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Conceptual Information about Size of Objects in Nouns

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Abstract

Two experiments provide evidence that information about the real-life size of objects is elicited by nouns. A priming paradigm was used with a category membership verification task. The results showed that targets were responded to faster when preceded by a same size prime, and that large entities were processed faster than small ones. Overall, our results significantly extend previous work on perceptual information elicited by concepts [e.g., Zwaan & Yaxley, 2004, Lateralization of object-shape information in semantic processing. *Cognition, 94,* B35-B43] and, in particular, on size information [e.g., Rubinstein & Henik, 2002, Is an ant larger than a lion? *Acta Psychologica*, *111,* 141-154] by means of a size-unrelated paradigm.

Keywords: Conceptual Knowledge; Categorization; Size

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Conceptual Information about Size of Objects in Nouns

Recent theories have stressed the embodied character of cognition, stating that concepts are grounded in the situations and actions that activate them (Barsalou, 1993; Glenberg, 1997; Thelen & Smith, 1994). Within such a framework, objects' perceptual characteristics play a fundamental role in shaping conceptual knowledge in both children (Jones & Smith, 1998) and adults (e.g., Borghi, Glenberg & Kaschak, 2004).

It has been shown that nouns elicit information about objects' perceptual characteristics (e.g., Caramelli, Setti & Maurizzi, 2004) and situations (Lin & Murphy, 2001; Borghi & Caramelli, 2003), as well as activating information about the possible actions people can perform with them (Borghi, 2004; Borghi et al., 2004).

Brain imaging studies have shown that the same brain regions are active when objects are presented visually and information about them is retrieved (see Martin, 2007 for a review). For example Chao, Haxby and Martin (1999) found a differentiated activation of the lateral and medial regions of the fusiform gyrus for animals and tools both when the picture of objects and their names were presented. Moreover Simmons, Ramjee, Beauchamp, McRae, Martin and Barsalou (2007) found that retrieving information about the color of an object through its name and perceiving its color both activated a region of the left fusiform gyrus, thus showing that the same neural substrate is active for knowing and perceiving color.

In this line of work a number of behavioral studies show that perceptual information about objects is activated by both images (e.g., Flores d'Arcais, 1987) and linguistic stimuli (e.g., Zwaan Stanfield, Yaxley, & Richard, 2002).

The aforementioned studies have focused on the activation of objects' perceptual characteristics such as shape, parts, or color. To our knowledge few studies have focused on conceptual information on objects' size activated by nouns. The aim of this study is to investigate whether real-life size of objects is conveyed by their names. Both neuroimaging and behavioral studies lead us to hypothesize that they do.

Information on objects' size is acquired through vision and action with objects and this information is strictly connected with how people interact with them. For this reason, activating objects’ size with linguistic stimuli implies both activation of the ventral (what) and dorsal (how) pathways. Oliver & Thompson-Schill (2003) in a fMRI study on size, shape and color characteristics, showed that when participants were presented with objects’ names and they were asked to judge the size, small or large, of the object, the activation of the dorsal pathway was registered for size and shape more than for color.

Real life size is also activated when participants are not asked to directly judge on this characteristic. Rubinstein & Henik (2002) used a size-judgment task in order to investigate the automatic activation of size information by nouns with a Stroop-like paradigm. They hypothesized that, if nouns of animals elicit information about their size, this information should interfere with the evaluation of the size of the written animals’ names, i.e., the font size of the word. Participants, when presented with the names of two animals, had to choose either the name written in the largest font (physical comparison) or the name of the largest animal in real-life (semantic comparison). In the physical comparison condition, which is of most concern in this study, participants were asked to judge the relative size of the font. The stimuli were congruent when the name of the largest animal coincided with the largest font, e.g., lion ant. They were neutral when the animal referred to by the two names was the same, but the two names were written in different size fonts, e.g., lion lion. They were incongruent when the name of the largest animal in real-life was written in the smallest font, e.g., lion ant. Participants responded faster to the congruent than to the neutral condition, i.e., there was a facilitation effect, and they responded slower in the incongruent than in the neutral condition, i.e., there was an interference effect. This study indeed shows that the processing of the names of animals activates conceptual information about real-life animals' size even in the font-size judgment, i.e., when the size information of the animals is irrelevant to the task. An objection could, however, be made, that the activation of real-life animals' size could have been a by-product of the same task, which required the assessment of size, even if it was the size of the font, instead of the animals.

In our study we, therefore, tested a stronger hypothesis, i.e. that nouns elicit information on objects' size in a task that is completely unrelated to information on size. Our task requires a judgment on category, not a comparison on size. If size is activated, then further evidence will be provided in support of theories assuming that nouns elicit perceptual information and are grounded in experience. In order to test our hypothesis we choose a category decision task, i.e. we paired names of objects belonging to the same super-ordinate category or not, and we asked the participants to decide whether the two objects belonged to the same category.

This task was chosen after considering the specificity of size relative to other perceptual characteristics of objects such as shape or color in regard of context-dependency.

As Barsalou (1982) has stressed, concepts are variable and situation-bounded so that context dependent properties of objects, which are activated only when an appropriate context is provided, have to be distinguished from context independent properties. Depending on the situations in which a given concept is activated, some objects' properties can become more often associated to the concept than others. Thus, for example, the concept "basketball" can elicit information about the characteristic "can float" only in specific cases, while information about its spherical shape is probably always activated (Barsalou, 1982). Although size may be considered as a context independent characteristic of objects, due to its relevance for people's interactions with objects in every day life, to our knowledge no study in the literature allowed us to assume that size is context independent. In addition, size being a relative property, it is difficult to establish if an object is large or small in absolute terms. For example a watermelon is large compared to other fruits but small when compared to other natural kinds such as trees.

In order to avoid confounding variables in our study due to this peculiarity of size, we used the category, though not explicitly mentioned, to provide both an appropriate context and an apt frame of reference for size information. Indirect support for this choice comes from the Shoben and Wilson's (1998) study where information about stimuli being large or small in their category was found to be activated when participants had to judge the relative magnitude of two stimuli. Shoben and Wilson (1998) explained their result by assuming that, when presented with two nouns referring to, for example, two animals for size judgment, participants automatically activated their super-ordinate category, i.e., 'animal', from which they derived two sub-categories, one for 'small animals' and the other for 'large animals'. These sub-categories, then, provided the context according to which the relative size of the animals was evaluated.

In the present experiments a priming paradigm was used. Participants were asked to decide whether prime and target could belong to the same category or not. Within the same category, prime and target were characterized by the same or different size.

Schreuder et al. (1984) have found a priming effect for objects characterized by the same shape, presenting participants with prime and target nouns that might be associated or not, and that referred to objects characterized by same or different shape. Although the reliability of the perceptual priming they found has been questioned (Pecher, Zeelenberg & Raaijmakers, 1998), this study suggests that it is possible to obtain semantic priming due to the perceptual relations among prime and target stimuli. In a study with an association judgment task Zwaan and Yaxley (2004) have found an interference effect for non-associated pairs of nouns referring to objects sharing shape. In particular, the effect was reliable when the target was presented to the right hemifield. They concluded that perceptual information about shape is activated by a semantic judgment, not involving shape, and that this activation is the result of the activation of visual information in the left hemisphere.

According to this literature, in the present study it could be hypothesized that the activation of information elicited by prime and target referring to same-size objects should require less time than that elicited by prime and target referring to different-size objects independently of their categories (e.g., car – elephant). A purely perceptual priming, e.g., pizza – coin, was obtained only when the context enhanced the activation of the perceptual characteristic being tested, i.e., shape, as shown by Pecher et al. (1998). We have already discussed the difference between absolute, i.e., shape, and relative, i.e., size, perceptual features. By setting category as an implicit frame of reference for size, we aimed at avoiding confounds between relative and absolute size information. Accordingly, our hypothesis is that size information should be activated when the information elicited by prime and target pairs is size-unrelated, as is the case with the same/different category judgment once an apt frame of reference/context, i.e., the category, is provided.

Experiment 1

In Experiment 1 the activation of size information was tested by measuring both the speed of processing and accuracy in deciding if a prime noun belonged to the same category as the following target noun. In the “same category” pairs, prime and target could refer either to a large or to a small exemplar of the category. Thus, each target, referring to a large or a small exemplar of the category, was preceded by both a same size prime (e.g., large prime-large target: *elephant-giraffe*) and a different size prime (e.g., small prime-large target: *hare-giraffe*). For more detailed examples refer to the Materials and Design section. The original materials are in Italian as the experiment was run with Italian mother tongue participants.

In particular, the following hypothesis was tested:

If information about objects' size is activated by noun prime-target pairs, a processing difference should be expected when both prime and target refer to large or to small exemplars of the category, i.e., they are characterized by the same size. Same size pairs (large-large and small-small) should be expected to be responded to faster than different size pairs as a result of the priming effect. We decided not to include an unrelated/base-line condition as is the norm in classical priming experiments because we were specifically interested in assessing differences in response time and accuracy between related pairs belonging to the same category but differing, or not, in size.

In addition, if concepts are grounded in perception and their activation implies a partial re-enactment of perceptual processes, we predict a processing advantage of large over small sized items, Large objects occupy a larger portion of the visual field relative to the background: for this reason for example very young children prefer to look at large objects than smaller ones (Newman, Atkinson, & Braddik, 2001). Visual processing of large and small objects differs also in regard to the different kinds of actions they afford (Jannerod, 1988).

Method

Participants

Thirty students at the University of Bologna volunteered for their participation in the experiment. All participants had normal or corrected to normal vision.

Materials and Design

The independent variables were the relationship between prime and target (same vs. different size) and the size of the target stimuli (large vs. small). In order to balance the experimental design, each target was paired with two primes belonging to the same category that could refer either to a large, e.g., *elephant-giraffe*, or a small (e.g., *hare-giraffe*) exemplar of the category. The targets were repeated in the 'same size' and 'different size' conditions in order to eliminate potential differences between target-words, such as frequency, that could bias the results. Thus, in one trial prime and target shared the same size (LL or SS) and in the other they were of different sizes (LS or SL). Half of the stimuli were natural kinds and half were artifacts.

It is worth noting that in Italian no nouns database is currently available from which to extrapolate all the stimuli for the experiment. Thus, prime and target nouns were selected using the following pre-tests: 1. Size assessment: selection of Large vs. Small exemplars; 2. Familiarity assessment; 3. Association assessment; 4. Typicality assessment.

Size assessment: Selection of Large vs. Small exemplars. In order to select nouns referring to small- and large-sized exemplars of categories, a pre-test was carried out. Eighty exemplars belonging to 4 different natural kind concepts (20 animals, 20 fruits, 20 flowers, and 20 plants) and 80 exemplars belonging to 4 different artifact concepts (20 clothes, 20 vehicles, 20 furniture, and 20 tools) were selected and submitted to an independent group of 16 university students. Participants received a booklet on each page of which the 20 exemplar nouns belonging to the same category were presented in a random order. Beside each exemplar a seven-point scale was provided where participants were asked to assess the size of the exemplar compared to that of the other exemplars of the category (1= small exemplar; 7= large exemplar). In the booklets the 8 categories were presented in 4 different randomized orders. On the scores obtained, both the mean and the median for each exemplar were calculated. The exemplars were considered as 'small' when their mean and median scores were lower than the overall category mean/median scores, and as 'large' when their mean and median scores were higher than the overall category mean/median scores. The mean size score for small-sized exemplars was 2.14 and that for large-sized exemplars was 4.92. In order to check for the reliability of size differences between small and large exemplars, a two tailed t-test was performed on size scores. Results showed that large-sized exemplars obtained a significantly higher score than small-sized exemplars ($p < .001$). The ratings for each of the selected categories are reported in Table 1.

Before selecting the exemplars to be used in the experiment, a familiarity assessment was also performed.

Insert Table 1 about here

Familiarity assessment. A second independent group of 16 university students rated the familiarity of the 20 exemplars of each category on a seven point scale (1= unfamiliar/unknown; 7= familiar/very well known). The materials were arranged as in the size assessment and participants were asked to evaluate how familiar/known each exemplar in the category was. The mean score for each exemplar was calculated. As all the exemplars obtained a score higher then 5, all of them were considered as familiar and well known.

The six exemplars that obtained the highest mean scores in both the size and familiarity assessments were, then, selected from each category to be used in the experiment. Five of them were chosen as the large-sized targets and the other one was chosen as the large-sized prime. The same criterion was followed in selecting small-sized targets and primes. Thus, the complete set of the experimental material was composed of 10 exemplars (5 small and 5 large) X 8 categories (4 natural kind and 4 artifact categories) = 80 exemplars to be used as targets and by 2 exemplars (1 small and 1 large) X 8 categories (4 natural kind and 4 artifact categories) = 16 exemplars to be used as primes.

All the 96 concept-nouns (80 targets and 16 primes) thus selected were tested in order to check for pre-existing associations among the nouns.

Association assessment. The rationale behind this pre-test was to check whether there were pre-existing associations between primes and targets, i.e., whether the prime nouns were produced in response to the targets and vice versa. Given that norms on the association degree of large pools of words do not exist for Italian (see Latent Semantic Analysis for English: see Landauer & Dumais, 1997), we used an associations production task, along with previous studies in the field (e.g. Borghi, 2004). We decided to avoid using a task in which participants were explicitly required to evaluate whether and to what extent items with the same or with different size were associated. We were interested in implicit word association processing. We reasoned that a more explicit task, such as the association rating one, could have induced out of control strategies due to the 'off line' nature of the task. This might be particularly true for association evaluation tasks, due to the fact that the task requires combining a pair of items rather than evaluating an object characteristics such as object size or familiarity *per se*. A consolidated way of testing words association in the literature (see Moss & Older, 1996) is by asking participants what is the first word that come to mind when a certain word is given. If two words are strongly associated one will be the typical response to the other (e.g. '*cat*' in response to '*dog*' and vice versa). In a priming task, when a word is presented, its lexical associates are activated in a 'lexical spurt'. Following this early lexical activation, semantic knowledge is activated if the task requires it (see the reference to the Language And Situated Simulation theory (LASS) in the General Discussion section).

The associates production pre-test, although does not allow to determine the association rate between the words, ensures that stimuli in different conditions will not be among those immediately activated through lexical access. The kind of task used in the present study, i.e. category decision, will also ensure that conceptual processing will be undertaken to perform the task.

Another independent group of 24 university students took part in this pre-test. Participants received a list with the 96 nouns in 4 different random orders across participants and they were asked to write beside each of them 'the first thing that comes to your mind after reading the word' (see Moss et al., 1995). The frequency of the produced associations and the percentage of the total number of associations produced for each noun were calculated (singular and plural, nouns and adjectives, and synonyms were considered as instantiations of the same association, e.g., child and children). As to primes produced in response to the related targets, no association was found. As to targets produced in response to the related primes, 2 participants produced the target in response to the prime in only one pair. Thus, overall, all but one on a total of 160 of the experimental pairs can be considered as not associated. The pair for which the target was associated to the prime was produced by only 2 out of 24 participants, so that it can be concluded that the association is very low. The need for a balanced experimental set of nouns and the difficulty in replacing the target noun suggested preserving this pair.

Thus, the experimental materials consisted of 80 targets, out of which 40 were natural-kind nouns belonging to 4 categories (10 animals, 10 fruits, 10 flowers, and 10 plants) and 40 were artifact nouns belonging to 4 categories (10 clothes, 10 vehicles, 10 furniture, and 10 tools). In each category, 5 nouns were small exemplars of the category (e.g. *polecat* in the category 'animals') and 5 nouns were large exemplars of the category (e.g. *elephant* in the category 'animals'). In each category the 10 targets (5 small-sized and 5 large-sized exemplars) had the same number of syllables in Italian. The number of letters did not significantly differ between large and small targets (large targets M=7.2; small targets M=7.17) (t-test, $p = .8$).

As already mentioned, each target was paired with two primes one of which was same sized and the other was differently sized. The 16 primes belonged to the same category as the targets and none of them was presented in the target position. Accordingly, the prime-target pairs resulted in four conditions: large prime-large target (LL), large prime-small target (LS), small prime-large target (SL), and small prime-small target (SS). The complete list of stimuli can be found in Appendix A.

Typicality assessment. The rationale behind this test was to verify whether the selected targets differed in the degree of typicality in their categories, as typicality could influence the following on line task. Thus, another independent group of 24 university students was asked to list the first 10 exemplars for each category that came to their mind. The frequencies of production and the order of their production (e.g., first animal named, second, etc.) were calculated for each target. In order to assess possible differences among the experimental sets of exemplars, two by materials ANOVAs were performed. Both ANOVAs were run with Ontological kind (natural kinds vs. artifacts) and Target size (large vs. small) as factors. The first ANOVA was run on the frequencies of production and the second on the ratio between the frequencies and the order of production (e.g., frequency 10/ position 3). No significant results were found in the first ANOVA [Ontological kind F (1,76) = 0.16; Target size: F (1,76) = 3.17; Interaction F (1,76) = 0.13; all $p > .05$, nor in the second one [Ontological kind F (1,76) = 0.75; Target size: F (1,76) = 1.36; Interaction F (1,76) = 0.22; all $p > .05$]. Thus, we can discard the biasing effect of typicality in the experimental materials.

Fillers selection. In order to set up the same/different category judgment task, an additional set of 160 filler pairs was prepared with primes and targets, which did not belong to the same category (same vs. different category pairs ratio = 0.5). The filler pairs belonged to categories of objects and substances (e.g., *plate-mercury*) different from those used in the experimental stimuli and in each pair the prime and the target belonged to different categories. Thus, the final set of stimuli was composed of 320 prime-target pairs, the half of which required a 'Yes' response. The same size items were 25% of the total items, the different size items were also the 25% of the total items. Each target was presented twice, once preceded by a large (e.g., *elephant-giraffe*) and once by a small (e.g., *hare-giraffe*) prime. Combined together, the same size (25%) and the different size items (25%) amounted to 50% of the total item set and they required a 'Yes' response to the task. The other 50% of the items was constituted by the fillers that required a 'No' response.

Another set of 10 same category and 10 different category prime-target pairs was prepared with the same criteria as those devised for the experimental set to be used in the training session. None of the items for the training session was presented in the experiment.

Procedure

The experimental session lasted about 30 minutes and participants were tested one at a time. They sat in front of a computer screen and were asked to keep their hands ready on the keyboard. The experiment was run using the software MEL. Participants were told that they would see a word followed by another word at the center of the computer screen. They were asked to judge as quickly and as accurately as possible if the two objects referred to by the nouns belonged to the same category. It was made clear through examples that specific categories had to be considered, such as animals, plants, tools, etc. Participants had to press one key for a "yes" and another for a "no" response. The set of the 320 pairs was presented in two different blocks, within each block each target appeared only once and the variables were balanced. In each block the presentation order of the prime-target pairs was randomized across participants.

A trial started with a fixation cross displayed for 1000ms at the center of the computer screen, which was replaced by the prime displayed for 400ms followed by a blank screen for 250ms, resulting in a SOA of 650ms. Then, the target was displayed at the same location as the prime, starting the timer which stopped when the response key was pressed. Response keys were balanced across participants. The experiment started with the 20 training trials, followed by the two blocks of 160 trials each, with a short interval between the first and the second block.

Results

The data of three participants were excluded from the analyses due to high error rates (28-30%). The data of one participant was omitted because he was not an Italian native speaker. Thus, the analyses were performed on the data from 26 participants. Only correct responses to targets belonging to the 'same category' set (excluding 'different category' fillers) were analyzed (errors = 7.3%).

Participants mean response times were calculated in each condition and entered into a two way ANOVA with the within-participants factors Prime-target relationship (Same vs. Different) and Size of target (Large vs. Small). For the participants analyses (indicated by F_{part}), condition means were obtained by averaging across items, and for the materials analyses (indicated by F_{items}) they were obtained by averaging across participants. Before calculating the means, one value was eliminated as outlier from the data. The by participants analysis showed an effect of Prime-target relationship [$F(1,25) = 4.18$, $MSe = 983$, $p = .05$], as response times were faster when participants responded to a target preceded by a same-size prime than by a different size prime, the effect did not reach significance in by items analysis. This factor interacted with Size of target. Target size also affected performance, as participants responded faster to large targets than to small ones [$F_{part}(1,25) = 34.7$, $MSe = 2568$, $p < .001$; $F_{items}(1,78) = 8.06$, $MSe = 18267$, $p < .01$]. However it should be noted that differences other than size between these two sets of stimuli potentially biasing this result can not be completely ruled out. The interaction between the two variables showed an effect in by participants analysis [F (1,25) = 4.2, $MSe = 1456$, $p = .05$] (see Figure 1). The facilitating effect of prime and target having the same size ('same-size effect') was limited to large targets, as shown by a post hoc Newman-Keuls analysis ($p < .05$) (Large targets same-size *M* = 782ms; Large targets different-size M = 810ms; Small targets same-size M = 856ms; Small targets different-size M = 853ms). In order to confirm this analysis we conducted separate t-tests on large and small targets in the 'same' vs. 'different size' conditions and we found that only for the first type of stimuli the analysis showed a significant difference (t = -3.7, $p < .001$; t = 0.2, $p = 0.8$). Same-size small targets were responded to slower than both same- and different-size large targets and different-size large targets were responded to faster than different-size small targets (see Figure 1).

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insert Figure 1 about here

The ANOVA on errors showed that participants were more accurate in responding to same-size prime-target pairs (*M*= 0.05) than to different size ones (*M*=0.09) [$F_{part}(1,25) = 8.73$, $MSe = 0.004$, $p < .01$; $F_{items}(1,78) = 12.56$, $MSe = 0.004$, $p < .001$] (see Figure 2). Participants were also more accurate in responding to large targets (M = 0.06) than to small ones (M= 0.09) [F_{part} (1,25) = 11.7, $MSe = 0.002$, $p < .01$; $F_{items}(1,78) = 3.93$, $MSe = 0.04$, $p = .05$]. The interaction between the two variables was not significant. Hence, the 'same size effect' that was limited to large prime – large target pairs in RTs, was registered in both large-large and small-small pairs in accuracy.

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insert Figure 2 about here

Discussion

As hypothesized a "same-size effect" was registered. LL pairs were processed faster than SL pairs, although no significant difference was found between LS and SS pairs. This effect was registered in both LL and SS pairs on accuracy. In sum, the expected priming effect between same size object concepts was found as hypothesized. Moreover, an overall large target processing advantage was also registered. When nouns were activated, they conveyed information about the size of the referred objects as shown both by the priming effect and by the processing advantage of large targets. In fact, as the task did not require to explicitly activating information on size, the "large target effect" can be accounted for by the activation of information on size when semantic information was addressed in order to establish category membership.

It has been shown that concepts convey the perceptual characteristic of objects (e.g., Borghi et al., 2004; Zwaan et al., 2002) and that nouns and images are processed differently depending on the real life size of the objects they refer to (Kosslyn, 1976). Kosslyn (1976) showed that, in a part-verification task with objects' nouns, objects' large parts were responded to faster than small ones when participants were asked to form a mental image of the object before responding (see also Kosslyn, Ball & Reiser, 1978; Kosslyn, Reiser, Farah & Fliegel, 1983). In the present task participants were asked to decide whether prime and target belonged to the same category. In line with the embodied theories of concepts we hypothesized that participants would have accessed perceptual information (as well as other pertinent information) in solving the task. This perceptual simulation can require different time depending on the object. Considering the similarity between mental imagery and activation of perceptual information (Solomon & Barsalou, 2004) we argue that perceptual information of large objects is accessed faster than that of small objects. For this reason the effect of 'same size' is only registered for large targets. We hypothesized that an explicit access to mental imagery would allow richer perceptual information on the size of small objects to be activated. Experiment 2 was devised in order to test this hypothesis.

Experiment 2

In Experiment 1 the hypothesized same size effect was registered only for large targets in RTs, and a large target effect was also found. Information on size could have been accessed with a process similar to mental imagery, so that nouns referring to large objects were processed faster than nouns referring to small ones (see Kosslyn, 1994; 1976).

In Experiment 2 we asked participants explicitly to access objects' mental images and we advanced the following hypotheses:

1. Objects' size activation should be higher with the image formation task than in Experiment 1, where no image formation was explicitly required, thus the same-size priming effect should be registered both for large and small targets and both in RTs and accuracy.

2. Large targets should be processed faster and more accurately than small ones, thus replicating Experiment 1 results.

Method

Participants

Twenty university students at the University of Bologna who did not take part in the preceding experiment volunteered their participation in Experiment 2.

Materials and design

The materials and the experimental design were the same as those in Experiment 1. The independent variables were "Prime-target relationship" (same vs. different), and "Size of target" (large vs. small).

Procedure

The procedure was the same as that of Experiment 1. However, the task was modified: Participants were required to read the first word appearing on the computer screen and to form a mental image of the object, then to read the second word and to form a mental image of the second object and, finally, decide if the objects belonged to the same category or not (see instructions for Experiment 1).

Results

One participant's data was excluded due to error rate (40%). Mean response times were calculated on correct responses (errors = 8.6%) to targets in the prime target 'same category' pairs. Eight outlier response times (> 6000ms) were eliminated (0.26% of the 'same category' data). Response times were entered into a two way ANOVA with the within-participants factors Prime-target relationship (Same vs. Different) and Size of target (Large vs. Small). Results showed a significant main effect of the Prime-target relationship both by participants and by items [$F_{part}(1,18) = 31.18$, $MSe = 2209$, $p < .0001$; $F_{items}(1,78) = 4.15$, $MSe = 25781$, $p < .05$] and of Size of target by participants [$F_{part}(1,18) = 15.85$, $MSe = 4769$, $p < .001$] while a trend was registered by items [$F_{items}(1,78) = 2.82$, $MSe = 42390$, $p = .09$]. Target preceded by a same-size prime were responded to 60ms faster (M = 969ms) than targets coupled with a different-size prime (1029ms) (see Figure 3). The 'same-size effect' was found both for large and small targets. In order to confirm this result we conducted separate t-tests on large and small targets in the 'same' vs. 'different size' conditions and we found a significant difference for both kinds of targets (t = -2.45, $p < .05$; t = -0.3, $p < 0.1$). The overall advantage for large targets registered in Experiment 1 was replicated in this experiment. In fact, targets referring to large exemplars of the category (M = 967ms) were responded to 63ms faster than those referring to small ones (M = 1030ms). The interaction between Prime-target relationship and Size of target did not reach significance.

One way of indirectly testing whether participants were forming a mental image in Experiment 2 was to check if their response times were slower in the imagery than in the condition without imagery (see Kosslyn, 1980). We performed a one-way by items ANOVA with Experiment 1 vs. 2 as independent variable and RTs as dependent variable. RTs were significantly faster in Experiment 1 (M = 827ms) than in Experiment 2 (M = 991ms) [$F(1,318) = 85.58$, MSe = 25077, $p < .001$].

Insert Figure 3 about here

The ANOVA on errors showed that participants were more accurate in responding to same-size prime-target pairs (M= 0.07) than to different-size ones (M=0.1) [F_{part} (1,18) = 6.13, $MSe = 0.003$, $p < .05$; F_{items}(1,78) = 5.39, $MSe = 0.078$, $p < .05$] (see Figure 4). Participants were also more accurate in responding to large targets (M = 0.06) than to small ones (M= 0.1) [F_{part} (1,18) = 22.08, $MSe = 0.002$, $p < .01$; F_{items}(1,78) = 4.59, $MSe = 0.004$, $p < .05$]. The interaction between the two variables was not significant.

Insert Figure 4 about here

Discussion

These results have shown that, when participants were required to form a mental image of the prime and target stimuli before deciding on their category membership, information on objects' size was activated (see Kosslyn, 1980).

As hypothesized, a priming effect was found in same size prime-target pairs (LL; SS), which were responded to faster and more accurately than different size pairs (SL; LS respectively). This result replicates the finding of Experiment 1, extending the same size effect to small targets in RTs.

Size, being a perceptual characteristic of objects, was highly activated by mental images leading to a stronger same-size effect than when it was not enhanced by image formation (Experiment 1). In fact, participants activated a mental image for both large and small stimuli, thus leading to a same-size effect similar to the same shape effect registered by Schreuder et al. (1984) and Zwaan and Yaxley (2004) with similar tasks. Moreover, the expected priming effect was found on accuracy, as participants were more accurate when prime and target shared the same size.

As in Experiment 1, large targets (nouns) were responded to faster and more accurately than small ones, in line with a processing advantage for large over small images (Kosslyn, 1994; 1978).

Taken together these results show that information about objects' size is activated by nouns when participants are asked to decide about category membership with imagery instructions.

In conclusion, both the 'same size' and the large target processing advantage can be accounted for by theories that ground concepts in situations and perception, which predict that perceptual information is activated by nouns, as already demonstrated for other types of perceptual dimensions, e.g., shape.

General Discussion

This research has provided new evidence for the activation of size information by nouns in two tasks. As hypothesized information about the size of the objects referred to by nouns is elicited even when the task is size-unrelated, i.e. it does not require explicitly referring to size and it can be performed without referring to size. In Experiment 1 and 2, in order to decide if prime and target nouns belonged to the same category, participants had to activate conceptual knowledge about the referred objects. To enhance the activation of objects perceptual characteristics, following Kosslyn (1976), in Experiment 2 participants were also required to form a mental image of the objects before responding. In both experiments a same-size effect was found both in RTs and accuracy. The effect was more consistent in the imagery than in the no-imagery task. While in Experiment 1 the same-size effect was found only in RTs to large targets (LL < SL), in Experiment 2 it was found in responding to both large (LL < SL) and small (SS < LS) targets. When conceptual knowledge is accessed in order to assess category membership, size information is activated and a priming effect takes place in same size exemplars of the category. Accordingly, it can be concluded that nouns activate information about the small or large size of the objects they refer to even when this type of information is not required by the task.

Considering the SOA of 650ms and the task used (i.e. decision on the category) we can not rule out completely the use of strategies. This method was chosen taking into account the debate on automaticity of semantic priming (see Lucas, 2000 for a review). In particular some studies report a lack of semantic priming with short SOAs (e.g. Shelton & Martin, 1992) claiming that short SOAs tap more on lexical access. In this line of thought the Language And Situated Simulation theory (LASS) (Simmons, Hamann, Harenski, Hu, & Barsalou, 2008) proposes that words undergo different levels of processing (Craik & Lockhart, 1992) depending on the characteristics of the task and only some tasks require embodied simulation (or access to the experiential content of concepts). Simmons et al. (2008) review behavioral evidences and present fMRI data in support of this view. As stated by Simmons et al. (2008, p.117) “An experiment is likely to demonstrate contributions from the linguistic system when linguistic stimuli are used, processing time is short, the task is easy, and the task can be performed primarily with information available in the linguistic system.”. By using a categorization task and a long processing time we aimed at ensuring that activation of the simulation system or, in other term, of the experiential content of concepts occurred.

Another consideration needs to be taken into account in interpreting the present results. Categories are based on similarity between the members on different criteria (Goldstone, 1994) and size could be one of them. For this reason we can not exclude that participants relied on size as one of the criteria to determine similarities across the items upon which to base their categorization judgment. However considering that among the ‘same category’ items only half were characterized by the same size, and that participants were presented with filler pairs (intermixed with the experimental items) which were also characterized by various sizes, relying only on this kind of strategy would not be economic. For this reason we argue that information about size activated in the present studies reflect the relevance of size in concepts.

This claim is supported by the result that large items were processed faster than small items (‘large target effect’) suggesting that size as perceptual, i.e. visual feature of the objects is activated by words, in line with previous studies on other features (see Barsalou, 2008 for a review).

These results corroborate with new experimental findings Rubinstein & Henik’s (2002) claim that ‘[words’] meaning seems to include some gross characteristics of the object indicated by the word, like gross size (i.e., large vs. small)’ (p.151). If this is the case, it is clear that the same-size effect is weaker when no imagery instruction is given than when participants are explicitly asked to use imagery. In fact imagery instructions lead to rich and detailed mental images (see Solomon, Barsalou, & Wu, 1999), which increase the same-size effect. It is worth noting that claiming that the tasks proposed in these studies are size unrelated does not imply that size is activated as an epiphenomenon in these tasks. Rather, our study demonstrates that size is a relevant dimension in categorization, because it is activated when the category is accessed (see Shoben and Wilson, 1998). This is particularly relevant as the task does not explicitly require the activation of size information, differently from previous studies. Size (large vs. small) is one of the organizing criteria in the category. Other criteria based on perceptual characteristics, such as shape, have been shown with different paradigms (e.g. Landau, Smith, Jones, 1998).

Our results also stress the relevant role played by the perceptual features of objects in conceptual knowledge, extending to size, the same/different effect obtained in shape. The large target effect, i.e., large targets were processed faster than smaller ones, was consistently found in both experiments, showing that, when targets refer to large objects, size information is automatically elicited. This effect seems to be corroborated by evidence from different and complementary domains. In fact, on one side it is consistent with the fact that mental images of large objects are “easier to see” than those of small objects (Kosslyn, 1976, p.291). In addition, it is in keeping with results showing that categorization of large objects graspable with a power grip (e.g., apple, bottle), is faster than categorization of small objects, requiring a precision grip (e.g., cherry, fork) (Borghi, Bonfiglioli, Lugli, Ricciardelli, Rubichi & Nicoletti, 2007; Vainio, Symes, Ellis, Tucker, & Ottoboni, in press). Finally, it is also consistent with Clark’s (Klatzky, Clark, & Macken, 1973; Banks, Clark, & Lucy, 1975) study on the acquisition of polar adjectives, according to which size information activated by default is ‘large’. Unmarked adjectives, e.g. ‘good’, ‘tall’, ‘large’ are processed differently than marked ones, e.g., ‘bad’ ‘short’ ‘small’.

Overall, the results yielded by Experiments 1 and 2 allow one to conclude that nouns elicit information on objects’ size even in size unrelated tasks. Accordingly, the perceptual dimension of objects’ size may be considered as relevant in conceptual knowledge as the much more studied dimensions of shape and manipulability (Gerlach, Law, & Paulson, 2002;

Myung, Blumstein, & Sedivy, 2006). In fact, on speculative grounds, it may be argued that conceptual information on objects' size, like that of their shape and manipulability, is elicited by unrelated tasks due to the ecological validity of these perceptual dimensions, which yields objects' use, their functions and the possible interactions between people and objects.

Thus, the role of information about objects' size in conceptual knowledge highlighted in this study provides support for the views that stress the role of experience in shaping conceptual knowledge (Barsalou, 1993; Barsalou, Simmons, Barbey, & Wilson, 2003; Glenberg, 1997; Goldstone & Barsalou, 1998; Jones & Smith, 1998; Smith & Heise, 1992) and it allows to argue that real life size is a basic characteristic of objects that is always retrieved when an object concept is activated, i.e. it could constitute a 'semantic primitive' (Martin, 1998). The present studies were not aimed to investigate the nature, perceptual or conceptual, of information on size. However our results, in particular the large target effect and the influence of imagery, demonstrate that during categorization object size is activated, even if the task did not explicitly refer to size. This reveals that characteristics relevant for sensorimotor interaction with objects, such as size, become part of our conceptual knowledge, in line with embodied theories of cognition (Barsalou, 1999; Glenberg, 1997; Gallese & Lakoff, 2005).

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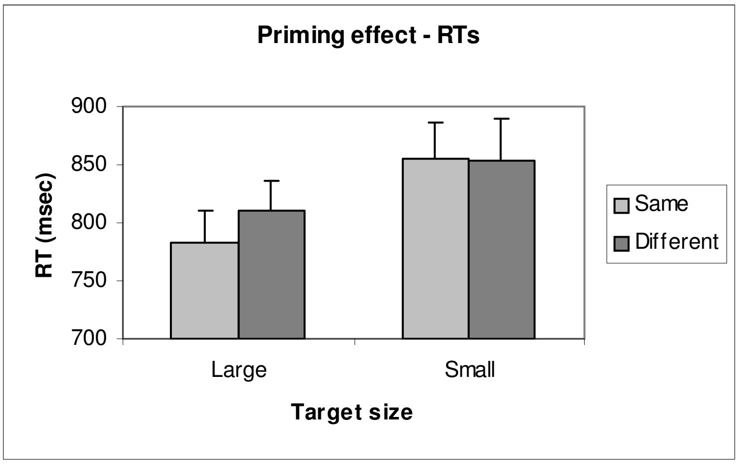

Figure 1. Experiment 1. Mean response times in the four conditions.

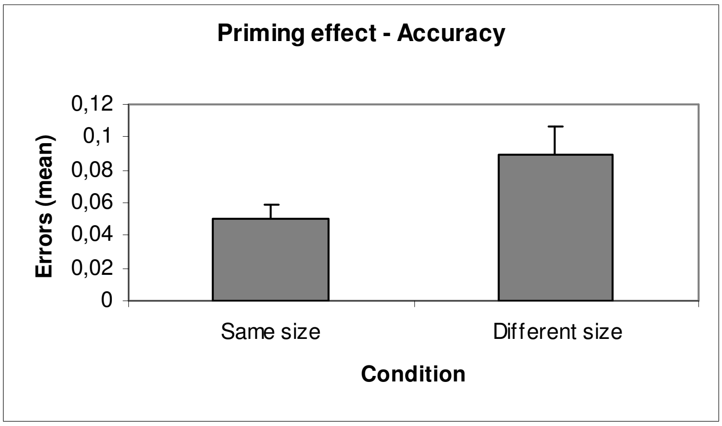

Figure 2. Experiment 1. Mean errors in 'same size' and 'different size' prime-target pairs.

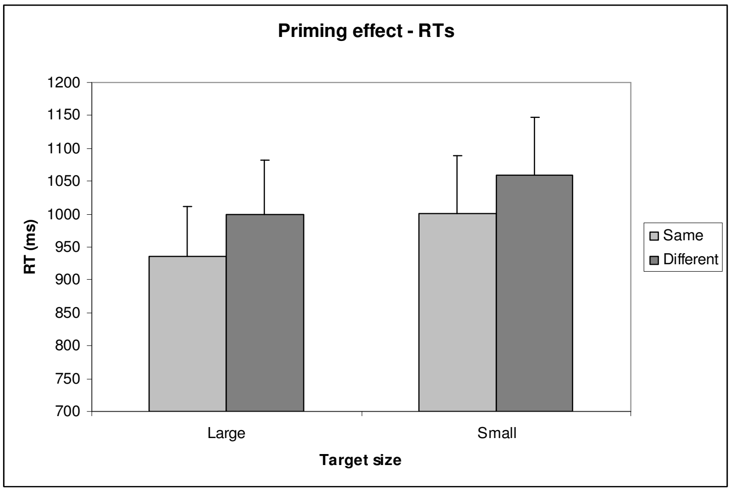

Figure 3. Experiment 2. Mean response times in the four conditions.

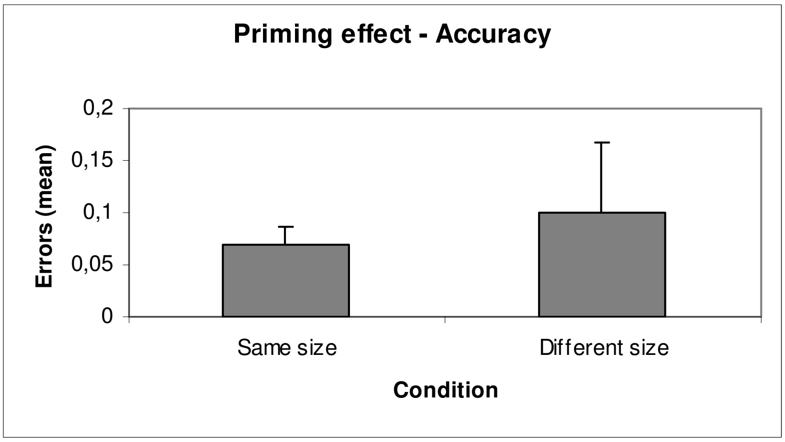

Figure 4. Experiment 2. Mean errors in ‘same size’ and ‘different size’ prime-target pairs.

Table 1

Size ratings for natural kinds and artifact concepts

Ontological Kind	**Small**	**Large**	**Ontological Kind**	**Small**	**Large**
Animals	1.9	5.8	Clothes	1.9	5.0
Fruits	1.4	4.5	Vehicles	3.4	6.0
Flowers	1.8	3.2	Furniture	2.4	5.1
Plants	2.9	5.6	Tools	2.1	4.0
NATURAL K.	**2.0**	**4.7**	**ARTIFACTS**	**2.4**	**5.0**