Title
The Role of Shape in Semantic Memory Organization of Objects

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 35(35)

ISSN
1069-7977

Authors
Van Weelden, Lisanne
Schilperoord, Joost
Stewarts, Marc
et al.

Publication Date
2013

Peer reviewed

The Role of Shape in Semantic Memory Organization of Objects

Lisanne van Weelden (L.vanWeelden@uvt.nl)

Joost Schilperoord (J.Schilperoord@uvt.nl)

Marc Swerts (M.G.J.Swerts@uvt.nl)

Tilburg centre for Cognition and Communication (TiCC), Tilburg University,
PO Box 90153, 5000 LE Tilburg, The Netherlands

Diane Pecher (Pecher@fsw.eur.nl)

Department of Psychology, Erasmus University,
PO box 1738, 3000 DR Rotterdam, The Netherlands

Abstract

Visual information contributes fundamentally to the process of object categorization. The present study investigated whether the degree of activation of visual information in this process is dependent on the situational relevance of this information. We used the Proactive Interference (PI) paradigm. In two experiments, we manipulated the information by which objects could be retrieved from memory: by both semantic and shape information or by shape information only. The pattern of PI-release showed that if objects could be stored and retrieved both by semantic and shape information, then shape information was overruled by semantic information. If, however, semantic information could not be (satisfactorily) used to store and retrieve objects, then objects were stored in memory in terms of their shape.

Keywords: Object shape; proactive interference; memory; categorization.

Introduction

If we observe a cat-like creature in the zoo, even if it is a type that we have never seen before, we may classify that animal as belonging to the same category as lions, tigers and pumas. Presumably, the reason for doing this is that the observed animal shares some observable properties with those of the other cat-like animals that we remember having seen before. Object categorization is hence a fundamental process in constructing and using our memory, as it helps to organize our knowledge and relate (novel) objects to other objects in order to assign meaning to them.

This process of object categorization is driven by mental representation. When we encounter an object, we create a mental representation based on sensory and semantic information. In order to categorize the object, the mental representation is compared to a mental prototype that represents category members (Rosch & Mervis, 1975) or to other category exemplars in memory (Nosofsky, 1986). The representations are compared on both sensory and semantic information, however the relative weighting of these two types of information varies across concepts and semantic categories (Humphreys & Forde, 2001; Warrington & McCarthy, 1987). For example, the shape of an animal or the color of a fruit might be more important to assign the object to the correct category than the shape or color of a kettle. In the present study, we investigate the role of sensory features in the categorization of visual objects. We focus on the visual sensory feature *shape* and investigate whether the relative weighting of shape and semantic information affects the organization of semantic memory.

Barsalou (1999) proposed that sensory information plays a critical role in cognition. According to his Perceptual Symbols theory, perception, action, and cognition share processing mechanisms. He views mental representation as a process of sensory-motor simulation. Central in his theory are perceptual symbols by which a mental representation is defined. A mental representation is constructed of a combination of several perceptual symbols for different components of the concept. This perceptual symbol formation process does not only concern the concept's visual features (e.g., its color, shape, and orientation), but operates as well on other sensory modalities such as audition, haptics, olfaction, and gustation. As such, perceptual symbols are learned through actual experiences with concepts. Modality-specific sensory-motor systems capture such experiences and hierarchical association areas integrate experiences from different modalities. Hence, these association networks represent knowledge of the concept that can be recruited for cognitive processing via the process of simulation (i.e., mental representation).

Evidence supporting the PS theory is provided by work that shows that visual sensory information is indeed activated during language comprehension (e.g., Huettig & Hartsuiker, 2008; Pecher, Van Dantzig, Zwaan, & Zeelenberg, 2009; Pecher, Zeelenberg, & Raaijmakers, 1998; Stanfield & Zwaan, 2001; Van Dantzig, Pecher, Zeelenberg, & Barsalou, 2008; Van Weelden, Schilperoord, & Maes, in press; Zwaan, Stanfield, & Yaxley, 2002). For example, Huettig and Hartsuiker (2008) showed that naming a category exemplar (e.g., musical instrument – saxophone) elicited eye movements to a picture of a semantically unrelated object that was similar in shape (e.g., ladle). This activation of visual sensory information is context related. Zwaan, Stanfield, and Yaxley (2002) showed, for example, that context can affect the particular shape of the object that is represented. In their experiment, participants were presented with sentences like ‘The ranger saw the eagle in the sky’ or ‘The ranger saw the eagle in its nest,’ which were followed by a line drawing of the object described in the sentence, in this case an eagle with outstretched wings or an eagle with folded wings. Participants recognized the picture faster if the implied shape of the object in the sentence matched the shape of the object in the picture. In the same line, Van Weelden, Schilperoord, and Maes (in press) showed that sentence structure (which can define the relation between multiple objects) influences the shape of the represented object(s) as well. In their experiment, participants were presented with sentences that invited to compare two objects like ‘*A spinning top is like a ballerina*,’ which were followed by two line drawings of the objects described in the sentence. The two drawings either had a similar or dissimilar shape. Participants recognized the pictures faster if they were similarly shaped. Hence, a sentence structure that invites to (conceptually) compare two objects affects the shape of their mental representation.

While language has been shown to elicit perceptual representations, there is also work that shows that the opposite occurs as well, that is, that semantic information is activated during visual object perception. Boucart and Humphreys (1997) suggest that as a result of the strong interplay between sensory and semantic information, people cannot even attend selectively to the global shape of an object without automatically processing its semantic properties. Caramazza, Hillis, Rapp, and Romani (1990) try to explain this interaction with their Organized Unitary Content Hypothesis (OUCH). Their theory is based on the idea that, contrary to a word for a particular concept, the object itself tends not to have an arbitrary relationship to its meaning. Some visual sensory features are directly related to the semantic properties of the object that specify its function (cf. Gibson's affordance theory; 1977, 1979). These features are therefore perceptually salient. As such, shape is very frequently a salient perceptual feature.

Accordingly, visual sensory information contributes fundamentally to the process of object identification and categorization. In the present study, we propose that the *degree* of activation of visual information in the process of object categorization might depend on the *situational relevance* of this information (Chaigneau, Barsalou, & Samani, 2009; Pecher et al., 1998). We define this situational relevance as the result of the visual and semantic relations between the objects. For example, we might predict that when we have to look for an overarching category for a number of presented objects, visual features, such as shape, might play a bigger role if objects belong to different semantic categories as compared to when they stem from the same semantic category. Therefore, in the present study, we investigate whether shape information is encoded differently in our semantic memory for objects from similar and dissimilar semantic categories.

One way to investigate how visual information is encoded, and hence whether the objects are organized in semantic memory by means of their shape, is by looking at the process of retrieval of this particular information. The encoding and retrieval of the encoded information are interdependent; a retrieval cue will be effective if and only if the information in the cue was generated at encoding (Blaxton, 1989; Morris, Bransford, & Franks, 1977; Tulving & Thomson, 1973). Hence, by examining whether the shape of objects is used as a retrieval cue when trying to retrieve objects from memory, we can determine whether shape information was encoded in the semantic memory.

To do so, we use the Proactive Interference (PI) paradigm (Wickens, 1970). Proactive interference occurs when previously encountered information interferes with the memorial access of more recently encountered information. The standard procedure to test this interference is to present a triad of items from the same semantic category and, subsequently, have the participant perform a 25-s rehearsal-preventing task, such as a backward counting task. Then, participants recall the triad. This procedure is repeated for four trials. The idea is that because the items are members of the same semantic category, the meaning of the items is being encoded and so is the meaning of the non-presented category under which they subsume. The PI paradigm results in decreasing performance on the recall task as more triads from the same semantic category are presented. Because participants use the same category cue to recall the items, increasing interference arises. If, however, the semantic category shifts on the fourth (i.e., the critical) trial, the category cue will change as well. Therefore, the discriminability and accessibility of the items will increase, resulting in an increased performance on the recall task. This mechanism is called *release from interference*.

In previous studies, the PI paradigm has been used to investigate the magnitude of the semantic distance between exemplars from different semantic categories (i.e., shift from fruits to vegetables as compared to shifts from fruits to professions), phonemic categories (i.e., shift from words with ‘air’ sound to ‘eye’ sound), and sensory features (i.e., shift from ‘round’ words to ‘white’ words) (Wickens, Dalezman, & Eggemeier, 1976; Zinober, Cermak, Cermak, & Dickerson, 1975). The main conclusion drawn from these studies is that the degree of release from interference is inversely related to the number of common characteristics. That is, a shift between categories with a high overlap in characteristics (i.e., from fruits to vegetables) obtains a lower release from interference as compared to a shift between categories with no overlapping characteristics (i.e., from fruits to professions).

Marques’ (2000) study showed release from interference as a result of a shift from nonliving to living things. Interestingly, Marques tested this living/nonliving distinction for both words and pictures of the objects. The visual stimuli yielded the same types of interference effects as verbal stimuli. Accordingly, this study shows that the PI paradigm can also be used to investigate which retrieval cues people use to recall *visual* objects from their memory and, hence, which information was encoded when the visual objects were processed.

The present study employs the PI paradigm with the visual manipulation of object shape. We refer to shape as the outline of the picture of a particular object, rather than its inherent shape. We predict that if depictions of objects are encoded in such a way as to include information about the shape of the objects, then objects with a particular shape should form a different category than objects with another shape. Therefore, interference should build up as objects with similar shapes are presented on successive trials, and a release from interference should occur with a shift of shape. Yet the relative weighting of shape information might differ as a result of the situational relevance of this information. In two experiments, we manipulate the semantic and shape similarity between the objects and, thereby, the situational relevance of shape. In Experiment 1, we combine a shift of shape with a semantic shift. For this type of shift, we expect that a semantic category cue will be sufficient to recall the objects from the critical trial. So, for this situation, the role of shape might be inferior. In Experiment 2, we will only manipulate a shift of shape, keeping the semantic category similar throughout the experiment. For this situation, we expect shape to be a distinguishing factor and to be used as a retrieval cue.

Experiment 1

This first experiment evaluated the role of shape in the PI-release situation with both a shape and semantic categorical shift. The semantic shift comprised a shift between two natural categories, fruits and flowers. We used this type of shift because living things are primarily differentiated on the basis of perceptual features (Humphreys & Forde, 2001; Warrington & McCarthy, 1987). That is, most types of natural objects have a high perceptual overlap, and therefore small perceptual differences are highly informative. Hence, it can be expected that visual information will have a relatively high weighting as compared to other types of information in the representation of living things.

Both the participants in the Shift and No-Shift condition received three fruits triads followed by a flower triad. In the No-Shift condition, the shape of the fruits and flowers did not change throughout the experiment. The objects either were round in shape or were shaped irregularly. In the Shift condition, however, the shape of the objects changed on the critical trial. The critical trial established a shift from irregularly shaped objects to round shaped objects or vice versa.

For both the Shift and No-Shift condition, we predicted release from interference to occur as the change from fruits to flowers reduces or eliminates interference. However, there may be gradual differences in the amount of release, both as a result of the shape shift itself and the type of shape shift. We expected the release to be most prominent for the Shift condition as there is an additional shift of shape. Considering the type of shape shift, we predicted the release to be stronger when triads changed from round shaped objects to irregularly shaped objects than the other way around. If pictures of objects are encoded in such a way as to include information about the shape of the objects, then the buildup of interference is stronger for round objects, which might result in a stronger release effect.

For the No-Shift condition, we predicted the release from interference to be hampered when the triads of the four trials consist of round objects. Although there was a semantic change from fruits to flowers, the objects remained perceptually similar. As a result, the previously seen objects may continue to interfere with the objects presented on the critical trail. When the triads of the four trials consist of irregularly shaped objects, however, this interference effect may be more moderate as the objects are not perceptually similar. The semantic shift would then be sufficient to eliminate such interference effects.

Method

Participants Eighty Tilburg University undergraduates (57 women) participated for course credit. The mean age was 21 years, ranging from 18 to 34.

Materials[1] The stimulus pictures consisted of 18 pictures of fruits (9 round shapes and 9 irregular shapes) and 6 pictures of flowers (3 round shape and 3 irregular shapes). The pictures were arranged in triads (6 for fruits and 2 for flowers). In arranging these triads, we controlled for various factors. For the fruits triads, we controlled for typicality. In a typicality pretest, ten participants (who did not participate in the future PI experiment) were asked to sort the pictures of the objects from most typical member of the category ‘fruits’ to the least typical member of this category. Based on this taxonomy, every fruits triad was assigned a low, medium, and high typical member of the category. In addition, every fruits and flowers triad consisted of three differently colored objects. We kept the visual complexity similar across triads in terms of mean JPEG file sizes (Chikhman et al., 2012; Donderi, 2006).

Design The experiment had a 2 x 2 x 4 design, with Condition (levels: Shift and No-Shift) and Triad Shape (levels: Round shape and Irregular shape) as between-subjects factors and Trial (levels: 1, 2, 3, and 4) as within-subjects factor.

[1] See dcilab.uvt.nl/LisanneVanWeelden/materials.pdf for the materials of Experiment 1 and 2.

Procedure The participants were informed that the purpose of the experiment was to test their ability on both backward counting and their memory of triads of objects. During each trial, participants first saw a fixation cross in the center of the screen for 2 s. Subsequently, the objects of one triad were presented one-by-one for 2 s each (with no inter-stimulus interval). Participants were instructed to identify the objects silently, to remember them, and also to remember the order of the objects. They were told that they had to recall the objects in the right order afterwards. A three-digit number was then presented in the middle of the screen for 25 s during which the participant had to count backwards by threes out loud. Participants were instructed to count backwards as fast as possible while still being accurate. After 25 s the question 'Which three objects did you see?' appeared, signaling the beginning of the 12 s recall period. Participants typed the names of the three objects. After 12 s the question was replaced with "Time's up" to indicate the end of the recall period. Participants pressed a button to continue to the next trial. The next trial started again with the fixation cross. Participants trained on both the counting backward and memory task with a four trial training block.

Results and discussion

For each participant, the mean recall score was computed for each trial. Following the procedure of Wickens, Dalezman, & Eggemeier (1976), one point was given for each object recalled correctly and one extra point was assigned when the three objects were recalled in the correct order. So, for each trial, there was a maximum of 4 points. The mean scores per Condition and Trial are presented in Figure 1.

PI-buildup and PI-release effects were analyzed independently. The PI-buildup analysis was performed on the first three trials. The PI-release analyses were performed on (1) the third and fourth trial and (2) on the fourth trial separately. For all three analyses an ANOVA was conducted with Condition (levels: Shift and No-Shift) and Triad Shape (levels: Round shape and Irregular shape) as between-subjects factors. For the PI-buildup analysis the latter factor concerned the Shape of the first three triads, whereas for the PI-release analyses this regarded the Shape of the fourth triad. The PI-buildup analysis also involved the within-subjects factor Trial (levels: 1, 2, and 3).

For PI-release, the analysis on the third and fourth trial revealed a main effect of Trial, $F(1, 152) = 31.19$, $p < .001$, $\eta^2_p = .17$. The mean recall score was higher on the fourth trial (M=3.55, SD=.95) than on the third trial (M=2.53, SD=1.31). Participants recalled more items after the semantic shift. There was no effect of Condition, $F < 1$, or Triad Shape, $F < 1$, and there were no two- or three-way interactions between the factors, $F < 1$. The analysis on the fourth trial alone revealed neither a main effect of Condition, $F < 1$, and Triad Shape, $F < 1$, nor an interaction between the two, $F(1, 76) = 1.98$, $p = .16$. Thus, the semantic shift did result in release from interference, but there were no (gradual) differences in release as a result of the shift in shape on the fourth trial.

For PI-buildup, the analysis showed a main effect of Trial, $F(2, 228) = 9.31$, $p < .001$, $\eta^2_p = .08$. Participants recalled fewer items as the number of trials increased. Post hoc analyses showed that the decrease from trial 1 to trial 2 was significant, $p < .05$. The decrease from trial 2 to trial 3 did not reach significance, $p = .22$. There was no effect of Condition, $F < 1$, nor an effect of Triad Shape, $F < 1$. The analysis did not reveal any two- or three-way interactions between the factors.

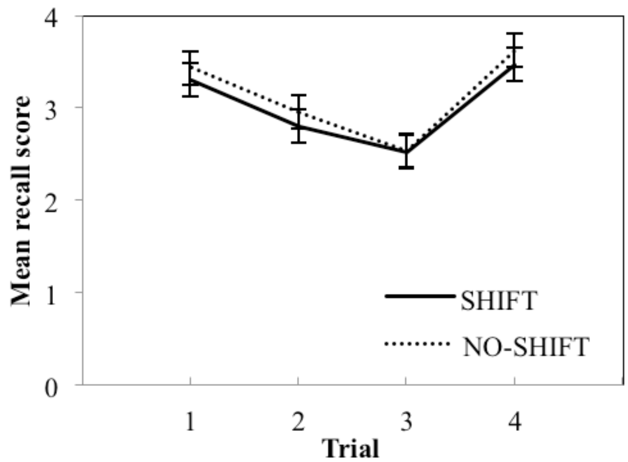

Figure 1: Mean recall scores on each trial for the Shift and No-Shift condition in Experiment 1.

These results show that shape information was overruled by semantic information. Only semantic information was used as retrieval cue, as indicated by the build-up of interference during the first three trials and the release from interference when the semantic category changed. The change in shape did not affect performance. We expected that the role of shape becomes more prominent if a semantic retrieval cue is not sufficient to recall the objects of the critical trial. This possibility was explored in Experiment 2.

Experiment 2

This second experiment evaluated the role of shape in the PI-release situation without a semantic categorical shift. Participants in both the Shift and No-Shift condition received four fruits triads. Identical to Experiment 1, the shape of the fruits was similar throughout the four trials in the No-Shift condition, in the sense that the objects either had a round shape or were shaped irregularly. In the Shift condition, the shape of the objects changed on the critical trial. The change concerned a shift from irregularly shaped objects to round shaped objects or vice versa.

For the Shift condition, we predicted release from interference to occur as a result of the shape shift. Again, we expected the release to be more prominent when triads changed from round shaped objects to irregularly shaped objects than when they shifted in the opposite direction. For the No-Shift condition, we predicted that the buildup of interference would continue throughout the four trials. The decrease in performance was expected to be the strongest for the round shaped objects as compared to the irregularly shaped objects.

Method

Participants Eighty Tilburg University undergraduates (57 women) participated for course credit. The mean age was 22 years, ranging from 18 to 33.

Materials The triads of the first three trials were the same as in Experiment 1. The experimental materials for these triads consisted of consisted of 18 pictures of fruits (9 round shapes and 9 irregular shapes). For the present experiment, the triads of the fourth trial consisted of 6 pictures of fruits (3 round shapes and 3 irregular shapes). In arranging these triads, we controlled again for typicality, color, and visual complexity.

Design and procedure The design and procedure were the same as in Experiment 1.

Results and discussion

For each participant, the mean recall score was computed for each trial. As in Experiment 1, there was a maximum of 4 points. The mean scores per Condition and Trial are presented in Figure 2.

PI-buildup and PI-release effects were analyzed independently in the same manner as Experiment 1. For PI-release, the analysis on the third and fourth trial revealed a trend of an effect of Condition, $F(1, 152) = 2.76$, $p = .09$. The analysis also showed a trend of an interaction between Condition and Trial, $F(1, 152) = 2.89$, $p = .09$. There was no main effect of Triad Shape, $F < 1$, or Trial, $F < 1$, nor any other two- or three-way interactions. The analysis on the fourth trial alone revealed a main effect of Condition, $F(1, 76) = 5.70$, $p < .05$, $\eta^2_p = .07$. The mean recall score was higher for the Shift condition (M=2.58, SD=1.30) than for the No-Shift condition (M=1.92, SD=1.05). Participants recalled more items after the shape shift. There was no main effect of Triad Shape, $F < 1$, nor an interaction between Condition and Triad Shape, $F(1, 76) = 2.21$, $p = .14$. So, the shape shift resulted in release from interference, causing an increase of the recall scores on the fourth trial.

For PI-buildup, the analysis showed a main effect of Trial, $F(2, 228) = 18.40$, $p < .001$, $\eta^2_p = .14$. Post hoc analyses showed that both the decrease from trial 1 to trial 2, $p < .01$, and from trial 2 to trial 3, $p < .001$, was significant. There was no effect of Condition, $F < 1$, nor an effect of Triad Shape, $F < 1$. The analysis did not reveal any two- or three-way interactions between the factors.

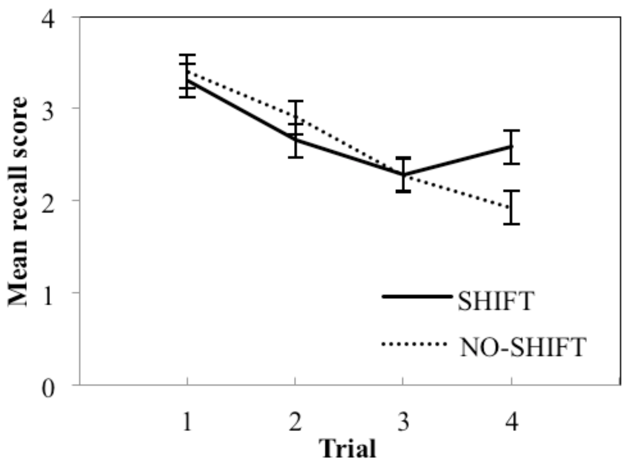

Figure 2: Mean recall scores on each trial for the Shift and No-Shift condition in Experiment 2.

These results show that if semantic information is insufficient to recall the objects of the critical trial, shape comes into play. The fact that shape is used as a retrieval cue to recall objects from memory suggests that the objects are assigned to a subordinate shape category within the semantic category of ‘fruits’.

General discussion

The purpose of the present study was to investigate the role of shape in semantic memory organization of visual objects. We predicted that if depictions of objects are encoded in such a way as to include information about the shape of the objects, then objects with a particular shape should form a different category than objects with another shape. We also predicted that the degree of activation of shape information might depend on the situational relevance of this information. Therefore, in two experiments, we investigated semantic memory organization in two different situations using the PI paradigm. We created these different situations by manipulating the objects’ shape and semantic nature. The results of the present study suggest that semantic memory organization of objects is indeed dependent on the interaction between semantic and shape information.

Experiment 1 showed that if objects can be categorized both on semantic and shape information, then shape information is overruled by semantic information. Namely, as indicated by the release from interference as a result of the semantic category change, semantic information was used as retrieval cue, which was not affected by the shift in shape. Hence, it seems that object categorization is largely driven by semantic features, as those features received higher activation than perceptual features.

Experiment 2 showed however that shape does play an important role in object categorization, that is, if semantic information is not a distinguishing factor and therefore does not receive high activation. In this experiment a situation was created in which the semantic information remained unchanged, whereas the shape of the objects did change. The release from interference as a result of the shift in shape showed that object shape was indeed used as retrieval cue. So, in this situation, objects are categorized based on their shape.

To summarize, object categorization is driven by semantic information to a large extent, yet if semantic information cannot be (satisfactorily) used to store and retrieve objects, then shape comes into play.

Acknowledgments

This research is part of the project "Visual Metaphor: A Psycholinguistic Perspective," which is funded by an "Open Competition" grant from the Netherlands Organization for Scientific Research (NWO).

References

Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences, 22*, 577-660.

Blaxton, T. A. (1989). Investigating dissociations among memory measures: Support for a transfer-appropriate processing framework. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 15*, 657-668.

Boucart, M., & Humphreys, G. W. (1997). Integration of physical and semantic information in object processing. *Perception, 26*, 1197-1209.

Caramazza, A., Hillis, A. E., Rapp, B. C., & Romani, C. (1990). The multiple semantics hypothesis: Multiple confusions? *Cognitive Neuropsychology, 7*, 161-189.

Chaigneau, S. E., Barsalou, L. W., & Samani, M. (2009). Situational information contributes to object categorization and inference. *Acta Psychologica, 130*, 81-94.

Chikhman, V., Bondarko, V., Danilova, M., Goluzina, A., & Shelepin, Y. (2012). Complexity of images: Experimental and computational estimates compared. *Perception, 41*, 631-647.

Donderi, D. C. (2006). Visual complexity: A review. *Psychological Bulletin, 132*(1), 73-97.

Gibson, J. J. (1977). The theory of affordances. In R. Shaw & J. Bransford (Eds.), *Perceiving, Acting, and Knowing: Toward an Ecological Psychology*. Hillsdale, NJ: Lawrence Erlbaum.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston, MA: Houghton Mifflin.

Huettig, F., & Hartsuiker, R. J. (2008). When you name the pizza you look at the coin and the bread: Eye movements reveal semantic activation during word production. *Memory & Cognition, 36*, 341-360.

Humphreys, G. W., & Forde, E. M. E. (2001). Hierarchies, similarity, and interactivity in object recognition: "Category-specific" neuropsychological deficits. *Behavioral and Brain Sciences, 24*, 453-509.

Marques, J. F. (2000). The "living things" impairment and the nature of semantic memory organisation: An experimental study using PI-release and semantic cues. *Cognitive Neuropsychology, 17*, 683-707.

Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behavior, 16*, 519-533.

Nosofsky, R. M. (1986). Attention, similarity, and the indentification-categorization relationship. *Journal of Experimental Psychology: General, 115*, 39-57.

Pecher, D., Van Dantzig, S., Zwaan, R. A., & Zeelenberg, R. (2009). Language comprehenders retain implied shape and orientation of objects. *Quarterly Journal of Experimental Psychology, 62*, 1108-1114.

Pecher, D., Zeelenberg, R., & Raaijmakers, J. G. W. (1998). Does pizza prime coin? Perceptual priming in lexical decision and pronunciation. *Journal of Memory and Language, 38*, 401-418.

Rosch, E., & Mervis, C. B. (1975). Family resemblances: Studies in the internal structure of categories. *Cognitive Psychology, 7*, 573-605.

Stanfield, R. A., & Zwaan, R. A. (2001). The effect of implied orientation derived from verbal context on picture recognition. *Psychological Science, 12*, 153-156.

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review, 80*, 352-373.

Van Dantzig, S., Pecher, D., Zeelenberg, R., & Barsalou, L. W. (2008). Perceptual processing affects conceptual processing. *Cognitive Science, 32*, 579 - 590.

Van Weelden, L., Schilperoord, J., & Maes, A. (in press). Evidence for the role of shape in mental representations of similes. *Cognitive Science*.

Warrington, E. K., & McCarthy, R. A. (1987). Categories of knowledge: Further fractionations and an attempted integration. *Brain, 110*, 1273-1296.

Wickens, D. D. (1970). Encoding categories of words: An empirical approach to meaning. *Psychological Review, 77* , 1-15.

Wickens, D. D., Dalezman, R. E., & Eggemeier, F. T. (1976). Multiple encoding of word attributes in memory. *Memory & Cognition, 4*, 307-310.

Zinober, J. W., Cermak, L. S., Cermak, S. A., & Dickerson, D. J. (1975). A developmental study of categorical organisation in short-term memory. *Developmental Psychology, 11*, 398-399.

Zwaan, R. A., Stanfield, R. A., & Yaxley, R. H. (2002). Language comprehenders mentally represent the shapes of objects. *Psychological Science, 13*, 168-171.