירב

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