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When you name the pizza you look at the coin and the bread: Eye movements reveal semantic activation during word production

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Two eyetracking experiments tested for activation of category coordinate and perceptually related concepts when speakers prepare the name of an object. Speakers saw four visual objects in a 2 × 2 array and identified and named a target picture on the basis of either category (e.g., "What is the name of the musical instrument?") or visual-form (e.g., "What is the name of the circular object?") instructions. There were more fixations on visual-form competitors and category coordinate competitors than on unrelated objects during name preparation, but the increased overt attention did not affect naming latencies. The data demonstrate that eye movements are a sensitive measure of the overlap between the conceptual (including visual-form) information that is accessed in preparation for word production and the conceptual knowledge associated with visual objects. Furthermore, these results suggest that semantic activation of competitor concepts does not necessarily affect lexical selection, contrary to the predictions of lexical-selection-by-competition accounts (e.g., Levelt, Roelofs, & Meyer, 1999).

When referring to objects, speakers are influenced by the activation of concepts related to the concept they are about to put into words. If someone intends to name, for instance, a pizza, the conceptual representations of other members of the food category (e.g., BREAD) also become active, and accumulated evidence has indicated that this spurious activation has repercussions for both the accuracy of language production (e.g., Fay & Cutler, 1977) and the efficiency of this process (e.g., Schriefers, Meyer, & Levelt, 1990).

Most evidence for category coordinate effects comes from experimental studies using the picture naming task (e.g., Cattell, 1886; Glaser & Glaser, 1989; Schriefers et al., 1990; Starreveld & La Heij, 1996). For instance, in picture–word interference tasks (e.g., Schriefers et al., 1990), participants are presented with a line drawing of an object that contains a printed distractor word to be ignored. These studies have demonstrated that picture naming is slower when the distractor word is from the same conceptual category as the picture than when the distractor is unrelated.

According to many accounts of word production, the semantic interference effect reflects competition for selection at the lexical level (e.g., Belke, Meyer, & Damian, 2005; Bloem, van den Boogaard, & La Heij, 2004; Caramazza & Costa, 2000; Damian & Bowers, 2003; Hantsch, Jescheniak, & Schriefers, 2005; Levelt, Roelofs, & Meyer, 1999; Roelofs, 1992, 1993, 2001, 2003; Starreveld & La Heij, 1995, 1996; Vigliocco, Vinson, Lewis, & Garrett, 2004). For example, the WEAVER++ model (Levelt et al., 1999; Roelofs, 1997) assumes a unitary conceptual representation for each word in the lexicon (a lexical concept), and these representations are thought to be arranged in a semantic network (Collins & Loftus, 1975; Collins & Quillian, 1969). According to this model, if you decide to name the picture of a pizza with its basic-level term, the lexical concept PIZZA will be activated and in turn will activate its corresponding lexical representation (the *lemma*). Activation in the semantic network will spread to the concepts of other foodstuffs (e.g., BREAD), which in turn activate their corresponding lemmas. The probability of selecting the correct lemma (*pizza*) is assumed to be the ratio of the degree of activation of that lemma to the total activation of all the other lemmas (such as *bread*). Active alternative lemmas therefore result in competition for selection and slow down the selection process. Semantic interference results from the lemmas of semantically related distractor words (e.g., "bread") being activated by both the distractor word and the conceptual representation, whereas the lemmas of unrelated words are only activated by the distractor word itself.

Other theories of word production (e.g., Caramazza & Hillis, 1990; Dell, 1986), however, do *not* assume that selec-

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tion latencies are modulated by the activation levels of unselected representations (see Costa, Alario, & Caramazza, 2005; Finkbeiner & Caramazza, 2006; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007; Miozzo & Caramazza, 2003). These models of speech production are simpler, in that they only assume that the representation with the highest activation after a certain number of time steps, or the one that first reaches a predetermined threshold, is selected. These models do not make the additional assumption that highly activated nontarget representations compete for selection and thereby slow down selection latencies.

A key test of lexical-selection-by-competition accounts is whether semantically related distractor stimuli slow down naming latencies. Indeed, there are many reports of category coordinate interference effects in the picture–word interference task. However, several recent studies have shown that further tests with different types of semantic relationships do not confirm the selection-by-competition account. For example, Alario, Segui, and Ferrand (2000) observed that associative relationships (dog–leash) between picture name and distractor name did not result in semantic interference (see also Abdel Rahman & Melinger, 2007). Similarly, Costa et al. (2005) observed that part–whole relations (car–bumper) resulted in semantic facilitation rather than inhibition. Recently, Mahon et al. (2007) found that perceptual relatedness (orange–ball) also did not result in significant semantic interference.[1]

In addition, there is no semantic interference when the distractor is presented as a picture rather than a word. Damian and Bowers (2003) found that a semantic relation between a printed distractor word and a target, but *not* between a pictorial distractor and a target, delayed reaction times. Even more wounding for a selection-by-competition account are the results of a series of studies by La Heij and colleagues. These authors showed that briefly presented prime pictures resulted in semantic facilitation (rather than interference) in picture naming (La Heij, Heikoop, Akerboom, & Bloem, 2003); that distractor pictures resulted in semantic facilitation in word translation (Bloem & La Heij, 2003); and that even distractor words can result in semantic facilitation in that task, if they are presented early enough (Bloem et al., 2004). Of course, one account of the facilitation effects with picture distractors that might salvage a lexical-selection-by-competition account is the finding that picture distractors gain access only to conceptual, not to lexical, codes (Bloem & La Heij, 2003; Damian & Bowers, 2003). This explanation is challenged, however, by several studies showing that pictures activate lexical representations (e.g., Griffin & Bock, 1998; Huettig & McQueen, 2007; Morsella & Miozzo, 2002; Peterson & Savoy, 1998). Huettig and McQueen, for instance, found that picture processing advanced as far as retrieval of the picture's name in a comprehension task that did not require the naming of pictures. In addition, Hartsuiker, Pickering, and De Jong (2005) found semantic facilitation when two pictures were named in rapid succession. Because the first (distractor) picture was overtly named, there must have been access to the corresponding lexical representation.

A final challenge to the lexical-selection-by-competition account comes from recent studies that tested further predictions of this account in the picture–word interference task. Miozzo and Caramazza (2003) found that low-frequency distractors interfere more than high-frequency distractors. This finding is at odds with the lexical-selection-by-competition account because low-frequency names would lead to relatively low levels of lexical activation, and should therefore interfere less than high-frequency names. In addition, Mahon et al. (2007) found that verb distractors (as opposed to noun distractors) did not delay the naming of target objects (with nouns), even though both types of distractor were semantically related to the targets, and thus should both cause lexical competition.

If the selection-by-competition account of semantic interference were to prove incorrect, this would have major implications for theories of language production. However, it may be too early to draw this conclusion. As discussed above, semantic interference appears to be restricted to category coordinate relationships and to paradigms with word distractors. In principle, selection-by-competition accounts predict semantic interference from any kind of semantic relation, but it is a precondition that the semantic representation of the target activates the semantic representation of the distractor *to a sufficient degree*. Only if there is enough activation spreading at the conceptual level will the distractor's lexical representation be substantially more active than that of an unrelated distractor, so that lexical competition occurs. This then raises the question of whether, for example, part–whole (car–bumper) or perceptual (orange–ball) relations result in sufficient conceptual activation for competition to occur. Unfortunately, this question cannot be answered using picture–word interference, since a null effect on naming latencies in that paradigm may reflect either a lack of conceptual activation spreading or that the distractor's lexical representation, although active, does not compete with the target. Therefore, this article uses a visual-world eyetracking paradigm (Cooper, 1974; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995) to attempt to tap into semantic activation during picture naming.

In the visual-world paradigm, participants are presented with an array of visual objects, usually while they listen to spoken utterances. This paradigm provides fine-grained eye movement measures of ongoing cognitive processing, in the form of fixations to different positions in the visual display over time. For instance, Huettig and Altmann (2005) investigated whether semantic properties of individual lexical items can direct eye movements toward objects in the visual field. They presented participants with a visual display containing four pictures of common objects. During the course of a trial a spoken sentence was presented, and the participant's eye movements were tracked as the sentence unfolded. Huettig and Altmann (2005) found that participants directed overt attention immediately toward a picture of an object (such as a trumpet) when a semantically related but nonassociated target word (e.g., "piano") acoustically unfolded. Three different measures of semantic relatedness (i.e., McRae feature norms [Cree & McRae, 2003], latent semantic analysis [Landauer & Dumais, 1997], and contextual similarity [McDonald, 2000]) each correlated well with fixation behavior (Huettig & Altmann, 2005; Huettig, Quinlan, McDonald, & Altmann, 2006). These data are therefore strong evidence that language-mediated eye movements to objects in the concurrent visual environment are a sensitive measure of conceptual activation.

Furthermore, some recent studies using the visual-world paradigm found that looks were directed to visually related (e.g., by visual form or prototypical color) but semantically inappropriate objects (Dahan & Tanenhaus, 2005; Huettig & Altmann, 2004, 2007). For instance, participants shifted overt attention to a picture of a cable during the acoustic unfolding of the word "snake" (a snake and a cable have similar global visual forms; Huettig & Altmann, 2007). Similarly, participants looked significantly more at the picture of (green) lettuce on hearing "frog" (a typically green animal) than at completely unrelated distractor objects (Huettig & Altmann, 2004). In sum, these studies provided clear evidence for a visual-form relatedness effect in auditory comprehension.

A main aim of the present study was to test whether conceptual activation during picture naming is reflected by the patterns of eye movement to competitor pictures that were semantically related or unrelated to a target picture. As a benchmark, one condition included competitor pictures from the same conceptual category as the target pictures. Critically, a further condition included competitor pictures related in visual form. As mentioned above, there is no compelling evidence that visual-form relations can lead to a slowdown (or speedup) in the picture–word interference task. If this is because form-related concepts hardly activate each other, people should then be no more likely to fixate a form-related object than an unrelated object. If, however, people are more likely to fixate form-related objects, this would provide evidence for spreading of activation between the corresponding concepts. All things being equal, such a finding would imply that the corresponding lexical representations are viable competitors, making the lack of semantic interference with those items hard to account for under a selection-by-competition model.

Plan of This Study

To test for semantic activation during object naming, we conducted two visual-world eyetracking experiments using a new methodology. We presented participants with displays containing a target picture (e.g., a plate), a semantically related object (e.g., a stove), and two unrelated pictures. The instructions identified one of the pictures as the target (i.e., the one that needed to be named), but of course without mentioning the name of the target, in order to exclude contributions of comprehension or repetition to any effects. To test whether semantic activation spreads to concepts with a similar visual form, we included a condition in which an object was included with a visual form similar to that of the target picture. We presented participants with displays containing a target picture (e.g., a saxophone), a picture of an object with a visual form similar to the target (e.g., a ladle), and two unrelated pictures.

To assess whether there is increased overt attention to (category-coordinate- or to visual-form-related) objects, we determined the proportion of fixations to the target and the related objects as compared with the distractors. To test whether such overt attention affected lexical selection, we also measured naming latencies. Note that an essential precondition for a test of our hypothesis is that speakers make eye movements to other objects in the visual field during the process of picture naming (i.e., that they fixate other pictures while preparing the name for the target picture). That precondition is not trivial; in fact, previous eyetracking research into word production has found that participants keep fixating the target until they have retrieved its phonological form (e.g., Griffin, 2004). Meyer (2004) argued that participants complete production processes (up to completion of morphological form retrieval), and only then do they shift their gaze to the next object (i.e., 200–300 msec before articulation of the target's name). If people generally show this particular pattern of eye movements, there is no reason to suspect that they will make any spurious eye movements to categorically or visually related objects (at least not before they have first completed form encoding of the target).

However, it is very much conceivable that eye movement patterns are a function of the task demands. For example, Meyer, Sleiderink, and Levelt (1998) presented one picture on the left side of the screen and another one on the right side and gave participants specific instructions to name the objects from left to right. In this task, the participants could predict which object to name with complete certainty. Likewise, van der Meulen, Meyer, and Levelt (2001) arranged their objects in a circle and asked participants to name them clockwise or counterclockwise. Again, task-specific top-down control might have prevented eye movements to the other objects in the display.

In order to reduce certainty about which picture a speaker should fixate at a given moment, we presented participants with instructions like "What is the name of the circular object?" or "What is the name of the musical instrument?" (see Figure 1). Given a "visual instruction," the critical object was always a category coordinate of the target; given a "semantic instruction" (i.e., given a category name), the critical object was always related in shape to the target.

In addition to the core processes of interest here—conceptual preparation and lexical access—this task has several lead-in processes (Figure 2). At the moment of display onset (Time 1 in the figure), participants may still "wrap up" comprehension of the instruction. Given a semantic instruction, the participants inspect the display, recognize the objects, and determine the categories of these objects. Given a visual instruction, the display is also inspected, and the visual shape of the objects is determined. The target category (or shape) is then compared with that of the objects in the display, until a match is found. Once a match is found (i.e., the target object is identified), the core processes of interest begin. Following most models of word production (Dell, 1986; Roelofs, 2003; Starreveld & La Heij, 1995), we assume that task activation is sent to the concept of the target object. Ac-

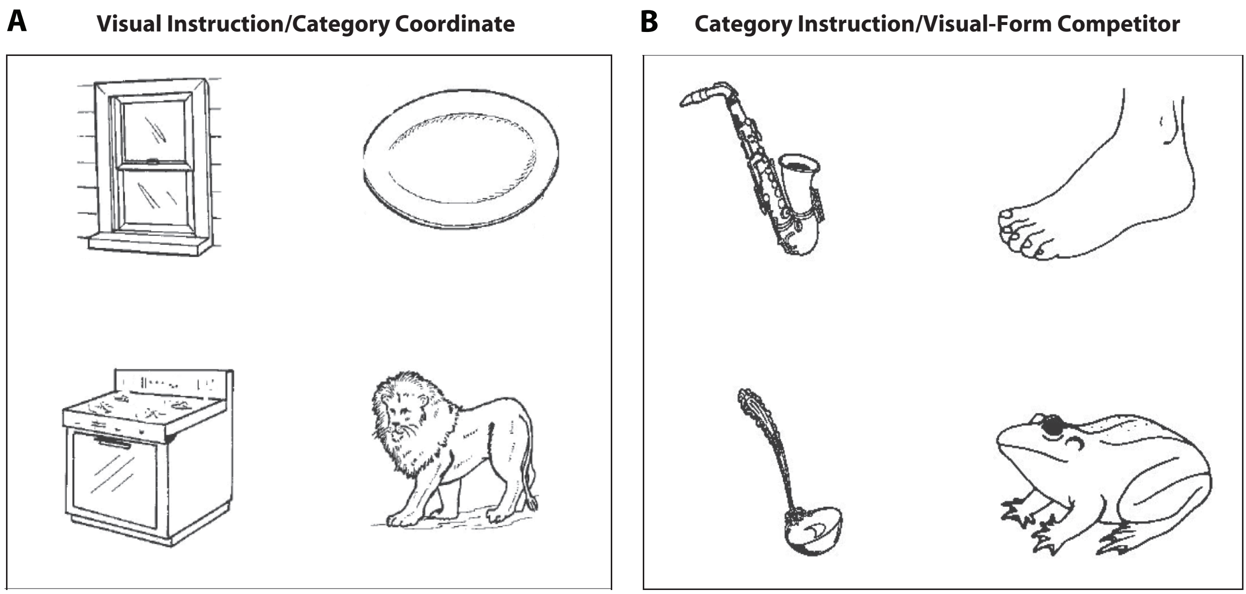

Figure 1. An example of the types of visual displays used in Experiment 1 for (A) visual instruction/semantic competitor (depicting target object [plate], semantic competitor [stove], and two unrelated distractors) and (B) semantic instruction/visual competitor (depicting target object [saxophone], visual-form competitor [ladle], and two unrelated distractors).

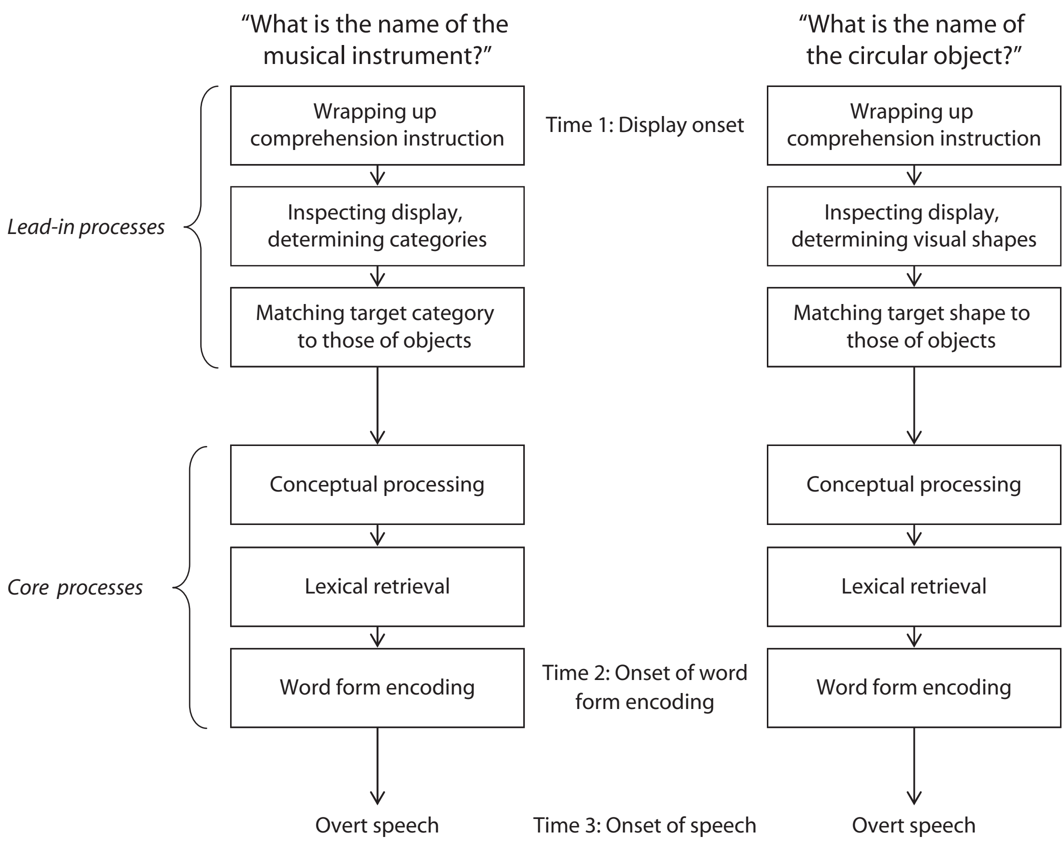

Figure 2. Task analysis.

tivation from the conceptual level spreads to the lexical level, and lexical selection takes place. The selected lexical representation then undergoes word form encoding (i.e., establishing the phonological form and assembling a speech motor program) and articulation (execution of speech motor commands).

Note that the processes of interest (conceptual processing and lexical access) occur within the time window from display onset to onset of word form encoding (the interval between Times 1 and 2). We can only directly measure Times 1 and 3, but we will estimate Time 2 on the basis of Indefrey and Levelt's (2004) meta-analysis of word production studies.

It is also important to note that both types of instructions allowed the participant to uniquely identify the referent (i.e., if the instruction asked for a "circular object," there was only one circular object on the display—e.g., a plate) and that nothing in the instructions could directly activate the related object. Thus, if the concept STOVE became more active than that of unrelated distractors, this could only have been the result of activation spreading from the concept PLATE.

In sum, we tested whether we could observe increased overt attention to objects categorically or visually related to the target objects. If visually related objects were attended (thus showing spreading of activation from the target's semantic representation), this would pose a challenge to lexical-selection-by-competition accounts—namely, the challenge of explaining why no form-related interference effects occur in picture–word interference.

EXPERIMENT 1

Experiment 1 was designed to test for semantic and visual-form activation during object naming using the visual-world paradigm.

Method

Participants. Twenty-four Ghent University students, all native speakers of Dutch, participated in exchange for course credit. All had normal or corrected-to-normal vision.

Stimuli. The experiment included 50 experimental items and 50 filler items. On each trial, participants heard a spoken instruction. At the acoustic offset of the spoken instruction, participants were presented with a visual display containing line drawings of four spatially distinct objects.

The spoken instruction required the naming of a target object ("What is the name of the . . ."). For 25 experimental items, the spoken instruction specified a distinct conceptual category (e.g., "What is the name of the musical instrument?") according to the updated version of the Battig and Montague (1969) category norms (Van Overschelde, Rawson, & Dunlosky, 2004). The conceptual categories were BODY PART, CARPENTER'S TOOL, FRUIT, KITCHEN UTENSIL, MUSICAL INSTRUMENT, BUILDING PART, THING THAT FLIES, THING THAT WOMEN WEAR, TYPE OF CLOTHING, TYPE OF READING MATERIAL, and VEGETABLE. For the other 25 experimental items, the spoken instruction specified a distinct global shape (e.g., "What is the name of the circular object?"). The shape categories were T-shaped object; long, circular, pointed object; O-shaped object; long, thin, flexible object; long, thin, rigid object; long, bent object; short, cylindrical object; rectangular object; crescent-shaped object; cone-shaped object; long, barbed object; long, chained object; and circular object. Appendix A1 shows the experimental items with a visual instruction and a semantic competitor in the display. Appendix A2 shows the experimental items with a semantic instruction and a visual competitor in the display. Twenty-five filler items contained a shape instruction, and the other 25 contained a conceptual category instruction. The instructions were recorded in advance at a normal speaking rate by a female native speaker of Dutch.

Each visual display contained a target object (the object to be named), one competitor object, and two unrelated distractor objects, with one object in each corner. For the 25 items with the shape instruction (e.g., ". . . circular object?"), the competitor object (e.g., a stove) belonged to the same conceptual category as the target object (e.g., a plate) according to Van Overschelde et al. (2004) but had a different global shape (see Figure 1A). For the 25 items with the conceptual category instruction (e.g., ". . . musical instrument?"), the competitor object (e.g., a ladle in Figure 1B) had the same global shape as the target object (e.g., a saxophone) but belonged to a different conceptual category (e.g., kitchen utensil vs. musical instrument) than did the target. Fifty filler items were also included. The visual displays for the filler items did not include any competitor objects.

The approximate size of each object was 8×8 cm. The objects were randomly assigned to quadrants of the display. The individual black-and-white line drawings were taken from the Severens, Van Lommel, Ratinckx, and Hartsuiker (2005) set. The item naming latencies with a conceptual category instruction (998 msec, $SE = 39$) did not differ significantly from those with a visual instruction (1,065 msec, $SE = 43$) when the items were named in isolation in their set [$t(47) = 1.15$, $p > .1$]. The names of the pictures within a display each started with a different phoneme, so that no phonological competitors were present. In addition, the pictures were matched on name agreement ($F < 1$) and log word frequency of their names ($F < 1$).

Procedure. Participants were seated at a comfortable distance (their eyes approximately 50 cm from the display) in front of a 17-in. monitor and wore an SMI EyeLink 1 head-mounted eyetracker. They were told that they would be asked a short question, such as "What is the name of the fruit?" or "What is the name of the T-shaped object?" They were also told that after the question, they would see four objects on the computer screen in front of them and that their task was to say the name of the object specified in the instruction. The participants were asked to fixate a central fixation cross that appeared 2 sec prior to the onset of the visual display. This visual display was presented at the acoustic offset of the spoken instruction. During each trial, a voice key was triggered when participants started to name an object. Each trial was terminated by the experimenter after an object had been named. The experiment lasted approximately 30 min.

Results

Trials in which participants named an object other than the target were excluded from the analysis (1.17% of trials; on 0.92% of these trials, participants named a distractor, and on 0.25% a competitor). In addition, trials in which the voice key did not register a response were discarded (19.9% of the trials). We first report the naming latencies and then the eyetracking data.

Naming latencies. Figure 3 shows the naming latencies in Experiment 1. In the trials with a visual instruction and a category coordinate in the display, the mean target naming time was 2,022 msec ($SE = 58$). In the trials with a semantic instruction and a visual-form competitor in the display, the mean target naming time was 1,550 msec ($SE = 38$). This 472-msec difference was both significant in a paired-samples t test by participants [$t_1(23) = 7.43$, $p < .001$] and in an independent-samples t test by items [$t_2(48) = 2.64$, $p < .05$].

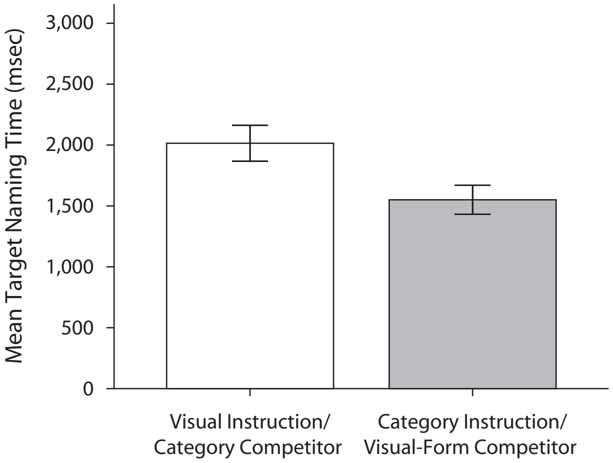

Figure 3. Average naming latencies in Experiment 1 (error bars represent 95% confidence intervals).

We observed a significant difference in target naming latencies between the condition with category competitors and the one with visual-form competitors. However, Experiment 1 does not show whether this result was due to differences in the instruction (visual [e.g., "What is the name of the circular object?"] vs. category [e.g., "What is the name of the musical instrument?"]) or to differences in the nature of the related object (category vs. visual-form competitor). We return to this issue in the Discussion section of Experiment 1.

Analysis of eye movements. Figure 4 shows a time course graph that illustrates the fixation proportions at 20-msec intervals for the various types of pictures over the course of the average trial. In computing these values, eye position was categorized according to the currently fixated quadrant. We will use the term *p*(target) to refer to the fixation proportion of the target picture at a particular moment in time, *p*(competitor) to refer to the fixation proportion of the competitor, and *p*(distractor) to refer to the fixation proportion of the unrelated distractors. The proportion of fixations to the distractors was averaged across the two distractor pictures. Zero represents the onset of the visual display.

The graphs show that as time unfolds, *p*(target) and *p*(competitor) diverge from *p*(distractor) for both types of experimental manipulations. Figure 4 also shows strong biases in overt attention toward the target objects at naming onset. Thus, there was a strong tendency for eye gaze to coincide with actual articulation of the object's name.

For the statistical analyses, we computed the mean fixation proportions for each type of picture over a time interval starting at 200 msec and continuing at 20-msec intervals. We calculated the ratio between the proportion of fixations to the target and the sum of the target and distractor fixation proportions. Similarly, we calculated the ratio between the proportion of fixations to the particular competitor (shape or semantic) and the sum of the particular competitor and distractor fixation proportions. We then compared the mean ratios (by participants and items) with .5. A ratio greater than .5 would show that, of all the fixations directed at the particular competitor and the unrelated distractors, the competitor attracted more than half of those fixations (see Dahan & Tanenhaus, 2005; Huettig & McQueen, 2007). In order to establish whether increased activation occurred during the core processes of naming, we conducted separate analyses for two time regions: (1) display onset + 200 msec to onset of word form encoding and (2) onset of form encoding to naming onset. Indefrey and Levelt (2004) estimated the duration of form encoding (phonological code retrieval, syllabification, phonetic encoding until initiation of articulation) during object naming to range from 217 to 530 msec, with a mean of 350 msec. We therefore estimated the onset of form encoding in the present study to be 350 msec prior to articulation.

Display onset to onset of form encoding (from 200 to 1,672 msec for trials with a visual instruction and a category coordinate in the display; from 200 to 1,200 msec for trials with a category instruction and a visual competitor). One-sample *t* tests showed that the target objects [mean ratio of .78; $t_1(23) = 28.28$, $p < .001$; $t_2(24) = 11.44$, $p < .001$] and the category coordinates [mean ratio of .61; $t_1(23) = 10.14$, $p < .001$; $t_2(24) = 3.62$, $p < .01$] were fixated more than the unrelated distractors in the trials with a visual instruction.

Similarly, one-sample *t* tests showed that the target objects [mean ratio of .80; $t_1(23) = 25.94$, $p < .001$; $t_2(24) = 10.50$, $p < .001$] and the visual-form competitors [mean ratio of .59; $t_1(23) = 6.33$, $p < .001$; $t_2(24) = 2.82$, $p < .05$] were fixated more than the unrelated distractors in the trials with a category instruction.

Onset of form encoding to onset of naming (from 1,672 to 2,022 msec for trials with a visual instruction and a category coordinate; from 1,200 to 1,550 msec for trials with a category instruction and a visual competitor). During this time interval, the target objects [mean ratio of .81; $t_1(23) = 15.66$, $p < .001$; $t_2(24) = 11.23$, $p < .001$] but not the visual competitors [mean ratio of .51; t_1 and $t_2 < 1$] were fixated more than the unrelated distractors. Similarly, the target objects [mean ratio of .68; $t_1(23) = 6.68$, $p < .001$; $t_2(24) = 6.51$, $p < .001$] but not the category coordinates [mean ratio of .52; $t_1(23) = 1.13$, $p > .1$; $t_2 < 1$] were fixated more than the unrelated distractors.

In sum, between display onset + 200 msec and the estimated onset of form encoding, both category coordinates and visual-form competitors received significantly more overt attention than did the unrelated distractors. During form encoding, only the target objects received increased overt attention.

Discussion

The most important findings of Experiment 1 were that (1) when preparing the names of objects, people direct spurious eye movements to other objects that share only partial relationships with the to-be-named target objects; (2) this increased activation is not restricted to objects from the same conceptual category; participants also fixate objects with a similar visual form more often than unrelated distractor objects; and (3) this increased activation (as indicated by increased overt attention to the related objects)

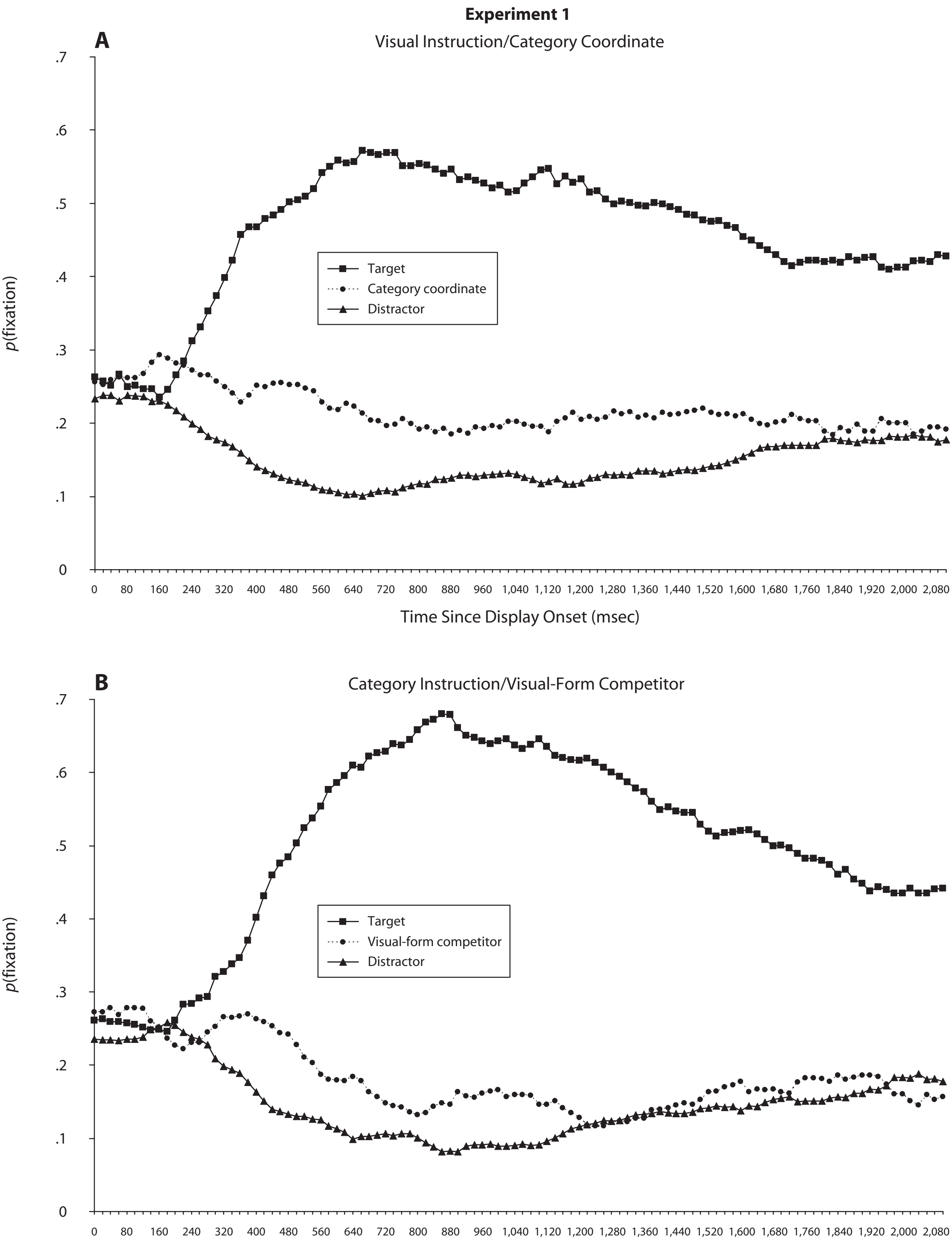

Figure 4. Time course graph for Experiment 1, showing the fixation probabilities for the target, competitor, and distractors in (A) visual instruction/semantic competitor trials and (B) semantic instruction/visual competitor trials. Zero on the time axis refers to the display onset.

persists at least until the stage of word form encoding. In addition, we observed that our participants kept fixating the target (see Figure 4) well into the time window when the name is overtly produced (in contrast to studies that used a task based on fixed spatial cues; e.g., Meyer et al., 1998). Finally, although the eye movement patterns were very similar in the conditions with a visual competitor distractor and with a category coordinate distractor, the naming latencies were much longer in the condition with a category coordinate distractor.

However, there are a number of alternative explanations for the present findings. First, Experiment 1 did not rule out the possibility that the related objects received increased attention because of characteristics other than their relation to the target. For example, participants may have fixated the competitor objects more often simply because they found them more interesting than the distractors. Second, the participants may have been aware that the display always contained objects in at least one of two types of relation, because the design drew their attention to the two types of relation (since each participant received both types of instruction). Third, Experiment 1 did not rule out the notion that the visual-form competitor effect may arise from having two similar items in the display. That is, two visually similar objects in a display may attract attention simply because of their similarity. Fourth, although the difference in naming latencies between the two conditions might be interpreted as the result of stronger semantic interference in the category coordinate condition than in the visual-form condition, the experiment did not rule out that these differences reflect differences in the instructions.

Experiment 2 was thus designed to replicate the main findings of Experiment 1 using a different design and additional controls.

EXPERIMENT 2

This experiment differs from Experiment 1 in two primary respects. First, we now manipulated the type of instruction (category or visual-form) between participants. This addresses the possible concern that spurious eye movements are an artifact of presenting both types of instruction to each participant, thus drawing attention to both types of relation. Second, we included a control condition in which participants were shown displays that served as experimental displays for other participants, but for which the current participant was instructed to name an unrelated distractor. This addresses the possible concern that people fixated the (category coordinate or visual-form) competitors more because these competitors captured attention for unknown reasons; it also addresses the concern that objects are fixated more when a similar object occurs in the display. If either concern is justified, there should be spurious eye movements to the competitor and/or the target in this "named-distractor" condition. Third, we included a control condition in which the target object occurred with three unrelated competitors. This baseline condition allowed us to compare naming latencies in the conditions with and without a (category coordinate or visual-form) distractor, while keeping the instruction and the target object constant.

Method

Participants. Forty further Ghent University students, all native speakers of Dutch, participated in exchange for course credit. All had normal or corrected-to-normal vision.

Stimuli and Design. The experiment used 48 of the targets from Experiment 1 (see the lists in Appendix B). Type of instruction (category vs. visual shape) was manipulated between participants, with random assignment of participants to conditions and to counterbalanced lists within conditions.

In the category instruction condition, there were 24 critical displays. Twelve of these occurred in the experimental condition (Figure 5A). They contained the target (e.g., apple), a visual-form competitor (e.g., ball), and two unrelated distractors (e.g., chair, bat). The other 12 occurred in the control condition (Figure 5B). These contained the target (e.g., door) and three unrelated distractors (e.g., shark, arm, lettuce). In addition, 24 named-distractor displays implemented a further control. The object to be named in these displays was always unrelated to the other three objects, but in 12 of the displays (Figure 5C) two of the three objects were from the same category (e.g., a clamp to be named occurred with an eye, thumb, and chicken; eye and thumb are both body parts); in the remaining 12 displays (Figure 5D), all objects were unrelated (e.g., an elephant to be named occurred with a shoulder, orange, and motorcycle).

Two counterbalanced lists were constructed, so that across the lists each critical display appeared once in the experimental condition and once in the control condition (in which the related object was replaced by an unrelated object). Each named distractor thus occurred once with two category-related objects and once with all unrelated objects (i.e., with one of the related objects replaced by an unrelated object).

The visual-form condition was constructed similarly. The 24 critical displays were the named-distractor displays from the category condition. Twelve contained a target (e.g., a thumb), a category competitor (e.g., an eye), and two unrelated distractors (e.g., a clamp and chicken), and 12 contained a target (e.g., an orange) and three unrelated distractors (e.g., a shoulder, elephant, and motorcycle). The 24 named-distractor displays, in turn, were the critical displays from the category condition. Twelve contained two visually similar objects (e.g., a bat to be named occurred with an apple, ball, and chair; apple and ball have similar shapes), and 12 consisted of objects that were all different (e.g., an arm, door, shark, and lettuce). Again, two counterbalanced lists were constructed so that each critical display appeared once in the experimental condition and once in the control condition, and each named distractor appeared once with two related objects and once with all unrelated objects.

Procedure. The same procedure was used as in Experiment 1, with the exceptions that eye movements were now monitored using an Eyelink 1000 eyetracker and that naming latencies were no longer collected using a voice key; instead, we recorded the speech to WAV files using an ASIO driver and manually measured naming latencies using a speech waveform editor.

Results

A total of 12.66% of trials were excluded from the analysis. These were trials in which participants did not name any object, named an object other than the intended one, or named the intended object incorrectly. We again report first the naming latencies and then the eye movement data.

Naming latencies. Figure 6 shows the average target naming times in Experiment 2. In the trials with a visual

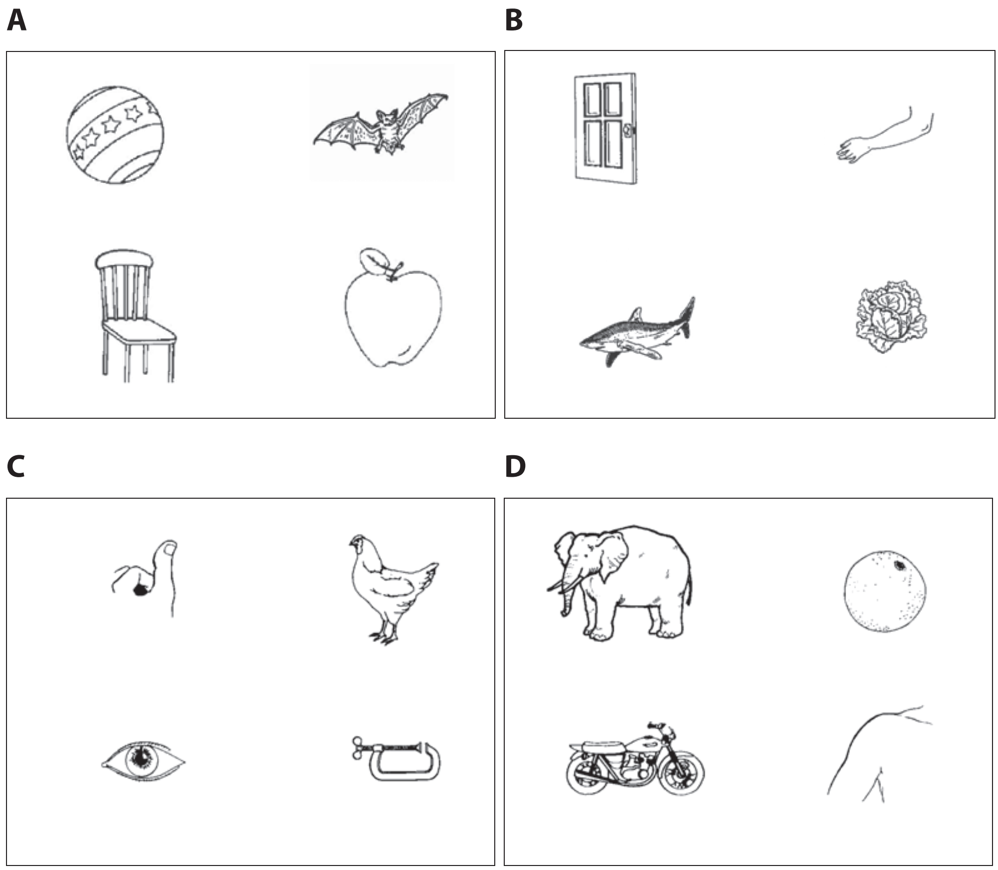

Figure 5. An example of the types of visual displays used in Experiment 2. (A) Experimental condition: target (apple), visual-form competitor (ball), and two unrelated distractors (chair, bat). (B) Control condition: target (door) and three unrelated distractors (shark, arm, lettuce). (C) Named distractor condition A, which included two objects from the same category (here, a clamp to be named occurs with an eye, thumb, and chicken; eye and thumb are both body parts). (D) Named distractor condition B, in which all objects were unrelated (here, an elephant to be named occurs with a shoulder, orange, and motorcycle).

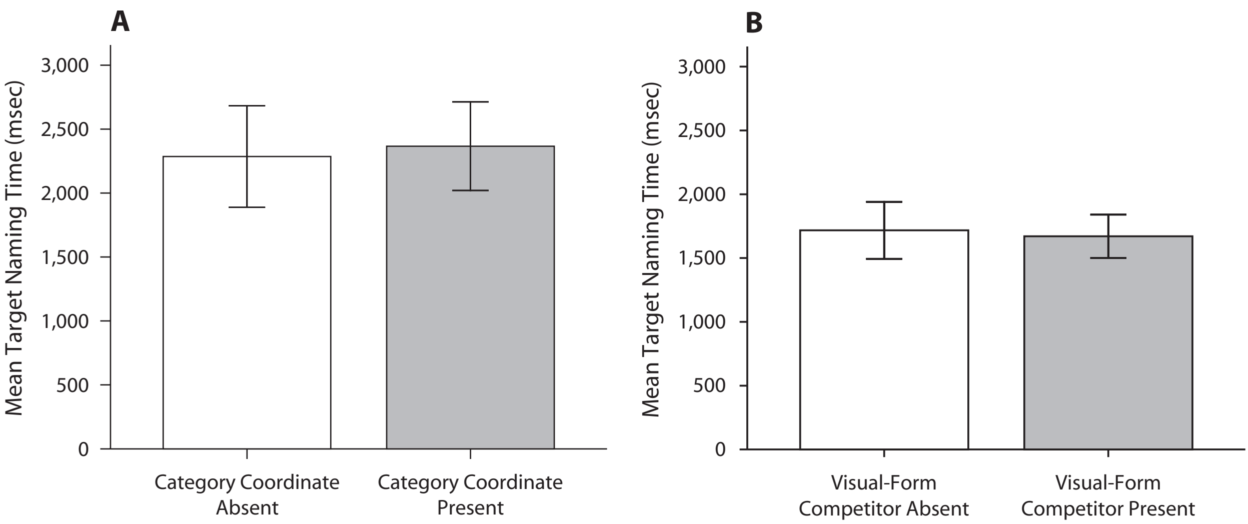

Figure 6. Average naming latencies in Experiment 2 (error bars represent 95% confidence intervals) with (A) visual instructions and (B) category instructions.

instruction and a category coordinate in the display, the mean naming time was 2,366 msec (*SE* = 167). The mean naming time in the corresponding control condition (in which the category coordinate was replaced by an unrelated distractor) was 2,285 msec (*SE* = 192). There was no significant difference in target naming times between these conditions (t_1 and $t_2 < 1$).

In the trials with a category instruction and a visual-form competitor in the display, the mean target naming time was 1,670 msec (*SE* = 82). The mean naming time in the corresponding control condition (in which the visual-form competitor was replaced by an unrelated distractor) was 1,717 msec (*SE* = 108). Again, there was no significant difference in target naming times between these conditions (t_1 and $t_2 < 1$).

As in Experiment 1, naming latencies were more than half a second longer in the trials with a visual-form instruction rather than a category instruction. The comparison with a control condition in the present experiment shows that this difference cannot be attributed to the presence or absence of particular distractors; instead, we suspect that the naming time differences between category and visual trials are due to the different types of instruction.

Eye movements. Figure 7 shows a time course graph that illustrates the fixation proportions (at 20-msec intervals) to the various types of pictures over the course of the average trial. The graph shows, as in Experiment 1, that as time unfolds, *p*(target) and *p*(competitor) diverge from *p*(distractor) for both types of experimental manipulations.

Display onset to onset of form encoding (from 0 to 2,016 msec for the trials with a visual instruction and category competitor; from 0 to 1,320 msec for the trials with a category instruction and a visual competitor). One-sample *t* tests showed that the target objects [mean ratio of .77; $t_1(19) = 11.85, p < .001; t_2(23) = 10.00, p < .001$] and the category coordinates [mean ratio of .56; $t_1(19) = 4.13, p < .01; t_2(23) = 2.75, p < .05$] were fixated more than the unrelated distractors in trials with a visual instruction and a category competitor in the display.

Importantly, there were no such differences between target objects and unrelated distractors [mean ratio of .48; $t_1 < 1; t_2(23) = -1.33, p > .1$] and between category coordinates and unrelated distractors [mean ratio of .52; $t_1(19) = 1.18, p > .1; t_2 < 1$] in the control condition in which an unrelated object (the named distractor) had to be named.

Similarly, one-sample *t* tests showed that the target objects [mean ratio of .78; $t_1(19) = 26.43, p < .001; t_2(23) = 14.15, p < .001$] and the visual-form competitors [mean ratio of .57; $t_1(19) = 5.15, p < .001; t_2(23) = 3.97, p < .01$] were fixated more than the unrelated distractors in the trials with a category instruction and a visual-form competitor in the display.

Again, there were no significant differences between target objects and unrelated distractors [mean ratio of .55; $t_1(19) = 2.03, p > .05; t_2(23) = 1.4, p > .1$] and between visual-form competitors and unrelated distractors [mean ratio of .55; $t_1(19) = 1.96, p > .05; t_2(23) = 1.79, p > .05$] in the control condition in which an unrelated object (the named distractor) was named.

Onset of form encoding to onset of naming (from 2,017 to 2,366 msec for the trials with a visual instruction and a category coordinate in the display; from 1,321 to 1,670 msec for the trials with a category instruction and a visual competitor). During this time interval, the target objects [mean ratio of .79; $t_1(19) = 7.92, p < .001; t_2(23) = 11.13, p < .001$] but not the category coordinates [mean ratio of .52; $t_1 < 1; t_2(23) = -1.32, p > .1$] were fixated more than the unrelated distractors in the trials with a visual instruction and a category competitor in the display. In the control condition in which an unrelated object (the named distractor) had to be named, only the named distractor received increased attention.

Similarly, the target objects [mean ratio of .75; $t_1(19) = 7.92, p < .001; t_2(23) = 7.96, p < .001$] but not the visual-form competitors [mean ratio of .46; t_1 and $t_2 < 1$] were fixated more than the unrelated distractors in the trials with a category instruction and a visual competitor in the display. Again, in the control condition in which an unrelated object (the named distractor) had to be named, only the named distractor received increased attention.

In sum, between display onset + 200 msec and the estimated onset of form encoding, both category coordinates and visual-form competitors received significantly more overt attention than did the unrelated distractors. In a control condition that required naming of an unrelated (previous distractor) object, no differences in attention were observed between category coordinates and distractors and between visual-form competitors and distractors. During form encoding, only the target objects received increased overt attention.

Discussion

Experiment 2 showed that the effects of increased overt attention to both category coordinates and visually related objects are robust. Experiment 2 rules out a number of alternative interpretations of the results of Experiment 1. First, it rules out that the visual-form effect occurred because the visual instruction on category competitor trials focused participants' attention on shape information throughout the experiment, and vice versa for visual trials. All of our participants received only one type of instruction (either category or visual). Second, it rules out that participants fixated the related objects more often simply because they found them more interesting than the distractors. Our participants directed more attention to the related objects only when the target had to be named, not when a control object (a distractor completely unrelated to our competitor objects) had to be named. Third, it rules out that the visual-form effect results from having two similar items in the display—namely, that two visually similar objects in a display simply attract attention because of their similarity. When a control object had to be named, participants directed more attention to neither the competitor nor the target than to the unrelated distractor. Finally, there was no evidence that increased attention to competitor objects affected naming latencies.

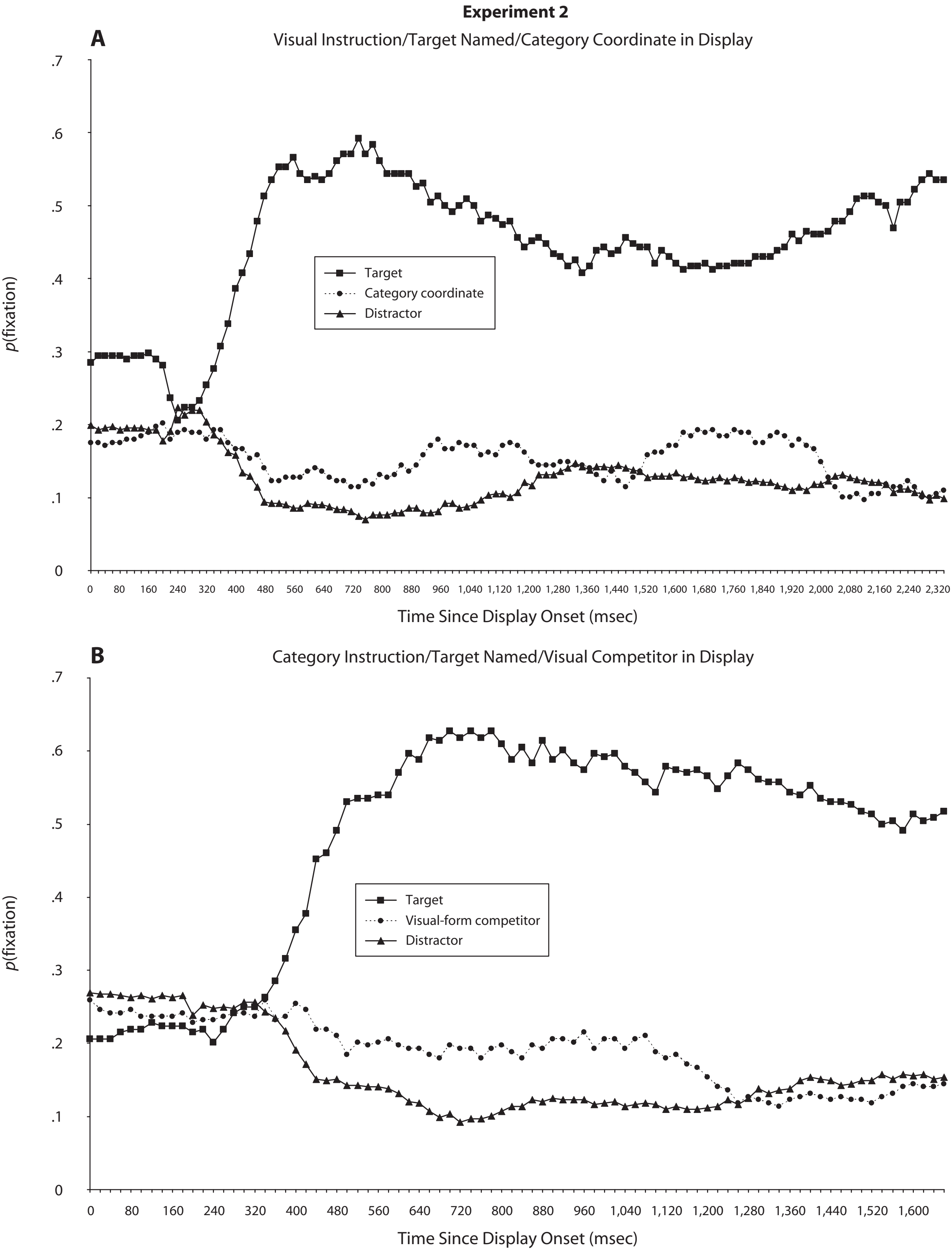

Figure 7. Time course graph for Experiment 2, showing the fixation probabilities for the target, competitor, and distractors in (A) visual instruction/semantic competitor trials and (B) semantic instruction/visual competitor trials. Zero on the time axis refers to the display onset.

GENERAL DISCUSSION

We have reported two visual-world eyetracking experiments that attempted to tap into semantic activation during picture naming. First we will discuss how successful this attempt was, and then turn to the theoretical implications of the findings.

The Visual-World Task

The fact that more looks were directed to category coordinates and visually related objects suggests that the semantic representations of these objects were more highly activated than those of unrelated distractor objects. The results of Experiment 2, in which no increased overt attention was directed to these related objects when an unrelated distractor object had to be named, show that it was the naming of the (partially related) target object, and not some other property of the particular objects, that caused these effects. Therefore, the increased activation found here is not an artifact of the present task. In other words, the present study provides strong evidence that during the naming of a target, the semantic representations of categorically and visually related objects are more highly activated than those of unrelated objects. Thus, the present research provides the first clear evidence for increased visual-form activation in preparation for word production.

In this regard, note that all distractor objects were in the immediate visual environment. This means that part of the activation of the distractor concepts resulted from bottom-up activation (i.e., from the visual presentation of the objects). However, we emphasize that this bottom-up activation holds for both the distractor objects and for the visual or category coordinate distractor objects. The fact of more fixations on the related objects than on completely unrelated distractors, therefore, must have resulted from a flow of activation from the semantic representation of the target to that of the related object. (Note that this logic is similar to that in the picture–word interference task, in which the distractor concept also receives bottom-up activation, in that case from word perception.)

Another methodological issue is that the eye movement patterns observed in earlier studies arose in the context of fixed spatial instructions. Such studies showed that people keep fixating the target picture and move their eyes to the next picture in the short interval before the acoustic onset of the first picture's name. Our experiment showed that this specific pattern does not always hold. In our task, there was initial uncertainty about which of the four objects to name. In addition, our task required that only one object be named. We suggest that in our study the initial uncertainty factor played a role in the elicitation of spurious eye movements to other objects in the display, and the second factor was responsible for the tendency to *not* move away from the target just before and during overt naming. To draw an analogy from hunting, if someone tries to shoot two ducks, he or she will move the eyes (and gun) toward the next duck once a shot has been fired at the first duck, but if the hunter shoots only *one* duck, he or she will keep looking at it long after the shot has been fired.

Note also that the visual-form competitor effect is unlikely to reflect visual confusion. We did not ask our participants to look for the saxophone, in which case they might have then mistaken the ladle for a saxophone; they were asked instead to name the musical instrument. In order to perform the task, the four objects in the display had to be assigned to their respective *categories*: body part for foot, kitchen utensil for ladle, musical instrument for saxophone, and so on (see Figure 1B). If the task had been to look for the saxophone (or some other visual rather than category instruction), increased fixations on the ladle might have indicated temporary visual confusion. However, as noted, our participants were given a category and *not* a visual instruction. Thus, the visual competitor effect does *not* reflect visual confusion but indicates instead that, during the process of name preparation, category coordinates and objects with similar visual forms are more highly activated than unrelated distractors.

In sum, one main contribution of this study is that we have presented a new method that allows for tapping into semantic activation during picture processing. Particularly, looks to related objects demonstrate whether or not there is substantial spreading of activation to related concepts. We have demonstrated this for the case of category coordinates and visually related items, but we argue that our method can be equally fruitfully applied to study other kinds of relations between concepts.

Evidence Against Lexical Selection by Competition in Word Production

Our data, however, do more than attest to semantic and visual-form activation in preparation for word production. In particular, the finding that the concepts of form-related objects are activated in picture naming is hard to reconcile with the absence of visual-form effects in the picture–word interference paradigm, at least according to a lexical-selection-by-competition account. This is because such accounts predict that semantic activation should lead to a spreading of activation to the lexical level, so that form-related competitors should compete for selection with the target. Instead, there is no compelling evidence for visual interference in the picture–word interference task. In addition, the present Experiment 2 (which included an appropriate baseline) found no category coordinate or visual effects on naming latencies. The data thus demonstrate that semantic activation strong enough to influence visual attention for extended periods of time can exist without influencing naming latencies (and, ipso facto, lexical competition).

As mentioned in the introduction, results from the picture–picture and related paradigms (Bloem & La Heij, 2003; Bloem et al., 2004; Damian & Bowers, 2003; La Heij et al., 2003) have likewise suggested that semantic activation of competitors does not delay naming. Our results go beyond such findings by showing that, although semantically (and visually) related objects do not result in semantic interference, their semantic representations were more highly activated than those of unrelated objects. Thus, our findings strongly suggest that lexical-selection-by-competition accounts (e.g., La Heij, Kuipers, & Starreveld, 2006; Levelt et al., 1999) must be revised.

One might object that possible explanations of these and other findings could be devised within lexical-selection-by-competition models. We will discuss, and reject, three such explanations. First, one might argue that there is lexical competition between the names of visually related concepts but that reaction time data are not sensitive enough to detect it. However, this argument fails to explain why picture–word interference experiments generally do detect category coordinate competition, but not visual competition; our experiments reveal considerable semantic activation of both types of distractors. Second, a further argument might be that lexical competition is restricted to items within a set of task-relevant responses. Roelofs (2003), for example, makes this assumption in order to account for smaller Stroop interference when the presented color words are not the names of the target colors. The problem with this argument is that in picture–word interference experiments, the distractor words usually do not appear as targets. Thus, response set membership should equally affect the category coordinate conditions (which usually show interference) and the visual competitor conditions (which show null effects). Third, one might argue that the reaction data show null effects because of a combination of priming at the conceptual level and competition at the lexical level. However, according to most accounts of semantic interference, there is more priming from target to distractor than from distractor to target (because only the target receives additional task activation), and this activation cascades to the lexical level. Thus, priming decreases the activation difference between the two lexical representations, and should therefore increase lexical competition.

Our findings thus provide support for Finkbeiner and Caramazza's (2006) suggestion that the semantic interference effect in the picture–word interference paradigm is restricted to a "highly specific set of stimuli and experimental contexts and, thus, hardly seem to reflect a general property of the lexical selection mechanism" (p. 1035).

In conclusion, our data reveal that participants fixated both category coordinates and visually related objects more often than pictures of unrelated objects in preparation for word production. The findings demonstrate that eye movements are a sensitive measure of the overlap between the conceptual (and visual-form) information that is accessed in preparation for word production and the conceptual knowledge associated with visual objects. The finding that only semantic coordinates interfere with production in picture–word interference is problematic for lexical-selection-by-competition accounts. The present study shows that this account cannot be salvaged by assuming that no, or only little, spreading of activation takes place to concepts that are related in another way: Visual distractors were found to be highly active but nevertheless to not compete with the target. In conjunction with other studies (e.g., Mahon et al., 2007), this suggests that lexical-selection-by-competition accounts (e.g., La Heij et al., 2006; Levelt et al., 1999) must be revised.

AUTHOR NOTE

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NOTE

1. Interference of visual similarity (namely, color similarity) has been found in the color–word Stroop task (Klopfer, 1996). Note, however, that this manipulation (e.g., the word "blue" printed in green or yellow) confounds visual similarity and category membership.

APPENDIX A1
Visual Instruction/Category Competitor in Experiment 1

Item	Target	Category of Target	Category Competitor	Category of Competitor	Distractor 1	Category of Distractor 1	Distractor 2	Category of Distractor 2
26	orange	fruit	pear	fruit	shoulder	body part	block	toy
27	peach	fruit	strawberry	fruit	dolphin	type of fish	trumpet	musical instrument
28	sun	weather phenomenon	cloud	weather phenomenon	slipper	type of shoe	duck	bird
29	hammer	carpenter's tool	drill	carpenter's tool	dog	four-footed animal	pineapple	fruit
30	pick	gardener's tool	watering can	gardener's tool	bus	vehicle	puzzle	toy
31	rake	gardener's tool	wheelbarrow	gardener's tool	baby	thing that makes noise	teeth	body part
32	nail	carpenter's tool	saw	carpenter's tool	bat	thing that flies	dresser	furniture
33	ring	thing that women wear	dress	thing that women wear	airplane	vehicle	grasshopper	insect
34	necklace	thing that women wear	heel	thing that women wear	spider	insect	bench	thing made from wood
35	rope	weapon	gun	weapon	melon	fruit	pig	four-footed animal
36	water hose	gardener's tool	shovel	gardener's tool	bell	thing that makes noise	bowl	kitchen utensil
37	tie	type of clothing	shoe	type of clothing	mosquito	thing that flies	doll	toy
38	knife	kitchen utensil	cup	kitchen utensil	fly	insect	leaf	thing that is green
39	leg	body part	molar	body part	cutting board	kitchen utensil	chicken	bird
40	thumb	body part	eye	body part	rifle	weapon	organ	musical instrument
41	toe	body part	chest	body part	harp	musical instrument	fox	four-footed animal
42	neck	body part	lips	body part	telephone	thing that makes noise	TV	furniture
43	bricks	part of a building	roof	part of a building	banjo	musical instrument	cherry	fruit
44	bed	article of furniture	stool	article of furniture	worm	insect	bicycle	vehicle
45	bean	vegetable	pepper	vegetable	cat	thing that makes noise	yo-yo	toy
46	mountain	natural earth formation	tree	natural earth formation	violin	musical instrument	bug	insect
47	teepee	type of human dwelling	trailer	type of human dwelling	donkey	four-footed animal	rose	type of flower
48	lightning	weather phenomenon	rain	natural earth formation	fist	weapon	bird	thing that flies
49	train	vehicle	helicopter	vehicle	horse	four-footed animal	pot	kitchen utensil
50	plate	kitchen utensil	stove	kitchen utensil	window	part of a building	lion	four-footed animal

APPENDIX A2
Category Instruction/Visual-Form Competitor in Experiment 1

Item	Target	Category of Target	Visual-Form Competitor	Category of Competitor	Distractor 1	Category of Distractor 1	Distractor 2	Category of Distractor 2
1	lamp	article of furniture	flower	flower	hand	body part	whale	type of fish
2	finger	body part	arrow	weapon	house	human dwelling	table	furniture
3	heart	body part	lemon	fruit	couch	furniture	canoe	type of boat
4	nose	body part	horn	musical instrument	jacket	clothing	church	religious building
5	bone	body part	wrench	carpenter's tool	piano	musical instrument	whistle	thing that makes noise
6	ruler	carpenter's tool	fork	kitchen utensil	bee	insect	radish	vegetable
7	screw	carpenter's tool	carrot	vegetable	zebra	four-footed animal	sweater	clothing
8	apple	fruit	ball	toy	chair	furniture	shirt	clothing
9	banana	fruit	sword	weapon	ostrich	bird	alarm clock	thing that makes noise
10	spoon	kitchen utensil	guitar	musical instrument	glove	clothing	car	thing that makes noise
11	flute	musical instrument	asparagus	vegetable	sailboat	type of ship	sock	clothing
12	saxophone	musical instrument	ladle	kitchen utensil	frog	thing that is green	foot	body part
13	door	part of a building	book	type of reading material	shark	type of fish	lettuce	vegetable
14	kite	thing that flies	boat	vehicle	spatula	kitchen utensil	tiger	four-footed animal
15	lipstick	thing that women wear	screwdriver	carpenter's tool	penguin	bird	drum	musical instrument
16	hat	type of clothing	igloo	human dwelling	bat	weapon	peas	vegetables
17	skirt	type of clothing	tent	human dwelling	submarine	type of boat	sheep	four-footed animal
18	belt	type of clothing	snake	snake	speaker	thing that makes noise	paper	thing made from wood
19	pants	type of clothing	pliers	carpenter's tool	volcano	natural earth formation	ear	body part
20	scarf	type of clothing	jump rope	toy	eagle	bird	truck	vehicle
21	letter	type of reading material	carpet	part of a building	arm	body part	butterfly	insect
22	corn	vegetable	pencil	carpenter's tool	boot	type of shoe	motorcycle	vehicle
23	tomato	vegetable	bomb	weapon	skateboard	vehicle	radio	thing that makes noise
24	potato	vegetable	rock	natural earth formation	squirrel	four-footed animal	desk	furniture
25	celery	vegetable	hair	body part	mixer	kitchen utensil	owl	bird

APPENDIX B1
List A in Experiment 2

Item	Target	Competitor	Unrelated Distractor	Named Distractor	Distractor 3
1	lamp	flower	hand	watermelon	
2	finger	arrow	house	cutting board	
3	heart	lemon	couch	window	
4	nose	horn	mixer	submarine	
5	bone	wrench	piano	TV	
6	ruler	fork	airplane	cherry	
7	screw	carrot	zebra	alarm clock	
8	apple	ball	chair	bat	
9	banana	sword	ostrich	radish	
10	spoon	guitar	glove	paper	
11	flute	asparagus	sailboat	fist	
12	saxophone	ladle	frog	mosquito	
13	door		shark	arm	lettuce
14	kite		spatula	dresser	tiger
15	lipstick		penguin	table	drum
16	skirt		peacock	dolphin	lizard
17	belt		pig	bee	doll
18	pants		volcano	bug	doctor
19	scarf		eagle	fly	sheep
20	letter		bird	bus	butterfly
21	corn		boot	bowl	turtle
22	tomato		dentist	worm	bat
23	potato		squirrel	gun	pineapple
24	celery		butcher	speaker	owl
25	orange		shoulder	elephant	motorcycle
26	peach		block	accordion	turkey
27	sun		slipper	goat	desk
28	hammer		dog	palm tree	blimp
29	pick		rose	mouse	trumpet
30	rake		baby	pumpkin	dinosaur
31	nail		lion	tractor	radio
32	ring		ear	cow	puzzle
33	necklace		spider	grapes	cook
34	rope		duck	skateboard	pot
35	water hose		bell	parrot	fireman
36	tie		teeth	yo-yo	leaf
37	knife	cup	mushroom	swan	
38	leg	molar	fox	onion	
39	thumb	eye	chicken	clamp	
40	toe	chest	bear	can opener	
41	neck	lips	harp	anvil	
42	bricks	roof	rhino	rocket	
43	bed	stool	banjo	axe	
44	mountain	tree	violin	hat	
45	teepee	trailer	donkey	lawnmower	
46	lightning	rain	police man	paintbrush	
47	train	helicopter	organ	stairs	
48	plate	stove	horse	sled	

Note—All participants with List A received visual instructions (for Items 1–24, the shape of the "named distractor," and for Items 25–48, the shape of the target).

APPENDIX B2
List B in Experiment 2

Item	Target	Competitor	Unrelated Distractor	Named Distractor	Distractor 3
1	lamp		hand	watermelon	whale
2	finger		house	cutting board	bench
3	heart		couch	window	canoe
4	nose		mixer	submarine	church
5	bone		piano	TV	whistle
6	ruler		airplane	cherry	pelican
7	screw		zebra	alarm clock	kangaroo
8	apple		chair	bat	deer
9	banana		ostrich	radish	bicycle
10	spoon		glove	paper	car
11	flute		sailboat	fist	sock
12	saxophone		frog	mosquito	foot
13	door	book	shark	arm	
14	kite	boat	spatula	dresser	
15	lipstick	screwdriver	penguin	table	
16	skirt	tent	peacock	dolphin	
17	belt	snake	pig	bee	
18	pants	pliers	volcano	bug	
19	scarf	jump rope	eagle	fly	
20	letter	carpet	bird	bus	
21	corn	pencil	boot	bowl	
22	tomato	bomb	dentist	worm	
23	potato	rock	squirrel	gun	
24	celery	hair	butcher	speaker	
25	orange	pear	shoulder	elephant	
26	peach	strawberry	block	accordion	
27	sun	cloud	slipper	goat	
28	hammer	drill	dog	palm tree	
29	pick	watering can	rose	mouse	
30	rake	wheelbarrow	baby	pumpkin	
31	nail	saw	lion	tractor	
32	ring	dress	ear	cow	
33	necklace	heel	spider	grapes	
34	rope	gun	duck	skateboard	
35	water hose	shovel	bell	parrot	
36	tie	shoe	teeth	yo-yo	
37	knife		mushroom	swan	jacket
38	leg		fox	onion	telephone
39	thumb		chicken	clamp	beaver
40	toe		bear	can opener	sweater
41	neck		harp	anvil	monkey
42	bricks		rhino	rocket	shirt
43	bed		banjo	axe	giraffe
44	mountain		violin	hat	rabbit
45	teepee		donkey	lawnmower	alligator
46	lightning		police man	paintbrush	truck
47	train		organ	stairs	wolf
48	plate		horse	sled	ant

Note—All participants with List B received visual instructions (for Items 1–24, the shape of the "named distractor," and for Items 25–48, the shape of the target).

APPENDIX B3
List C in Experiment 2

Item	Target	Competitor	Unrelated Distractor	Named Distractor	Distractor 3
1	lamp	flower	hand	watermelon	
2	finger	arrow	house	cutting board	
3	heart	lemon	couch	window	
4	nose	horn	mixer	submarine	
5	bone	wrench	piano	TV	
6	ruler	fork	airplane	cherry	
7	screw	carrot	zebra	alarm clock	
8	apple	ball	chair	bat	
9	banana	sword	ostrich	radish	
10	spoon	guitar	glove	paper	
11	flute	asparagus	sailboat	fist	
12	saxophone	ladle	frog	mosquito	
13	door		shark	arm	lettuce
14	kite		spatula	dresser	tiger
15	lipstick		penguin	table	drum
16	skirt		peacock	dolphin	lizard
17	belt		pig	bee	doll
18	pants		volcano	bug	doctor
19	scarf		eagle	fly	sheep
20	letter		bird	bus	butterfly
21	corn		boot	bowl	turtle
22	tomato		dentist	worm	bat
23	potato		squirrel	gun	pineapple
24	celery		butcher	speaker	owl
25	orange		shoulder	elephant	motorcycle
26	peach		block	accordion	turkey
27	sun		slipper	goat	desk
28	hammer		dog	palm tree	blimp
29	pick		rose	mouse	trumpet
30	rake		baby	pumpkin	dinosaur
31	nail		lion	tractor	radio
32	ring		ear	cow	puzzle
33	necklace		spider	grapes	cook
34	rope		duck	skateboard	pot
35	water hose		bell	parrot	fireman
36	tie		teeth	yo-yo	leaf
37	knife	cup	mushroom	swan	
38	leg	molar	fox	onion	
39	thumb	eye	chicken	clamp	
40	toe	chest	bear	can opener	
41	neck	lips	harp	anvil	
42	bricks	roof	rhino	rocket	
43	bed	stool	banjo	axe	
44	mountain	tree	violin	hat	
45	teepee	trailer	donkey	lawnmower	
46	lightning	rain	police man	paintbrush	
47	train	helicopter	organ	stairs	
48	plate	stove	horse	sled	

Note—All participants with List C received category instructions (for Items 1–24, the category of the target, and for Items 25–48, the category of the “named distractor”).

APPENDIX B4
List D in Experiment 2

Item	Target	Competitor	Unrelated Distractor	Named Distractor	Distractor 3
1	lamp		hand	watermelon	whale
2	finger		house	cutting board	bench
3	heart		couch	window	canoe
4	nose		mixer	submarine	church
5	bone		piano	TV	whistle
6	ruler		airplane	cherry	pelican
7	screw		zebra	alarm clock	kangaroo
8	apple		chair	bat	deer
9	banana		ostrich	radish	bicycle
10	spoon		glove	paper	car
11	flute		sailboat	fist	sock
12	saxophone		frog	mosquito	foot
13	door	book	shark	arm	
14	kite	boat	spatula	dresser	
15	lipstick	screwdriver	penguin	table	
16	skirt	tent	peacock	dolphin	
17	belt	snake	pig	bee	
18	pants	pliers	volcano	bug	
19	scarf	jump rope	eagle	fly	
20	letter	carpet	bird	bus	
21	corn	pencil	boot	bowl	
22	tomato	bomb	dentist	worm	
23	potato	rock	squirrel	gun	
24	celery	hair	butcher	speaker	
25	orange	pear	shoulder	elephant	
26	peach	strawberry	block	accordion	
27	sun	cloud	slipper	goat	
28	hammer	drill	dog	palm tree	
29	pick	watering can	rose	mouse	
30	rake	wheelbarrow	baby	pumpkin	
31	nail	saw	lion	tractor	
32	ring	dress	ear	cow	
33	necklace	heel	spider	grapes	
34	rope	gun	duck	skateboard	
35	water hose	shovel	bell	parrot	
36	tie	shoe	teeth	yo-yo	
37	knife		mushroom	swan	jacket
38	leg		fox	onion	telephone
39	thumb		chicken	clamp	beaver
40	toe		bear	can opener	sweater
41	neck		harp	anvil	monkey
42	bricks		rhino	rocket	shirt
43	bed		banjo	axe	giraffe
44	mountain		violin	hat	rabbit
45	teepee		donkey	lawnmower	alligator
46	lightning		police man	paintbrush	truck
47	train		organ	stairs	wolf
48	plate		horse	sled	ant

Note—All participants with List D received category instructions (for Items 1–24, the category of the target, and for Items 25–48, the category of the "named distractor").

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