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An effect of semantic memory on immediate memory in the visual domain

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Abstract

The present study extends the findings of Hemmer and Steyvers (2009a) by investigating the influence of semantic memory on short-term visual memory. In an experiment we tested how prior knowledge moderates serial position effects, using familiar (vegetables) and non-familiar stimuli (random shapes). Participants (Ps) saw lists of six images; each list held images of vegetables or random shapes. Immediately after list presentation, one of the items was presented again, in a new, randomly determined size. Ps were asked to resize the image so that it was as close as possible to the size of the just-presented item. Results showed that, for the familiar items (vegetables), memory for the item's size was supported by prior knowledge of the normal size of the objects; this was not the case for the random shapes. Moreover, there was a stronger serial position effect for random shapes than vegetables suggesting that for the serial positions where memory is typically lowest, the serial position effect was moderated through the support from long-term knowledge.

Keywords: Semantic Memory, Short-term Memory, Visual domain, Long-term memory,

Introduction

Have you ever returned to a place of your childhood—a place where you have rarely been since growing up? When you entered the place, did you get the impression that everything seems small or at least smaller than you remember? The phenomenology of such an experience is evidence for a profound effect of long-term memory (LTM) on your immediate perception of the world around you.

Such effects are not restricted to perception but have been found to extend to other cognitive capacities such as decision-making and memory. A whole host of research in the area of false memories has demonstrated systematic intrusions of associated words from LTM (e.g., McDermott & Watson, 2001; Norman & Schacter, 1997; Roediger & McDermott, 1995). Norman and Schacter (1997), for instance, presented participants with lists of words that were associated to a theme word, the latter not being presented at all. Participants frequently reported that they remember seeing the not-presented theme word. The effect persisted even when participants were asked to describe precisely the moment at which the item was presented during the study phase. Despite being able to report more sensory and contextual information for the studied items than for non-presented theme words, participants continued to report remembering the theme word.

The influence of LTM is not only detrimental but can have beneficial effects. For instance, recent trends in research on judgment and decision-making have emphasized the role of LTM as a basis for evaluating current decision options (e.g., Stewart, 2009; Weber & Johnson, 2006). The underlying idea is that people base their judgments on samples of information drawn from LTM of experienced events. Rather than being irrational, deviations from normative value functions—which ignore any influences other than the immediate decision context—can be explained by the fact that people use their LTM to aid their evaluations of current decision options.

Beneficial effects of LTM can similarly be found in verbal short-term memory (STM). Saint-Aubin and Poirier (1999), for instance, demonstrated that word frequency and familiarity—as well as concreteness and lexicality—have a positive influence on word recall. Similar phenomena are observed at the sub-lexical level; when trying to remember non-words, items containing more familiar phonemic components are better recalled (Thorn & Frankish, 2005).

The growing body of research demonstrating the influence of LTM on STM has led to the development of a group of increasingly influential memory models (e.g., Burgess & Hitch, 2006; Schweickert, 1993). These models suggest that the LTM systems involved in language processing are more closely related to short-term recall than was previously thought. In essence, these models move away from the classic suggestion that verbal STM relies on separate phonological representations of the target items. Rather, the premise is that presenting linguistic information involves the activation of stored long-term knowledge. In turn, the characteristics of these representations can influence recall including semantic levels of representation (e.g., Thorn, Frankish, & Gathercole, 2009).

If this is true for verbal content, it should also hold for non-linguistic forms of knowledge. A satisfactory theory of STM should explain the interaction between knowledge and STM in other important domains. The aim of the present paper is to explore the influence of LTM on STM in the visual domain.

Visual domain

Research in the visual domain has started to look for the influence of LTM on current task performance. In one of the early studies that explicitly tried to disentangle the influence of LTM and STM contribution to performance in the visual domain, Hitch, Brandimonte and Walker (1995) suggest that short-term visual memory maintains mainly surface descriptions and long-term visual memory preserves both surface and abstract descriptions. Using an articulatory suppression task they also demonstrated a link between task performance and verbal LTM suggesting that the verbal encoding of the visual stimuli supports the use of abstract visual descriptions. The influence of LTM in form of abstract level descriptions has similarly been reported in research on imagery-induced interference (Ishai & Sagi, 1997). What studies like these suggest is that, just as in the verbal domain, in the visual domain we store abstract level information, in this case of visual characteristics of objects, in LTM.

More recent studies support this idea that LTM exerts an influence at different levels of abstraction. One manner in which our cognitive system deals with the complexity of information in our environment is to form categories. Thus in order to see whether task performance is influenced by LTM at different levels of abstraction, one approach would be to look at the hierarchical structure of our semantic categories. Hemmer and Steyvers (2009a) did precisely that. In their study, they asked participants to reconstruct the size of objects that they had previously been shown on a screen. The objects were either natural objects like fruit and vegetables or they were random shapes. In a preceding norming study, the average size, as well as the largest and smallest acceptable size of these fruit and vegetables, were obtained. For the experimental task, they used a continuous recognition paradigm in which both study and test items were presented inter-leaved. The objects were shown at varying sizes that deviated to a greater or lesser extent upwards or downwards from their mean norm size (a plate was shown on a separate screen as reference object). For each test item participants were asked whether they had seen the item previously and to resize the object to the size they had seen previously. With the norming data, Hemmer and Steyvers (2009a) were able to determine the influence of the long-term representations of these objects during reconstruction at test. In contrast to previous research (e.g., Crawford, Huttenlocher, & Engebretson, 2000; Huttenlocher, Hedges, & Vevea, 2000), their approach enabled a separation of the influence at category from that at object level. With no prior long-term representation, random shapes are only able to form a category during the task and consequently only showed a bias towards the central tendency of the presented items—random shapes presented large were underestimated and those presented small were overestimated (cf. Duffy, Huttenlocher, Hedges, & Crawford, 2010). In addition to showing a bias towards the central tendency of their respective category, fruit and vegetables also demonstrated an influence at the object level—the lower level of abstraction. Figure 1 illustrates the influence of LTM at both category and object level. A small vegetable (e.g., artichoke) that was presented smaller than its norm object size, is more likely to be overestimated than a small vegetable (e.g., mushroom) that is presented larger than its norm object size. In Figure 1 both object and category bias pull in the same direction for artichokes but opposite directions for mushrooms.

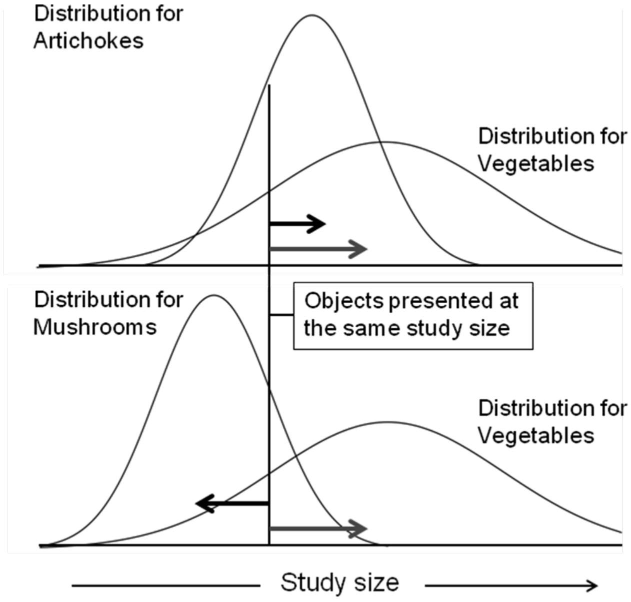

Figure 1: Objects presented at the same study size show distinct biases depending on whether they were presented larger or smaller than their norm object size.

The approach to use norming data in order to measure the influence of prior knowledge on current task performance is commonplace in the verbal domain. Hemmer and Steyvers (2009a), however, have applied this approach to the visual domain and have since replicated it successful in different settings (Hemmer, Shi, & Steyvers, 2010; Hemmer & Steyver, 2009b). Their approach was aimed at differentiating an effect of LTM at different levels of abstraction. In order to have a sizeable effect of LTM they used a continuous recognition paradigm in which study and test items are intermingled in the task. This however did not afford tight control of the time span between study and test. Furthermore the paper did not report any effects of retention intervals on the level of LTM influence. In what follows we used their paradigm to investigate the LTM effects over a short-term interval with tight control of the retention span.

Our aim and strategy

In the present paper we set out to replicate Hemmer and Steyvers (2009a) findings in an immediate memory task. It is envisaged that the influence of LTM on current task performance diminishes as the retention span gets shorter. In an immediate memory task, the memory traces will be stronger and hence less susceptible to influences from LTM. In that sense, the current study tests the lower limit of the LTM effect demonstrated by Hemmer and Steyvers. If we can find a LTM effect, a short-term serial position manipulation provides a tight control over the retention span and enables us to test whether different levels of memorability over the short-term present with varying levels of a LTM effect.

Our study used the same underlying logic as the previous study. We presented participants with two types of visual stimuli—one with a long-term mental representation (i.e., photographs of vegetables) and one without (i.e., random shapes)—and asked them to resize from memory one of the previously seen objects. The task we used was a standard serial-position paradigm with lists of 6 items each. After each list we asked participant to resize one of the objects from the just-seen list. A difference in the pattern of results—as well as the absolute error across serial position—between vegetables and shapes would demonstrate an effect of the long-term representation.

In terms of the predictions, we anticipate to replicate Hemmer and Steyvers (2009) general findings. An LTM effect will be observed at both the category and object level for vegetables, whereas random shapes should only show an effect of the running mean of the size of the presented item (Duffy et al., 2010). In addition, we expected to find a standard serial position curve of the absolute error with items in the middle of the list showing a greater error than those at either end. Lastly a difference in absolute error should be observed between vegetables and shapes. If LTM supports performance in the current task as in previous research then absolute error should be smaller for vegetables.

Experiment

Method

Participants. Participants were 24 students from City University, London, who volunteered or received course credits for their participation.

Materials. All materials were identical to those used by Hemmer and Steyvers (2009a) and consisted of a set of 24 high-resolution color images of vegetables with an average size of 1175 × 878 pixels photographed against a white background. The images depicted common vegetables such as cabbage, cucumber and peppers, but also less typical items like garlic, artichoke and ginger. In addition there were 24 images of random shapes.

These items were used to randomly create 6-item lists with the constraint that each list contained a particular item only once. However, across 24 trials per category (i.e., vegetable & random shapes) items were repeatedly presented.

At each trial the images were presented sequentially at a rate of 1.5 seconds. For the vegetables, each image randomly varied in size around its norm mean size limited to a variation up to the largest or smallest acceptable size according to the norms. The random shapes were yoked to the vegetables such that the presentation size of the random shapes matched those of the vegetables. The study size of a particular item was the same for every participant.

Each trial consisted of the presentation of 6 items, followed by the test for a single item selected from positions 2 to 5 of the list—primacy and recency items in the list were not tested due to the limited number of stimuli. The presentation size of the item at test varied randomly. Each position was tested 6 times.

Procedure. Participants were tested individually. After reading the instruction, participants had 5 practice trials followed by the opportunity to ask question about the procedure. For each trial participants first saw a series of images (Figure 2) and were then asked to resize one of those objects to match the size of the images they had seen.

Figure 2: Example of a study sequence and test.

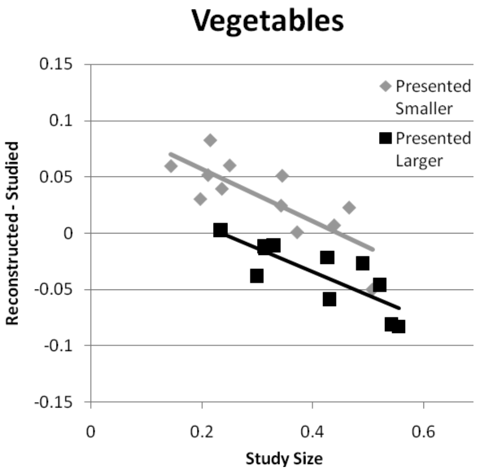

Figure 3: Reconstruction error as a function of study size for vegetables presented smaller or larger than their norm mean size.

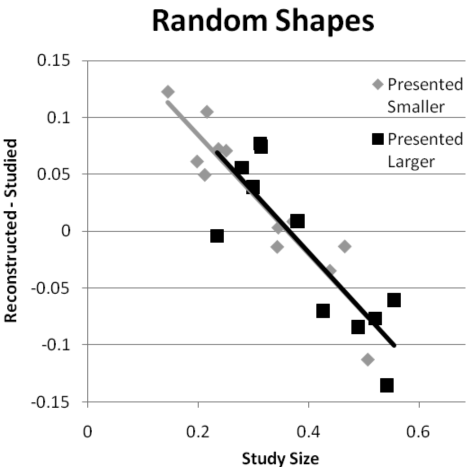

Figure 4: Reconstruction error as a function of study size for random shapes yoked to the study size of vegetables.

Participants used a slider bar to resize the object (Figure 2). Responses were measured on a scale from 0 to 1 where 0 corresponded to an object smaller than one pixel on the screen and 1 corresponded to the object filling either the height or the width of the screen.

Results

Regression analyses

Figure 3 & 4 present the reconstruction error as a function of study size for each item of the vegetables and random shapes category. The norming data provided by Hemmer and Steyvers (2009a) enabled us to categorize the vegetables into items that were presented larger or smaller than their norm mean size.

Data for both vegetables and shapes show a negative slope with items studied small being overestimated and items studied large being underestimated. This is consistent with a general tendency to regress towards the mean. However, a clear difference between the two figures is that for vegetables there were two distinct regression lines for items presented either larger or smaller relative to the norm size; for the random shapes, the two regression lines were on top of each other. As the random shapes were yoked for study size to the vegetables, the difference cannot be due to study bias.

Table 1: Average b-values across participants for the two predictors of the regression analyses.

	Vegetables		Shapes	
Predictors	M	SD	M	SD
Slope	-.221	.174	-.527	.156
Relative Presentation Size	-.046	.023	.003	.028

In order to confirm the pattern of results in Figure 3 & 4, separate regression analyses were carried out for each participant predicting recall error from study size and relative presentation size (smaller or larger relative to norm mean size).

Table 1 provides the average b-values for the two predictors of the regression model. One-sample *t*-tests confirmed that the slopes for both vegetables and shapes were significantly different from zero. Furthermore a paired-sample *t*-test indicated that the shapes showed a steeper slope than the vegetables ($t(23) = 6.8$, $p < .001$). This suggests that for vegetables the regression towards the mean was moderated by the influence of the relative presentation size. Objects studied large were more underestimated and objects studied small were more overestimated among shapes than vegetables.

One-sample *t*-tests of the relative presentation size parameter confirmed a difference in intercept for the regression of the two types of objects for vegetables ($t(23) = 9.68$, $p < .001$), but not for shapes ($t(23) = .593$, $p = .559$). Items presented larger relative to their norm size were more likely to be underestimated than items which were studied at the same size, but were smaller relative to their norm size. For instance, a mushroom was more likely to be underestimated when it was presented larger than its norm size, but at the exact same study size as a cabbage presented smaller than its norm size. The cabbage, in contrast, was more likely to be overestimated. This can be seen across all study sizes. When inspecting data points located at the same study size, the grey points among vegetables are almost exclusively located above the black ones (Fig.3), whereas those for shapes are intermingled (Fig.4). This pattern of result replicates Hemmer and Steyvers (2009a) findings in an immediate memory paradigm.

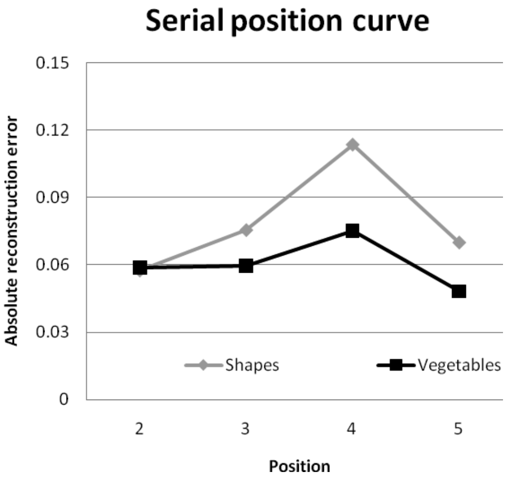

Figure 5: Absolute reconstruction error for vegetables and shapes as a function of serial position in the list.

Serial position analyses

In order to investigate the influence of memorability over the short-term further, we looked at the influence of the serial position on the absolute error in reconstruction. Figure 5 shows the serial position curves across the middle 5 positions for vegetables and random shapes. The absolute reconstruction error exhibits the clear serial position shape with items in the middle positions showing greater absolute error than those on either end of the list. This pattern however seems to be more attenuated in the case of shapes compared to vegetables.

To test the reliability of this pattern of results, the data were submitted to a repeated measures analysis of variance (ANOVA) with Serial Position (positions 2 to 5) and Category of object (vegetables and random shapes) as within-subjects factors. ANOVA confirmed a main effect of Serial Position ($F(3,69) = 21.69$, $p < .001$) as well as a main effect of Category ($F(1,23) = 50.01$, $p < .001$). Both main effects were qualified by a significant two-way interaction ($F(3,69) = 5.86$, $p < .01$). Simple main effect comparisons between vegetables and shapes at each serial position using Bonferroni adjustments showed that the average reconstruction errors for shapes were significantly higher for all except the 2nd position in the list (P_2: $t(23) = -.239$, $p = .814$; P_3: $t(23) = 3.9$, $p < .01$; P_4: $t(23) = 4.1$, $p < .01$; P_5: $t(23) = 3.8$, $p < .01$). Planned comparisons for consecutive positions for each category of object separately showed that for shapes all consecutive positions were significantly different from one another ($P_{2\text{-}3}$: $t(23) = -2.7$, $p < .05$; $P_{3\text{-}4}$: $t(23) = -5.1$, $p < .001$; $P_{4\text{-}5}$: $t(23) = 5.9$, $p < .001$). The data for the vegetables, however, showed a less pronounced serial position curve with no difference between position 2 and 3, only a marginally significant difference between 3 and 4, but a classic recency effect between 4 and 5 ($P_{2\text{-}3}$: $t(23) = -.18$, $p = .855$; $P_{3\text{-}4}$: $t(23) = -1.97$, $p = .061$; $P_{4\text{-}5}$: $t(23) = 3.26$, $p < .01$).

Discussion

The data of the present study support three conclusions. First, in replicating the findings of Hemmer and Steyvers (2009a), the present results demonstrate that long-term semantic memory about the ‘normal’ size of objects can have an influence on current task performance. As such, the results extend previous research demonstrating LTM effects in STM (e.g., Saint-Aubin & Poirier, 1999) from the verbal to the visual domain. Second, items without a LTM representation show a greater influence of serial position on reconstruction error than items with an LTM representation. And lastly, in the present STM task, LTM representations of the items supported rather than undermined task performance. Responses to shapes showed a significantly higher absolute reconstruction error than responses to vegetables.

Do the results really constitute a long-term semantic memory effect or is the reconstruction merely influenced by the running mean of the presented objects (Duffy, Huttenlocher, Hedges, & Crawford, 2010)? There are two reasons why the running mean hypothesis does not hold in the present case. First, if the running mean rather than the long-term semantic representation was the main influence at reconstruction, the results for vegetables and shapes should have been identical, because shapes and vegetables were yoked for presentation size and the running means were virtually identical ($r = .99$, $p < .001$, $N = 24$). Second, looking at the correlations between the reconstruction error and the running mean, be it for the whole set of items or within a category (vegetable or shapes), we find no significant correlations and adding the running mean as a predictor in the regression for each participant improved the model significantly only for 2 out 24 participants. This suggests that next to the memory trace the best predictor for the reconstruction performance for items with a long-term representation is not the running mean of the presented items sizes but the relative presentation size.

An alternative explanation for the differences in the shape of the serial position curve and the size of the absolute error between shapes and vegetables could be a difference in the strength of the memory trace. People remember vegetables better than they remember random shapes. Rather than supporting task performance at reconstruction through an input from LTM, the greater accuracy is due to stronger memory traces for vegetables than for shapes. Given the immediate memory paradigm used in the present experiment, we refrained from asking participants whether they remembered seeing the test item in the list. It is, hence, not possible to test whether people actually remembered fewer shapes than vegetables. For the serial position data it is therefore difficult to differentiate whether the effect occurs at retention (i.e., better memory trace) or at reconstruction (i.e., additional input from LTM). However the regression data supports the latter rather than the former of the two hypotheses. The differences between vegetables and shapes observed in the regression models cannot be explained by stronger memory traces among vegetables.

The greater strength in memory traces should be invariant across the relative presentation sizes of the vegetables and hence is unable to account for the influence of that predictor in the regression models.

General Discussion

One of the most fundamental functions that memory performs is to enable the past to support and guide our present interactions with the world. Yet, we know little about this central if seamless interaction between previous knowledge and current preoccupations. In the present paper, we contribute in, at least, two distinct ways to a growing literature that tries to elucidate this interaction between long-term semantic memory and current task performance.

Most of what we know regarding LTM effects on short-term retrieval is based on studies utilizing language (e.g., Saint-Aubin & Poirier, 1999; Thorn & Frankish, 2005). This is not a surprise considering how important language is in human activity. The present study extends previous research by demonstrating an LTM effect on STM in the visual domain. Long-term mental representations of visual characteristics of objects seem to aid the reconstruction of those characteristics during a short-term memory task.

In building on previous research in the visual domain (e.g., Duffy et al. 2010; Hemmer & Steyvers, 2009a; 2009b; Huttenlocher et al., 1991; 2000), the current results replicate the findings of Hemmer & Steyvers (2009a) and extend their findings to an immediate memory task. This suggests that LTM effects may be more pervasive than has previously been thought. As such the present paper supports a number of models that suggest a strong involvement of LTM systems in current task performance, be it in memory (e.g., Burgess & Hitch, 2006; Schweickert, 1993) or decision making (e.g., Stewart, 2009; Weber & Johnson, 2006).

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