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Evidence for the Role of Shape in Mental Representations of Similes

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Abstract

People mentally represent the shapes of objects. For instance, the mental representation of an eagle is different when one thinks about a flying or resting eagle. This study examined the role of shape in mental representations of *similes* (i.e., metaphoric comparisons). We tested the prediction that when people process a simile they will mentally represent the entities of the comparison as having a similar shape. We conducted two experiments in which participants read sentences that either did (experimental sentences) or did not (control sentences) invite comparing two entities. For the experimental sentences, the ground of the comparison was explicit in Experiment 1 ("*X has the ability to Z, just like Y*") and implicit in Experiment 2 ("*X is like Y*"). After having read the sentence, participants were presented with line drawings of the two objects, which were either similarly or dissimilarly shaped. They judged whether both objects were mentioned in the preceding sentence. For the experimental sentences, recognition latencies were shorter for similarly shaped objects than for dissimilarly shaped objects. For the control sentences, we did not find such an effect of similarity in shape. These findings suggest that a perceptual symbol of shape is activated when processing similes.

Keywords: Perceptual symbol theory; Metaphor; Simile; Mental representation; Object shape

1. Introduction

The Perceptual symbol theory assumes that people activate perceptual representations during language comprehension (Barsalou, 1999). For example, if we talk about a table, we typically activate the representation of an object with a flat surface and four legs. This representation is the residue of our perceptual experiences with, in this case, a table. According to Barsalou (1999), such a representation is defined by the combination of

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several *perceptual symbols* for different components of the referent (e.g., the color, shape, orientation, and type of wood of the table). There is an analog relationship between these perceptual symbols and the referent. That is, the way an object is mentally represented is related to the way such an object is perceived in reality. For example, if the table is turned upside down, so too will the representation. This implies that if one reads a sentence stating that a table is turned upside down, then the mental representation will contain information about this specific orientation of the table. So any transformation of the referent implied by the sentence should cause analogous transformation in its representation.

Stanfield and Zwaan (2001) found evidence for this hypothesis in their study on the effect of implied orientation on mental representation. They presented participants with sentences such as *He hammered the nail into the wall* and *He hammered the nail into the floor*. Subsequently, participants saw a line drawing of the object mentioned in the sentence (i.e., the nail). The object was presented either in horizontal or vertical orientation, creating a match or mismatch with the representation evoked by the preceding sentence. They found faster recognition responses for pictures matching the orientation of the object implied by the sentence. Hence, their study shows that a perceptual symbol of *orientation* is activated in language comprehension and offers support for the theory of perceptual symbol systems.

Research by Zwaan, Stanfield, and Yaxley (2002) has shown that people also create a perceptual symbol for the *shape* of the object. 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. So this study shows that the shape of objects is related to their function or action (e.g., outstretched wings correspond to flying).

The shape of objects has been found to play an important role in the categorization of objects as well (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976; Sloutsky, 2003; Tversky & Hemenway, 1984). Related work has shown that similarly shaped objects are perceived to have similar functions and hence tend to be assigned to the same conceptual category (Gentner, 1978; Landau, Smith, & Jones, 1998; Van Weelden, Maes, Schilperoord, & Cozijn, 2011). For example, Van Weelden et al. (2011, Experiment 3) showed that finding a conceptual relation between two objects that stem from different conceptual categories is facilitated by similarity in shape between the two objects.

Along similar lines, Desmarais, Dixon, and Roy (2007) showed that visually similar objects paired with similar actions were confused more often in memory than when these objects were paired with dissimilar actions. In their experiment, participants were shown a novel object accompanied by its nonword label, and an action was performed on the object. During test trials, participants were asked to name the object that was placed in front of them. Participants made more errors in identifying similarly looking objects that were paired with similar actions than with dissimilar actions. This confusion of similarly looking objects with similar actions arises from interference as they are assigned to the same conceptual category. Objects that have the same function or ability to perform the same action are expected to look similar as well.

The purpose of the experiments reported here is to elaborate on these findings by studying the role of shape in mental representations of sentences that invite readers to compare two concepts to find conceptual correspondences between them. This way, we combine the aforementioned theories on the role of shape in mental representations and the relation between shape and conceptual knowledge in object comparisons.

We are particularly interested in the role of shape in mental representations of two compared concepts that stem from *different* categories as they generally do not share perceptual features, unlike concepts that belong to the same taxonomic category (e.g., animals or fruits) (Rosch et al., 1976). A cognitive mechanism that structures our reasoning, experience, and everyday language by the comparison of concepts from distinct conceptual categories is *metaphorical mapping* (Gibbs, 2006; Lakoff & Johnson, 1980a,b, 1999). Metaphorical mappings arise naturally, automatically, and unconsciously through everyday experiences by means of conflation (Grady, 1997). For example, pouring wine in a glass and seeing the level rise results in the metaphoric relation of "*more is up*." In everyday language, this metaphor is manifested in sentences like *"The price of cucumbers is very high"* or *"Inflation has risen."* As opposed to this indirect use of metaphor, metaphors can also be expressed more directly using the syntactic structure of a comparison, such as "*The mind is (like) a computer*" (Steen, Dorst, Herrmann, Kaal, & Krennmayr, 2010). As such, they highlight correspondences between the base and target concept, for instance that the mind (target) processes information in a similar manner as a computer (base) does. So, in interpreting a metaphor, we need to map our knowledge of the base domain onto the target domain.

There are different approaches to how these metaphoric mappings take place. The first approach to metaphor comprehension is that metaphors are comparisons that highlight similarities between the target and base concept (Bowdle & Gentner, 2005; Ortony, 1979). According to Gentner's (1983) Structure-Mapping Theory, a metaphor is interpreted by (a) aligning the representation of the base and target concept and by (b) mapping particular features from the base onto the target concept. The types of features that are mapped can be common relational structures (e.g., both entities can perform the same action or can be used to accomplish the same goal) or common attributive features (e.g., both entities look similar), with the constraint that people tend to prefer relational similarities over attributive similarities in their interpretations of metaphors (Gentner & Clement, 1988).

The second approach to metaphor comprehension is that metaphors are understood as categorization statements rather than as comparison statements (Glucksberg, 2003). According to this view, metaphors establish taxonomic relations between concepts from disparate conceptual domains. Rather than the idea that the target concept is being compared to the base concept to see what they have in common, the target concept is assigned to the metaphoric category activated by the base concept. For instance, in interpreting "*My job is a jail,*" all features characterizing the metaphoric category elicited by "jail" (i.e., an unpleasant and confining situation) are mapped onto the concept of "job." According to Glucksberg, McGlone, and Manfredini's (1997) Interaction property attribution model, base concepts do not elicit just one metaphoric category, but rather a number of possible metaphoric categories (i.e., a lonely place or a situation that excludes you from society).

Bowdle and Gentner's (2005) Career of Metaphor hypothesis reconciles these two approaches and proposes that there is a shift in type of mapping (i.e., from comparison to categorization) as metaphors become conventionalized. Novel metaphors involve base concepts that are not (yet) associated with a metaphoric category and, therefore, they are processed as comparisons, in which the target concept is compared to the base object. Conventional metaphors, on the other hand, involve base terms that, due to recurrent use, already refer to a metaphoric category. Conventional metaphors can therefore be processed through categorization, by seeing the target concept as member of the category that is activated by the base concept.

Interestingly, these different comprehension strategies can also be evoked by different linguistic structures. Conventional metaphors typically take the structure of a *metaphor*: "*An X is a Y*." This structure is identical to the structure of a literal categorization, such as *An orange is a fruit*. Akin to a literal categorization, a metaphor invites to classify the target concept as a member of the category that is represented by the base concept. Novel comparisons typically take the structure of a *simile*: "*An X is like a Y*," which is grammatically similar to a literal comparison, such as *An orange is like a mandarin*. The comparative term *like* invites to compare the two concepts mentioned in the sentence. Hence, simile comprehension involves an online comparison process.

Shape might play an important role in this comparison process. That is, we know that in interpreting metaphoric relations, people have a preference for conceptual similarities (i.e., common relational structures) over perceptual similarities (i.e., common attributive features) (Gentner & Clement, 1988) and that conceptually similar objects are expected to look similar as well (Desmarais et al., 2007). Accordingly, thinking of conceptual similarities between concepts might result in a mental representation of similar looking objects. Hence, in this study, we hypothesize that the identification of conceptual similarity during simile comprehension leads to an assumption of shape similarity, resulting in a mental representation of two similarly shaped objects.

In sum, where Zwaan et al. (2002) studied the effect of implied shape resulting from a specific event description on the mental representation of single objects, we study the effect of implied shape of similes (i.e., sentences that invite to compare the objects) on the representation of pairs of objects. We predict that when people process a simile they will mentally represent the entities of this comparison as having a similar shape. To test this prediction, we examine the effect of similarity in shape on recognition latencies to two simultaneously presented pictures of the objects, either similar or dissimilar in shape that were mentioned in a preceding sentence which either did (very explicitly in Experiment 1 and rather implicit in Experiment 2) or did not invite to compare the two entities.

2. Experiment 1

In Experiment 1, an experimental group receives explicit comparison sentences. That is, participants receive similes explicitly describing a conceptual similarity between two objects, for example "*A forklift lifts heavy things, just like an elephant*." A control group receives sentences with a sentential structure that does not invite to compare two objects. That is, participants of this group receive sentences describing a locational relation between two entities, such as "*A forklift was located in front of an elephant*." Both groups of participants will then be presented two line drawings of the mentioned objects. The two drawings either have a similar or dissimilar outline. Participants are asked to judge as fast as possible whether the two presented objects were mentioned in the preceding sentence. If a metaphoric relation implies shape similarity between entities, then recognition latencies should be faster for objects that are similar in shape as compared to objects that are not similar in shape. For the location sentences, the sentence structure does not invite to compare the two entities and therefore, for these sentences, we do not expect differences between the recognition latencies to the similar and dissimilar-shaped objects.

2.1. Method

2.1.1. Participants

Sixty-nine Tilburg University undergraduates (51 women and 18 men) participated in this study for course credit. Their mean age was 21 years, ranging from 18 to 30. All participants were unaware of the purpose of the experiment and had normal or corrected-to-normal vision. None of the participants had participated in the materials pretest (see next section).

2.1.2. Materials

We created 80 Dutch sentences: 20 (explicit) similes and 20 location sentences (see the Appendix for the Dutch sentences and English translations) and 40 filler sentences. The similes described a conceptual correspondence between two entities from different conceptual categories in an "*X has the ability to Z, just like Y*" construction. The conceptual correspondence was made explicit in the sentence (i.e., "*has the ability to Z*") so that the participants could not relate the entities solely on perceptual features. We created the sentences either with an action verb (1) or with a conjugation of the verb *to be* followed by a conceptual characteristic (2). The location sentences were created with the intention to mention both the target and base entity, but to prevent that the two entities were compared to each other in any way. Therefore, the location sentences only described a spatial relation between the target and the base entity. To create state of affairs, we used sentences with verbs expressing a state of being (3) and/or with action verbs in the past tense (4). We avoided using prepositions of location such as "next to" or "opposite of," because the actual presentation of the target object was "next to" or "opposite of" the base object. These prepositions could elicit expectations about the visual presentation of the objects, which could affect the recognition latencies. Instead, we used prepositions such as "in front of," "above," or "behind." The experimental sentences required a "yes" response. Therefore, an equal number of filler sentences mentioned a base entity that differed from the object that was presented in the picture, and thus required a "no" response.

(1) Een motor trekt heel snel op, net als een luipaard.
A motorcycle accelerates very fast, just like a leopard.

(2) Een pion is van relatief lage waarde, net als een soldaat.
A pawn is of relatively little value, just like a soldier.

(3) Een bulldozer stond op een mier.
A bulldozer stood on top of an ant.

(4) Een helikopter zweefde boven een libel.
A helicopter hovered above a dragonfly.

We used 20 experimental picture sets, each containing one target object and two base objects (see Data S1), and 20 filler picture pairs, each consisting of one target and one base object.[1] The pictures were simple black-and-white line drawings, placed in an area of 200 × 200 pixels. The shape of the base object was depicted either similar (+Shape) or dissimilar (−Shape) to the target object, see Fig. 1. By shape, we mean the outline of the picture of a particular object.

2.1.2.1. Shape similarity pretest: Manipulations of object shape were pretested by subjective ratings of shape similarity. Seventeen participants were presented with the 40 experimental picture pairs and were asked to rate their perceptual similarity. They were instructed to move a slider along a track from 0 (not similar) to 1 (similar) to indicate

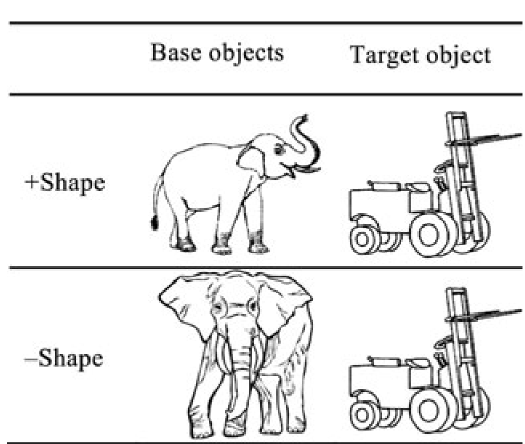

Fig. 1. Example picture set with two picture pairs: +Shape and −Shape.

their judgment about the shape similarity of the object pairs. A *t* test revealed a significant difference between the ratings for the +Shape (.63) and the −Shape pairs (.26); $t(16) = 12.16$, $p < .001$.

2.1.2.2. Affordance pretest: Gibson's (1977, 1979) Affordance theory postulates that objects are not only perceived in terms of their shapes and spatial relationships but also in terms of their affordances, that is, the object's possible function. For example, we sometimes use our T-shirt to clean our glasses. The nature of the shirt (i.e., a "square" of soft absorbent fabric) affords that we can use it that way. So the shape and affordances of an object are inseparable. The +Shape and −Shape base objects therefore highlight different affordances. This might make the conceptual feature described in the metaphoric sentence more or less apparent in the subsequently presented base object. For example, the feature "to fly" is more apparent for the +Shape variant of the swan (i.e., the flying swan) than for the −Shape variant (i.e., the sitting swan). These differently highlighted affordances might affect the recognition latencies for the +Shape and −Shape object pairs. To control for this effect, we pretested which affordances are activated by the different types of base objects. Forty participants were presented with one of two lists of base objects, each containing 10 +Shape and 10 −Shape base objects. The two lists counterbalanced items and shape condition. Participants were instructed that they were presented with a number of pictures of objects and that, for each picture, they had to produce as many characteristic features as they could within a 15-s time span. They were encouraged to speak out everything that came to mind. On the basis of these production data, we were able to choose conceptual features that were mentioned equally often for two shape versions of the base objects. Therefore, for the swan-airplane pair, for instance, we chose the feature "to land softly" rather than "to fly."[2]

2.1.2.3. Prototypicality pretest: Another factor that might affect the recognition latencies for the +Shape and −Shape object pairs is the prototypicality of the different shapes of the base objects. The base objects from the similarly shaped pairs might have a more prototypical shape than the base objects from the dissimilarly shaped pairs, or the other way around. This might make it easier to identify and recognize base objects from one of the two shape conditions. To control for this effect, we conducted a prototypicality test in which 10 participants chose the most prototypical picture from the two base pictures. In this test, participants were instructed to read a presented word, imagine what the object described by the word would look like, and then, from two objects, pick the object that provided the closest match to their imagined object. A chi-square analysis did not reveal a difference between the prototypicality of the +Shape (54.3%) and −Shape (45.7%) base pictures; $\chi^2(1, N = 200) = .50$, $p = .48$.

2.1.3. Design

The experiment had a 2 × 2 × 2 design, with Type of sentence (levels: simile and location) and List (levels: List 1 and List 2) as between-subjects factors and Shape (levels: +Shape and −Shape) as within-subjects factor. The two lists counterbalanced picture sets and shape condition.

2.1.4. Procedure

Participants were instructed to read each sentence and subsequently decide if the objects that followed were mentioned in the preceding sentence. They were also told that reaction times were being measured and that it was important to make their decisions as quickly as possible. During each experimental trial, participants first saw a fixation cross in the center of the screen for 1,000 ms. Subsequently, the sentence appeared, which either did or did not mention both objects presented later. Participants pressed the "yes" button when they had understood the sentence after which another fixation cross appeared in the center of the screen for 500 ms, followed by the simultaneous presentation of the two object pictures. The picture of the target object was always presented on the left side and the picture of the base object on the right side. Participants then had to determine whether both objects were mentioned in the preceding sentence. They produced their response by pressing a key on a button panel. The "yes" response key was always located on the dominant hand side of the participants. Immediately after their judgment, feedback indicated whether the answer was correct, incorrect, or given too late, that is, after more than 2 s. Directly following the feedback, the next trial started with a fixation cross on the screen.

Participants were assigned to one of the four conditions (Type of sentence × List) in the same order as they came to the lab. Participants were instructed that they were going to take part in a reaction time experiment and that it was important for them to make the decisions about the pictures as quickly as possible. Each participant saw 20 sentence–picture pairs, requiring "yes" responses, and 20 filler pairs, requiring "no" responses. The experiment started with five practice trials to familiarize the participants with the task.

E-Prime software[3] was used to control the presentation durations of the fixation crosses and pictures, to randomize the sentence–picture pairs, and to collect the recognition latencies.

2.2. Results and discussion

We conducted a 2 × 2 × 2 analysis of variance (ANOVA), with Type of sentence (levels: simile and location) and List (levels: List 1 and List 2) as between-subjects factors and Shape (levels: +Shape and −Shape) as within-subjects factor, on the recognition response latencies. Table 1 displays the median response latencies. The analyses of the response latencies focused on the response latencies of the correct responses; 3.4% of the data was excluded for this reason. Following Stanfield and Zwaan (2001) and Zwaan et al. (2002), we used the median correct response time per participant per condition in the analyses to decrease the effects of extreme outliers.[4]

We did not find an effect of List on response latency ($F_1 < 1$; $F_2 < 1$). Neither the two-way interaction between List and Shape ($F_1(1, 65) = 2.83$, $p = .10$; $F_2 < 1$) nor the three-way interaction between List, Type of sentence, and Shape ($F_1 < 1$; $F_2 < 1$) was

Table 1
Median object response latencies in ms (SD in parentheses) for Experiment 1 and Experiment 2

	Shape		
Type of Sentence	+Shape	−Shape	/d/
Experiment 1			
Location	791 (149)	802 (145)	11
Simile (explicit)	730 (133)	793 (188)	63
Experiment 2			
Simile (implicit)	725 (144)	757 (142)	32

significant. The two-way interaction between List and Type of sentence was only significant in the analysis by items ($F_1 < 1$; $F_2(1, 18) = 5.52$, $p < .05$, $\eta^2_p = .23$). As a result, we excluded the factor List from the rest of the analyses.

There was an effect of Shape on response latency: Responses were faster for objects that were similar in shape than for objects that were dissimilar in shape, $F_1(1, 67) = 8.94$, $p < .01$, $\eta^2_p = .12$; $F_2(1, 19) = 3.42$, $p = .08$. The effect of Type of sentence was only significant in the analysis by items, $F_1 < 1$; $F_2(1, 19) = 4.54$, $p < .05$, $\eta^2_p = .19$. The analysis (by participants) showed that the two factors interacted, $F_1(1, 67) = 4.68$, $p < .05$, $\eta^2_p = .07$; $F_2(1, 19) = 1.51$, $p = .23$. Post hoc analyses revealed that for the simile sentences response latencies were significantly faster for objects that were similar in shape as compared to objects that were dissimilar in shape, $F_1(1, 37) = 13.30$, $p < .01$, $\eta^2_p = .26$, $F_2(1, 19) = 5.45$, $p < .05$, $\eta^2_p = .22$. Yet for the location sentences it did not matter whether two objects were similar or dissimilar in shape ($F_1 < 1$; $F_2 < 1$).

These results show that for the similes recognition latencies were shorter for similarly shaped objects than for dissimilarly shaped objects. For location sentences, however, we did not find any differences in recognition latencies to the two types of object pairs. This indicates that the recognition of two objects that were mentioned in a simile (of which the sentential structure invites to compare the two entities) was influenced by the similarity in shape of the two objects, and that this is not the case for the recognition of two objects that were mentioned in a location sentence (which sentential structure does not invite to compare the two entities). These findings support the hypothesis that people mentally represent the entities of a simile as having a similar shape.

The invitation to compare the concepts was quite explicit in the similes used in the present experiment, as the conceptual "ground" of the metaphoric relation was already given in the sentences. As a result, one might argue that our findings, at least for a couple of items, can be explained in terms of an amodal propositional structure (Kintsch, 1998; Kintsch & van Dijk, 1978), as, for example, the sentence "*A fan unfolds, just like a peacock*" activates the idea of an open folded object, which therefore might result in faster recognition latencies to a peacock with open feathers than to a peacock with closed feathers. Yet similes can be more implicit as well in that they leave the task of finding conceptual correspondences to the reader. An effect of similarity in shape for these implicit similes would strengthen our interpretation of the results in favor of perceptual symbols, rather than amodal symbols.

3. Experiment 2

The presented alternative explanation for the findings of Experiment 1 would be disproved if we would find the same results with implicit similes, as this typical "*An X is like a Y*" structure leaves the nature of the correspondence unspecified. Therefore, Experiment 2 examines the role of shape in mental representations of similes with this structure. If we assume that people indeed have a preference for metaphoric interpretations based on conceptual correspondences and that the identification of this type of similarity indeed invites to the assumption of shape similarity, then we should find the same results as we did in Experiment 1.

3.1. Method

3.1.1. Participants

Thirty-three Tilburg University undergraduates (21 women and 12 men) participated in this study for course credit. Their mean age was 21 years, ranging from 18 to 29. All participants were unaware of the purpose of the experiment and had normal or corrected-to-normal vision. None of the participants had participated in Experiment 1 or the materials pretest.

3.1.2. Materials and procedure

The 20 experimental picture sets and 20 filler picture pairs were identical to those of Experiment 1. Yet the experimental sentences had an "*An X is like a Y*" construction, for example "*A motorcycle is like a leopard*." Compared to Experiment 1, the conceptual (or perceptual) correspondence between the target and base concept was left implicit, rather than explicitly stated.

The procedure was the same as in Experiment 1; however, this time the between-subjects factor Type of sentence was not included. Hence, participants were only assigned to one of the two lists in the same order as they came to the lab.

3.1.3. Design

The experiment had a 2 × 2 design, with List (levels: List 1 and List 2) as between-subjects factors and Shape (levels: +Shape and −Shape) as within-subjects factor. The two lists counterbalanced picture sets and shape condition.

3.2. Results and discussion

We conducted a 2 × 2 ANOVA, with List (levels: List 1 and List 2) as between-subjects factor and Shape (levels: +Shape and −Shape) as within-subjects factor, on the recognition response latencies. Table 1 displays the median response latencies. The analyses of the response latencies focused on the response latencies of the correct responses; 3.7% of the data was excluded for this reason.

Again, we did not find an effect of List on response latency ($F_1 < 1$; $F_2 < 1$). There was also no two-way interaction between List and Shape ($F_1(1, 31) = 2.22$, $p = .15$; $F_2 < 1$). As a result, we excluded the factor List from the rest of the analysis. The analysis showed an effect of Shape on response latency: Responses were faster for objects that were similar in shape than for objects that were dissimilar in shape, $F_1(1, 32) = 4.64$, $p < .05$, $\eta^2_p = .13$; $F_2(1, 19) = 8.43$, $p < .01$, $\eta^2_p = .31$.

Similar to the findings of Experiment 1, this finding shows that the recognition of two objects that were mentioned in an "*An X is like a Y*" sentence was influenced by the similarity in shape of the two objects. The recognition of the mentioned objects was faster for the similarly shaped objects as compared to the dissimilarly shaped objects. These findings provide additional support for the hypothesis that people mentally represent the entities of a simile as having a similar shape.

4. General discussion

The purpose of this study was to examine whether a perceptual symbol of *shape* is activated when processing similes (i.e., metaphoric comparisons). We tested the prediction that the invitation to identify conceptual similarities between the base and target concept leads to an assumption and representation of shape similarity. Hence, for the task in which participants read similes (with or without explicit conceptual correspondence) and subsequently had to determine whether two presented objects were mentioned in the preceding sentences, we expected shorter recognition latencies to similarly shaped objects as compared to dissimilarly shaped objects. Our results confirmed this expectation. For the similes presented in both Experiment 1 and 2, participants were faster in recognizing similarly shaped objects as compared to dissimilarly shaped objects. Furthermore, such an effect was absent for the control sentences, which did not invite to compare the two mentioned concepts. Thus, our results indeed suggest that a perceptual symbol of *shape* is activated when processing similes.

Although we conducted an affordance pretest, one might argue that for some of the experimental items the similarly shaped base object fitted the conceptual ground of the simile better than its dissimilarly shaped counterpart, which could have influenced the obtained results. A follow-up analysis without the potentially confounding items (i.e., item 1, 3, 4, 5, 11, 14, and 20), however, still showed an effect of Shape for both the explicit and implicit similes, and for the control sentences the effect remained absent.[5] Thus, our finding that the recognition of two objects mentioned in a simile was influenced by their similarity in shape was not caused by such an affordance bias.

Our study seems to broaden the insights of Stanfield and Zwaan (2001) and Zwaan et al. (2002) on the activation of visual information in mental representations in two ways. First, just like context (e.g., *X in the sky*) can evoke a perceptual symbol of *shape*, our study shows that *sentence structures* (i.e., *X is like Y*) can evoke such a symbol as well. Second, where Zwaan et al. (2002) show the effect of implied shape (through context) on the mental representation of single objects, this study shows the effect of implied shape (through metaphorical relations) on the mental representations of *multiple* objects.

Interestingly, recent work by Vandeberg, Eerland, and Zwaan (2012) on the *strength* of a visual representation in memory showed that reading about a present object (e.g., *Jennifer saw a water fountain*) results in a stronger visual representation of the object (i.e., the water fountain) than when reading about an absent object (e.g., *Jennifer saw no water fountain*). If we apply this to our results, then this may predict that explicitly mentioned conceptual correspondences resulted in stronger visual representations than implicit conceptual correspondences. Closer inspection of our findings suggests that this indeed might be the case. As can be seen in Table 1, there was a 63-ms effect for the explicit similes and a 32-ms effect for the implicit similes. Given that the recognition latencies to the similarly shaped objects were almost equal for both types of similes, the latencies to the dissimilarly shaped objects seem to be increased for the explicit similes. This might be the result of additional cognitive processing. As proposed, the explicit conceptual correspondences might have underlined the commonalities between the two concepts, thereby creating a stronger visual representation. As a result, the presented dissimilarly shaped objects may have been highly incongruent with this representation, leading to prolonged recognition latencies.

The findings of this study also align with findings on the role of shape in comparing objects. In previous work, we showed that finding a conceptual relation between two (conceptually different) objects is facilitated by shape similarity (Van Weelden et al., 2011). Furthermore, in a recent study we showed that similarity in shape facilitates the process of interpreting visual metaphors (Van Weelden et al., 2012). Both findings confirmed the hypothesis that similarity in shape affects conceptual (and metaphorical) processing. So shape similarity seems to suggest conceptual similarity. This study shows that this relationship also works the other way around. That is, the conceptual correspondence suggested by the "*An X has the ability to Z, just like a Y*" and "*An X is like a Y*" structures results in a mental representation of two similarly shaped objects. Hence, conceptual similarity suggests shape similarity.

This two-way interaction between perceptual and conceptual information can be represented theoretically by extending Humphreys and Forde's (2001) Hierarchical interactive theory (HIT), which models the identification process of visual objects. The theory posits three types of stored knowledge of objects: (a) structural descriptions, (b) semantic knowledge, and (c) name representations. When we see an object, its visual features activate a *structural description* that captures information about the object's outer appearance. Structural descriptions spread activation to stored *semantic knowledge* of the object. The main tenet of HIT is that activated semantic knowledge feeds back to structural descriptions; first, visual information provides access to nonvisual semantic information, and, second, this semantic information reinforces visual information of the object.

Based on this theory, Van Weelden et al. (2012) predicted that similarity in shape between visual objects facilitates finding conceptual correspondences as the overlapping structural descriptions activate semantic knowledge that is relevant to both objects; see the top-down arrows in Fig. 2. The experiments presented here offer evidence for the

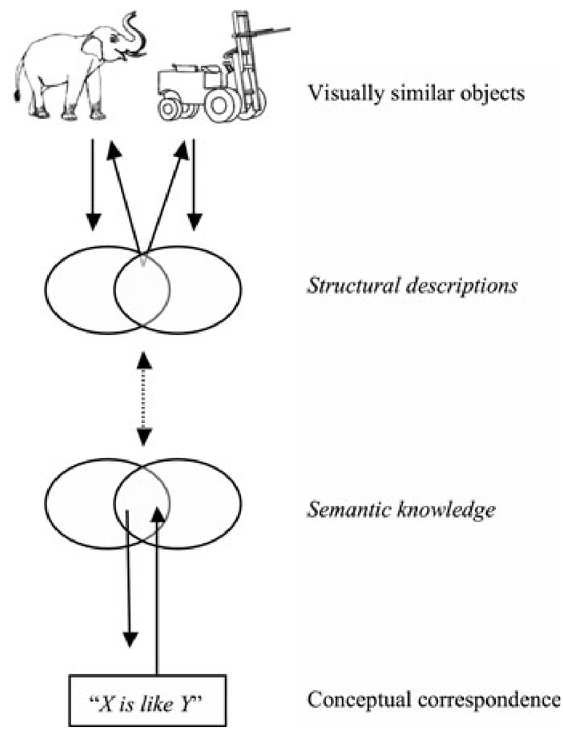

Fig. 2. A model of how perceptual similarity (i.e., structural descriptions) affects conceptual knowledge (i.e., semantic knowledge), derived from the HIT framework as proposed by Humphreys and Forde (2001). Based on the results of the studies in this article, the top-down visual objects processing model (see Van Weelden et al., 2012) is extended by a bottom-up process modeling the way in which a verbal invitation to create conceptual correspondences suggests similarly shaped mental representations of visual objects.

reverse of this process; see the bottom-up arrows in Fig. 2. They show that the structure of a simile, which invites readers to search for conceptual correspondences (i.e., overlapping semantic knowledge), comes with the assumption of overlapping structural descriptions (i.e., visual features), which suggests the construction of similarly shaped mental representations.

To what degree can our findings be applied to the comprehension of all metaphors? Due to the experimental control of our experiments, we studied metaphorical comparisons between concrete concepts, whereas metaphors and similes typically employ abstract concepts as the target and concrete or physical concepts as their base. It seems reasonable to assume that readers activate shape when they mentally represent two concepts, as shape is one of the most intrinsic characteristics of objects. Obviously, *similarity* in shape only applies if a concrete shape can be activated for both the target and the base concept, or, in HIT terminology, when a structural description can be activated for both. For example, in interpreting a metaphor like "*Democracy is like a delicate flower*," it is hard to see how shape would be relevant, as a structural description of democracy is hard to conceive. Yet even if structural descriptions can be activated for both concepts, *similarity* in shape might be more appropriate for some comparisons than others. Consider for example Shakespeare's "*It is the east, and Juliet is the sun*." Although we can activate a shape for Juliet, we probably do not assume she is round like the sun. For these cases it might well be that, initially, an assumption of overlapping structural descriptions is activated, but that this assumption needs to be suppressed for the final interpretation of the metaphor. Evidence for the role of *executive control* in analogy comprehension might support this idea. Executive control is defined as a set of cognitive processes that, instead of representing mental states directly, influence and organize such states in the context of some internal goal (Elliott, 2003). Research has shown that executive control plays a central role in situations where salient associations come immediately to mind but are not relevant to the analogy problem (Richland, Morrison, & Holyoak, 2006; Thibaut, French, & Vezneva, 2010). In interpreting metaphors like "*Juliet is the sun*," shape associations might come to mind, but as the metaphor crucially depends on relational correspondences additional cognitive processing is needed to adjust the mental representation.

On the other end of the scale, there are metaphors which are crucially dependent on mental imagery, like image (or resemblance) metaphors (Lakoff, 1987; Urena & Faber, 2010). In this type of metaphor, conventional mental images are mapped onto other conventional mental images. As shape is an important ingredient of mental images, it is likely to assume that our results typically apply here. Consider, for example, this metaphor in André Breton's poem *Free Union*, "*My wife whose waist is an hourglass*." We understand this metaphor only by the mapping of the shape of an hourglass onto the waist of a woman. Thus, these metaphors show that perceptual attributes (like shape) can be crucial in the interpretation of metaphors.

Our results, however, show that the role of perceptual similarity goes beyond cases in which similarity is the only ground of the metaphoric comparison: Shape is involved in metaphor processing irrespective of whether or not it has a meaningful link with the conceptual correspondences involved in the comparison.

Yet shape is not the only perceptual feature relevant in metaphor processing. Many other perceptual features (e.g., size, verticality, distance, and color) are known to have strong metaphorical meaning as well (e.g., Boot & Pecher, 2010; Casasanto, 2008; Schubert, 2005). Abstract concepts might activate one of these perceptual features. For example, the mental representation of *love* could contain the color red and *life* might be represented as an increasing rather than a decreasing line. So the mental representation of abstract-concrete or abstract–abstract pairs of concepts might involve similarity in terms of perceptual features as well.

The concepts used in this study call for ad hoc comparisons as the combinations of target and base concepts are rather novel. We assume that this process is different in the case of comprehension of conventional metaphors. Hence, an interesting alley for future research would be to investigate the effect of conventionality on the mental representations of metaphoric sentences. As described in the Introduction, Bowdle and Gentner's (2005) Career of Metaphor hypothesis proposes that there is shift in type of mapping (i.e., from comparison to categorization) as metaphors are conventionalized. These different types of mappings might result in different mental representations. That is, for conventional metaphors, the target concept can directly be assigned to the metaphoric category which is activated by the base concept. For novel metaphoric relations, however, the target concept needs to be compared to the base concept to find similarities between the two. As shown by this study, this comparison process results in a mental representation of similarly shaped objects. Yet when processing conventional metaphors, this comparison process is superfluous as the base concept is already associated with a metaphoric category. As a consequence, the role of shape in mental representations of conventional metaphors might be less prominent. A neat way to test this hypothesis would be to design an experiment using Bowdle and Gentner's (2005, Experiment 3) in vitro conventionalization paradigm. In the study phase of this paradigm, participants receive triads of novel similes using the same base concept. The first two similes of each triad contain different target concepts but are similar in meaning. For the third simile, the participant has to fill in the target term. This way, the novel base concept becomes conventionalized. The test phase following this study phase could then be identical to the present experiment. To investigate whether there are differences in the role of shape in the mental representations of novel and conventional similes, a between-subjects factor would test differences in recognition latencies between participants who performed only the test phase (novel condition) or both the study and test phase (conventional condition).

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Notes

1. About 14 of the 20 experimental picture sets were also used in a previous study of Van Weelden, Maes, Schilperoord, and Swerts (2012).
2. Because this pretest was part of a previous experiment in which we only used sets 1–14 (Van Weelden et al., 2012), we had no production data of sets 15–20. For these sets, we made sure that the conceptual feature was not afforded by the shapes of one of the base objects.
3. See http://www.pstnet.com/eprime/cfm.
4. Analyses done on the means yielded the same pattern of results as the analyses on the medians.

5. Explicit simile: $F_1(1, 37) = 9.43$, $p < .01$, $\eta^2_p = .20$; $F_2(1, 12) = 5.25$, $p < .05$, $\eta^2_p = .30$. Implicit simile: $F_1(1, 32) = 5.90$, $p < .05$, $\eta^2_p = .16$; $F_2(1, 12) = 1.97$, $p = .19$. Control sentences: $F_1(1, 30) = 1.15$, $p = .29$; $F_2(1, 12) = 1.36$, $p = .27$.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Data S1. Picture sets.

Appendix

Set	Simile (explicit; Experiment 1)	Simile (implicit; Experiment 2)	Location (Experiment 1)
1	Een motor trekt heel snel op, net als een luipaard *A motorcycle accelerates very fast, just like a leopard*	Een motor is als een luipaard *A motorcycle is like a leopard*	Een motor stond voor een luipaard *A motorcycle stood in front of a leopard*
2	Een jeep gaat door het water, net als een nijlpaard *A jeep goes through water, just like a hippo*	Een jeep is als een nijlpaard *A jeep is like a hippo*	Een jeep bevond zich achter een nijlpaard *A jeep was located behind a hippo*
3	Een waaier vouwt uit, net als (bij) een pauw *A fan unfolds, just like a peacock*	Een waaier is als een pauw *A fan is like peacock*	Een waaier lag voor een pauw *A fan lay in front of a peacock*
4	Een vliegtuig landt zachtjes, net als een zwaan *An airplane lands softly, just like a swan*	Een vliegtuig is als een zwaan *An airplane is like a swan*	Een vliegtuig landde net voor een zwaan *An airplane landed just in front of a swan*
5	Een vuurtoren is van verre te zien, net als een giraf "*A lighthouse can be seen from far away, just like a giraffe*"	Een vuurtoren is als een giraf *A lighthouse is like giraffe*	Een vuurtoren stond voor een giraf *A lighthouse stood in front of a giraffe*
6	Een heftruck tilt zware dingen, net als een olifant *A forklift lifts heavy things, just like an elephant*	Een heftruck is als een olifant *A forklift is like an elephant*	Een heftruck bevond zich voor een olifant *A forklift was located in front of an elephant*
7	Een caravan is een verplaatsbaar huis, net als (bij) een schildpad *A caravan is a movable house, just like a turtle*	Een caravan is als een schildpad *A caravan is like a turtle*	Een caravan stond op een schildpad *A caravan stood on top of a turtle*
8	Een dartpijltje prikt, net als een mug *A dart stings, just like a mosquito*	Een dartpijltje is als een mug *A dart is like a mosquito*	Een dartpijltje bevond zich boven een mug *A dart was located above a mosquito*
9	Een helm beschermt, net als een schelp *A helmet protects, just like a shell*	Een helm is als een schelp *A helmet is like a shell*	Een helm lag over een schelp *A helmet covered a shell*
10	Een pion is van relatief lage waarde, net als een soldaat *A pawn is of relatively little value, just like a soldier*	Een pion is als een soldaat *A pawn is like a soldier*	Een pion stond voor een soldaat *A pawn stood in front of a soldier*

(continued)

Table (continued)

Set	Simile (explicit; Experiment 1)	Simile (implicit; Experiment 2)	Location (Experiment 1)
11	Een fotocamera stelt scherp, net als een oog *A camera focuses, just like an eye*	Een camera is als een oog *A camera is like an eye*	Een fotocamera hield je voor een oog *A camera was held in front of an eye*
12	Een tol draait snel rond, net als een ballerina *A spinning top spins very fast, just like a ballerina*	Een tol is als een ballerina *A spinning top is like a ballerina*	Een tol stond achter een ballerina *A spinning top stood behind a ballerina*
13	Een klok geeft de tijd aan, net als de zon *A clock indicates the time, just like the sun*	Een klok is als de zon *A clock is like the sun*	Een klok stond in de zon *A clock stood in the sun*
14	Een computermuis wijst iets aan, net als een hand *A computer mouse points at something, just like a hand*	Een computermuis is als een hand *A computer mouse is like a hand*	Een computermuis lag onder een hand *A computer mouse lay under a hand*
15	Een vlieger zweeft op de wind, net als een meeuw *A kite floats on the wind, just like a seagull*	Een vlieger is als een meeuw *A kite is like a seagull*	Een vlieger belandde achter een meeuw *A kite landed behind a seagull*
16	Een helikopter zweeft bewegingloos in de lucht, net als een libel *A helicopter hovers motionless in the sky, just like a dragonfly*	Een helikopter is als een libel *A helicopter is like a dragonfly*	Een helikopter zweefde boven een libel *A helicopter hovered above a dragonfly*
17	Een weg is onvoorspelbaar, net als een slang *A road is unpredictable, just like a snake*	Een weg is als een slang *A road is like a snake*	Op een weg bevond zich een slang "*On a road, a snake was located*"
18	Een bulldozer is heel sterk, net als een mier *A bulldozer is very strong, just like an ant*	Een bulldozer is als een mier *A bulldozer is like an ant*	Een bulldozer stond op een mier *A bulldozer stood on top of an ant*
19	Een kantoorgebouw is een centrum van bedrijvigheid, net als een bijenkorf *An office building is a centre of activity, just like a beehive*	Een kantoorgebouw is als een bijenkorf *An office building is like a beehive*	In een kantoorgebouw bevond zich een bijenkorf "*In an office building, a beehive was located*"
20	Een wekker maakt je wakker, net als een haan *An alarm clock wakes you up, just like a rooster*	Een wekker is als een haan *An alarm clock is like a rooster*	Een wekker stond achter een haan *An alarm clock stood behind a rooster*