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Mechanisms of word concreteness effects in explicit memory: Does context availability play a role?

Randolph S. Taylor[1] · Wendy S. Francis[1] · Lara Borunda-Vazquez[1] · Jacqueline Carbajal[1]

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Abstract
One explanation for why concrete words are recalled better than abstract words is systematic differences across these word types in the availability of context information. In contrast, explanations for the concrete-word advantage in recognition memory do not consider a possible role for context availability. We investigated the extent to which context availability can explain the effects of word concreteness in both free recall (Exp. 1) and item recognition (Exp. 2) by presenting each target word in isolation, in a low-constraint sentence context, or in a high-constraint sentence context at study. Concreteness effects were consistent with those from previous research, with concrete-word advantages in both tasks. Embedding words in sentence contexts with low semantic constraint hurt recall performance but helped recognition performance, relative to presenting words in isolation. Embedding words in sentence contexts with high semantic constraint hurt both recall and recognition performance, relative to words in low-constraint sentences. The effects of concreteness and semantic constraint were consistent for both high- and low-frequency words. Embedding words in high-constraint sentence contexts neither reduced nor eliminated the concreteness effect in recall or recognition, indicating that differences in context availability cannot explain concreteness effects in explicit memory.

Keywords Free recall · Recognition · Concreteness · Word frequency · Context availability

Verbal memory performance is known to vary as a function of the semantic and lexical properties of the words to be remembered. Word concreteness has marked effects on explicit memory tasks, including free recall and recognition (e.g., Balota & Neely, 1980; Glanzer & Adams, 1985; Holmes & Langford, 1976), but there is no consensus as to the mechanisms underlying these effects. In the present study we examined whether context availability contributes to the effects of word concreteness in explicit memory. Specifically, we examined whether context manipulations at encoding moderate the effects of concreteness on free recall and item recognition performance. We also examined the impact of these encoding contexts and semantic constraint on explicit memory for words.

✉ Randolph S. Taylor
rstaylor506@gmail.com

[1] University of Texas, El Paso, TX, USA

Word concreteness effects in explicit memory

The concreteness of a word is the extent to which its referent can be experienced by the senses (Walker & Hulme, 1999). For example, a concrete word like *house* represents a tangible object, whereas an abstract word like *truth* represents an intangible quality or state of being. Concrete words also more readily invoke familiar mental images than do abstract words. In the present study, we focused on the effects of concreteness, as defined by concreteness ratings from published sources.

The general finding that concrete words have an advantage over abstract words is known as the *concreteness effect*. This finding has been reported in memory tasks including free, serial, and cued recall (e.g., Holmes & Langford, 1976; Richardson, 2003; Romani, McAlpine, & Martin, 2008; Walker & Hulme, 1999) and recognition (e.g., Glanzer & Adams, 1985; Glanzer, Adams, Iverson, & Kim, 1993; Hirshman & Arndt, 1997), as well as in lexical processing tasks (e.g., Schwanenflugel, Harnishfeger, & Stowe, 1988; van Hell & de Groot, 1998, 2008). However, the mechanisms and processes that underlie this advantage remain a subject of debate.

One of the most well-known explanations of the concreteness effect is *dual-coding theory* (for a review, see Paivio, 1991). This account details two processing systems, a verbal system and an image system. Under this theory, it is assumed that concrete words are processed in both systems, whereas abstract words are processed only in the verbal system. As a result of being processed in two systems, and thus having two possible retrieval routes, concrete words are retrieved more easily than abstract words. One challenge to this model was that it could not explain why the concreteness effect was eliminated when stimuli were embedded within contextually rich materials (Wattenmaker & Shoben, 1987). Specifically, concrete target sentences were recalled better than abstract sentences when they were presented in random orders; however, when sentences were placed in a coherent paragraph format, there was no difference in the recall of concrete and abstract sentences.

This limitation of dual-coding theory was the impetus for the development of the *context availability* framework (Kieras, 1978; Schwanenflugel, Akin, & Luh, 1992; Schwanenflugel et al., 1988; Schwanenflugel & Shoben, 1983; van Hell & de Groot, 1998, 2008). This account posits that comprehension is aided by access to contextual information, such as environmental information, semantic information, or content that serves to provide detail and specify the meaning of the word or the situation in which it is encountered. Episodic contexts are encoded along with the word itself. Benefits of context can come from accessing prior exposure contexts or processing a new context (Schwanenflugel et al., 1988). When it becomes easy to access the features of an episodic context, the word has high *context availability.*

Under the context availability account, the concrete advantage in lexical processing and memory arises due to differential availability of contextual information for concrete and abstract words. Indeed, rated concreteness and rated context availability are highly correlated (de Groot, Dannenburg, & van Hell, 1994). One possible reason for this relationship is that abstract words (of comparable frequency) are associated with more different episodic contexts than are concrete words (Schwanenflugel & Shoben, 1983). Because the associations of abstract words are divided across more contexts, these associations are generally weaker than the associations of concrete words. It is therefore more difficult to access contextual information for abstract than for concrete words. For example, a concrete word such as *microscope* appears almost exclusively in a scientific context, so this association is strong. However, an abstract word such as *boredom* is associated with a variety of contexts (e.g., waiting in line at the department of motor vehicles, in class listening to a monotonous professor, being stuck in traffic, being forced to watch golf on TV, etc.), so each individual contextual association is weaker. This difficulty in accessing the contexts associated with abstract words leads to lexical processing and memory advantages for concrete words.

Evidence for the context availability account

The reasoning of the context availability account has been supported by findings showing that the concreteness effect is reduced or eliminated when concrete and abstract words have equal access to contextual information. Two approaches have been used to equalize access to contextual information and to test the context availability effect. One approach was to control for participant-rated context availability across word types. Context availability ratings of concrete and abstract words were obtained by asking participants to rate, on a Likert scale, the ease with which they could think of a context or circumstance in which the words would be used (e.g., Schwanenflugel et al., 1988). Matching concrete and abstract words on context availability eliminated concreteness effects in lexical processing tasks (Schwanenflugel et al., 1988; van Hell & de Groot, 1998). However, in free recall, matching context availability for concrete and abstract words produced mixed results. In one experiment with intentional learning as the encoding task, controlling for context availability did not eliminate the advantage for concrete words (Schwanenflugel et al., 1992). However, in a second experiment, controlling for context availability eliminated the concreteness effect only when the encoding task was to judge the context availability of each word. With intentional-learning or imagery instructions, the concrete advantage remained.

The second approach to reducing context availability differences across concrete and abstract words has been to embed the words in the context of sentences or paragraphs. Providing such contexts impacts both lexical processing and memory, and performance varies with the degree of semantic constraint provided by the sentence. *Semantic constraint* can be thought of as the degree to which a sentence biases processing toward a particular target word. High-constraint sentence frames lead to high predictability and a high probability that a reader will complete the sentence with the intended target word. For example, the sentence *He got the leash and collar to take a walk with his* ________. is highly constraining toward the target *dog.* On the other hand, the sentence *The woman needed to go to the store to buy some more* _________. is low-constraint, because many potential targets could fit with that frame. Semantic constraint in a sentence generates a set of semantic features that increases activation of the target or reduces competition by decreasing activation of competitors, thus facilitating identification and comprehension of the target word (e.g., Griffin & Bock, 1998; Schwanenflugel & LaCount, 1988; Schwanenflugel & Shoben, 1985). Manipulations of semantic constraint serve as a method to increase priming and/or reduce lexical competition in lexical processing. Embedding target words in a sentence context rather then presenting them in isolation speeds both comprehension and production, and this effect is stronger with a semantically constraining sentence context than with a neutral or incongruent context (e.g., Balota, Pollatsek, & Rayner, 1985; Forster, 1981; Gollan et al., 2011; Griffin & Bock, 1998; Rayner, Ashby, Pollatsek, & Reichle, 2004).

Embedding words within a sentence context also impacts explicit memory performance, but the impact of semantic constraint is less clear. Nouns presented in sentence contexts were recalled less well than nouns presented in isolation (Cofer, 1968; Wood, 1970). In a study in which the encoding task was to judge whether target words at the end of sentences made sense in their sentence contexts, target words were recalled better when they were presented in high-constraint sentences than when presented in low-constraint sentences (McFalls & Schwanenflugel, 2002). In recognition, studying words in sentence contexts diminished performance relative to studying words presented in isolation (Schwartz, 1975). Embedding high-frequency words in the context of the experiment instructions, an incidental encoding task, reduced recognition relative to isolated presentation, but low-frequency words were recognized equally well after contextualized or isolated presentation (Coane & Balota, 2010). We could find no studies that have examined the effects of semantic constraint on later recognition of target words. Thus, with only one study of semantic constraint effects on recall, and no studies of its effects on recognition, little is known about how semantic constraint impacts explicit memory.

Providing sentence or paragraph contexts, particularly contexts with high semantic constraint, reduced or eliminated concreteness effects in lexical processing tasks (Schwanenflugel & Shoben, 1983; van Hell & de Groot, 2008). For concrete words, prior contexts are easily accessed, so the current (experimental) context does not increment accessibility as much as it does for abstract words, for which it is more difficult to access a prior context (Schwanenflugel et al., 1988). Providing a sentence context just before the target word makes it easier to access an appropriate context. The disadvantage for abstract words is reduced or eliminated, because it becomes easy to access contextual information for both concrete and abstract words. For either word type, there is the option simply to access the sentence context that is still in working memory. The availability of a current experimental context provides a mechanism for closing the accessibility gap between abstract and concrete words. For the same reason, when this context is more specific and salient, as in high-constraint sentences, the benefit will be greater for abstract than for concrete words, closing the accessibility gap. It is unknown whether this differential facilitation carries over into the encoding and/or retrieval processes of explicit memory.

The concreteness effect persists in free recall for concrete and abstract sentences. In one study, sentences containing concrete nouns, such as *Adult elephants are protected by strong skins*, were recalled better than sentences containing abstract nouns, such as *Large companies are regulated by strict rules*. Not only did participants recall fewer abstract sentences, but they also recalled fewer specific words from abstract sentences (Holmes & Langford, 1976). In another study of sentence recall, when concrete and abstract sentences were organized in a random order, a concrete advantage emerged, but when sentences were presented in a coherent paragraph context, abstract and concrete sentences were recalled equally well (Marschark, 1985; Wattenmaker & Shoben, 1987). One possible explanation for these results is that although constraint levels were neither manipulated nor controlled, a coherent paragraph context provided the constraint necessary to equate context availability for concrete and abstract sentences, and thereby eliminate the concreteness effect. Because semantic constraint was not manipulated at the sentence or paragraph level, and because the focus was on recalling entire sentences rather than individual concrete or abstract words, these studies provide only limited evidence for the role of context availability in the concreteness effect in explicit memory.

The present study

The primary motivation of the present study was to test whether the context availability hypothesis of the concreteness effect can be appropriately extended to explicit memory. Although the context availability hypothesis has considerable support in lexical processing, its support in explicit memory is mixed and limited. When preexperimental context availability was matched for concrete and abstract words, the only condition that eliminated the concreteness effect was when the encoding task was to judge context availability itself (Schwanenflugel, et al., 1992). The only studies of how sentence context manipulations would impact the concreteness effect have used paragraph-level manipulations with concrete and abstract sentences (Marschark, 1985; Wattenmaker & Shoben, 1987). These studies did not include manipulations of sentence constraint, which proved important for tests of the context availability hypothesis in lexical processing. Therefore, it remains unknown whether studying words in high-constraint sentences would reduce the concreteness effect in the recall of individual target words. Experiment 1 tested the context availability hypothesis by examining the effects of concreteness in the recall of individual words that were studied in isolation, in low-constraint sentences, or in high-constraint sentences.

Because concreteness effects extend to recognition memory, and because there have been no previous tests of the context availability hypothesis as an explanation for concreteness effects in recognition memory, we wanted to perform this test.

Experiment 2 tested the context availability hypothesis by examining the effects of concreteness in the recognition of words that were studied in isolation, in low-constraint sentences, or in high-constraint sentences. Under the context availability hypothesis, providing a context, particularly a high-constraint context, would disproportionately increase context availability for abstract words, thus closing the context availability gap between concrete and abstract words,. Closing this gap by providing a sentence context, particularly a high-constraint sentence context, would in turn reduce or eliminate the concreteness effect typically observed for isolated words in recognition memory.

A second motivation of the study was to extend previous research on the effects of semantic constraint on explicit memory performance. Although a small number of studies have shown that embedding words in a sentence context hurts both recall and recognition performance, a number of processing differences between isolated words and sentences, other than context differences, could potentially explain these effects. A more interesting question is whether semantic constraint impacts memory for words embedded in sentence contexts.

The only study to make such a comparison showed better free recall performance for target words at the end of high-constraint sentences than for target words at the end of low-constraint sentences (McFalls & Schwanenflugel, 2002). We contend that this result does not provide a definitive answer to this question, for two reasons. First, their encoding task was to judge whether each target word made sense in its sentence context, which drew the focus of attention to the sentence context, and therefore to the constraint manipulation, because the words would clearly make more sense in the high-constraint than in the low-constraint contexts. Second, the congruent sentences in which the target words made sense were mixed with incongruent sentences in which the target words did not make sense, and this mixture could have changed how the congruent sentences were processed. In Experiment 1 we make this comparison in free recall using a more neutral encoding task—simply reading the sentences aloud and attempting to commit the final target words to memory—and using only sentences in which the target words made sense. Whereas recall is thought to depend to a great degree on inter-item processing, recognition is thought to depend more on intra-item processing (e.g., Hunt & Einstein, 1981). Because semantic constraint seemed likely to alter the balance of inter-item (between-sentence) and intra-item (within-sentence) processing, we thought it would be informative to know whether the effects of semantic constraint on recall and recognition are the same or different. We therefore examined the effects of semantic constraint on recognition memory for the first time in Experiment 2.

Although it was not the primary focus of the study, we included a word frequency manipulation for three reasons. First, in the only prior study of context effects in recognition memory, context hurt the recognition of high-frequency but not of low-frequency words (Coane & Balota, 2010). This means that it was important to consider whether any context effects found in the present study also interacted with word frequency, and whether the effects would generalize across words of different frequency levels. Second, semantic constraint is known to reduce word frequency effects in word production tasks (Gollan et al., 2011; Griffin & Bock, 1998), but not in comprehension tasks (e.g., Balota et al., 1985; Forster, 1981; Gollan et al., 2011; Rayner et al., 2004). If we consider the encoding task to be a comprehension task, recall to be a production task, and recognition to be a comprehension task, this pattern of effects suggests that semantic constraint would reduce the frequency effect in recall but not in recognition. If word frequency and semantic constraint indeed interact for recall but not recognition, the implication would be that semantic constraint impacts not only how words are encoded but also how words are retrieved. On the other hand, if word frequency and semantic constraint do not interact for either test task, the implication would be that semantic constraint impacts encoding but not retrieval. Third, the effects of word frequency on recall and recognition go in opposite directions, with high-frequency words being recalled better and low-frequency words being recognized better (e.g., Balota & Neely, 1980; Kinsbourne & George, 1974; MacLeod & Kampe, 1996; Mandler, Goodman, & Wilkes-Gibbs, 1982). These three reasons make it interesting to include a word frequency manipulation to enable tests of its possible interactions with context and constraint, how well any effects of context and constraint generalize across more and less familiar words, and how these effects might differ across recall and recognition tasks.

Thus, the goals of the study were to (1) test the context availability hypothesis of the concreteness effect in explicit memory, (2) examine the effects of semantic constraint in explicit memory, and (3) find out whether the effects of context in explicit memory depend on word frequency. These goals were addressed in two experiments that included manipulations of context (isolated words, low-constraint sentences, or high-constraint sentences), concreteness, and word frequency. In each experiment, the study task was to read words or sentences aloud and to attempt to commit the target words to memory. The test task was free recall in Experiment 1 and item recognition in Experiment 2.

Experiment 1

In Experiment 1 we examined the effects of word concreteness, word frequency, and sentence constraint in a free recall task. Previous work had shown that controlling for participant-rated context availability can reduce the concreteness effect in recall tasks, and providing participants with sentences to serve as context can reduce the concreteness effect in lexical processing. Thus, the primary goal of Experiment 1 was to determine whether studying words in high-constraint sentence contexts would reduce the concreteness effect in free recall of individual target words. It was hypothesized that the concreteness effect would be reduced or eliminated in the high-constraint condition, as previously reported for lexical processing tasks (van Hell & de Groot, 2008), but remain in the low-constraint conditions, as in previous research with lexical processing tasks (van Hell & de Groot, 2008) and free recall (Holmes & Langford, 1976; Marschark, 1985; Wattenmaker & Shoben, 1987), thereby supporting the context availability account. A second goal was to test the effects of semantic constraint on free recall with a protocol that included only congruent sentences and that featured an encoding task, reading aloud, that would not draw attention to the constraint manipulation.

Method

Power and sample size We wanted to have 80% power to detect an effect of small to medium size (f = .175), which would require 67 participants. Because complete counterbalancing of the assignment of items to contexts and presentation orders required a multiple of 36 participants, 72 participants were recruited.

Participants The participants were 72 students (45 women, 27 men) from the University of Texas at El Paso, with a median age of 20 years (SD = 4.1). Participants were recruited from psychology courses and earned their choice of credit toward a course research requirement or $10. All were proficient speakers of English. Two additional volunteers began the protocol but wished to end the session before it was complete; these individuals had to be replaced because their data were incomplete.

Design The experimental conditions formed a 2 (concreteness) × 2 (frequency) × 3 (study context) within-subjects design. The concreteness factor divided stimuli into concrete and abstract words, and the frequency factor divided stimuli into high- and low-frequency words. The context factor included words presented in isolation, words presented in low-constraint sentence frames, and words presented in high-constraint sentence frames. The dependent variable was recall proportion.

Materials The stimuli were selected from three published sources (Altarriba, Bauer, & Benvenuto, 1999; Miller & Roodenrys, 2009; Tokowicz & Kroll, 2007) in which normed abstract and concrete words were provided. Word frequency information for the stimuli was obtained using CELEX (Baayen, Piepenbrock, & Gulikers, 1995). For items to be included as low-frequency words, the reported occurrence per million had to be no greater than 40. To be included as a high-frequency word, the item needed to have a reported occurrence per million of at least 70. The median word frequencies for each stimulus category are provided in Table 1.

High- and low-constraint sentence frames were developed and pilot tested using a cloze procedure (see Griffin & Bock, 1998). Each high-constraint sentence frame was written to make the target word highly predictable. Low-constraint sentence frames were written to avoid biasing predictions toward any particular word and to make the target words plausible but not predictable. It should be noted that the low-constraint sentences were not devoid of content or meaning, as in some previous studies (e.g., Griffin & Bock, 1998)—they were simply less restrictive than high-constraint sentences in their range of plausible completions. The target words were always presented as the last word of the sentence and in all capital letters. Thirty-two pilot participants drawn from the same population as the experimental sample read sentence frames from which the final word had been omitted, and they were asked to type in the word that they thought would end the sentence. For high-constraint sentences, the 36 sentences of each word type with the highest proportion of expected responses were selected, along with low-constraint sentences matched as closely as possible on target frequency. Table 1 shows the mean proportions of times that participants responded with the intended target word for high-constraint and low-constraint sentences ending with target words of each type, and Table 2 shows examples of the sentences for each word type and constraint level.

The final stimulus set included 144 target words (36 words for each stimulus category) that were randomly distributed across 12 lists (three lists for each stimulus category) of 12 targets each. The assignment of lists to study context conditions was counterbalanced across participants using a Latin square.

Apparatus The stimuli were presented on a Macintosh computer, and the experiment was programmed using PsyScope X software (Cohen, MacWhinney, Flatt, & Provost, 1993a). The

Table 1 Median frequencies of target words and mean cloze probabilities for the stimulus sentences

	Concrete Words		Abstract Words	
Item Property	HF	LF	HF	LF
Word frequency[a]	156	21	158	25
High-constraint cloze	.90	.82	.86	.75
Low-constraint cloze	.04	.02	.03	.05

HF = high frequency; LF = low frequency. [a] Frequency per million from CELEX (Baayen et al., 1995)

Table 2 Examples of sentences of each type used in Experiments 1 and 2

Target Concreteness	Sentence Type	
Target Frequency	High Constraint	Low Constraint
Concrete Target		
High frequency	The new kids in town were nervous for their first day of SCHOOL.	The photographer took a picture of the SCHOOL.
Low frequency	During the national anthem the soldiers saluted the country's FLAG.	From where she was sitting she couldn't see the FLAG.
Abstract Target		
High frequency	As soon as they saw each other the couple fell in LOVE.	The painter said her biggest inspiration is LOVE.
Low frequency	The young boy wouldn't listen to anyone because he was so STUBBORN.	Everyone knew the woman was very STUBBORN.

participant recall responses were recorded for later transcription using a Sony IC voice recorder.

Procedure Participants were tested individually in sessions lasting approximately 45 min. After English proficiency screening, the participants completed brief language and demographic background questionnaires. For the main experiment, participants sat in front of a computer in a small experiment room. The experimenter explained that the participant's responses would be recorded for the purposes of later transcription.

Participants then completed 12 study–test cycles in which they were first presented a sequence of 12 words or sentences one at a time, and after the 12th item, they were asked to recall as many of the target words as they could remember. They were instructed to read each target word or sentence out loud and to commit the target words to memory. The target word was always the final word of the sentence and appeared in all capital letters. Once the participant had read the word or sentence aloud, he or she pressed a button to advance to the next item, which would appear after 500 ms; thus, the presentations were self-paced. The reason for this self-paced study was twofold. First, different participants have different reading rates, and we wanted to make sure they all had time to read aloud every sentence. Second, although this aspect of the procedure made the effective presentation rates different for the isolated and sentence encoding conditions, the primary reason for more accurate memory with slower presentation rates is increased rehearsal (Bhatarah, Ward, Smith, & Hayes, 2009). In the sentence conditions, the time between presentations of the target words was filled with reading the sentences aloud, thus limiting rehearsal, so we did not want participants to have long gaps between words in the isolated conditions that would give them time for many more rehearsals than in the sentence conditions. The study–test cycles were blocked by context and stimulus category, such that there were four cycles for each context condition (one for each stimulus category). The orders of the context conditions and stimulus types were counterbalanced across participants.

Results

Recall proportions (see Fig. 1) were calculated in each condition for each participant. These values were submitted to a 2 (concreteness) × 2 (frequency) × 3 (study context) repeated measures analysis of variance (ANOVA). More high-frequency words were recalled than low-frequency words, $F(1, 71) = 11.21$, $MSE = .017$, $p = .001$, $\eta_p^2 = .14$, and more concrete words were recalled than abstract words, $F(1, 71) = 120.83$, $MSE = .011$, $p < .001$, $\eta_p^2 = .63$. We found a significant interaction of frequency and concreteness, $F(1, 71) = 12.57$, $MSE = .010$, $p = .001$, $\eta_p^2 = .15$, indicating that the concreteness effect was larger for high-frequency than for low-frequency words.

There was a significant main effect of study context, $F(2, 142) = 35.68$, $MSE = .015$, $p < .001$, $\eta_p^2 = .33$. Planned comparisons (pairwise contrasts on the main effect) showed that targets presented in isolation were recalled more than were the targets in either low-constraint sentences, $F(1, 71) = 29.53$, $MSE = .007$, $p < .001$, $\eta_p^2 = .45$, or high-constraint sentences, $F(1, 71) = 57.11$, $MSE = .009$, $p < .001$, $\eta_p^2 = .29$. Targets in low-constraint sentences were also recalled more than targets in high-constraint sentences, $F(1, 71) = 10.98$, $MSE = .006$, $p = .001$, $\eta_p^2 = .13$. Study context did not interact with either frequency, $F(2, 142) = 2.64$, $MSE = .015$, $p = .075$, $\eta_p^2 = .04$, or concreteness, $F < 1$, $\eta_p^2 < .01$. However, the three-way interaction of frequency, concreteness, and context was significant, $F(2, 142) = 4.07$, $MSE = .012$, $p = .019$, $\eta_p^2 = .05$. Breaking this effect into simple interactions showed that for low-frequency words, the effect of concreteness was larger for words studied in isolation than for words studied in high-constraint sentences, $F(1, 71) = 5.32$, $MSE = .027$, $p = .024$, $\eta_p^2 = .07$, but for high-frequency words, this interaction was not reliable, $F(1, 71) = 2.68$, $MSE = .021$, $p = .106$, $\eta_p^2 = .04$. For low-frequency words, tests of simple effects showed that

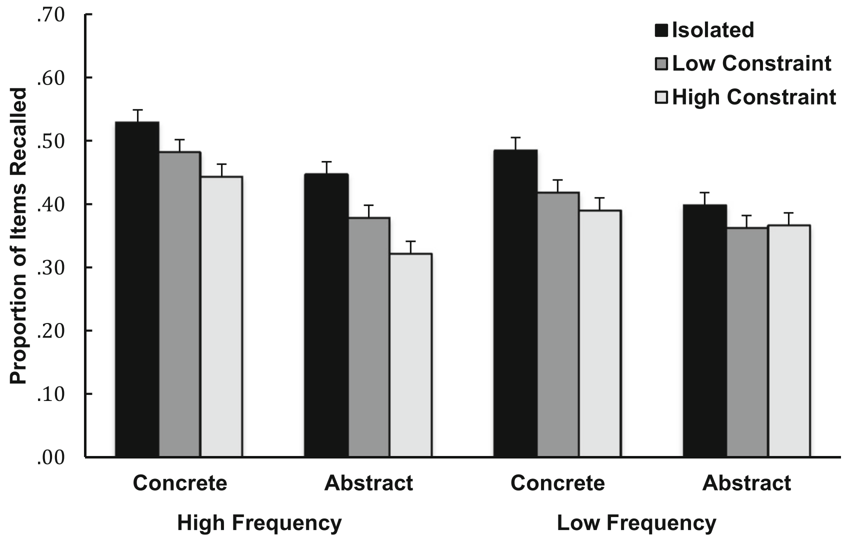

Fig. 1 Recall scores in Experiment 1 as a function of concreteness, word frequency, and encoding context. Error bars represent standard errors of the means

the concreteness effect was significant for isolated words, $F(1, 71) = 20.12$, $MSE = .013$, $p < .001$, $\eta_p^2 = .22$, and words in low-constraint sentences, $F(1, 71) = 11.61$, $MSE = .010$, $p = .001$, $\eta_p^2 = .14$, but not for words in high-constraint sentences, $F(1, 71) = 2.06$, $MSE = .010$, $p = .156$, $\eta_p^2 = .03$.

Discussion

As expected, recall proportions were higher for concrete than for abstract words, demonstrating the typical concreteness effect. Isolated words were recalled better than words presented in the context of sentences, consistent with the findings from prior research (Cofer, 1968; Wood, 1970). Words from high-constraint sentences were *less* likely to be recalled than words from low-constraint sentences. This result stands in contrast to the results of the only previous study to have examined the effect of semantic constraint at study on free recall performance. In that study, words from high-constraint sentences were *more* likely to be recalled than words from low-constraint sentences (McFalls & Schwanenflugel, 2002).

Important methodological differences between the McFalls and Schwanenflugel (2002) study and Experiment 1 likely explain the different results obtained. First, and most importantly, the encoding tasks differed across studies. In the previous study, participants made semantic decisions about whether the target words made sense in the sentence context, so semantic processing of the target words and semantic integration of the target words with the sentences were essential parts of the encoding task and would provide additional retrieval routes. These processes would likely be enhanced for the high-constraint sentences, giving words in high-constraint sentences more possible retrieval routes than words in low-constraint sentences. In contrast, the participants in Experiment 1 simply read the sentences aloud and attempted to commit the target words to memory, and there was little basis to expect greater semantic processing of the target words in high-constraint sentences. Second, in the previous study congruent high-and low-constraint sentences in which the target words made sense were mixed with incongruent sentences in which the target words did not make sense, whereas in the present study, only congruent sentences were included.

Three other methodological differences are important to mention, although they seem less likely to explain the discrepancy in findings. There was a marked difference in the level of constraint that defined the low-constraint conditions. The prior study had reported the mean cloze percentage for low-constraint sentences as being 38% (McFalls & Schwanenflugel, 2002), which is much higher than the rate of approximately 4% in Experiment 1. Previous studies that have examined the effects of sentence constraint on lexical processing provide support for operationalizing low constraint at this lower level (e.g., Fischler & Bloom, 1979; Griffin & Bock, 1998; van Hell & de Groot, 2008). Because there was no overlap in the ranges of cloze probabilities for the "low-constraint" item sets used in the two studies, the results are not necessarily contradictory. Second, the mean frequency of the target words in the previous study was comparable to the mean frequency of the low-frequency word set in the present study. Third, in the previous study all items were studied in one block and recalled in a second block, whereas the present study divided items into 12 study–test cycles of 12 words each and did not mix constraint levels within the cycles. Therefore, although Experiment 1 utilized a larger stimulus set, each study–test block was based on about half as many trials as in the previous study.

The two-way interaction of concreteness and context was not reliable, as might be expected under the context availability account. However, a significant three-way interaction of frequency, concreteness, and context revealed that for low-frequency words (but not for high-frequency words) there was a significant interaction component for concreteness and context. Specifically, for low-frequency words, the concreteness effect was larger for isolated words than for words presented in high-constraint sentences, where the effect was eliminated. The reduction/elimination of the concreteness effect in the high-constraint condition, though limited to low-frequency words, is consistent with the context availability hypothesis. However, under the context availability hypothesis we would expect this effect to extend to high-frequency words as well as to the comparison between the low-constraint and high-constraint sentence conditions. Therefore, taken together, the results of Experiment 1 do not support the context availability hypothesis of the concreteness effect.

High-frequency words were recalled better than low-frequency words, replicating the typical high-frequency recall advantage, but the effect of word frequency did not interact with the context conditions. However, as we mentioned above, the interaction of concreteness and context was present for low-frequency but not for high-frequency words.

Experiment 2

In Experiment 2 we examined the same factors as in Experiment 1 using the same set of word and sentence stimuli, but with item recognition as the test task. The major goal of Experiment 2 was to examine whether the impact of context availability on the manifestation of the concreteness effect would extend to item recognition. It was hypothesized that, in accordance with the context availability account, the concreteness effect would be reduced or eliminated in the high-constraint condition relative to the isolated and low-constraint conditions. A second goal was to test for the first time how semantic constraint at encoding might impact recognition memory performance.

Method

Power and sample size We wanted to have 80% power to detect an effect of small to medium size (f = .175), which would require 67 participants. Because complete counterbalancing of the assignment of items to the contexts and presentation orders required a multiple of 48 participants, 96 participants were recruited.

Participants The participants were 96 students (56 women, 40 men) from the University of Texas at El Paso, with a median age of 22.5 years (SD = 5.7). Participants were recruited from psychology courses and earned their choice of credit toward a course research requirement or $10. All were proficient speakers of English. Two additional volunteers who completed the protocol were excluded for failure to follow the test instructions and were replaced to preserve counterbalancing. Ten additional volunteers (not included in participant count above) were screened out for low English proficiency and did not complete the memory protocol.

Design The experimental conditions formed a 2 (concreteness) × 2 (frequency) × 4 (study context) within-subjects design. The concreteness factor divided stimuli into concrete and abstract words, and the frequency factor divided stimuli into high- and low-frequency words. The context factor included words presented in isolation, words presented in low-constraint sentence frames, words presented in high-constraint sentence frames, and words not presented at study. The dependent variables included hit rates, false-alarm rates, and d'.

Materials Experiment 2 utilized the same stimulus set as had Experiment 1. Thus, there were 36 high-frequency concrete words, 36 high-frequency abstract words, 36 low-frequency concrete words, and 36 low-frequency abstract words. The recognition task required withholding some items at study to serve as foils at test. Thus, the 36 target words of each type were randomly assigned to four sets of nine targets each. These sets were rotated through the isolated, low-constraint, high-constraint, and not-studied (foil) conditions across participants using a Latin square. Experiment 2 also utilized the same demographic and language background questionnaire as had Experiment 1.

Apparatus The stimuli were presented on a Macintosh computer, and the experiment was programmed using PsyScope X software (Cohen, MacWhinney, Flatt, & Provost, 1993b). Responses were recorded using an ioLab Systems button box.

Procedure Participants were tested individually in sessions lasting approximately 45 min. After English proficiency screening, the participants completed language and demographic background questionnaires. For the main experiment, participants sat in front of a computer and button box in a small experiment room. At study, they completed three blocks of 36 trials for each context condition (isolated, low constraint, or high constraint). Within each context block, presentations were blocked by word type. The orders of blocks and target word types within blocks were counterbalanced across participants. Participants were asked to read each stimulus word or sentence aloud and to try to commit the target words to memory. The target word was always the final word of the sentence and appeared in all capital letters. After reading each word or sentence, the participant pressed a button to advance to the next item, which would appear after 500 ms.

Immediately after the study trials were completed, instructions were given for the test trials. At test, participants were administered a yes/no recognition task. The test trials consisted of two blocks of 72 trials in which all target words were presented, including those that had not been presented at study. Of the 144 trials, 108 of the items were studied, and 36 items were new. Participants were instructed to press one of two buttons on the button box to indicate whether or not they recognized each word from the study phase.

Results

Discrimination Hit rates and false-alarm rates (given in Table 3) were used to calculate the detection parameter d' in each condition for each participant using the equal-variance model. Values of d' (given in Fig. 2) were then analyzed using a 2 (concreteness) × 2 (frequency) × 3 (study context) repeated measures ANOVA. A significant effect of frequency indicated that low-frequency words were recognized more accurately than high-frequency words, $F(1, 95) = 22.82$, $MSE = .858$, $p < .001$, $\eta_p^2 = .19$. A significant effect of concreteness revealed that concrete words were discriminated better than abstract words, $F(1, 95) = 4.01$, $MSE = .850$, $p = .048$, $\eta_p^2 = .04$. The effects of frequency and concreteness did not interact, $F < 1$, $\eta_p^2 < .01$.

We observed a main effect of context, $F(2, 190) = 5.12$, $MSE = .419$, $p = .007$, $\eta_p^2 = .05$. Planned comparisons (simple contrasts on the main effect) showed that the targets in low-constraint sentences were recognized better than either targets in isolation, $F(1, 95) = 8.22$, $MSE = .231$, $p = .005$, $\eta_p^2 = .08$, or targets in high-constraint sentences, $F(1, 95) = 8.58$, $MSE = .146$, $p = .004$, $\eta_p^2 = .08$. Although the full interaction of context and frequency did not reach significance, $F(2, 190) = 2.86$, $MSE = .301$, $p = .06$, $\eta_p^2 = .03$, simple interactions revealed that the low-frequency advantage for high-constraint sentences was larger than for words studied in isolation, $F(1, 95) = 4.53$, $MSE = .759$, $p = .036$, but not larger than the low-frequency advantage for words studied in low-constraint sentences, $F(1, 95) = 1.86$, $MSE = .512$, $p = .175$. Context did not interact with concreteness, $F < 1$, $\eta_p^2 = .01$, and the three-way interaction was not significant, $F(2, 190) = 1.04$, $MSE = .232$, $p = .355$, $\eta_p^2 = .01$.

Table 3 Mean (*SE*) recognition performance in Experiment 2

Frequency Study Context	Hit Rate	False-Alarm Rate
Concrete		
High Frequency		
Isolated	.626 (.02)	—
Low constraint	.681 (.02)	—
High constraint	.601 (.02)	—
Not presented	—	.218 (.02)
Low Frequency		
Isolated	.623 (.02)	—
Low constraint	.691 (.02)	—
High constraint	.683 (.02)	—
Not presented	—	.166 (.01)
Abstract		
High Frequency		
Isolated	.652 (.02)	—
Low constraint	.666 (.02)	—
High constraint	.636 (.02)	—
Not presented	—	.253 (.02)
Low Frequency		
Isolated	.674 (.02)	—
Low constraint	.721 (.02)	—
High constraint	.705 (.02)	—
Not presented	—	.230 (.02)

Discussion

Detection (d') scores were higher for concrete than for abstract words, producing the expected concreteness effect. Words embedded in low-constraint sentences elicited higher detection scores than did words embedded in high-constraint sentences and words presented in isolation. This pattern of performance across context conditions diverged from the results of the only prior studies to examine the effects of context or semantic constraint on recognition, in which recognition accuracy decreased when words were presented in sentence contexts (Coane & Balota, 2010; Schwartz, 1975). Although the level of semantic constraint in the Schwartz study is unknown, inspection of the stimuli for the Coane and Balota study suggests that the sentences had relatively low constraint. Although we found main effects of concreteness and context, the two factors did not interact as would be expected under the context availability account. Thus, the results of Experiment 2 do not support the context availability hypothesis of the concreteness effect in recognition memory.

Low-frequency words exhibited higher detection scores than did high-frequency words, with both higher hit rates and lower false alarm rates, replicating the typical low-frequency advantage in recognition. The low-frequency recognition advantage was greater for words studied in high-constraint sentence contexts than for words studied in isolation. This effect parallels the results of a previous study in which the low-frequency advantage was more pronounced when words were presented in a paragraph context than when they were presented in isolation (Coane & Balota, 2010).

General discussion

In the present study we examined the effects of sentence context and semantic constraint on explicit verbal memory performance, with the goal of understanding how context

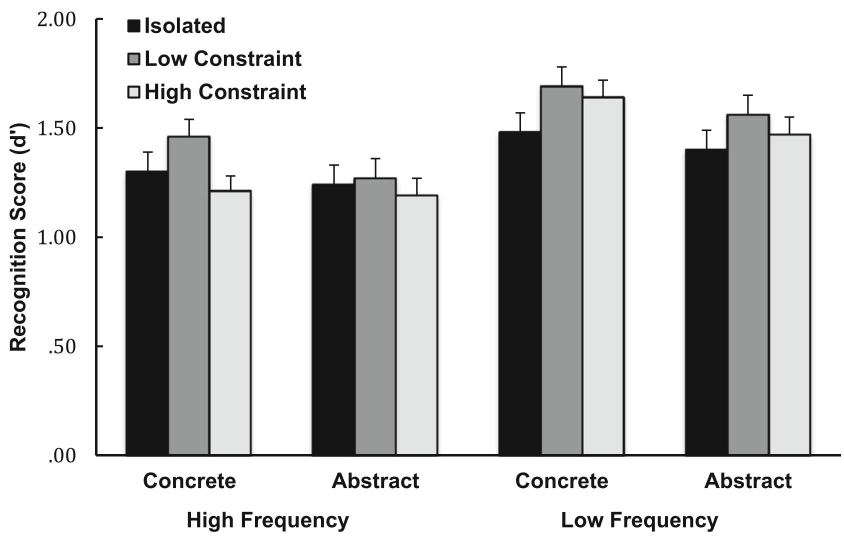

Fig. 2 Recognition scores (*d'*) in Experiment 2 as a function of concreteness, word frequency, and encoding context. Error bars represent standard errors of the means

availability might contribute to the well-established effects of concreteness. In the following sections, we elaborate on the nature of sentence context and semantic constraint effects on memory performance and the implications of our results for theories of the concreteness effect.

Context and semantic constraint in explicit verbal memory performance

The effects of context were significant in both experiments. In free recall, words studied in isolation were recalled at a higher rate than were words presented in low-constraint sentences, and words presented in low-constraint sentences were recalled better than words presented in high-constraint sentences. The negative impact of sentence context on recall is consistent with previous results (Cofer, 1968; Wood, 1970). The explanation given was that embedding words in sentence contexts at study disrupted the formation of new interitem associations, thereby negatively affecting recall.

The finding of superior recall for target words in low-constraint as compared to high-constraint sentences stands in contrast to the results of a previous study that reported the opposite pattern (McFalls & Schwanenflugel, 2002). However, as we explained in the Discussion for Experiment 1, the use of an encoding task that drew attention to the different types of context may have been responsible for the high-constraint advantage in the previous study. In the present study, the reasons for a low-constraint advantage may have been twofold. First, high semantic constraint facilitates identification and comprehension of the target word (e.g., Balota et al., 1985; Forster, 1981; Gollan et al., 2011; Griffin & Bock, 1998; Rayner et al., 2004), and this easier processing may reduce attention to the target word or eliminate the desirable difficulties (Bjork, 1994) that would be present and enhance memory in low-constraint conditions. Second, extending the reasoning of two early studies (Cofer, 1968; Wood, 1970), high-constraint sentences ought to elicit even more within-sentence processing than do low-constraint sentences, because of the stronger semantic connection between the sentence frame and the target word. This increase in within-sentence processing for high-constraint sentences would further reduce between-sentence, or interitem, processing relative to low-constraint sentences, and have a stronger negative impact on recall performance.

In recognition, words studied in low-constraint sentences were discriminated better than words studied in isolation, contrary to previous findings (Coane & Balota, 2010; Schwartz, 1975). Experiment 2 showed for the first time that words studied in low-constraint sentences were recognized better than words studied in high-constraint sentences. Given that rehearsal and inter-item processing are not as important for recognition memory as for free recall, any differences in inter-item processing would be unlikely to produce a recognition performance difference. Therefore, a more plausible explanation is that the ease of target word processing afforded by the high-constraint sentence frames eliminated desirable difficulties relative to the low-constraint sentence conditions.

To get a better idea of the processes affected by sentence context and constraint manipulations, we examined interactions of these manipulations with word frequency. As in previous research, high-frequency words were recalled better and low-frequency words were recognized better (e.g., Balota & Neely, 1980; MacLeod & Kampe, 1996). We examined whether words embedded in sentence contexts and words presented in isolation would exhibit different frequency effects, as in one previous study (Coane & Balota, 2010). In Experiment 2, the low-frequency advantage for recognition was greater for targets studied in high-constraint sentences than for targets studied in isolation, consistent with the larger frequency effects in recognition for contextualized relative to isolated words in the previous study. In Experiment 1, no such interactions were observed in recall performance.

We tested whether the interactions of word frequency and semantic constraint seen in lexical processing studies would be paralleled in explicit memory. In contrast to those studies, the word frequency effects in recall and recognition did not differ in high- and low-constraint sentence conditions. The lack of an interaction in recall suggests that the production processes used at test were not impacted by the constraint manipulation. Instead, it would seem that for both tasks, semantic constraint only affected the comprehension processes during encoding, where no interaction would be expected.

Implications for theories of concreteness effects in explicit memory

Concrete words were recalled and recognized better than abstract words, as in previous research. According to the context availability framework, the concrete advantage arises due to the differential availability of associated context information for concrete and abstract words. Specifically, it is assumed that associated context information is easier to access for concrete than for abstract words, thereby leading to benefits in lexical processing and memory. On the basis of this logic, we expected a reduction in the advantage for concrete words when they were embedded in high-constraint sentence contexts at study. In Experiment 1, although the concreteness effect for low-frequency words was smaller in the high-constraint than in the isolated condition, this pattern was not observed for high-frequency words, and we observed no difference in the magnitudes of the concreteness effect for low- and high-constraint sentence conditions. In Experiment 2, there was no indication of an interaction of concreteness and context condition. Thus the present results do not support the context availability framework.

The present results indicate that context availability is not an important factor underlying concreteness effects *in explicit memory*. As we explained in the introduction, the results of prior studies examining whether context availability moderates concreteness effects in free recall have been mixed (Marschark, 1985; Schwanenflugel et al., 1992; Wattenmaker & Shoben, 1987). Although the sentence context manipulation utilized in the present experiment had not been applied in previous studies of concreteness effects *on memory*, this manipulation did reduce concreteness effects in lexical processing tasks (van Hell & de Groot, 2008), indicating that it is a sufficiently powerful context manipulation to reduce or eliminate concreteness effects.

The two approaches to manipulations of context availability in previous research may have tapped into different phenomena. In some studies, context availability was treated as a long-standing property of target words, based on their preexperimental history of episodic contexts (Schwanenflugel et al., 1992; Schwanenflugel et al., 1988; van Hell & de Groot, 1998). Context availability was manipulated by comparing word sets with higher and lower subjective ratings of context availability. In contrast, in the present study and some other studies (Schwanenflugel & Shoben, 1983; van Hell & de Groot, 2008), the approach was to provide contexts at encoding in an effort to temporarily boost preexperimental levels of context availability, with the expectation that providing a context at encoding would have a bigger impact on words with lower preexperimental context availability. It is as yet unknown whether common mechanisms underlie the effects of preexperimental context availability and the effects of experimental manipulations of context availability.

Although support for the context availability explanation of concreteness effects in lexical processing is compelling, support for the context availability explanation of concreteness effects in explicit memory is minimal. It therefore appears that concreteness effects have different bases in lexical processing and in explicit memory. On the basis of the results of previous lexical processing studies, the high-constraint sentence frames in the present study should have equalized the ease of processing of the concrete and abstract target words, but that did not equalize the memory performance for concrete and abstract words. Concrete and abstract words therefore must differ in some characteristics other than context availability that are important for memory but not for lexical processing. One possibility is that these are characteristics that do not have anything to do with context. For example, some candidate differences might include more precise meanings or more distinctive orthography for concrete words (as was suggested by Hirshman & Arndt, 1997) or more possible retrieval routes for concrete words because of imagery (as in the dual-coding theory, Paivio, 1991).

Another possibility is that a different contextual variable may be responsible for concreteness effects in explicit memory. Context variability is associated with explicit memory performance, such that words with low context variability are recalled and recognized better (e.g., Steyvers & Malmberg, 2003). Context variability, which has been implicated in explaining word frequency effects in both lexical processing (Adelman, Brown, & Quesada, 2006) and explicit memory (e.g., Buchler & Reder, 2007; Marsh, Meeks, Hicks, Cook, & Clark-Foos, 2006), is another candidate explanation for concreteness effects in explicit memory. Although one previous study showed no interaction of context variability and word concreteness in free recall (Marsh et al., 2006), in that case, context variability was manipulated by changing the external environment in which targets were studied and tested, rather than changing the semantic context. That environmental approach to episodic context is quite different from the semantic approach to episodic context addressed by the present study and by Criss, William, and Smith (2011). Therefore, it may be fruitful to explore further whether context variability helps explain concreteness effects.

Conclusions

The effects of context, word concreteness, and word frequency were examined in both free recall and recognition memory tasks. Although there were significant effects of concreteness and context in both memory tasks, the magnitude of the concreteness effects in recall and recognition did not differ for words studied in high- and low-constraint sentence contexts. These results therefore do not support extending the context availability hypothesis beyond lexical processing to explain concreteness effects in explicit memory performance. Semantic constraint hurts both recall and recognition performance, which suggests that the facilitating effect of semantic constraint on processing the target word reduces either attention to the target word or the desirable difficulty that would be present in a low-constraint context.

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