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Encoding of Episodic Context with Abstract and Concrete Concepts

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Encoding of Episodic Context with Abstract and Concrete Concepts

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Abstract

In theories of grounded cognition, abstract concepts, like concrete ones, are grounded in our experiences with the world. However, rather than emphasizing the sensorimotoric aspects of our experience as they do for concrete concepts (e.g., *coffee*), grounded theories emphasize situational and internal factors for the representation of abstract concepts (e.g., *decision*). Despite some success in showing that situational and internal factors are important for abstract concepts, a mechanism by which such contextual factors are encoded and re-instantiated with the concept has yet to be elucidated. The present study sought to make headway on finding such a mechanism by using the source memory paradigm to determine whether we attend to *episodic* context more when processing abstract concepts as compared to concrete concepts. In Experiments 1 and 2, participants were presented with abstract and concrete words in a (red or green) colored box frame and performed a synonym judgment 1-back task at encoding. At retrieval, participants were better able to recognize the color of the frame for concrete than abstract concepts. In Experiment 3, the colored box frames were replaced with male and female voices, which participants were asked to recognize at retrieval. The same pattern of results emerged as in Experiments 1 and 2: participants were better able to recognize the speaker at encoding for concrete concepts than for abstract ones. Overall, the pattern of results suggests that the processing of concrete concepts is more sensitive to simple arbitrary episodic contextual detail. If representations of abstract concepts are indeed derived from situational context, the contexts may need to be more elaborate, temporally extended, or systematic than the simple associations examined here.

Keywords: concepts, semantic memory, episodic memory, abstract concepts, concreteness

Encoding of Episodic Context with Abstract and Concrete Concepts

Grounded theories of cognition postulate that sensory, perceptual, and motor parts of the brain are fundamental to conceptual processing. Grounded frameworks also emphasize the importance of context in concept processing (e.g., Barsalou & Wiemer-Hastings, 2005; Yee & Thompson-Schill, 2016), suggesting that the way that a concept is represented depends on the context in which it is being processed. For instance, when trying to detect a black coffee on the bar amidst other orders of cappuccinos and lattes, its dark brown color (which differs from the foamy texture and lighter color of the other beverages) will be more salient than the shape of the mug (all the mugs are the same) or its smell (the smell of roasted beans is permeating the room). Grounded theories are well-supported for the representation of concrete concepts, laying out a clear and convincing framework in which concrete concepts are generally learned through our sensory, motoric, and perceptual experiences with the world, encoded as accumulated instantiations of those experiences, and processed as re-experiencing or simulating the brain states implicated in experiencing the concepts. However, they have difficulty explaining how abstract concepts are represented—what sensory or motor attributes could constitute our representation of *decision*?

Some grounded theories suggest that abstract concept representations rely on emotional systems, thus recruiting limbic structures like the amygdala, which are involved in emotion processing (Kousta et al., 2011). While this is a powerful explanation for abstract concepts involving emotion (e.g., *love*, *bliss*), many abstract concepts are non-emotional (e.g., *democracy*, *decision*), and indeed it might be better to consider an emotion-based continuum separate from a continuum from concrete to abstract in semantic representation (Hollis & Westbury, 2016; Skipper & Olson, 2014). An account more inclusive of the broad range of possible abstract concepts might instead draw upon another point of emphasis in grounded cognition—context sensitivity (Barsalou & Wiemer-Hastings, 2005; also see Yee & Thompson-Schill, 2016, for discussion). In discussing the role of context in processing abstract concepts within a grounded cognition framework, it is helpful to consider another term often used interchangeably with grounded cognition: *situated cognition* (see Barsalou, 2003, 2005, 2015; Yeh & Barsalou, 2006). Returning to our coffee example, if we simulate what it is like to experience *coffee* whenever we process the concept *coffee* (e.g., in language), we do so within a situated context. That is, we do not simulate what coffee is like in isolation, but against the background of the coffee bar (for a review, see Yeh & Barsalou, 2006). The precise simulation carried out depends on the context in which the concept is being processed, whether the context is situational or linguistic. The effect of context on concept processing may be particularly pronounced in processing abstract concepts, which do not have direct sensorimotor referents—that is, we cannot directly perceive abstract concepts in the physical world. Accordingly, in processing the meaning of *decision*, we might be more sensitive to what is happening in the situation (e.g., a judge deciding on a sentence for a felon), or the words that co-occur with *decision* (e.g., *judge, felon, battery*), and those contextual factors might affect the way that we construe the meaning of *decision*. As it turns out, explaining this distinction between abstract and concrete concepts in terms of reliance on context has a long history in cognitive psychology, predating the discussion on how grounded theories of cognition can accommodate abstract concepts. We now turn to a brief consideration of the historical context surrounding the representation of abstract and concrete concepts, noting that the review is not meant to be exhaustive, but only to broadly capture views on concept representation which suggest that sensitivity to contextual information, or some associated information, might underpin representation of abstract concepts.

Classical Views on Abstract and Concrete Concepts

Concrete concepts are typically processed faster than are abstract concepts. This is referred to as the concreteness effect and has been demonstrated at both the single word (e.g., Schwanenflugel & Shoben, 1983) and sentence level (e.g., Paivio & Begg, 1971). This has led to the suggestion that concreteness is an important organizing factor for conceptual knowledge, where abstract concepts may be representationally impoverished in some way. This view is best captured by two highly influential seminal theories of concept representation: dual-coding theory and context-availability theory.

Dual-coding theory. Paivio's (1971, 1991) dual-coding theory suggests that while concrete concepts are represented by both linguistic (i.e., abstract; the *logogen* system) and imagistic (i.e., concrete; the *imagen* system) codes, abstract concepts are represented only or primarily by linguistic codes. Essentially, dual-coding theory suggests that abstract concepts are harder to process than are concrete concepts because the brain has more devoted resources to processing concrete concepts as compared to abstract ones. Specifically, while concrete concepts rely on bilateral representation in both the language-dominant left hemisphere and image-dominant right hemisphere, abstract concepts rely solely on a left hemisphere network (Paivio, 1991). Dual-coding theory explains well why in neutral contexts we see comprehension time advantages for concrete over abstract concepts: simply, there are fewer neural resources devoted to processing abstract concepts. However, it fails to explain an important finding: the concreteness advantage disappears when a rich context is provided to support abstract concepts (see, e.g., Schwanenflugel & Shoben, 1983).

Context availability hypothesis. Consider the sentences "Many sailors evacuated the sinking vessel" and "Many factors affected the crucial decision." The former is faster to comprehend in sentence comprehension tasks, and dual-coding theory would suggest that this is because the second sentence can only rely on linguistic codes. However, this concreteness advantage is diminished or even eliminated when an extended, relevant context is provided (e.g., the latter sentence is embedded in a richly informative paragraph, where a protagonist is in line at the coffee shop at 9pm debating whether to order another coffee or opt for something more soothing like tea or hot chocolate). This suggests that concrete concepts have stronger implicit links to context, and that comprehension of abstract concepts benefits from being tied to a particular context (context-availability theory; e.g., Schwanenflugel & Shoben, 1983). At its root, context-availability theory suggests that comprehension is an ongoing, interactive process between the current situation and an individual's history of knowledge (Schwanenflugel, 1991). Abstract concepts have weaker associations to specific contexts in an individual's history of experience, primarily because they occur in such a wide variety of contexts. This context variability means that the current situation needs to be highly constraining for fluid comprehension to occur. While context-availability theory does well to explain (a) concreteness effects themselves and (b) why concreteness effects are eliminated when contextual information is provided, it still suffers from critical flaws, saying little about how these differing representations between abstract and concrete concepts are instantiated at the neural level.

Contemporary Views on Abstract and Concrete Concepts

Neuropsychological work has suggested that there are distinct neural circuits devoted to abstract and concrete concepts (Warrington, 1975, 1981; Warrington & Shallice, 1984), a view stemming from the observation of a double dissociation between abstract and concrete concepts in some patients with aphasia. This suggests that different brain networks underpin abstract and concrete concepts, counter to the claim that there are simply fewer resources available for abstract concepts. A related criticism of both dual-coding and context-availability theory is that they suggest abstract concept representations to be impoverished (Pexman, Hargreaves, Edwards, Henry, & Goodyear, 2007), despite the fact that abstract concepts tend to be versatile as well as contextually and semantically diverse (Hoffman, Lambon Ralph, & Rogers, 2013). Another major issue with the classical views is a poor specification of the neural architecture underlying the representational differences between abstract and concrete concepts: dual-coding theory suggests broadly that there is hemispheric asymmetry in the representation of abstract and concrete concepts (e.g., Paivio, 1991), while context-availability theory makes no claims about how the representational differences between the two emerge, or how these differences manifest neurally (Schwanenflugel, 1991). Accordingly, contemporary views on concept representation rely on the many tools of cognitive neuroscience and neuropsychology to better appreciate the representational differences between abstract and concrete concepts at a neural level.

Qualitatively different representations. The qualitatively different representations hypothesis (Crutch & Warrington, 2005; see also Warrington, 1981) has its root in neuropsychological work showing a double dissociation between comprehension of concrete and abstract concepts (Warrington, 1975; Warrington & Shallice, 1984), and suggests that the representational systems underpinning concrete and abstract concepts have qualitatively different organizational properties: while concrete concepts are represented by category (i.e., taxonomy; animal → mammal → dog), abstract concepts are represented by association (i.e., theme; *time*: past, present, future). Patients with semantic refractory access dysphasia show interference among associated abstract words and among categorically related concrete words, but not *vice versa*, suggesting that abstract concepts rely on associative and not categorical relations (Crutch & Warrington, 2005). However, work testing the qualitatively different representations approach in non-impaired populations has failed to find evidence that abstract concepts activate strictly associative semantic networks, finding instead that the interference effect of category relations is greater than that of associative relations in both abstract and concrete concepts (Geng & Schnur, 2015), and that concrete words tend to activate associative relationships faster (and more) than do abstract words (measured as eye-movement fixations; Brozdowski, Gordils, & Magnuson, 2013). These findings suggest that abstract concepts likely do not rely *exclusively* on thematic associations.

Grounded and situated cognition. While the qualitatively different representations hypothesis has been challenged by ensuing empirical work, we suggest here that there is at least a kernel of truth to its claims: associative relationships by definition rely on cooccurrence (in space, time, and language), and it has been suggested that such relations in semantic memory rely more strongly on event representations, context sensitivity, and the episodic memory system (see Davis & Yee, under review; Mirman, Landrigan, & Britt, 2017). And as outlined at the outset, grounded or situated cognition—similar to context-availability theory—suggests that abstract concepts are more dependent on contextual information for processing. It is suggested that because abstract concepts do not have a spatially circumscribed locus (compare *theory* to *coffee*), they rely more on the situation than do concrete concepts. For example, in an open-ended association task, abstract concepts generated a greater proportion of responses related to situations (e.g., communication, social institutions) and introspection (e.g., beliefs), suggesting that these contextual factors are important in abstract concept representations (Barsalou & Wiemer-Hastings, 2005). Reliance on detailed context, particularly that related to situation and/or introspection, is an appealing explanation, and it resonates with classical theories of context availability (Schwanenflugel, 1991) as well as the emphasis on association in the qualitatively different representations framework. However, like classical views, grounded cognition theories have not offered a specific mechanism by which this sensitivity is instantiated at a cognitive or neural level, leaving the theoretical framework underspecified. While consideration of the content of abstract concepts is helpful in narrowing down how abstract concepts are represented, a focus on the mechanism underlying their processing is critical in building a comprehensive theory of concept representation which is broadly inclusive of concepts ranging from concrete to abstract. Here, we propose such a mechanism, speculating that increased reliance on the episodic memory system, which supports retrieval of contextually detailed memories and is supported neurally by the hippocampal system, might serve to ground abstract concepts in accompanying contextual detail (i.e., to 'tune us in' to context when processing abstract concepts).

Episodic Memory and Context Encoding

In this section, we explore one possible mechanism for the binding of context to concept in abstract concepts: because of the involvement of the episodic memory system in retrieving contextually detailed memories and the importance of contextual information in processing abstract concepts, we attend more to episodic information when processing abstract concepts. Episodic memory is classically defined as explicit memory for unique events, allowing us to recall specific experiences (Tulving, 1983, 2002), as compared to semantic memory, which is better conceptualized as the aggregate knowledge over a number of experiences with a particular entity. Episodic context is the detail that colors a scene. It may be the bag hanging over your dining room chair when you walk into the kitchen (this bag likely will not become a component of your *chair* concept moving forward), or it may be the rush of cold air when you succeeded in reaching the peak of your first mountain summit (at first glance, that rush of frigid air seems unlikely to become part of your *success* concept moving forward). In tasks probing the episodic memory system, contextual detail is often operationally defined as some aspect of a percept or situation that is irrelevant to the central stimulus—in a memory task, this is often operationalized as whether a test word is presented in red or green font, whether a line drawing is presented within a red or green frame (see Migo, Mayes, & Montaldi, 2012), or whether stimuli are presented by a male or female voice (e.g., Wilding & Rugg, 1996).

There are circumstances under which we are more likely to *encode*, and therefore, *recall* the arbitrary contents of a particular episode (e.g., the color of the frame or font, or the identity of a speaker). The standard paradigm for assessing this ability is the subsequent memory procedure, a common variant of this being the source memory task (for discussion, see Davachi, 2006). In this explicit task, participants are asked to determine whether the item (e.g., a word) was presented in an exposure phase, and then probed as to whether they can additionally recognize or recall some contextual detail (e.g., font color, frame color, or voice source; Migo et al., 2012; Rugg et al., 2012). In such tasks, participants are typically asked how confident they are in whether they saw the item at exposure. Greater confidence in having seen a word at exposure is associated with greater likelihood of having encoded—and therefore, successfully recognizing or recalling—the contextual detail (e.g., Kirwan, Wixted, & Squire, 2008; Yu, Johnson, & Rugg, 2012). Confidence judgments, the distinction between *remembering* something and merely *knowing* that you experienced it, and the ability to access specific details of an episode or event are thought to probe a fundamental distinction in dual-process theories of the memory system—that between *familiarity* and *recollection* (Jacoby, 1991; for reviews, see Yonelinas, 2001, 2002), where familiarity refers to a generalized feeling that some episode occurred, and recollection refers to the ability to determine not only that the episode occurred, but also detail of the context in which that episode occurred (e.g., the bag hanging over your chair when you entered the kitchen 3 days ago, the rush of frigid air when you successfully summitted that mountain).

At a neural level, hippocampal activity is consistently observed in tasks probing episodic memory, and specifically, it is believed that hippocampal activity is selectively active for episodes of recollection, while other neural mechanisms (e.g., perirhinal cortex) might underlie familiarity processes (for review, see Yonelinas, 2002; see also Davachi, 2006). However, debate exists as to whether hippocampal activity is related purely to strength of the memory (e.g., Kirwan et al., 2008; Smith, Wixted, & Squire, 2011) or whether the ability to remember the context in which an item was presented at encoding is associated with increased hippocampal activation at encoding (for a review, see Rugg et al., 2012). These measures are likely confounded to some degree—we are more likely to recall the detail of a situation when we have a strong memory of that situation. However, Rugg et al. (2012) suggest that it is not necessarily the absolute strength of a memory episode, but rather the amount of contextual information from a memory episode, that relates to degree of hippocampal activation. This suggests that the hippocampal system is critically involved in *relational* memory (Cohen & Eichenbaum, 1993)—that is, the process of binding contextual detail (e.g., a colored frame) to a target stimulus (e.g., a picture) when submitting these items to memory.

In addition to confidence in recollection or strength of the memory, emotionality in words, including both valence and arousal (Kensinger & Corkin, 2003), influences the likelihood of recalling the context in which something was presented, suggesting that the *content* of the stimuli at exposure can influence the likelihood that the *context* is identified at recognition, and more specifically, that *conceptual* content might affect likelihood of source encoding (and consequently, degree of hippocampal activation). In line with the prediction that contextual detail is more important for processing abstract than concrete concepts, this suggests that *if* contextual detail is more likely to be encoded with abstract concepts as compared to concrete concepts, then we should also see greater hippocampal activation in abstract concepts as compared to concrete concepts. However, it must first be demonstrated that, at a behavioral level, contextual detail is encoded with abstract concepts. This is the aim of the present set of experiments.

The Present Study

The notion that episodic context is more important for processing abstract than concrete concepts generates at least two predictions. First, when processing abstract concepts, we should be more sensitive to the episodic context in which they are placed and, in turn, be more accurate at retrieving the context when required. Second, there is an implication that the hippocampus, because of its criticality in memory/context encoding (for reviews, see e.g., Davachi, 2006; Lepage et al., 1998; Rugg et al., 2012), might be particularly engaged in processing abstract concepts. The aim here is to determine the relative importance of context in processing abstract concepts, as an initial step towards determining the neural circuits that facilitate context binding. The present thesis will address this aim only at the behavioral level. To address this aim, we will examine whether arbitrary contexts are better recognized when paired with abstract as compared to concrete concepts. Because memory is generally better for concrete than for abstract words (e.g., Nelson & Schreiber, 1992; Paivio, Walsh, & Bons, 1994; Wattenmaker & Shoben, 1987), we hypothesize that memory for concrete concepts will be better, but *when* abstract concepts are recognized, it is more likely that the context will be encoded along with them. Further, because high confidence in having seen an item is associated with greater likelihood of encoding the context in which that item was placed, we collected ratings of confidence in recognizing the word and box, predicting that confidence in having seen the *word* will be predictive of likelihood of encoding the *context*. The core experiments here will rely on the source memory paradigm, which pairs target stimuli with an arbitrary context, thereafter testing recognition of that context.

Experiment 1

Methods

Participants. Participants were 39 University of Connecticut undergraduates (15 men, 24 women, mean age = 19.3 years) with normal or corrected-to-normal vision. All participants provided written informed consent and received course credit for their participation. Three participants were excluded because they were not performing the task (i.e., pressed the same button on every or almost every trial), leaving a final *N* of 36. The study was approved by the University of Connecticut institutional review board.

Stimuli. In the encoding phase, 100 (60 target, 40 non-target) abstract (e.g., *success*) and 100 (60 target, 40 non-target) concrete object (e.g., *chair*) concepts were used. Stimuli were matched on word length and word frequency based on English Lexicon Project data (Balota et al., 2007), and were sorted into abstract and concrete word lists based on Brysbaert, Warriner, and Kuperman’s (2014) concreteness norms. Words were randomly assigned a box color prior to data collection, with half of the abstract and half of the concrete words receiving red and green boxes, respectively. In the recognition phase, an additional 160 words (80 abstract, 80 concrete), also matched on word length, word frequency, and sorted by the Brysbaert et al. (2014) concreteness norms, were added as distractors. For the full stimulus list, see Appendix 1.

Procedure. Participants performed a source memory task, which consisted of two phases and was designed to test the extent to which an episodic context is encoded when presented with a stimulus. Stimuli were presented visually one at a time, in a pseudorandomized order, with an arbitrary box context (either a red or a green box). On each word, participants performed a synonym-judgment 1-back task (i.e., “Press the 1 (one) key when the current word is a synonym of the previous word, and press the 0 (zero) key when it is not”) to ensure depth of semantic processing, while avoiding any potential confounds with concreteness (as would be conferred by, e.g., an animacy judgment task). The non-target trials were 20 abstract–abstract synonym pairs and 20 concrete–concrete synonym pairs. Stimuli were presented for 2000 ms with an interstimulus interval of 1000 ms. Participants were explicitly instructed that there would be a memory test on the words, and that they would be asked to recall both the word and the color of the box surrounding it.

In the recognition phase, an additional 160 words were included as distractors. Participants performed two tasks for each word, and the words were again presented in pseudorandomized order. First, they indicated whether they had seen the word in the encoding phase, indicating their degree of confidence in the decision (high, medium, and low confidence for either “old” or “new”), as confidence in having seen an item affects the likelihood of recognizing the context the item was presented in (e.g., Yu et al., 2012). Second, for old words, they indicated the color of the box on initial presentation (again, high, medium, and low confidence for either red or green). The task was the same for new words, except that they were asked simply to select the color they thought the box would have been had it been presented at encoding. Participants were given 3000 ms each for the old/new judgment and the box color judgment.

Data analysis. Data were analyzed using R statistical programming software (R Core Team, 2013). Recognition of items (i.e., words) and their contexts (i.e., box color) was first analyzed using descriptive statistics, calculating accuracy, hit rate, miss rate, correct rejections, false alarms, and d' (calculated as $z(\text{Hit}) - z(\text{FA})$) for all words, and accuracy was also assessed by level of confidence. Box recognition accuracy was calculated only for target hits, and was assessed across confidence levels. Box recognition accuracy was analyzed as a function of word type and confidence in having seen the word at encoding. We also analyzed response time data using the same models in Experiments 1–3. Because these models showed the same patterns as the accuracy data—and our hypotheses concerned recognition accuracy and not response times—only the models investigating recognition accuracy are reported. Logistic mixed effects models (lme4 package; Bates et al., 2017) were used to analyze the data, with subject and word as random effects, and word type (abstract or concrete) and level of confidence in the judgment (low, medium, high) as fixed effects. Analysis of d' was conducted using paired-samples *t*-tests, with word type as the independent variable.

Results

Word recognition. The accuracy and hit, miss, correct rejection, false alarm rates, and d' across *all* words in the recognition phase are shown in Table 1. In terms of overall accuracy, there was a significant main effect of word type ($\beta = .34$, $z = 4.18$, $p < .001$), with concrete words responded to more accurately than abstract, and confidence ($\beta = .56$, $z = 17.34$, $p < .001$), with accuracy increasing with higher levels of confidence, and a significant interaction between the two ($\beta = .13$, $z = 2.31$, $p = .02$; see Figure 1). Target (i.e., only non-synonym words presented at encoding) recognition accuracy by confidence rating is shown in Figure 2. Among targets only, there was a main effect of word type ($\beta = .25$, $z = 2.02$, $p = .04$), with greater accuracy for concrete words, and a main effect of confidence level ($\beta = .76$, $z = 13.23$, $p < .001$), with accuracy increasing with confidence. There was no interaction between word type and confidence ($\beta = .14$, $z = 1.42$, $p = .16$). Finally, d' analysis showed that even when taking response bias into account, recognition was better for concrete concepts, $t(34) = -7.089$, $p < .001$.

Table 1

Mean Word Recognition Accuracy

Word type	Acc	Hit	Miss	CR	FA	d'
Abstract	.705	.669	.331	.751	.249	1.216
Concrete	.770	.765	.234	.776	.224	1.616

Note. CR = correct rejection; FA = false alarm.

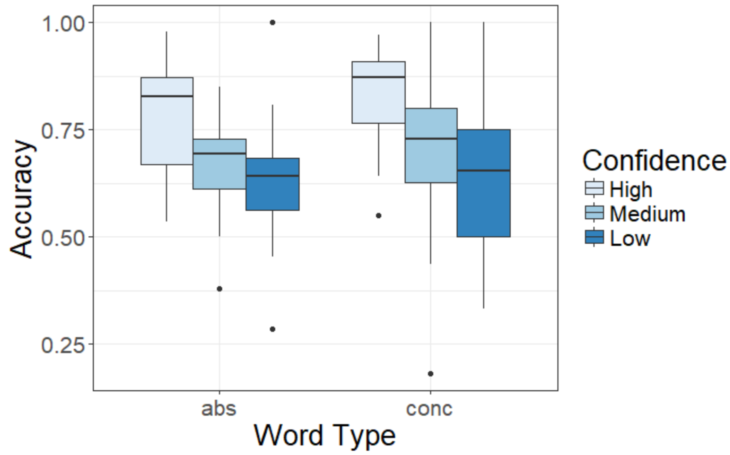

Figure 1. Box plot showing the interaction between word type and confidence on all words. Solid lines show median accuracy, boxes show interquartile range, and whiskers mark 95% of the distribution.

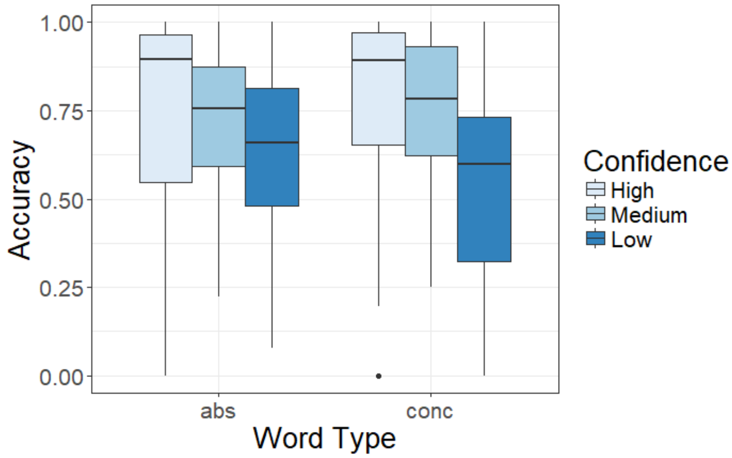

Figure 2. Box plot showing the interaction between word type and confidence in predicting

accuracy for target word recognition (i.e., non-synonyms presented at exposure). Solid lines show median accuracy, boxes show interquartile range, and whiskers mark 95% of the distribution.

Source recognition. In analyzing source recognition, we included only trials for which the word had been correctly identified. The main effects of word type (β = .15, *z* = 1.58, *p* = .11) and confidence (β = .04, *z* = 0.63, *p* = .53) were non-significant, as was the interaction (Figure 3).

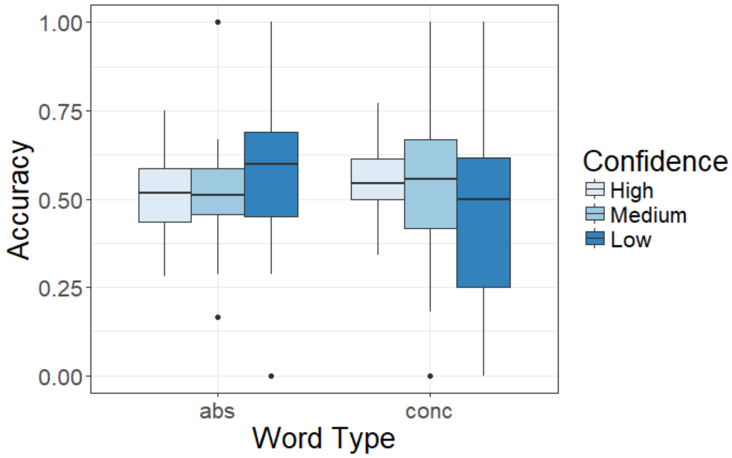

Figure 3. Box plot showing box recognition accuracy by word type and confidence rating. Confidence rating refers to confidence in having seen the word at encoding. Solid lines show median accuracy, boxes show interquartile range, and whiskers mark 95% of the distribution.

Discussion

As expected, concrete words were recognized better than abstract words were. This was true regardless of whether all words (i.e., including fillers and synonyms) or only targets were analyzed. Counter to our hypothesis, however, Experiment 1 suggested that source memory was better for concrete concepts than it was for abstract concepts, though the effect was non-significant in the logistic model (*p* = .11). It may be that this slight advantage is attributable to the explicit nature of the task (i.e., where participants were explicitly instructed to remember the word–box color pairings): that is, participants could have used a mnemonic device wherein “red table” was more amenable to memory encoding than was “green democracy.” However, the accuracy scores were close to chance in both conditions, suggesting that the task was particularly difficult, perhaps because of the large number of fillers used and the rapidity of the recognition phase. Accordingly, Experiment 2 was designed to ameliorate these issues and investigate the possibility that explicit attention to box color drove the marginal concreteness advantage.

Experiment 2

Experiment 1 failed to provide evidence that context is encoded to a greater extent in abstract than in concrete concepts. Instead, the opposite pattern emerged—context was better recognized for concrete concepts. In order to test whether the concrete word advantage was a byproduct of the explicit nature of the task in Experiment 1, Experiment 2 utilized an *implicit* task wherein participants only attended to the contextual detail (which was still the red or green box) by virtue of performing the task differently depending on whether the box was red or green. That is, they were unaware that box color would be part of a later memory task.

Methods

Participants. Participants were 42 University of Connecticut undergraduates (14 men, 28 women, mean age = 19.5 years) with normal or corrected-to-normal vision who had not participated in Experiment 1. All participants provided written informed consent and received course credit for their participation. One participant was excluded because s/he did not perform the task (i.e., repeatedly pressed a single button throughout the experiment), leaving $N = 41$. The experiment was approved by the University of Connecticut institutional review board.

Stimuli. The stimuli were the same as those in Experiment 1, although we eliminated nearly half of the original distractor words from the recognition phase set to reduce the difficulty of the implicit task. This means that the recognition phase included only 100 additional words (50 abstract, 50 concrete) to those included in the encoding phase.

Procedure. The procedure was largely the same as in Experiment 1, with an encoding and recognition phase, the use of box color as context to be encoded, and the use of a synonym judgment 1-back task in the encoding phase. However, instead of explicitly instructing participants to try to remember the words and the surrounding box color, they were only instructed to remember the words. Their response on the 1-back task depended on the color of the box, in that they used their left hand to respond to words in a green box and their right hand to respond to words in a red box, and on each hand, used one finger to indicate a synonym, and another finger to indicate a non-synonym (green boxes: 1 for non-synonyms, 2 for synonyms; red boxes: 9 for non-synonyms, 0 for synonyms).

Data analysis. Data were analyzed in the same way as in Experiment 1.

Results

Word recognition. The accuracy and hit, miss, correct rejection, and false alarm rates across all words are shown in Table 2. In terms of overall accuracy, there was again a significant main effect of both word type ($\beta = .25$, $z = 2.93$, $p = .003$) and confidence level ($\beta = .75$, $z = 22.75$, $p < .001$). Concrete words were better recognized than abstract, and accuracy increased with greater confidence, while the interaction was non-significant ($\beta = .09$, $z = 1.56$, $p = .11$; see Figure 4). Target (i.e., non-synonym words presented at encoding) recognition accuracy by confidence is shown in Figure 5. Among targets, there was no main effect of word type, but a main effect of confidence level ($\beta = 1.47$, $z = 23.35$, $p < .001$), with words recognized better with higher confidence. The interaction was non-significant. Finally, d' analysis showed that when considering response bias, accuracy was better for concrete concepts, $t(39) = -5.372$, $p < .001$.

Table 2

Mean Word Recognition Accuracy

Word type	Acc	Hit	Miss	CR	FA	d'
Abstract	.731	.771	.229	.650	.350	1.214
Concrete	.780	.813	.187	.713	.287	1.568

Note. CR = correct rejection; FA = false alarm.

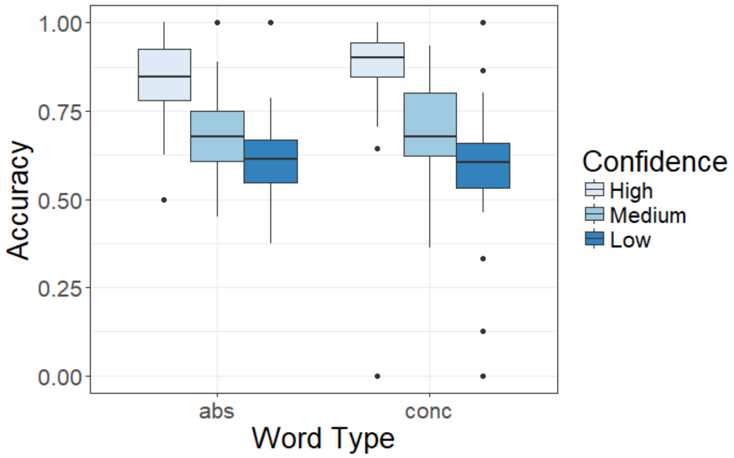

Figure 4. Box plot showing the interaction between word type and confidence in predicting overall word recognition accuracy. Solid lines show median accuracy, boxes show interquartile range, and whiskers mark 95% of the distribution.

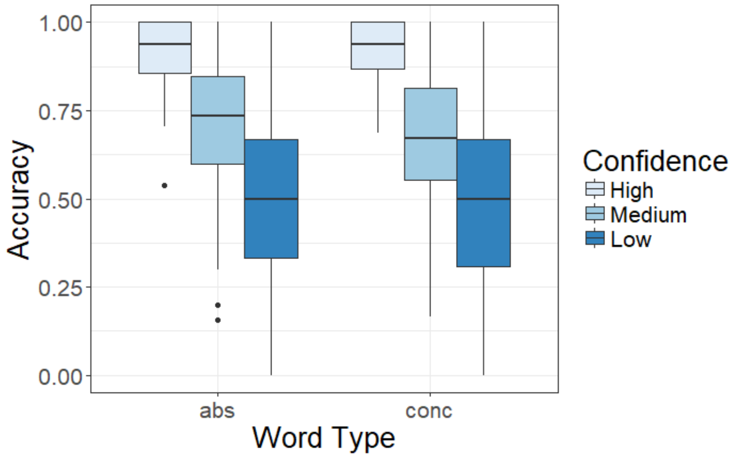

Figure 5. Box plot showing the effect of word type and confidence in predicting target recognition accuracy (i.e., only non-synonym words presented at encoding). Solid lines show median accuracy, boxes show interquartile range, and whiskers mark 95% of the distribution.

Source recognition. As in Experiment 1, in analyzing source recognition, we included only trials for which the word had been correctly identified. There was a main effect of word type ($\beta = .19$, $z = 2.31$, $p = .02$), where the box was more likely to be recognized for concrete words, but not of confidence level ($\beta = .07$, $z = 1.51$, $p = .13$). The interaction was also non-significant (Figure 6). Participants were more likely to recognize the box color correctly for concrete words as compared to abstract ones. However, because d' scores indicate that when taking response bias into account recognition was greater for concrete than it was for abstract concepts (see Table 2), there may have been a baseline advantage for recognizing concrete words, which would then bias the box recognition models. That is, even though we only analyzed box recognition trials on which the target word was correctly recognized, correct recognition trials for abstract words may have been less likely to reflect true hits where the word was in fact encoded. Accordingly, we also constructed models with d' as a predictor to determine whether the effect of word type remained significant after accounting for this baseline concreteness advantage. A likelihood ratio test comparing the model with both d' and word type versus the model with only d' was significant, $\chi^2(1) = 5.27$, $p = .02$, suggesting that the effect of word type, where box recognition was better in concrete than it was in abstract concepts, was significant even after accounting for the d' concreteness advantage.

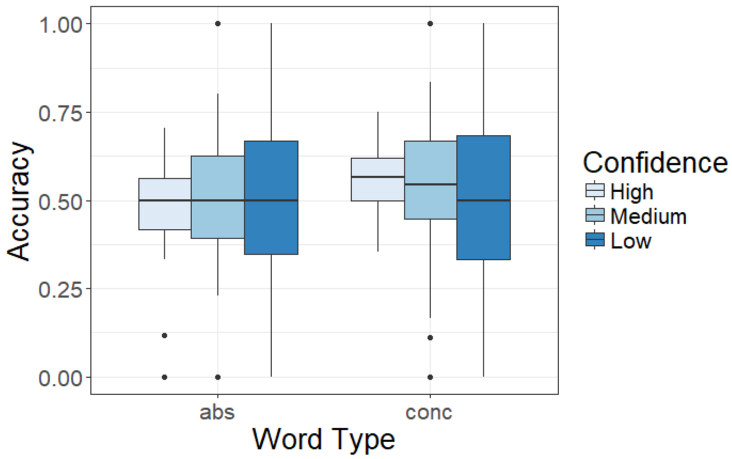

Figure 6. Box plot showing box recognition accuracy by word type and confidence rating. Confidence rating refers to confidence in having seen the *word* at encoding. Solid lines show median accuracy, boxes show interquartile range, and whiskers mark 95% of the distribution.

Discussion

As in Experiment 1, there was concreteness advantage in word recognition; however, unlike in Experiment 1, this was only true among all words (including fillers and synonyms). Once the data were analyzed by only targets, this effect disappeared, suggesting that the overall accuracy difference was buoyed by a higher false alarm rate for abstract concepts. Abstract targets were just as likely to be correctly recognized as concrete targets were. Nevertheless, source recognition accuracy was better for concrete concepts—participants were better able to recognize the context for concrete than abstract concepts, and this was true even after controlling for a concreteness advantage detected in d'. Thus, the results of Experiment 2, like those of Experiment 1, ran counter to our hypothesis: source memory was better for concrete words than it was for abstract words, even when participants were highly confident in having seen the word at encoding (see Figure 6). That is, participants were better able to recognize an arbitrary episodic context (i.e., box color) for concrete concepts. As discussed following Experiment 1, it may be that concrete concepts are more amenable to a mnemonic strategy wherein a color adjective (i.e., “red” or “green”) could readily be combined with concrete objects (e.g., “table”), making source recognition better for concrete words. That is, it is possible that the explicit nature of this task promoted *unitization* (see Jager, Mecklinger, & Kipp 2006; Migo et al., 2012; Quamme, Yonelinas, & Norman 2007), which is the tendency for the source to be treated as a feature of the item rather than as memory for the association of two elements. Under this explanation, we might argue that the colored box context is more easily paired with concrete than abstract concepts. Thus, it may be that contextual detail is encoded to a greater extent in abstract concepts, as initially predicted, but only when that contextual detail is not systematically related to concrete objects (where it may be argued that colored boxes *are* systematically related to concrete concepts). A second explanation, which would refute our hypothesis, is that the concreteness advantage simply extends to memory for arbitrary contextual details (i.e., recollection memory). That is, while we might anticipate that the concrete words would be better recognized *overall* than the abstract words based on a vast body of work demonstrating concrete word advantages in both memory and online processing, the present findings may also suggest that the advantage extends to the distinction between familiarity and recollection: we are better able to encode contextual details with concrete concepts. Experiment 3 was conducted to evaluate these two competing explanations.

Experiment 3

In Experiment 3, we utilized a variant of the source memory paradigm, where instead of the colored box, the context to be encoded was a male or female voice. That is, concepts were presented auditorily, spoken by either a male or female voice, and subsequent recognition was conducted on visually presented words (e.g., Wilding & Rugg, 1996). In line with the original prediction that contextual detail is encoded to a greater extent in abstract concepts than in concrete ones, it was predicted that, of words correctly recognized in the recognition phase, participants would be better at remembering the source of the concept (i.e., male or female voice) for abstract than for concrete concepts. This prediction is further buoyed by the finding that the percentage of person-related social properties generated in an open-ended associative task was found to be significantly higher for abstract (20%) than concrete concepts (6%; Barsalou & Wiemer-Hastings, 2005), suggesting that we might be particularly sensitive to person-related contextual detail (e.g., speaker information) in processing abstract concepts.

Methods

Participants. Participants were 42 University of Connecticut undergraduates (7 men, 35 women, mean age = 18.9 years) with normal or corrected-to-normal vision who had not participated in Experiment 1 or 2. Participants provided written informed consent and were given course credit for their participation, and the procedures were approved by the University of Connecticut institutional review board.

Stimuli. The stimuli were the same as those used in Experiment 2, but were instead recorded by a male and a female voice. There were no differences in the length of the sound files between the two speakers, and all files were normalized to a peak amplitude. As with the colored boxes, half of the words were assigned to be spoken by a male voice, and half were spoken by a female voice. The words that had previously been assigned red boxes were spoken in a female voice, and those that had been assigned green boxes were spoken in a male voice (i.e., half of the words for each word type were spoken by a male and female voice).

Procedure. In the encoding phase, the procedure was the same as in Experiment 2, except that instead of being told that their response would differ depending on the color of the box, they were told that they would respond with their left hand if the word was spoken by a female voice named “Jane” and with their right hand if the word was spoken by a male speaker named “Sid.” Thus, like in Experiment 2, participants were not told that they would be asked to recall the word–gender pairings. The same synonym judgment 1-back task was employed. In the recognition phase, the first judgment—whether the word was in the initial set (old) or not (new)—was the same. For the second judgment, participants were asked to indicate whether the person who said the word in the initial set was “Jane” or “Sid.” The recognition phase was conducted with visually presented words, as in Experiments 1 and 2 (for a similar paradigm with auditory encoding and visual recognition, see Wilding & Rugg, 1996).

Data analysis. Data were analyzed in the same way as in Experiments 1 and 2.

Results

Word recognition. The accuracy and hit, miss, correct rejection, and false alarm rates across all words are shown in Table 3. Among all words, there was a significant main effect of both word type ($\beta = .17$, $z = 2.02$, $p = .04$), with concrete words showing better recognition, and confidence level ($\beta = .72$, $z = 23.18$, $p < .001$), with greater confidence associated with better recognition. There was also a significant interaction ($\beta = .12$, $z = 2.23$, $p = .03$; Figure 7). Target (i.e., only non-synonym words presented at encoding) recognition accuracy by confidence rating is shown in Figure 8. Among target words, there was a significant main effect of confidence level ($\beta = 1.66$, $z = 27.00$, $p < .001$), with greater confidence associated with better recognition, but not of word type. The interaction was significant ($\beta = .31$, $z = 3.12$, $p = .002$). Finally, d' analysis again revealed that even after taking response bias into account, recognition accuracy was better for concrete as compared to abstract concepts, $t(40) = -3.488$, $p = .001$.

Table 3

Mean Word Recognition Accuracy

Word type	Acc	Hit	Miss	CR	FA	d'
Abstract	.696	.724	.276	.640	.360	1.040
Concrete	.734	.766	.234	.671	.329	1.277

Note. CR = correct rejection; FA = false alarm.

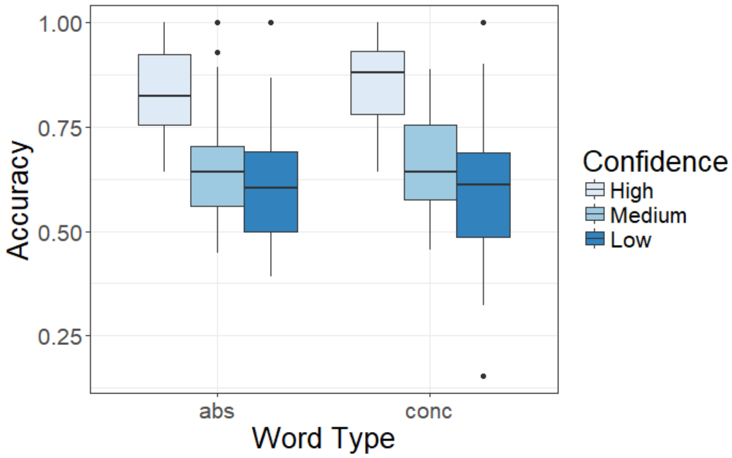

Figure 7. Box plot showing the interaction between word type and confidence in predicting overall word recognition accuracy. Solid lines show median accuracy, boxes show interquartile range, and whiskers mark 95% of the distribution.

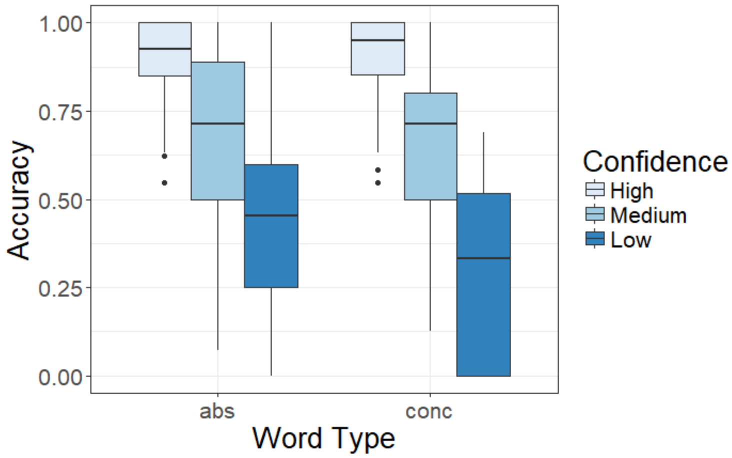

Figure 8. Box plot showing the interaction between word type and confidence in predicting target recognition accuracy (i.e., only non-synonym words presented at encoding). Solid lines show median accuracy, boxes show interquartile range, and whiskers mark 95% of the distribution.

Source recognition. As in Experiments 1 and 2, in analyzing source recognition, we included only trials for which the word had been correctly recognized. There was a main effect of word type ($\beta = .20$, $z = 2.10$, $p < .05$), with voice context better recognized for concrete words, and confidence level ($\beta = .25$, $z = 4.64$, $p < .001$), with voice context recognized better with greater confidence, and the interaction approached statistical significance ($\beta = .18$, $z = 1.77$, $p = .08$; Figure 9). Participants were again more likely to recognize the context (this time, voice source) correctly for concrete words as compared to abstract ones, and this ability appeared to increase with increased confidence in having heard the word at encoding. However, because d' was again greater for concrete than it was for abstract concepts (see Table 3), there may have been a baseline advantage for recognizing concrete words, which would then bias the voice recognition models. As in Experiment 2, we constructed models with d' as a predictor to determine whether the effect of word type remained significant after accounting for this baseline concreteness advantage. A likelihood ratio test comparing the model with both d' and word type versus the model with only d' was significant, $\chi^2(1) = 5.75$, $p = .02$, suggesting that the effect of word type, where voice recognition was better for concrete than it was for abstract concepts, was significant even after accounting for the d' concreteness advantage.

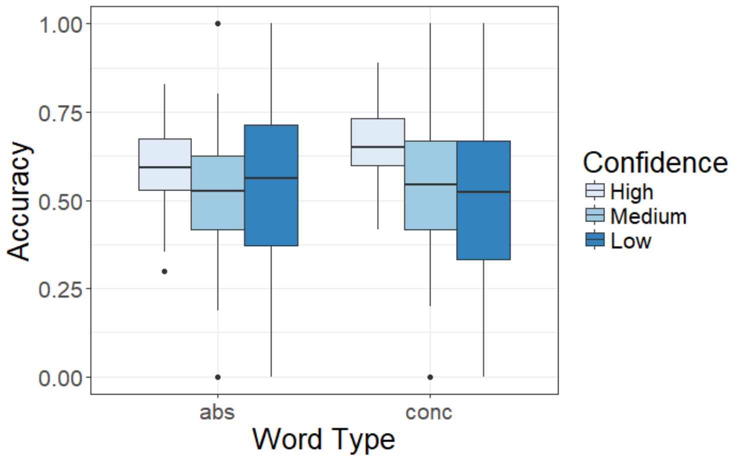

Figure 9. Box plot showing voice recognition accuracy by word type and confidence rating. Confidence rating refers to confidence in having seen the *word* at encoding. Solid lines show median accuracy, boxes show interquartile range, and whiskers mark 95% of the distribution.

Discussion

As in Experiments 1 and 2, there was a concrete word advantage in overall word recognition. As in Experiment 2, however, this advantage disappeared when examining targets alone, suggesting that the effect across all words may have been buoyed by a higher false alarm rate for abstract concepts. Moreover, counter to our prediction, in Experiment 3, voice source was better recognized for concrete than abstract concepts, and again this was the case even when participants were highly confident in having seen the word at encoding (see Figure 9). This provides support for the interpretation that the concreteness advantage, commonly observed in language processing and reviewed at the outset, also extends to episodic memory, at least for the recognition of simple and isolated episodic detail. The results of Experiments 1 and 2 do not appear to be well explained by the unitization of concept and context being better facilitated for concrete than abstract concepts. Below, we discuss possible explanations for the observed concreteness advantage, theoretical implications for representation of concrete and abstract concepts, and next steps for empirical pursuits in grounding abstract concept representations in the brain.

General Discussion

The present set of experiments sought to build on work suggesting that the content of abstract concept representations is determined largely by contextual information by investigating a potential mechanism by which context is attended to in abstract concepts. In doing so, the episodic memory system (and speculatively, the hippocampal system at a neural level), which is involved in encoding specific contextual details in memory episodes, was identified as a potential candidate for supporting the representation of abstract concepts, and specifically, for directing us toward or tuning us in to contextual information when processing abstract concepts. To investigate this hypothesis, a source memory paradigm was employed because of its association with hippocampal activity (see, e.g., Rugg et al., 2012), and arbitrary episodic contexts (either boxes of different colors or voices of different speakers) were paired with abstract and concrete concepts to determine whether context is better recognized for abstract concepts. Across three experiments, the opposite was true: there was a concreteness advantage for recognizing episodic contexts, regardless of whether the context was a colored frame surrounding visually presented words or the speaker of auditorily presented words (see, however, a near-significant effect in this direction in Experiment 1). Because the words were matched on length and frequency, it is unlikely that any lower-level characteristics could explain the effects. The findings suggest that simple episodic associations are better encoded for concrete than for abstract concepts.

In spite of these findings, contextual information more broadly is critical for understanding abstract concepts—this much is agreed upon across several areas of study, including classical work on lexical-semantic processing under context-availability theory (e.g., Schwanenflugel & Shoben, 1983), neuropsychological work suggesting qualitatively different representation of concrete and abstract concepts (e.g., Crutch & Warrington, 2005), and research investigating grounded or situated cognition (e.g., Barsalou & Wiemer-Hastings, 2005). However, there are differences across these frameworks in terms of the *type* of context specified as being critical to processing abstract concepts, ranging from semantically constraining linguistic context in context-availability theory, to thematic associations in the qualitatively different representations framework, to meaningful situational and internal factors in grounded cognition, and accordingly, the mechanism by which representations of abstract concepts are derived from or paired with contextual information has remained unclear. While this study sought to uncover a basic mechanism that might unify these approaches (i.e., sensitivity to episodic information), the results were unequivocal: there is a concreteness advantage in terms of how simple episodic detail in a source memory task is encoded with concepts. In the following, we seek to unpack this finding by exploring 1) potential relations between concreteness and the episodic memory system, 2) a brief review of neural activation that has been associated with concrete versus abstract concepts, 3) cases in which an *abstract* concept advantage emerges or concreteness effects are washed out (i.e., reversed concreteness effects), and 4) potentially promising avenues for further exploring the neural representation of abstract concepts.

Concreteness, Context, and Episodic Memory

Unsurprisingly, among all words presented at the recognition phase, accuracy for concrete words was consistently better than it was for abstract words. This has been shown repeatedly in previous work (e.g., Chen & Lin, 2012; Fliessbach, Weis, Klaver, Elger, & Weber, 2006; Nelson & Schreiber, 1992; Paivio et al., 1994; Wattenmaker & Shoben, 1987; Xiao, Zhao, Zhang, & Guo, 2012). Strikingly, however, this was not the case in Experiments 2 and 3 when the data were subsetted to include only target words (i.e., only non-synonym words seen at encoding), and moreover, among those targets, context was better recognized for concrete than for abstract concepts. This was true regardless of whether the context was a colored box or a voice source. Whether this is surprising or unsurprising depends on how one views source memory effects: if memory strength and the ability to recall contextual detail are viewed as highly confounded, inseparable constructs (e.g., Wais, Squire, & Wixted, 2010), then the effect is unsurprising, as concrete concepts presented in isolation are thought to produce a stronger memory trace than are abstract concepts. This stronger memory trace would then lead to a greater amount of contextual detail recalled. Note, however, that in Experiments 2 and 3 this did not appear to be the case for our target words, the only words for which source recognition was measured. As discussed in the introduction, one can also view the ability to recall contextual detail as a process independent of memory strength, as we have in this experiment (and as discussed in, e.g., Rugg et al., 2012; see also Vilberg & Rugg, 2007, 2009). On this view, there is an effect beyond that of memory strength to be explained. In this case, the results have interesting implications for how we think about concreteness effects and how far such effects extend in memory processes.

Concreteness is a powerful organizing factor in semantic memory (e.g., De Deyne, 2017; Hollis & Westbury, 2016). As discussed at the outset, concreteness effects are near ubiquitous in semantic processing. The present results suggest that such effects extend beyond stronger memory for concrete concepts, to better *relational memory* for concrete concepts, at least when the relation to be studied is a simple, arbitrary associated context. One important consideration here is the way in which we might expect context to be differentially recruited for processing concrete and abstract concepts, as this has implications for the relation between context sensitivity and concreteness. In a review of the pervasiveness of context effects in cognition and perception, Yeh and Barsalou (2006) present two primary theses for how context affects conceptualization: first, contexts and concepts mutually activate each other, such that when processing a context, associated concepts are activated, and vice versa; and second, when processing a concept in a particular context, properties of the concept which are relevant to that context become active. These two theses have different implications for the relation between context sensitivity and concreteness.

I will begin with exploring the second thesis, which may be more pertinent to abstract concept processing: when processing the concept *decision* in the context of your choice of beverage at 9pm in the local café, the activated properties will be different from when processing *decision* in the context of a judge determining the appropriate sentence for a felon convicted of battery. In this sense, *decision* has a number of possible interpretations, and its precise meaning or *sense* depends on the context in which it is processed. It is perhaps helpful to think of this in terms of semantic diversity, which refers to the number and diversity of different contexts in which a word can appear, and is positively correlated with error rate in a synonym judgment task (Hoffman et al., 2013). It is also strongly negatively correlated with concreteness, such that more contextually diverse items tend to be less concrete (i.e., more abstract). This suggests that in semantically demanding tasks such as synonym judgment, a greater variety of meanings and associated contexts will be activated for contextually diverse concepts. Concepts that occur in more diverse contexts may be synonyms, but this may only be the case in particular contexts—this would then make the search through contexts in which those concepts may be synonyms more effortful, as the concepts may not be synonyms in all cases. For example, an abstract concept like *decision* when paired with *judgment* might leave fewer resources available to process immediately available relational information (i.e., in the present study, the box color or the voice) because we must search for a context in which *decision* and *judgment* are in fact synonyms (i.e., a judge handing down a sentence, *but not* deciding on your beverage at the café). Following this thesis of Yeh and Barsalou (2006), abstract concepts may not be particularly sensitive to immediate contextual information (e.g., a box color or a voice), but rather, meaningful context may constrain the meaning of otherwise contextually and semantically diverse concepts like *decision*. If this were the case, it would account for why our immediate episodic contexts were not well remembered for abstract concepts: without meaningful context to constrain the meaning of *decision*, the semantic associates generated in the synonym judgment task would have left fewer resources available to process the immediately available relational information (i.e., the association with the box or voice source).

The first thesis—that concepts and contexts mutually activate each other—on the other hand resonates strongly with context availability theory, and likely suggests a concrete word advantage: concrete concepts activate contexts more strongly because they have stronger implicit connections to specific contexts. Thus, building implicit but direct associations between context and concept may have been facilitated by a similar mechanism to that which underpins context availability effects—if concrete concepts are typically associated with these sorts of immediate contexts, then such contexts (such as the boxes and voices in the present study) might be more likely to be encoded with concrete concepts. Further, it is possible that source memory effects (and presumably, hippocampal processing) are more closely related to the first thesis, as they deal with implicit, proximal connections between stimulus and context (for a review, see Eichenbaum, 2013). The neurophysiological evidence to relate source memory effects to concreteness and semantic memory more broadly is sparse, but some hints exist in the literature. For instance, an event-related potential study showed a greater P600 (a positive-going electrocortical component about 600 ms after stimulus presentation) for concrete than for abstract words in the retrieval phase of a directed forgetting paradigm (Xiao et al., 2012), which was attributed to a greater amount of implicit context being recalled for concrete concepts (see also Rugg & Allan, 2000). Moreover, an fMRI study of recognition memory for abstract and concrete concepts showed a relation between hippocampal activation and the behavioral concreteness effect (Fliessbach et al., 2006). In this same study, abstract concepts showed greater left inferior frontal gyrus activation at encoding, perhaps reflecting a more effortful search for relevant contexts and associations. These results suggest that left inferior frontal gyrus was involved in finding appropriate contexts and associations, a process more important for abstract concepts, and hippocampal activity handled more direct and implicit contextual associations, such as those implicated in context availability theory (see also Chen & Lin, 2012). If concrete concepts are indeed more sensitive to immediate contextual information, this might explain the present findings: implicit contextual associations, such as box color and voice source, are more likely to be encoded with concrete concepts because these types of direct contexts are similar to those typically recruited when processing concrete concepts.

Both the hippocampus and inferior frontal and prefrontal regions are important components of the episodic memory system, with the former critical in encoding and the latter fundamental to the retrieval system (Tulving, 2002). The present results provide an early indication that concrete concepts are more amenable to the implicit, immediate contexts to which the hippocampus is sensitive. Abstract concepts may be more dependent on frontal memory circuits (see also Grossman et al., 2002; Noppeney & Price, 2004; Pexman et al., 2007), which are involved in effortful recollection, and it may be that this frontal memory system helps to constrain the pattern of activation that emerges in processing abstract concepts (i.e., selecting the context-appropriate associations), depending on the situated context. Of course, testing these specific hypotheses using neuroimaging techniques (i.e., fMRI) as opposed to mere conjecture based on associated behavioral phenomena will be necessary, and we will return later to a potentially promising framework within which these effects might be interpreted. In the next section we consider whether what is currently known about the neural processing of abstract and concrete concepts is consistent with these hypotheses.

Neural Representation of Abstract and Concrete Concepts

Although the present study was behavioral, the goal was to probe potential neural mechanisms underlying representation of abstract concepts using a paradigm with well-established neurobehavioral correlates. Accordingly, it is worth briefly considering what *is* known about neural representation of abstract and concrete concepts in accommodating and considering the implications of the present findings. In line with the account presented in the previous section, meta-analyses have shown that abstract concepts are associated with inferior frontal gyrus activation, in addition to temporal regions such as middle and superior temporal gyrus. Concrete concepts, on the other hand, tend to show activation in fusiform gyrus, posterior cingulate cortex, and parahippocampal gyrus (Binder, Desai, Graves, & Conant, 2009; Wang, Conder, Blitzer, & Shinkareva, 2010). These findings have been interpreted in line with a dual-coding framework, suggesting greater linguistic processing in abstract concepts and greater image-based processing in concrete concepts (Wang et al., 2010; see also Binder, Westbury, McKiernan, Possing, & Medler, 2005). However, the pattern of activation found in meta-analyses is also consistent with a (not mutually exclusive) context-based account: inferior frontal gyrus is thought to mediate semantic retrieval (Thompson-Schill, 2003; Wagner, Pare-Blagoev, Clark, & Poldrack, 2001), which may be more important for abstract concepts because of their greater semantic diversity. On the other hand, the greater activation of, for instance, parahippocampal cortex in concrete concepts might be reflective of greater reliance on immediate and implicit contextual detail, as opposed to the more effortful search that characterizes abstract concepts. Indeed, when the task encourages broad semantic processing rather than requiring a constrained decision (as may be the case with synonym judgment), widespread cortical activation is observed in abstract concepts (across temporal, parietal and frontal cortices). This might reflect the highly distributed and diverse semantic representation of abstract concepts (Pexman et al., 2007). On the other hand, inferior frontal gyrus would be involved in selecting which among these distributed, diverse representations is contextually appropriate.

Concreteness Effects: Reversed

Potentially informative in understanding the present findings—and more broadly, the mechanisms underlying representation of abstract concepts—are situations in which concreteness effects are reversed (i.e., an advantage is observed for abstract over concrete concepts). Reverse concreteness effects are commonly observed in semantic dementia (e.g., Warrington, 1975; Breedin, Saffran, & Coslett, 1994), and some have even suggested that reverse concreteness effects are typical of semantic processing in semantic dementia (Grossman & Ash, 2004). Semantic dementia involves atrophy in the anterior temporal lobes which progresses posteriorly as the disease advances, and is characterized by domain-general impairments in semantic knowledge but otherwise preserved cognitive and linguistic abilities (for review, see Rogers & Patterson, 2007). Because much of this damage extends along the ventral stream (which is critical in object identification and processing) towards posterior temporal cortex, behavioral impairment may selectively affect concrete concepts (Bonner et al., 2009; Yi et al., 2007; but see Hoffman & Lambon Ralph, 2011; Jefferies, Patterson, Jones, & Lambon Ralph, 2009 for alternative explanations of reverse concreteness effects). In testing the reverse concreteness effect, Loiselle et al. (2012) showed that while patients with anterior temporal lobe resection presented with striking reverse concreteness effects, patients with medial temporal lobe resection (inclusive of hippocampus primarily, but also amygdala and perirhinal cortex) were equally impaired on abstract and concrete concepts. The concreteness deficit among those with medial temporal lobe resection was attributed to resection of the perirhinal cortex, which is critical in object discrimination (see Clarke & Tyler, 2014) and a sense of familiarity in episodic memory (Davachi, 2006), while the abstract concept deficit was attributed to damage to the amygdala (which might support emotion concept representation; see also Kousta et al., 2011; Vigliocco et al., 2014) and perhaps the hippocampus, which, as was initially hypothesized here, might support binding context to concept.

The concreteness effect can also be reversed at a behavioral level in non-impaired populations. Specifically, changing the encoding or retrieval context can affect the patterns of accuracy obtained (e.g., Hamilton & Rajaram, 2001; Ruiz-Vargas, Cuevas, & Marschark, 1996; ter Doest & Semin, 2005). For instance, concreteness effects are not observed when the recognition task tests implicit rather than explicit knowledge of the tested items (Hamilton & Rajaram, 2001; ter Doest & Semin, 2005). Related to the discussion in the previous section, it may be that explicit cued recall leads to reactivation of a word’s associates, and because abstract concepts have more diverse associative networks, interference may occur. Moreover, relational processing at encoding may exacerbate concreteness effects (Ruiz-Vargas et al., 1996), perhaps because encouraging relational processing activates the many semantic associates of contextually diverse abstract concepts (Hoffman et al., 2013). Thus, relational processing in abstract concepts may produce an interference effect at retrieval because more associates are activated at encoding, or it may leave fewer resources available to process immediately present contextual information at encoding (i.e., the box and voice source in our study).

These considerations might bear fruitful investigations into the mechanisms underlying processing of abstract concepts. Behaviorally, they suggest that altering encoding and/or retrieval conditions such that they do not explicitly facilitate relational processing or such that they constrain the types of associations that are activated might enhance processing of abstract concepts (and perhaps the contexts in which they are placed). Indeed, if abstract concepts are represented to a greater degree in associative semantic networks (i.e., Crutch & Warrington, 2005), then we might anticipate that encouraging relational processing (as we did here in the synonym judgment task) would activate more semantic associates of abstract concepts, leading to greater interference in the recognition phase, as the foils were selected to be lexically and conceptually similar to the targets (see Appendix 1). Evidence for this exists in the higher false alarm rates consistently observed for abstract concepts across the present three experiments (see Tables 1–3), but because misses were also higher in abstract concepts,[1] the nature of false memory in abstract concepts must be directly tested. At a neural level, the implications of reverse concreteness effects are less clear, given the lack of clarity on the conditions which give rise to such reversals. However, a recent model of controlled semantic cognition (Lambon Ralph, Jefferies, Patterson, & Rogers, 2017), which we turn to next, might be helpful in knitting together some of the speculations discussed above.

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[1] The higher miss rate for abstract concepts seems to be largely attributable to misses on synonyms. The hit rates for abstract and concrete concepts were 65% and 81%, 76% and 86%, and 72% and 83% in Experiments 1, 2, and 3, respectively.

Controlled Semantic Cognition: A Framework for Representation of Abstract Concepts

The controlled semantic cognition framework (Lambon Ralph et al., 2017) postulates that two systems underpin semantic processing, one for semantic representation and one for semantic control. Representation is broadly supported by the anterior temporal lobes (which, when damaged or resected, lead to reversed concreteness effects; e.g., Loiselle et al., 2012; Warrington, 1975), taking in input from modality-specific "spokes," which are located in distributed cortical regions for processing sensory, motor, and perceptual input. While the model considers this to be a domain-general 'hub' for semantic processing, we remain agnostic to whether anterior temporal lobe houses semantic representations, or is a large convergence zone at the confluence of many major white-matter tracts (see, e.g., Mirman et al., 2015). More importantly for the present purposes, semantic control is supported by a network of frontal regions as well as the area surrounding the temporoparietal junction. This system is involved in selecting the appropriate semantic properties among semantic associations in a given context. We might conjecture that abstract concepts rely to a greater degree on this semantic control system in processing, as more diverse meanings must be suppressed and appropriate associations retrieved depending on the context. This largely fits with the picture painted above in the section on Concreteness, Context, and Episodic Memory: concrete concepts implicitly activate their contexts, a result of being less contextually diverse and more imageable, and this implicit context activation might portend well to the direct contexts tested here, leading to the observed pattern of better recalled contextual information.[2] Concrete concepts are more amenable to the first thesis

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[2] Using Hoffman et al.'s (2013) semantic diversity norms, we tested this hypothesis on our data, despite not all items being available in the diversity norms (11% missing). Semantic diversity did not significantly predict *word* recognition across the three experiments, nor did it predict box recognition. However, in Experiment 3, it was a significant predictor of voice recognition. This leaves the role of semantic diversity unclear, and suggests that in order to tease out its role in relational memory, additional work targeting its role in a hypothesis-driven way is necessary.

of Yeh and Barsalou (2006), where concepts and contexts mutually activate each other. On the other hand, abstract concepts require *semantic control* for activation. This makes abstract concepts more amenable to the second thesis of Yeh and Barsalou (2006): that the specific context will determine the properties of the concept that are activated in conceptualization. Such a process might rely on the frontal memory system, which is implicated in semantic control, in order to drive context-dependent activation of meaning.

Limitations and Future Work

An important limitation in the present study was a baseline concreteness effect. Although participants were no better at recognizing non-synonym targets (i.e., the only words tested in the context recognition task) for concrete than abstract concepts, there was a baseline advantage for concrete concepts, as demonstrated in the d' analyses. While word type remained a significant predictor of box (Experiment 2) and voice (Experiment 3) recognition even after accounting for the d' concreteness advantage, it remains possible that concrete concepts simply produced a stronger memory trace, which then led to greater context recognition. Future work should use an approach that better addresses this baseline concreteness advantage experimentally. An immediate next step will involve presenting all words in boxes at the recognition phase, half with the context preserved and half changed; by this method, it could be determined whether there is a greater benefit of context preservation for concrete or abstract concepts. Formatting the recognition phase in this way would also reduce task demands in the recognition phase—the two-part response for word and context was complex, and this may have adversely affected task accuracy.

A further limiting factor of the present approach might be its oversimplification of the dimensionality of word meaning. While we attempted to look only at non-emotional abstract concepts such as *decision* to the exclusion of highly affective concepts like *love*, this necessarily leaves out affect, which is recognized as a critical organizing factor in semantic memory (see De Deyne, 2017; Hollis & Westbury, 2016), though it has been shown that abstractness and emotion are largely separable in terms of neural representation (Skipper & Olson, 2014). Moreover, while some effort has been made to determine the organization of abstract concepts (e.g., Troche, Crutch, & Reilly, 2014), we did not consider potential subdivisions within abstract or concrete concepts, nor did we consider the emotion dimension. Thus, the present effects cannot be considered as representative of all concepts, but instead as reflecting a coarse distinction between concrete object concepts and abstract concepts, despite abstractness likely being a continuum, with many dimensions (e.g., social, cognitive, philosophical) likely to be important to neural processing. For example, it is unclear whether effects of context are uniform across these dimensions, whether sensitivity to context varies continuously with concreteness, or whether there are important and unexamined interactions between emotion and concreteness in terms of sensitivity to context.

As indicated earlier, the synonym judgment task used in the encoding phase may have worked to a disadvantage: as abstract concepts tend to have more diverse meanings, synonym judgments may be more difficult for abstract concepts, as it must be determined whether *any particular sense* of the word is a synonym to the target (Hoffman et al., 2013). These systematic differences in selection demands may have led to difficulty encoding abstract concepts generally, and this possibility is reflected in the higher rates of false alarm observed for abstract concepts in the present study. This activation of associated word meanings may have left fewer resources available to process the contextual information (although a preliminary analysis of semantic diversity was not consistent with this hypothesis, systematic investigation on this explanation is warranted). Accordingly, finding a balance between a sufficiently low-level task to promote attention to the context (and avoid overactivation of semantic associates) while still encouraging ‘deep’ semantic processing will be critical in future attempts to investigate relational memory in abstract concepts. Relatedly, while work on episodic memory typically considers low-level contextual details such as box frames and voice source to be representative of the rich context that can be encoded in a memory episode, future research on context encoding in abstract and concrete concepts might benefit from departing from the low-level episodic contexts used in the present work. Specifically, while we focused on arbitrary episodic detail, it might be fruitful to instead explore *systematic* contextual relations. Indeed, the activation of systematic contextual information might even suppress attention to arbitrary details (see, e.g., van Kesteren et al., 2013).

Several suggestions have been made here with regard to the neural representation of abstract concepts. While some prior neurophysiological work has intimated at some of the suggestions made here (Chen & Lin, 2012; Fliessbach et al., 2006; Grossman et al., 2002; Noppeney & Price, 2004; Pexman et al., 2007; Xiao et al., 2012), the current findings present the possibility for novel and more theoretically constrained approaches to determining the neural mechanism underlying processing and representation of abstract concepts. Specifically, investigating the interaction between semantic *representation* and *control* in abstract versus concrete concepts might be an interesting avenue for exploring the neural mechanisms underlying the differential interaction between concept and context in concrete and abstract concepts.

Conclusions

The present set of experiments sought to determine an underlying mechanism uniting several approaches to abstract concept representation suggesting that contextual information is a critical aspect of the content of abstract concepts (e.g., Schwanenflugel, 1991; Crutch & Warrington, 2005; Barsalou & Wiemer-Hastings, 2005). However, the findings suggest that contextual information is better encoded for concrete concepts, at least when that information is a simple and immediate contextual detail such as a box color surrounding a visually presented word or the speaker of an auditorily presented word. This is despite the finding that concrete and abstract target words were recognized equally well—simply, the context was better encoded for concrete concepts. This may be because a similar mechanism underlying the implicit activation of contextual information (context availability; Schwanenflugel, 1991) permitted the binding of this immediate contextual information to concrete concepts. On the other hand, because abstract concepts tend to activate many associates (semantic diversity; Hoffman et al., 2013), and this effect is exacerbated by associative tasks like synonym judgment, fewer resources may have been available for processing the contextual information alongside abstract concepts. We suggest that the sensitivity of abstract concepts to context might be better thought of in terms of *semantic control*, which would help facilitate the appropriate activation of diverse semantic associates given the current context.

References

Balota, D. A., Yap, M. J., Hutchison, K. A., Cortese, M. J., Kessler, B., Loftis, B., … & Treiman, R. (2007). The English lexicon project. *Behavior Research Methods*, *39*(3), 445–459.

Barsalou, L. W. (2003). Situated simulation in the human conceptual system. *Language and Cognitive Processes*, *18*(5-6), 513–562.

Barsalou, L. W. (2005). Situated conceptualization. In H. Cohen & C. Lefebvre (Eds.), *Handbook of categorization in cognitive science* (pp. 619–650). St. Louis, MO: Elsevier.

Barsalou, L. W. (2015) Situated conceptualization: Theory and applications. Y. Coello & M. H. Fischer (Eds.), *Foundations of embodied cognition*. East Sussex, UK: Psychology Press.

Barsalou, L. W., & Wiemer-Hastings, K. (2005). Situating abstract concepts. In D. Pecher & R. A. Zwaan (Eds.), *Grounding cognition: The role of perception and action in memory, language, and thought* (pp. 129–163). Cambridge, UK: Cambridge University Press.

Bates, D., Maechler, M., Bolker, B., Walker, S., Christensen, R. H. B., Singmann, H., … & Grothendieck, G. (2014). Package ‘lme4’. Vienna: R Foundation for Statistical Computing.

Binder, J. R., Desai, R. H., Graves, W. W., & Conant, L. L. (2009). Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies. *Cerebral Cortex, 19*(12), 2767–2796.

Binder, J. R., Westbury, C. F., McKiernan, K. A., Possing, E. T., & Medler, D. A. (2005). Distinct brain systems for processing concrete and abstract concepts. *Journal of Cognitive Neuroscience*, *17*(6), 905–917.

Bonner, M. F., Vesely, L., Price, C., Anderson, C., Richmond, L., Farag, C., … & Grossman, M. (2009). Reversal of the concreteness effect in semantic dementia. *Cognitive Neuropsychology*, *26*(6), 568–579.

Breedin, S. D., Saffran, E. M., & Coslett, H. B. (1994). Reversal of the concreteness effect in a patient with semantic dementia. *Cognitive Neuropsychology*, *11*(6), 617–660.

Brozdowski, C. R., Gordils, J., & Magnuson, J. S. (2013). Contra the qualitatively different representation hypothesis (QDRH), concrete concepts activate associates faster than abstract concepts. Talk presented at the Annual Meeting of the Psychonomic Society, Toronto, ON.

Brysbaert, M., Warriner, A. B., & Kuperman, V. (2014). Concreteness ratings for 40 thousand generally known English word lemmas. *Behavior Research Methods*, *46*(3), 904–911.

Chen, T. C., & Lin, Y. Y. (2012). High neuromagnetic activation in the left prefrontal and frontal cortices correlates with better memory performance for abstract words. *Brain and Language*, *123*(1), 42–51.

Clarke, A., & Tyler, L. K. (2014). Object-specific semantic coding in human perirhinal cortex. *Journal of Neuroscience*, *34*(14), 4766–4775.

Crutch, S. J., & Warrington, E. K. (2005). Abstract and concrete concepts have structurally different representational frameworks. *Brain*, *128*(3), 615–627.

Davachi, L. (2006). Item, context and relational episodic encoding in humans. *Current Opinion in Neurobiology*, *16*(6), 693–700.

De Deyne, S. (2017). Mapping the lexicon using large-scale empirical semantic networks. Talk presented at the Annual Meeting of the Psychonomic Society, Vancouver, BC.

Eichenbaum, H. (2013). Memory on time. *Trends in Cognitive Sciences, 17*(2), 81–88. doi:10.1016/j.tics.2012.12.007

Fliessbach, K., Weis, S., Klaver, P., Elger, C. E., & Weber, B. (2006). The effect of word concreteness on recognition memory. *NeuroImage*, *32*(3), 1413–1421.

Geng, J., & Schnur, T. T. (2015). The representation of concrete and abstract concepts: Categorical versus associative relationships. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *41*(1), 22–41.

Grossman, M., & Ash, S. (2004). Primary progressive aphasia: A review. *Neurocase*, *10*(1), 3–18.

Grossman, M., Koenig, P., DeVita, C., Glosser, G., Alsop, D., Detre, J., & Gee, J. (2002). The neural basis for category-specific knowledge: an fMRI study. *Neuroimage*, *15*(4), 936–948.

Hamilton, M., & Rajaram, S. (2001). The concreteness effect in implicit and explicit memory tests. *Journal of Memory and Language*, *44*(1), 96–117.

Hoffman, P., & Lambon Ralph, M. A. (2011). Reverse concreteness effects are not a typical feature of semantic dementia: Evidence for the hub-and-spoke model of conceptual representation. *Cerebral Cortex*, *21*(9), 2103–2112.

Hoffman, P., Lambon Ralph, M. A., & Rogers, T. T. (2013). Semantic diversity: A measure of semantic ambiguity based on variability in the contextual usage of words. *Behavior Research Methods*, *45*(3), 718–730.

Hollis, G., & Westbury, C. (2016). The principals of meaning: Extracting semantic dimensions from co-occurrence models of semantics. *Psychonomic Bulletin & Review*, *23*(6), 1744–1756.

Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language*, *30*(5), 513–541.

Jäger, T., Mecklinger, A., & Kipp, K. H. (2006). Intra-and inter-item associations doubly dissociate the electrophysiological correlates of familiarity and recollection. *Neuron*, *52*(3), 535–545.

Jefferies, E., Patterson, K., Jones, R. W., & Lambon Ralph, M. A. (2009). Comprehension of concrete and abstract words in semantic dementia. *Neuropsychology*, *23*(4), 492–499.

Kensinger, E. A., & Corkin, S. (2003). Memory enhancement for emotional words: Are emotional words more vividly remembered than neutral words? *Memory & Cognition*, *31*(8), 1169–1180.

Kirwan, C. B., Wixted, J. T., & Squire, L. R. (2008). Activity in the medial temporal lobe predicts memory strength, whereas activity in the prefrontal cortex predicts recollection. *Journal of Neuroscience*, *28*(42), 10541–10548.

Kousta, S. T., Vigliocco, G., Vinson, D. P., Andrews, M., & Del Campo, E. (2011). The representation of abstract words: Why emotion matters. *Journal of Experimental Psychology: General*, *140*(1), 14–34.

Lambon Ralph, M. A., Jefferies, E., Patterson, K., & Rogers, T. T. (2017). The neural and computational bases of semantic cognition. *Nature Reviews Neuroscience*, *18*(1), 42–55.

Lepage, M., Habib, R., & Tulving, E. (1998). Hippocampal PET activations of memory encoding and retrieval: The HIPER model. *Hippocampus*, *8*(4), 313–322.

Loiselle, M., Rouleau, I., Nguyen, D. K., Dubeau, F., Macoir, J., Whatmough, C., … & Joubert, S. (2012). Comprehension of concrete and abstract words in patients with selective anterior temporal lobe resection and in patients with selective amygdalo-hippocampectomy. *Neuropsychologia*, *50*(5), 630–639.

Migo, E. M., Mayes, A. R., & Montaldi, D. (2012). Measuring recollection and familiarity: Improving the remember/know procedure. *Consciousness and Cognition*, *21*(3), 1435–1455.

Mirman, D., Landrigan, J. F., & Britt, A. E. (2017). Taxonomic and thematic semantic systems. *Psychological Bulletin*, *143*(5), 499–520.

Mirman, D., Zhang, Y., Wang, Z., Coslett, H. B., & Schwartz, M. F. (2015). The ins and outs of meaning: Behavioral and neuroanatomical dissociation of semantically-driven word retrieval and multimodal semantic recognition in aphasia. *Neuropsychologia*, *76*, 208–219.

Nelson, D. L., & Schreiber, T. A. (1992). Word concreteness and word structure as independent determinants of recall. *Journal of Memory and Language*, *31*(2), 237–260.

Noppeney, U., & Price, C. J. (2004). Retrieval of abstract semantics. *Neuroimage*, *22*(1), 164–170.

Paivio A. (1971). *Imagery and verbal processes*. New York, NY: Holt, Rinehart & Winston.

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology*, *45*(3), 255–287.

Paivio, A., & Begg, I. (1971). Imagery and comprehension latencies as a function of sentence concreteness and structure. *Perception & Psychophysics*, *10*(6), 408–412.

Paivio, A., Walsh, M., & Bons, T. (1994). Concreteness effects on memory: When and why? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*(5), 1196–1204.

Pexman, P. M., Hargreaves, I. S., Edwards, J. D., Henry, L. C., & Goodyear, B. G. (2007). Neural correlates of concreteness in semantic categorization. *Journal of Cognitive Neuroscience*, *19*(8), 1407–1419.

Quamme, J. R., Yonelinas, A. P., & Norman, K. A. (2007). Effect of unitization on associative recognition in amnesia. *Hippocampus*, *17*(3), 192–200.

R Core Team (2013). R: A language and environment for statistical computing. Vienna: R Foundation for Statistical Computing.

Rogers, T. T., & Patterson, K. (2007). Object categorization: Reversals and explanations of the basic-level advantage. *Journal of Experimental Psychology: General*, *136*(3), 451–469. doi:10.1037/0096-3445.136.3.451

Rugg, M. D., & Allan, K. (2000). Event-related potential studies of memory. In E. Tulving & F. I. M. Craik (Eds.), *The Oxford handbook of memory* (pp. 521–537). Oxford, UK: Oxford University Press.

Rugg, M. D., Vilberg, K. L., Mattson, J. T., Sarah, S. Y., Johnson, J. D., & Suzuki, M. (2012). Item memory, context memory and the hippocampus: fMRI evidence. *Neuropsychologia*, *50*(13), 3070–3079.

Ruiz-Vargas, J. M., Cuevas, I., & Marschark, M. (1996). The effects of concreteness on memory: Dual codes or dual processing? *European Journal of Cognitive Psychology*, *8*, 45–72.

Schwanenflugel, P. J. (1991). Why are abstract concepts hard to understand? In P. J. Schwanenflugel (Ed.), *The psychology of word meanings* (pp. 223–250). Hillsdale, NJ: Lawrence Erlbaum Associates.

Schwanenflugel, P. J., & Shoben, E. J. (1983). Differential context effects in the comprehension of abstract and concrete verbal materials. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *9*(1), 82–102.

Skipper, L. M., & Olson, I. R. (2014). Semantic memory: Distinct neural representations for abstractness and valence. *Brain and Language*, *130*, 1–10.

ter Doest, L., & Semin, G. (2005). Retrieval contexts and the concreteness effect: Dissociations in memory for concrete and abstract words. *European Journal of Cognitive Psychology*, *17*(6), 859–881.

Thompson-Schill, S. L. (2003). Neuroimaging studies of semantic memory: Inferring "how" from "where". *Neuropsychologia*, *41*(3), 280–292.

Troche, J., Crutch, S., & Reilly, J. (2014). Clustering, hierarchical organization, and the topography of abstract and concrete nouns. *Frontiers in Psychology*, *5*, 360.

Tulving, E. (1983). Elements of episodic memory. Oxford, UK: Clarendon.

Tulving, E. (2002). Episodic memory: From mind to brain. *Annual Review of Psychology*, *53*(1), 1–25.

Vigliocco, G., Kousta, S. T., Della Rosa, P. A., Vinson, D. P., Tettamanti, M., Devlin, J. T., & Cappa, S. F. (2013). The neural representation of abstract words: The role of emotion. *Cerebral Cortex*, *24*(7), 1767–1777.

Vilberg, K. L., & Rugg, M. D. (2007). Dissociation of the neural correlates of recognition memory according to familiarity, recollection, and amount of recollected information. *Neuropsychologia*, *45*(10), 2216–2225.

Vilberg, K. L., & Rugg, M. D. (2009). Functional significance of retrieval-related activity in lateral parietal cortex: evidence from fMRI and ERPs. *Human Brain Mapping*, *30*(5), 1490–1501.

Wais, P. E., Squire, L. R., & Wixted, J. T. (2010). In search of recollection and familiarity signals in the hippocampus. *Journal of Cognitive Neuroscience*, *22*(1), 109–123.

Wagner, A. D., Paré-Blagoev, E. J., Clark, J., & Poldrack, R. A. (2001). Recovering meaning: Left prefrontal cortex guides controlled semantic retrieval. *Neuron*, *31*(2), 329–338.

Wang, J., Conder, J. A., Blitzer, D. N., & Shinkareva, S. V. (2010). Neural representation of abstract and concrete concepts: A meta-analysis of neuroimaging studies. *Human Brain Mapping*, *31*(10), 1459-1468.

Warrington, E. K. (1975). The selective impairment of semantic memory. *The Quarterly Journal of Experimental Psychology*, *27*(4), 635–657.

Warrington, E. K. (1981). Concrete word dyslexia. *British Journal of Psychology*, *72*(2), 175–196.

Warrington, E. K., & Shallice, T. (1984). Category specific semantic impairments. *Brain*, *107*(3), 829–853.

Wattenmaker, W. D., & Shoben, E. J. (1987). Context and the recallability of concrete and abstract sentences. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *13*(1), 140–150.

Wilding, E. L., & Rugg, M. D. (1996). An event-related potential study of recognition memory with and without retrieval of source. *Brain*, *119*(3), 889–905.

Wilson-Mendenhall, C. D., Simmons, W. K., Martin, A., & Barsalou, L. W. (2013). Contextual processing of abstract concepts reveals neural representations of nonlinguistic semantic content. *Journal of Cognitive Neuroscience*, *25*(6), 920–935.

Xiao, X., Zhao, D., Zhang, Q., & Guo, C. Y. (2012). Retrieval of concrete words involves more contextual information than abstract words: Multiple components for the concreteness effect. *Brain and Language*, *120*(3), 251–258.

Yee, E., & Thompson-Schill, S. L. (2016). Putting concepts into context. *Psychonomic bulletin & Review*, *23*(4), 1015–1027.

Yeh, W., & Barsalou, L. W. (2006). The situated nature of concepts. *The American Journal of Psychology*, *119*(3), 349–384.

Yonelinas, A. P. (2001). Components of episodic memory: the contribution of recollection and familiarity. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *356*(1413), 1363–1374.

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language*, *46*(3), 441–517.

Yu, S. S., Johnson, J. D., & Rugg, M. D. (2012). Hippocampal activity during recognition memory co-varies with the accuracy and confidence of source memory judgments. *Hippocampus*, *22*(6), 1429–1437.

Appendix 1

Table A1

Encoding Phase Target Stimulus Words

Target words							
Abstract				Concrete			
Word	Length	log^F	Conc	Word	Length	log^F	Conc
agnostic	8	2.94	2	axe	3	5.52	5
allegory	8	2.48	2.07	basketball	10	6.99	4.97
allusion	8	1.79	1.58	binoculars	10	4.38	5
ambience	8	3.61	1.72	blender	7	4.44	5
analysis	8	6.33	2.56	bottle	6	7.86	4.91
anomaly	7	4.14	1.79	brick	5	6.25	4.83
belief	6	5.96	1.19	camera	6	7.97	5
caveat	6	2.83	2	candle	6	6.01	4.86
chivalry	8	4.11	1.88	cello	5	4.55	4.96
comparison	10	5.23	2	chopsticks	10	4.53	5
concept	7	6.32	1.41	doorknob	8	4.45	4.97
culture	7	6.57	2.04	envelope	8	6.24	4.93
democracy	9	5.82	1.78	equipment	9	7.17	4.83
essence	7	5.66	1.66	figurine	8	2.64	4.86
esteem	6	4.45	1.83	flashlight	10	5.71	5
ethos	5	1.95	1.58	football	8	7.56	4.73
faith	5	7.77	1.63	fork	4	6.11	4.9
future	6	8.57	1.86	gavel	5	3.66	4.88
genre	5	3.99	2.37	gearshift	9	2.40	4.64
gimmick	7	4.01	2.34	glove	5	6.24	4.97
gist	4	4.03	1.81	hammer	6	6.46	4.77
hint	4	6.15	2.33	handsaw	7	1.61	5
innuendo	8	3.83	1.88	harmonica	9	4.49	4.9
jargon	6	3.43	2.07	hatchet	7	4.61	4.93
justice	7	7.55	1.45	hose	4	6.02	4.87
karma	5	5.17	1.93	jar	3	6.05	5
knowledge	9	7.17	1.73	javelin	7	3.18	4.9
logic	5	5.83	1.72	lantern	7	4.63	5
luck	4	8.97	1.33	linoleum	8	3.30	4.85
merit	5	5.15	1.66	lipstick	8	6.11	4.9
metaphor	8	5.29	1.94	mallet	6	3.56	4.93
morale	6	5.35	1.85	mandolin	8	3.18	4.76
motive	6	6.51	1.5	marble	6	5.58	4.85
nostalgia	9	3.66	1.83	mop	3	5.35	4.97
nuance	6	3.04	1.85	napkin	6	5.21	4.93
oblivion	8	4.62	1.37	paintbrush	10	3.30	4.79

paradigm	8	3.61	1.73	pencil	6	6.22	4.88
persona	7	4.33	2.33	pipe	4	6.90	4.88
precedent	9	4.84	1.63	pitchfork	9	3.56	5
prelude	7	3.40	2.33	plate	5	7.18	4.77
principle	9	5.98	1.7	railing	7	4.32	4.79
proxy	5	3.83	2.07	rope	4	7.05	4.93
purpose	7	7.49	1.52	saxophone	9	4.45	5
religion	8	6.56	1.71	scissors	8	5.83	4.85
retrospect	10	3.58	1.75	screwdriver	11	4.85	4.9
rhetoric	8	3.04	1.5	seatbelt	8	3.85	4.79
sarcasm	7	4.98	1.63	shovel	6	5.86	4.97
satire	6	3.50	1.96	spatula	7	4.03	4.96
skeptic	7	3.22	2.31	sponge	6	5.83	5
soul	4	8.28	1.86	spool	5	3.26	4.62
spirit	6	7.83	1.6	stapler	7	3.78	4.62
stigma	6	3.30	1.76	stethoscope	11	3.87	4.86
strategy	8	6.18	1.93	sword	5	7.20	4.93
synergy	7	3.43	1.48	telescope	9	5.01	5
tactic	6	4.37	2.1	thermometer	11	4.72	4.96
theory	6	7.29	1.47	thimble	7	2.64	5
verge	5	5.12	2.32	toothbrush	10	5.54	5
vibe	4	5.58	1.89	ukulele	7	3.37	4.62
virtue	6	5.57	1.62	umbrella	8	5.95	5
wisdom	6	6.34	1.53	wrench	6	5.31	4.93
Mean	**6.72**	**5.03**	**1.82**		**7.05**	**5.06**	**4.90**

Table A2

Non-Target Synonym Pairs

Abstract								Concrete							
Word	Length	log^F	Conc	Word	Length	log^F	Conc	Word	Length	log^F	Conc	Word	Length	log^F	Conc
affinity	8	*NA*	*NA*	rapport	7	3.47	1.84	antiperspirant	14	1.95	4.25	deodorant	9	4.41	5.00
ambition	8	5.61	1.74	aspiration	10	3.37	1.81	bomb	4	7.91	4.84	grenade	7	5.46	4.90
appeal	6	6.50	1.73	plea	4	5.86	2.39	bucket	6	6.23	4.96	pail	4	3.87	4.93
aspect	6	5.28	1.82	dimension	9	5.09	2.50	casket	6	5.09	4.86	coffin	6	6.13	4.86
atonement	9	2.89	1.44	penance	7	4.29	1.52	cauldron	8	3.18	4.61	pot	3	7.05	4.81
beginning	9	8.08	2.50	origin	6	5.42	2.03	cigarette	9	7.21	4.88	smoke	5	8.11	4.96
being	5	10.12	1.93	existence	9	6.39	1.54	coat	4	7.67	4.97	jacket	6	7.44	4.86
bliss	5	5.08	1.37	ecstasy	7	5.09	2.04	cork	4	4.98	4.86	plug	4	6.27	4.64
circumstance	12	4.65	1.77	situation	9	8.34	2.03	cup	3	7.88	5.00	mug	3	5.86	4.80
comfort	7	6.78	2.89	solace	6	4.36	2.04	duvet	5	2.48	4.85	quilt	5	3.66	5.00
default	7	3.93	2.00	standard	8	6.85	1.83	fiddle	6	5.22	4.81	violin	6	5.49	4.96
destiny	7	7.07	1.67	fate	4	7.23	1.53	handbag	7	4.90	4.93	purse	5	6.92	4.90
enlightenment	13	4.30	1.50	insight	7	4.96	1.72	handkerchief	12	5.37	5.00	tissue	6	6.30	4.93
epiphany	8	4.19	1.60	realization	11	3.99	1.54	luggage	7	6.34	4.83	suitcase	8	6.53	4.97
fault	5	7.23	2.41	flaw	4	5.04	2.86	magazine	8	7.43	5.00	periodical	10	2.20	3.47
fiction	7	5.74	2.14	story	5	9.33	3.30	needle	6	6.41	4.93	syringe	7	4.60	4.81
forecast	8	4.56	2.86	prediction	10	4.19	2.36	oar	3	3.74	4.84	paddle	6	5.25	4.80
instant	7	6.31	2.70	moment	6	9.16	1.61	platter	7	5.00	4.93	tray	4	6.02	4.74
peak	4	5.71	4.20	zenith	6	3.09	2.83	safe	4	8.90	3.41	vault	5	6.42	4.62
rationale	9	2.94	2.13	reason	6	9.20	1.93	sculpture	9	5.07	4.79	statue	6	6.29	4.93
Mean	-	-	-		**7.26**	**5.73**	**2.09**		-	-	-		**6.19**	**5.68**	**4.79**

Table A3

Recognition Phase Filler Words

Abstract				Concrete			
Word	Length	$\log^F$	Conc	Word	Length	$\log^F$	Conc
abstinence	10	3.81	1.72	album	5	6.26	4.69
accord	6	4.42	1.57	*anvil*	5	3.47	4.96
adage	5	3.47	1.86	ball	4	8.59	5.00
advocacy	8	2.71	2.00	balloon	7	6.09	4.92
allure	6	3.40	1.92	bandanna	8	3.04	5.00
altruism	8	2.40	1.50	barrel	6	6.30	4.86
analogy	7	4.06	1.61	*bassinet*	8	2.89	4.71
anonymous	9	6.06	2.03	battery	7	6.45	4.67
aptitude	8	4.01	1.54	booklet	7	3.33	4.72
austerity	9	1.61	1.38	*boot*	4	6.34	4.96
axiom	5	1.95	2.00	*bulb*	4	5.30	4.93
basis	5	6.41	1.83	*burlap*	6	2.40	4.78
bias	4	4.41	1.68	button	6	7.27	4.96
caution	7	5.57	2.04	cabinet	7	6.05	4.89
chance	6	9.42	1.64	canteen	7	4.47	4.88
charade	7	4.72	1.93	catalogue	9	4.68	4.36
charisma	8	3.91	2.07	*chandelier*	10	4.28	4.79
choice	6	8.51	1.90	charcoal	8	4.50	4.85
closure	7	5.06	1.78	cloak	5	5.03	4.71
coincidence	11	6.85	1.57	clock	5	8.00	5.00
conspiracy	10	6.27	1.76	*corduroy*	8	3.53	4.56
courage	7	7.10	1.52	*crayon*	6	3.04	4.87
courtesy	8	6.03	1.77	*cushion*	7	4.70	4.68
creed	5	4.86	2.10	diamond	7	6.96	4.89
dilemma	7	4.89	2.00	*diaper*	6	5.38	4.82
dogma	5	2.56	1.79	*dice*	4	6.28	4.86
epitome	7	3.09	1.80	drawer	6	6.50	4.67
ethic	5	3.97	1.59	electronics	11	4.93	4.37
fascism	7	3.66	1.83	feather	7	5.82	4.90
freewill	8	1.61	1.85	fence	5	6.71	4.82
function	8	6.34	1.92	frisbee	7	4.55	4.70
greed	5	5.50	1.53	*garage*	6	7.24	4.96
hiatus	6	3.00	2.07	*goblet*	6	2.94	4.65
idea	4	9.82	1.61	helmet	6	6.18	4.92
identity	8	6.50	2.00	*kaleidoscope*	12	2.71	4.79
ideology	8	3.50	1.62	kayak	5	3.26	4.70
intent	6	5.66	1.52	kettle	6	4.96	4.75
irony	5	5.45	1.59	knot	4	5.24	4.87

jinx	4	5.32	2.03	*latch*	5	4.58	4.79
legacy	6	5.55	1.40	leash	5	5.39	4.89
lenience	8	0.69	1.39	locket	6	4.47	4.82
liberty	7	6.74	1.85	machete	7	3.97	4.82
malice	6	4.09	1.72	magnet	6	4.94	4.70
mercy	5	7.16	1.57	*marble*	5	5.58	4.85
monogamy	8	3.83	1.70	*medal*	5	6.38	4.89
mortal	6	6.19	1.96	*menu*	4	6.23	4.67
norm	4	5.14	2.11	nickel	6	6.07	4.79
opinion	7	7.67	1.93	*oven*	4	6.12	4.97
ordeal	6	4.80	2.04	*parachute*	9	5.09	4.78
outlook	7	4.63	1.97	parcel	6	4.26	4.81
patience	8	6.66	1.66	*pebble*	6	4.17	4.86
peace	5	8.17	1.62	photograph	10	6.36	4.89
phenomenon	10	5.46	2.26	plastic	7	6.86	4.79
piety	5	3.37	1.56	poncho	6	3.78	4.97
plan	4	8.91	3.40	*pottery*	7	4.54	4.72
plight	6	4.14	2.04	razor	5	5.86	4.90
potential	9	6.87	1.91	ribbon	6	5.55	4.89
prestige	8	4.25	1.61	*sash*	4	4.06	4.67
priority	8	6.25	1.76	scalpel	7	5.08	4.86
privilege	9	6.30	1.93	*scarf*	5	5.48	4.97
prophecy	8	5.77	1.93	shield	6	6.04	4.66
protocol	8	5.95	1.97	*shingle*	7	3.64	4.82
psyche	6	4.94	1.34	*sickle*	6	3.33	4.88
quantum	7	5.65	1.90	silk	4	6.21	4.70
reform	6	5.21	2.00	*spear*	5	5.45	5.00
respect	7	8.20	2.04	splint	6	3.78	4.69
revenge	7	6.88	1.54	stairs	6	7.10	5.00
risk	4	7.82	1.63	*stethoscope*	11	3.87	4.86
ruse	4	4.44	1.57	tablet	6	4.33	4.82
simile	6	2.56	2.04	*thread*	6	5.57	4.83
solitude	8	4.62	2.07	*ticket*	6	7.75	4.70
symbol	6	6.08	3.11	trampoline	10	3.53	5.00
taboo	5	1.67	4.13	*trident*	7	3.18	4.50
tangent	7	2.94	2.08	tripod	6	3.83	4.72
tradition	9	6.55	1.69	trophy	6	5.95	4.89
utopia	6	4.04	1.71	vessel	6	6.17	4.66
valor	5	4.16	1.85	visor	5	3.40	4.66
value	5	7.00	1.62	wallet	6	7.06	4.81
variance	8	2.94	1.84	wire	4	7.25	4.72
vendetta	8	4.13	2.08	wool	4	5.08	4.86

Mean	**6.73**	**5.12**	**1.83**		**6.19**	**5.19**	**4.77**

Note. Words in italics only used in Experiment 1. Norms derived from Brysbaert et al. (2014).