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# The Cost and Benefit of Implicit Spatial Cues for Visual Attention

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Processing concepts with implicit spatial meaning or metaphorical spatial association has been shown to engage visuospatial mechanisms, causing either facilitation or interference with concurrent visual processing at locations compatible with the concepts. It is, however, unclear when interference or facilitation should be expected. It is possible that both effects result from the same processes that interact differently with different visual tasks (e.g., facilitating detection and interfering with discrimination). Alternatively, the 2 effects might represent different temporal stages of the same kind of processes, which can interfere with a congruent visual task at early stages but can cause facilitation at later stages. Finally, the 2 effects might be due to the differences in the underlying representations of concepts, particularly the differences between abstract and concrete concepts. Results of the present study are consistent with the view that interference and facilitation represent 2 temporal stages of the same kind of processes. In addition, the results reveal the unexpected importance of using multiple conceptual categories (as opposed to a single category) in observing the time course of the effects.

*Keywords:* visual attention, conceptual metaphor, embodied semantics, theory of event coding

The capacity for representing space is an essential component of perception and action; locating an object in space often has primacy over both perceptual identification of the object and acting upon the object (e.g., van der Heijden, 1993). More recently, it has been suggested that spatial representation continues to play a role in higher cognition and, particularly, in conceptual understanding (e.g., Barsalou, 2008; Coslett, 1999; Meier & Robinson, 2005; Zwaan & Yaxley, 2003). For instance, it is proposed that, analogous to how looking at a flying bird involves orienting upward, the concept "bird" can induce visuospatial activity in a manner consistent with looking up (Estes, Verges, & Barsalou, 2008). This proposal fits within the broader theoretical view that concept representation remains grounded in action-perception mechanisms, which allow acquisition of the concepts through experience or through forming metaphorical associations between concepts and perceptual features (Barsalou, 2008; Barsalou, Simmons, Barbey, & Wilson, 2003; Lakoff, 2008; Meier & Robinson, 2005; Pecher, Boot, & Van Dantzig, 2011).

Assuming that action-perception mechanisms contribute to forming concepts, activating a concept representation should activate a subset of associated perceptual information stored during the experience of the concept's referent (Barsalou, 1999). This proposed process is known as *simulation*, and it gives rise to the important prediction that conceptual processes can systematically impact concurrent perceptual tasks (Barsalou, 2008; Pecher et al., 2011; Zwaan, 2008). For instance, a task that requires visual orienting of attention upward or downward should be influenced as observers conceptually evaluate words referring to flying or nonflying animals (e.g., Estes et al., 2008; Šetić & Domijan, 2007). Finding such interaction between the linguistic processing of the animal concept (e.g., lexical decision) and visual orienting would support the view that perceptual components do contribute to forming representations of flying and nonflying animals.

In testing the proposal that conceptual processing activates both linguistic and perceptual information, several studies have shown that the location in which a word is presented influences efficiency of categorizing the word. For instance, Zwaan and Yaxley (2003) presented participants with vertically aligned word pairs (e.g., *SKY–GROUND*) and asked them to decide whether each pair was semantically related. Faster responses were found when the spatial arrangement of the word pair was congruent with the spatial arrangement of the words' referents (*SKY* presented above) than when it was incongruent (*GROUND* presented above). Similarly, Šetić and Domijan (2007) presented single words above or below fixation and asked participants to categorize the words (flying vs. nonflying in Experiment 1; living vs. nonliving in Experiment 2). Again, faster responses were found when the words were presented at locations congruent with their referents' typically perceived location in space. Both studies suggest that visuospatial mechanisms have a role in concept representation and that the spatial feature is automatically activated during conceptual processing.

Another paradigm used to examine the spatial component of concepts involves reading a single word at fixation and, shortly after, detecting or identifying a visual target (e.g., *X* or *O*) above or below fixation. This paradigm is a variant of the visual-attentional

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cuing task (Posner, 1980; Posner & Cohen, 1984), and it has been previously used to reveal automaticity of attentional cuing induced by other symbolic stimuli, such as arrows and direction words (e.g., Hommel, Pratt, Colzato, & Godijn, 2001; Tipples, 2002). A typical trial of a cuing task begins with the presentation of fixation mark at the center of the screen, followed by a noninformative cue (e.g., the word *UP*). Following the cue, a visual target appears at a peripheral location (e.g., above or below fixation). On cue–target *compatible* trials, the target appears at the location indicated by the cue (e.g., the cue *UP* followed by a target above fixation), whereas on cue–target *incompatible* trials the target appears at an alternative location. As with the word *UP,* words such as *HAPPY* and *GOD* have been shown to bias attention toward the metaphorically congruent location; thus, these words can be regarded as attentional cues, although their spatial referencing is implicit (e.g., Chasteen, Burdzy, & Pratt, 2010; Meier & Robinson, 2004; Pecher, Van Dantzig, Boot, Zanolie, & Huber, 2010; Schubert, 2005; Zanolie et al., 2012).

The advantage of the visual-attentional cuing paradigm is that the visual task is independent from the preceding linguistic stimulus; consequently, finding an interaction between the two (sub) tasks provides convincing evidence for the automatic activation of spatial information by concepts. Despite this advantage, the results from this paradigm have been somewhat unclear and have demonstrated how the current views of the perceptual grounding of concepts do not make specific predictions about the influence of concepts on concurrent visual tasks. In particular, it has been shown that words with implicit spatial meaning can both facilitate (e.g., Chasteen et al., 2010; Meier & Robinson, 2004; Zanolie et al., 2012) and interfere with processing targets at the compatible location (Bergen, 2005; Bergen, Lindsay, Matlock, & Narayanan, 2007; Estes et al., 2008; Richardson, Spivey, Barsalou, & McRae, 2003).

Among the first to employ an attentional cuing task in studying concepts were Meier and Robinson (2004, Experiment 2), who examined the effect of positive and negative concepts on visual processing. They instructed their participants to verbally categorize a single word per trial, as positive or negative, and predicted that the concepts' valence (e.g., *HAPPY*) would bias visual processing toward the metaphorically congruent location (i.e., above and below, respectively, for positive and negative concepts). Thus, immediately after the verbal response, a target letter (*p* or *q*) was presented above or below fixation, and participants were asked to identify the target letter as quickly as possible. Even though the location of the target letter was unrelated to the preceding word category, responses were faster when the target location was metaphorically congruent with the concept category (e.g., *HAPPY* followed by target above) than when the two were metaphorically incongruent. These findings were interpreted as support for the role of spatial attention along the vertical axis in representing the concepts of positive and negative valence (Meier & Robinson, 2005).

It is, however, possible that participants in the Meier and Robinson (2004) experiment simply aligned each of the two verbal responses to word stimuli (positive vs. negative) to one possible location of letter targets. That is, because of the binary dimensions of stimuli and responses (e.g., word categories and target location both had only two values), participants might have been encouraged to form associations between the polar values of these separate dimensions (Proctor & Cho, 2006). To reduce the chance of forming task-induced associations between categories and target locations, participants must either simply view the words without evaluation (e.g., Estes et al., 2008) or evaluate the words on a dimension orthogonal to the categories of interest (e.g., Šetić & Domijan, 2007, Experiment 2). Adhering to this criterion, Chasteen et al. (2010) conducted a set of experiments in which task-induced alignment between categories and locations was less likely. In that study, which examined the spatial grounding of religious concepts, participants viewed a single word per trial (e.g., *GOD*) and pressed the space bar as soon as they detected a luminance target in the periphery (e.g., above/below fixation). Importantly, participants responded only when the word referred to a religious concept (withholding response otherwise) and did not categorize words into divine and evil categories. Again, metaphorical congruency between word category and target location led to faster responses (*GOD* followed by target above) than when the two were incongruent.

In contrast to the above findings, it has been shown that implicit spatial cues can interfere with perception of targets at the compatible location (Bergen, 2005; Bergen et al., 2007; Estes et al., 2008; Richardson et al., 2003). For instance, Estes et al. (2008) presented observers with words referring to objects typically perceived above or below the visual midline (e.g., *HAT, BOOTS*), followed by a letter target (*X* or *O*) presented above or below fixation. They found slower and less accurate processing on cue–target compatible trials (e.g., *HAT* and target above) than on incompatible trials. This interference, Estes et al. reasoned, resulted from the perceptual simulation evoked by the cues. Because these perceptual simulations are spatially specific, engaging upward or downward attentional orienting in the simulation process, they selectively interfered with the target processing only at the compatible location (see also Bergen, 2005; Bergen et al., 2007; Richardson et al., 2003).

Thus, processing a concept that implicitly refers to a location in space can either facilitate or interfere with a concurrent visual task, and both patterns of results have been taken as evidence for the activation of visuospatial mechanisms during conceptual processing. These apparently conflicting interactions between the conceptual and perceptual processes might simply have resulted from some methodological differences. That is to say, interference and facilitation could be driven by the same type of conceptual processes that are manifested differently based on the details of the experimental task. The second possibility is that the two observations could be driven by the activation of genuinely distinct types of conceptual processes. In particular, the concrete concepts (Estes et al., 2008) may have different underlying representations than and the abstract concepts (Chasteen et al., 2010), such that their simulation would engage the visuospatial mechanisms differently. Confirming such a distinction would have important consequences for our understanding of concepts and perceptual grounding of concepts. Turning to the literature, however, both possibilities seem viable in light of the fact that facilitation and interference have been observed under conditions that differ in several ways.

Here, we attempt to understand whether the observed facilitation and interference have resulted from differences in methodological detail or whether the two effects are driven by two distinct classes of conceptual processing. To do so, we chose two representative experimental tasks, in which facilitation and interference have been previously observed (Chasteen et al., 2010; Estes et al., 2008). We replicated each finding and then systematically examined the role of each task characteristic in determining the nature of the observed effect. The differences, which include visual task (target discrimination vs. detection), cue–target stimulus onset asynchrony (SOA), concept type (concrete vs. abstract), and cue treatment (passive viewing vs. categorization), are summarized in Table 1 and discussed in more detail below.

First, we should consider whether the specific visual task performed by the observers plays a role in the observed compatibility effects. On the one hand, Chasteen et al. (2010) used a target *detection* task, in which participants make a keypress response as soon as they detect the luminance target above or below fixation. On the other hand, Estes et al. (2008) asked participants to *discriminate* between two possible target identities (*X* vs. *O*), necessitating greater visual processing depth before making a response. Visual identification relies on processes that are psychophysically distinct from target detection (i.e., having different sensitivity and time course; de la Rosa, Choudhery, & Chatziastros, 2011; Johnston, McCann, & Remington, 1995; Remington & Folk, 2001). Another potentially important outcome of coupling a discrimination task with a conceptual task is that it leads to a *partial* overlap of features on compatible trials. That is, when the visual target and the concept share a spatial code, they still have nonoverlapping features. The target (*X*/*O*), therefore, cannot be assimilated into processing the concept. By contrast, the luminance onsets of detection do not possess any relevant feature aside from location. Therefore, the luminance targets are more likely to be assimilated into other processes that share their spatial code. It is possible, therefore, that the overlap between concept representation and target location would benefit detecting visual targets while interfering with the more elaborate visual perception that is necessary for target discrimination.

Second, the temporal proximity between the activation of concept representation and the visual task may be responsible for interference. That is, if the visual task follows the processing of the concept after enough delay, the residual effect of concept processing may facilitate target processing in the compatible location (Bergen, 2007; Boulenger et al., 2006; Chersi, Thill, Ziemke, & Borghi, 2010). This seems consistent with the current literature; Estes et al. (2008) used SOAs between 150 and 350 ms, obtaining interference, and Chasteen et al. (2010) used SOAs between 800 to 1,200 ms, obtaining facilitation. Meier and Robinson (2004), who also observed facilitation, did not present the visual targets unless participants had already performed a separate vocal response to the cue (“positive” or “negative”). Designating separate responses to the cue and the target might have minimized the temporal overlap between the conceptual and perceptual processing, hence preventing any potential interference.

Table 1
*Task Characteristics in Reports of Interference and Facilitation Resulting From Cue–Target Compatibility*

| Characteristic | Inhibition | Facilitation |
|---|---|---|
| Representative report | Estes et al. (2008) | Chasteen et al. (2010) |
| Cue type | concrete concepts | abstract concepts |
| Cue–target SOA | short (150–350 ms) | long (800–1,200 ms) |
| Visual task | discrimination (choice RT) | detection (simple RT) |
| Cue treatment | passive viewing | categorization |

*Note.* SOA = stimulus onset asynchrony; RT = response time.

Third, the difference in the findings may be because of the different ways in which the cues were treated. On the one hand, Estes et al. (2008) asked participants to simply view the cues and then respond to the targets. On the other hand, Chasteen et al. (2010) made responses contingent upon cue category (i.e., respond only when the cue refers to a religious concept). Such a functional link between the cue and the response may have caused the cue and the target to be integrated into a single event, subsequently causing cue–target compatibility to produce facilitation compared to incompatible pairings. Accordingly, perhaps Estes et al. (2008) observed interference because they did not make such a link between the cue and responding to the targets, leaving the cue as a truly irrelevant stimulus. Preserving the functional separation between simultaneous mental processes has been proposed as a necessary condition for interference (e.g., Gozli & Pratt, 2011; Müsseler, 1999; Zwickel & Prinz, 2012). In addition, it has been shown that the way in which cues are categorized (e.g., lexical decision, semantic categorization) can influence the interaction between linguistic processing and sensorimotor processes (e.g., de la Vega, de Filippis, Lachmair, Dudschig, & Kaup, 2012; Sato, Mengarelli, Riggio, Gallese, & Buccino, 2008).

Finally, we should consider the possibility that concrete concepts (Estes et al., 2008) and abstract concepts (Chasteen et al., 2010) engage the visuospatial mechanisms in distinct ways. The representation of concrete concepts is thought to include more perceptual information (Wang, Conder, Blitzer, & Shinkareva, 2010; Wiemer-Hastings & Xu, 2005) and therefore impose a stronger perceptual bias during target processing relative to abstract concepts. Perhaps this strong perceptual association is the reason for the observed interference with a visual task. This suggestion would be supported if using abstract concepts as cues would lead only to facilitation. We could then conclude that the visual bias induced by the metaphorical association between the concepts and space is different from the bias induced by processing concrete concepts with typical locations.

In short, the following experiments test the role of all potentially relevant characteristics of the two representative studies (see Table 1) in order to pinpoint the specific conditions wherein facilitation or interference would be observed. By doing this, the results of these experiments will clarify (a) the nature of concept–target compatibility effects by examining these consequences across two visual tasks (i.e., target detection and target discrimination); (b) the time course of these consequences by examining them across different cue–target SOAs; and (c) the possibility that different types of concepts engage different visuospatial mechanisms, potentially revealing their distinct representational structure.

## Experiments 1A and 1B

The focus of these first experiments was on determining the role of type of visual task and cue–target delay in determining whether facilitation or interference is observed as a function of implicit cues. First, we asked whether the facilitated processing of cue–target compatible trials reported by Chasteen et al. (2010) can only be observed using a target detection task. Could this effect be eliminated or reversed in a visual task that demands more elaborate processing of the visual targets (i.e., target discrimination)? In both experiments, to address this question, we had each participant perform one block of target detection (similar to Chasteen et al., 2010) and one block of target discrimination.

Second, we asked whether the facilitated processing of cue–target compatible trials can only be observed using relatively long SOAs. Therefore, to test whether the effect can be reversed by using short SOAs, we used long SOAs (similar to Chasteen et al., 2010) in Experiment 1A and short SOAs in Experiment 1B (similar to Estes et al., 2008). The two experiments were similar in all other respects, except for cue–target SOA. The prediction that interference may arise with short SOAs is based on previous studies on the interaction between language and sensorimotor processes (Boulenger et al., 2006; Sato et al., 2008). For instance, Sato et al. (2008) found immediately processing verbs referring to manual actions interfered with performing manual action. This interference, however, disappeared if actions were performed after a delay of about 1,000 ms.

To preserve the characteristics of the original study by Chasteen et al. (2010), we used implicit cues referring to concepts of divine and evil, which were followed by targets along the vertical axis. If visual task alone can predict whether cue–target compatibility leads to facilitation or interference, we should observe facilitation in the detection task and interference in the discrimination task. If SOA alone can predict whether cue–target compatibility leads to facilitation or interference, we should observe early (short SOA) interference and late (long SOA) facilitation in both tasks. It is also possible that the combination of short SOA and target discrimination is necessary for observing interference. If so, we should expect to see interference only with short SOA and in the discrimination task. Last, if interference does not depend on either task or short SOA, facilitation should be observed across all the conditions.

## Method

**Participants.** Twenty-seven and 22 undergraduate students at the University of Toronto participated in Experiments 1A and 1B, respectively, in exchange for course credit. All participants had normal or corrected-to-normal vision. They were all unaware of the purpose of the study. All the experimental protocols were approved by the Research Ethics Board at the University of Toronto.

**Apparatus and procedure.** The experiments were run in Matlab (MathWorks, Natick, MA) using the Psychophysics toolbox (Brainard, 1997; Pelli, 1997), version 3.0.8. Stimuli were presented on a 14-in. × 10-in. CRT monitor set at 1,280 × 720 pixels resolution and 85 Hz refresh rate. The viewing distance from the monitor was fixed at 44 cm, using a chin/head rest. The participants' eyes were monitored in order to ensure compliance with the instruction.

Cue and target stimuli were presented in white against a clear, black background. Cue stimuli consisted of three different word categories: words associated with up (*GOD, LORD,* and *CREATOR*), words associated with down (*DEVIL, SATAN,* and *LUCIFER*) and neutral words (*BALL, HOUSE, DOOR, FLOWER, PENCIL,* and *BANANA*). Participants were instructed to respond to targets whenever the centrally presented word referred to a religious concept and to withhold response otherwise. Thus, religious concepts signified test trials, in which participants were required to respond to the targets, and neutral words signified catch trials, in which participants were required to withhold response. The cues were presented at the center of the screen in a 14-point Arial font. In the detection task, the target stimulus was a white square presented 8 ° above and below the central fixation point. In the discrimination task, target stimuli were the letters *X* and *O,* in 14-point Arial font and subtending .4 ° × .6 °, presented 8 ° above and below the central fixation point (see Figure 1).

Each trial began with a fixation cross (+) presented at the center of the screen, subtending .5 ° × .5 °. Participants were instructed to maintain fixation and wait for the cue. After 1,000 ms, the fixation cross was replaced by a cue word. After a short SOA (i.e., a randomly chosen duration from 200 to 400 ms; Experiment 1A) or a long SOA (i.e., a randomly chosen duration from 800 to 1,200 ms; Experiment 1B), the peripheral target appeared above or below the word and remained present until a response was made or 2,000 ms had elapsed.

During both the detection task and the discrimination task, participants were instructed to respond to the targets only when the cue referred to a religious concept. Thus, response performance was contingent upon cue category. In the detection task, participants were instructed to respond to the onset of the target as quickly as possible by pressing the space bar. On the discrimination task, participants were instructed to identify the target as quickly as possible by the *Z* key (for *O*) or the / key (for *X*). Participants received error feedback whenever their response times were shorter than 100 ms (*TOO QUICK!*) or longer than 2,000 ms (*TOO SLOW!*) on test trials, whenever they responded with a wrong key on a test trial, during the discrimination task (*MISTAKE!*), and whenever they made a response on a catch trial (*MISTAKE!*).

**Design.** Each participant performed in one block of target detection and one block of target discrimination task, the order of which was counterbalanced across participants. Each block consisted of 20 practice trials and 216 experimental trials (144 test trials and 72 catch trials). Cue category (i.e., up, down, neutral),

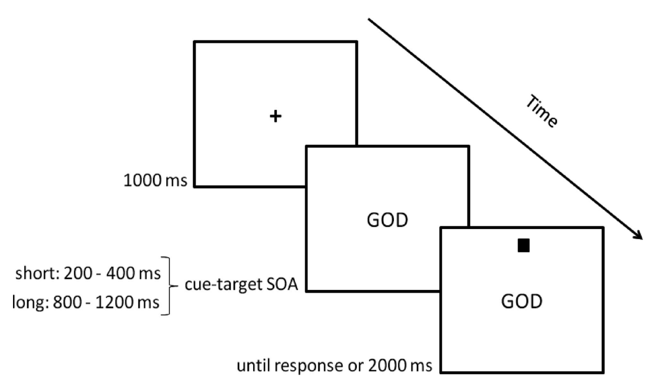


*Figure 1.* Sequence of events in a sample (compatible) trial of the detection task. Cue–target stimulus onset asynchrony (SOA) was categorically varied across experiments (i.e., long SOAs in Experiments 1A and 3B; short SOAs in Experiments 1B and 3A) and then was randomly chosen from an interval (e.g., 200–400 ms for short SOAs) for every trial. In the discrimination task, instead of the luminance target, a letter (*X* or *O*) was presented.

cue identity, target location, and target identity were randomized such that each combination was equally likely on any given trial in a block. Test trials were divided into cue–target compatible and incompatible groups. The two-level factor cue–target compatibility was used instead of the two underlying factors cue type and target location, in order to reduce error variance and simplify analysis. A report of mean response time of all the present experiments, divided based on cue type and target location, is provided in Appendix A.

## Results and Discussion

The two experiments were analyzed separately. One participant had to be replaced in each experiment for having a high error rate (>20%) on catch trials, indicative of a low degree of cue processing. We analyzed response time (RT) data after removing catch trials, error trials (i.e., RT < 100 ms or RT > 2,000 ms; wrong keypress during the discrimination task), and outliers (i.e., responses 2.5 *SD* faster or slower the mean RT), using a 2 × 2 repeated measures analysis of variance (ANOVA) with task type (detection vs. discrimination) and cue–target compatibility (compatible vs. incompatible) as factors (see Figure 2).

For Experiment 1A (long SOA), this ANOVA revealed a main effect of task type, $F(1, 26) = 155.47$, $MSE = 3{,}526.03$, $p < .001$, $\eta_p^2 = .857$, and a main effect of compatibility, $F(1, 26) = 8.89$, $MSE = 213.63$, $p < .01$, $\eta_p^2 = .255$, but no interaction between the two factors, $F(1, 26) = 1.13$, $MSE = 197.91$, $p = .297$, $\eta_p^2 = .042$. Responses on the detection task ($M \pm SE$ = 359 ± 14 ms) were faster than those on the discrimination task (502 ± 15 ms), and responses on compatible trials (426 ± 13 ms) were faster than those on incompatible trials (435 ± 14 ms).

Error data from Experiment 1A were submitted to a similar 2 × 2 ANOVA with task type and cue–target compatibility as independent factors. This ANOVA revealed a main effect of task type, $F(1, 26) = 9.50$, $MSE = .001$, $p < .001$, $\eta_p^2 = .268$. This is trivial because choosing a wrong keypress is possible only during the discrimination task (error rate = 4.5%), and the only errors on the detection task were due to anticipations and slow responses (2.7%). Importantly, however, no main effect of compatibility was revealed ($F < 1$). Nor was there an interaction between the two factors ($F < 1$). On average, the error rates on catch trials were low in both tasks (1.7%), indicating that participants were processing the cues and withholding response after neutral cues.

Findings from the detection task of Experiment 1A fully replicated the results reported by Chasteen et al. (2010). In addition, finding the same pattern of results in the discrimination task ruled out the possibility that the facilitated responses on compatible trials are dependent on not having to visually identify targets. Rather, it seems the locations compatible with the concept meaning were selectively favored in both detection and discrimination tasks. Therefore, it seems that the critical difference between the two studies is not the different types of responses to the visual targets. Note that the timing of Experiment 1A was matched with the experiment reported by Chasteen et al. (2010).

For Experiment 1B (short SOA), analysis of RTs also revealed a main effect of task type, $F(1, 21) = 229.93$, $MSE = 3{,}711.81$, $p < .001$, $\eta_p^2 = .916$, and a main effect of compatibility, $F(1, 21) = 5.01$, $MSE = 241.24$, $p < .05$, $\eta_p^2 = .193$, but no interaction ($F < 1$). Responses on the detection task ($M \pm SE$ = 334 ± 13 ms) were faster than those on the discrimination task (531 ± 14 ms). Most importantly, responses on cue–target compatible (429 ± 11 ms) trials were faster than those on incompatible trials (436 ± 12 ms).

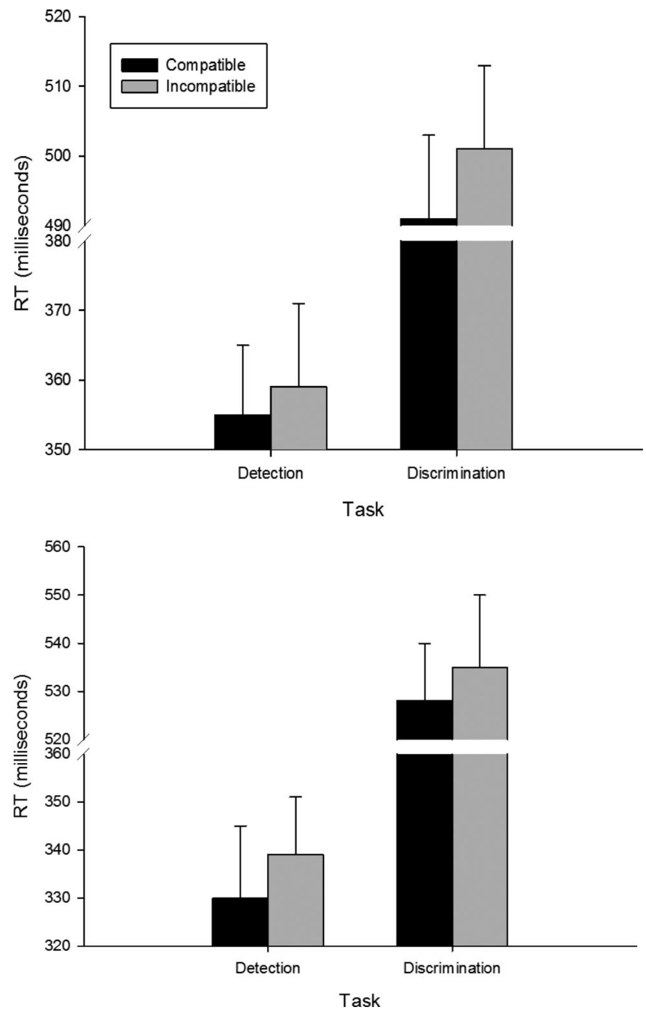


*Figure 2.* Response time (RT) data from Experiments 1A (upper panel) and 1B (lower panel) graphed as a function of task type and cue–target compatibility. Long and short cue–target SOAs were used in Experiments 1A and 1B, respectively. Error bars indicate within-subjects 95% confidence intervals (Cousineau, 2007). SOAs = stimulus onset asynchronies.

Error data from Experiment 1B were submitted to a similar 2 × 2 repeated measures ANOVA, which revealed no main effects or interaction ($F$s < 1), suggesting that the RT findings did not result from a speed–accuracy trade-off. On average, error rates were very low on catch trials (3% across both experiments), as well as on detection (3%) and discrimination (4%) test trials.

These findings suggest that reducing the temporal delay between the cue and the target is not what produces interference in implicit spatial cuing tasks. Therefore, it seems that at least with the cues used by Chasteen et al. (2010), interference with target processing at cue-compatible locations cannot be observed in either type of task or SOAs, constraining the possibilities for what predicts the direction of the effect.

Two limitations of Experiment 1 should be noted. First, only six cues (3 upward and 3 downward) were used over the 288 test trials of Experiment 1 (144 detection and 144 discrimination trials), which means that participants viewed each cue 48 times. This poses the question as to whether the same pattern could be observed without the repetitive exposure of the cues. Perhaps a task-induced mapping between cues and locations was formed, which relied on the large number of cue repetitions. Second, to rule out the influence of cue–target SOA, it would be more informative to randomize short and long SOAs within the same experimental block. These two limitations were necessary, as we had intended to run an exact replication of Chasteen et al. (2010) and only then match the visual task and SOA to those used in the Estes et al. (2008) task. Thus, we addressed these two issues in the following experiment.

## Experiment 2

This experiment had a twofold purpose. The first purpose was to determine whether the pattern of results in Experiment 1 could also be observed without extensive exposure to each word cue. This is because the repetition of cues in the previous experiment might have allowed the participants to learn task-specific stimulus–response associations. The second purpose was to test for the potential role of SOA by using randomized short and long SOAs within a single experimental block. If facilitation is observed with both SOAs, this would again rule out the possibility that SOA alone was the critical difference between the previous studies. Because of the relatively small number of words referring to the concepts of divine and evil, in this experiment we used words related to another abstract category, namely, concepts related to positive and negative affect. Only a single block of the visual discrimination task was used based on the findings of Experiment 1, which revealed no effect of visual task.

### Method

**Participants.** Twenty-two undergraduate students at the University of Toronto participated in the experiment, in exchange for course credit. All participants had normal or corrected-to-normal vision. They were all unaware of the purpose of the study.

**Apparatus and procedure.** These were identical to those in Experiments 1A and 1B, except for the following modifications. Cues consisted of eight words related to positive affect (*HAPPY, JOY, CHEERFUL, SMILE, JOYOUS, JOLLY, GLAD,* and *PLEASED*), eight words related to negative affect (*SAD, GLOOMY, FROWN, UPSET, UNHAPPY, SORROW, DEPRESSED,* and *MELANCHOLY*), and eight neutral words (*TABLE, DESK, CHAIR, OFFICE, LAMP, SHELF, WALLPAPER,* and *COUCH*). Participants were instructed to respond to targets (i.e., identifying *X* or *O*) whenever the centrally presented word was related to affect/mood and to withhold response otherwise. Thus, affect concepts signified test trials, and neutral words signified catch trials.

Cue–target SOA was randomized within the same experiment; on half of the trials, the visual target letter *X* or *O* appeared after a short delay following cue onset (200–400 ms), whereas on the other half of the trials, the target appeared after a longer delay following the cue (800–1,200 ms).

**Design.** Each participant performed one block of the target discrimination task, consisting of 10 practice trials and 192 experimental trials (128 test trials and 64 catch trials). Cue category (i.e., positive, negative, neutral), target location, and target identity, and cue–target SOA were all randomized such that each combination was equally probable. It should be noted that each word cue was presented only once in each possible combination of SOA, target location, and target identity, resulting in a total of 8 repetitions for each cue. Test trials were divided based on cue–target compatibility and SOA (short vs. long).

### Results and Discussion

We analyzed mean RTs after removing catch trials, error trials (i.e., RT $< 100$ ms or RT $> 2{,}000$ ms; wrong keypress during the discrimination task), and outliers (i.e., responses 2.5 *SD* faster or slower the mean RT), using a $2 \times 2$ repeated measures ANOVA with cue–target compatibility (compatible vs. incompatible) and cue–target SOA as factors (see Figure 3). This analysis revealed a main effect of compatibility, $F(1, 21) = 4.52$, $MSE = 420.52$, $p = .046$, $\eta_p^2 = .177$, and a main effect of SOA, $F(1, 21) = 68.10$, $MSE = 1.10 \times 10^3$, $p < .001$, $\eta_p^2 = .764$, but no interaction between the two factors ($F < 1$). Responses on cue–target compatible trials (e.g., target above after the word *HAPPY*; $M \pm SE = 535 \pm 11$ ms) were faster than those on incompatible trials ($544 \pm 13$ ms), and responses on trials with long SOA ($510 \pm 11$ ms) were faster than those on trials with short SOA ($568 \pm 13$ ms).

Error rates were submitted to a similar $2 \times 2$ ANOVA, which revealed only a main effect of SOA, $F(1, 21) = 5.94$, $MSE = .001$, $p = .024$, $\eta_p^2 = .220$. Consistent with the RT data, there were more errors with short SOA (3.2%) than with long SOA (1.4%). Error rates on catch trials were very low (<1%), indicating that participants were processing the cues and withholding response after neutral words.

These findings suggest that results of Experiment 1 were not an artifact of using a small set of words. The problem of cue repetition

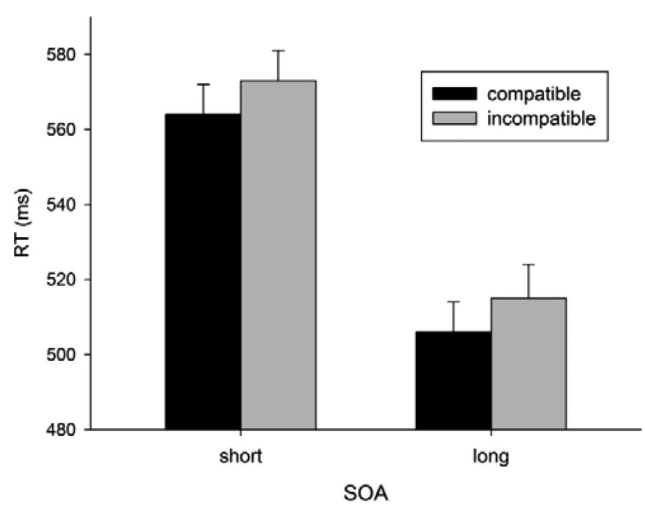


*Figure 3.* Response time (RT) data from Experiment 2 graphed as a function of cue–target SOA (short vs. long) and cue–target compatibility. Error bars indicate within-subjects 95% confidence intervals (Cousineau, 2007). SOA = stimulus onset asynchrony.

is, however, not entirely eliminated, because each cue was still repeated, although many fewer times than previously. The ideal experiment, in which each cue is presented only once, seems impractical, due to the necessity to repeat each cue at least once in each possible SOA × target characteristic. The issue of repetition is addressed further in Experiment 4.

In addition to addressing the concern about repeated cue exposure, Experiment 2 showed that the previously reported facilitation can be observed when short and long SOAs are randomized within a single experimental block. Given that neither a change in visual task nor reduction of cue–target SOA could turn facilitation into interference, the most important remaining candidate seems to be the difference related to the sets of cues used in the two studies of Chasteen et al. (2010) and Estes et al. (2008). That is, it is possible that the concepts to which the cues refer involve different kinds of representation. It has been previously suggested that concrete concepts are associated with richer perceptual properties, whereas abstract concepts are associated with affective and introspective states (Kousta, Vigliocco, & Campo, 2011; Wang et al., 2010; Wiemer-Hastings & Xu, 2005; see also Barsalou, 1999, 2008). It seems plausible, therefore, that the perceptual properties associated with concrete concepts are responsible for the interference with target processing at cue-compatible locations. Before directly comparing the effects of abstract and concrete concept types, to remove any concerns about unknown factors at work in these studies, we felt it was important to be able to generate interference with implicit spatial cues. Thus, we next attempted to replicate and extend the findings reported by Estes et al. (2008) both to tasks (detection and discrimination) and to SOAs (short and long) in the next two experiments. Once we establish that both facilitation and interference can be replicated with the present methodological characteristics, we could proceed to examining the potential effect of different cue types.

## Experiments 3A and 3B

After examining the representative task that resulted in facilitation of compatible targets (Chasteen et al., 2010), we attempted in these experiments to examine the task that has resulted in interference (Estes et al., 2008). In particular, we tested whether the interference with target processing found by Estes et al. is dependent on visual task, SOA, or both. If, for instance, the relatively elaborate visual processing demanded by the discrimination task is necessary for observing the interference, interference should not be observed in a detection task.

We used the design of the third experiment reported by Estes et al. (2008), in which each target is preceded only by a single word cue referring to an object with a spatial connotation along the vertical axis. It should be noted that in their first two experiments, Estes et al. presented a context word (e.g., *cowboy*) before each cue (e.g., *hat*) in order to add contextual information to facilitate simulation of the concept. Nevertheless, in their third experiment, they demonstrated that the context words were not necessary for the emergence of the interference effects.

As with Experiments 1A and 1B, the only difference between Experiments 3A and 3B was cue–target SOA. In Experiment 3A we followed Estes et al. (2008) and used relatively short SOAs, whereas in Experiment 3B we used relatively long SOAs to match those used by Chasteen et al. (2010). With long SOAs, the perceptual activation may subside, making it possible to observe the residual spatial bias in reaction time data in the form of facilitation (Bergen, 2007). Previous studies on the interference of linguistic processes on motor performance suggest that the interference effect disappears with longer delays between the two events (e.g., Sato et al., 2008) or turns into facilitation (e.g., Boulenger et al., 2006). Thus, if the implicit cues used by Estes et al. cannot cause the same facilitation at the compatible target location observed in Experiments 1A and 1B, we should not see any cuing effect with long SOAs.

### Method

**Participants.** Twenty-six and 27 undergraduate students at the University of Toronto participated in Experiments 3A and 3B, respectively, in exchange for course credit. All participants had normal or corrected-to-normal vision. They were all unaware of the purpose of the study.

**Apparatus and procedure.** The apparatus, stimuli, and procedure were similar to those in the previous experiments, except when noted otherwise. We used the original word stimuli used by Estes et al. (2008). In their first experiment, Estes et al. presented one of 30 context words on each trial, which was followed by a related second word that was associated either with up or with down (see Appendix B).[1] Because in the present experiments we used single-word cues, we used the context words in filler trials to reduce the chance of participants guessing the aim of the experiment (by consistently encountering words with upward or downward connotations). We did not include the filler words in the analyses. Importantly, as in the task used by Estes et al., participants always responded to the targets (without having to make a decision regarding the cue). The obvious disadvantage of this method is not being able to examine whether participants processed the cues. Nonetheless, this was an important task characteristic in the original study and was, therefore, preserved. Furthermore, similar to Estes et al. (2008) we used short cue–target SOAs (here, a random number between 200 and 400 ms) in Experiment 3A, and similar to Chasteen et al. (2010), we used long cue–target SOAs (a random number between 800 and 1,200 ms) in Experiment 3B.

These experiments differed from Experiment 3 of Estes et al. (2008) in two respects. First, as mentioned above, Estes et al. did not use filler words, whereas we did. Second, they presented the target after the cue disappeared, whereas in these experiments the cue remained on display until the trial ended. This was similar to Chasteen et al. (2010), and we did not expect this to have a major role in the nature of the effects. After all, the interaction between linguistic and spatial processes has been observed repeatedly in paradigms that display words until a response is performed, suggesting that activation of perceptual processes does not depend on the disappearance of the words (e.g., Pecher et al., 2010; Šetić & Domijan, 2007; Zwaan & Yaxley, 2003).

**Design.** Participants performed one block of target detection and one block of target discrimination, in counterbalanced orders.

[1] Without their preceding context words (Estes et al., 2008, Experiments 1 and 2), five of the words in each of the critical groups could no longer be associated with their designated category. Thus, we treated these words as fillers (see Appendix).

Each block consisted of 20 practice trials and 180 experimental trials (100 test trials and 80 filler trials). Cue category (i.e., up, down, filler), cue identity, target location, and target identity were randomized, and every possible combination was equally likely on any given test trial. Test trials were coded as cue–target compatible or incompatible.

## Results and Discussion

Data from the two experiments were analyzed separately. Response time (RT) data from all the correct trials were trimmed (in the same way as in Experiments 1 and 2) and were submitted to a 2 × 2 repeated measures ANOVA with task type (detection vs. discrimination) and cue–target compatibility as independent factors (see Figure 4). For Experiment 3A (short SOA), this analysis revealed a significant effect of task type, $F(1, 25) = 71.61$, $MSE = 2{,}920.78$, $p < .001$, $\eta_p^2 = .741$; no significant main effect of cue–target compatibility, $F(1, 25) = 2.25$, $MSE = 145.36$, $p = .146$, $\eta_p^2 = .083$; and a significant two-way interaction, $F(1, 25) = 8.33$, $MSE = 119.36$, $p < .01$, $\eta_p^2 = .250$. Examining each task separately showed no effect of compatibility in the detection task, $t(25) < 1$, with mean RTs being equal for compatible trials ($M \pm SE$ = 377 ± 16 ms) and incompatible trials (380 ± 15 ms). On the other hand, for the discrimination task, there was a significant effect of compatibility, $t(25) = 2.89$, $SE = 3.36$, $p < .01$. Consistent with the previous reports of interference, slower responses were found on compatible trials (473 ± 10 ms) than incompatible trials (463 ± 10 ms) on the discrimination task.

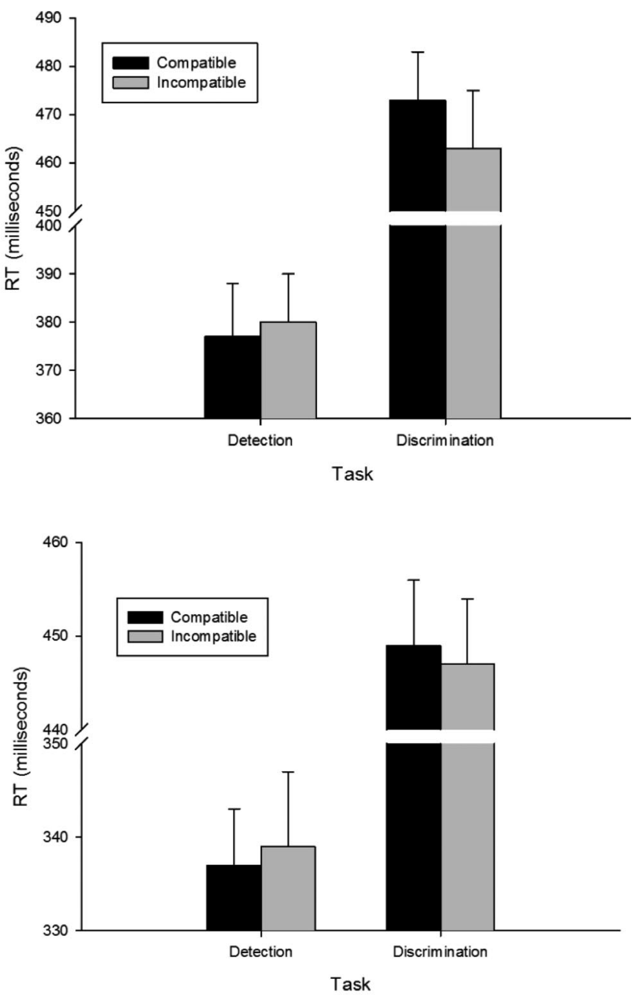


*Figure 4.* Response time (RT) data from Experiments 3A (short SOA) and 3B (long SOA) graphed as a function of task type and cue–target compatibility. Error bars indicate within-subjects 95% confidence intervals (Cousineau, 2007). SOA = stimulus onset asynchrony.

Error data from Experiment 3A were submitted to a similar 2 × 2 ANOVA, which revealed only the unimportant main effect of task type, $F(1, 25) = 11.4$, $MSE = .001$, $p < .01$, $\eta_p^2 = .314$, and no other main effect or interaction ($F$s < 1). Examining the two tasks separately did not reveal a main effect of compatibility on error rates ($t$s < 1), suggesting that the RT findings were not a product of a speed–accuracy trade-off.

For Experiment 3B (long SOA), response time data were similarly analyzed with a 2 × 2 repeated measures ANOVA with task type (detection vs. discrimination) and cue–target compatibility as independent factors (see Figure 4). This ANOVA revealed only a main effect of task type, $F(1, 26) = 273$, $MSE = 1{,}198$, $p < .001$, $\eta_p^2 = .913$. Neither a main effect of compatibility nor a two-way interaction was found ($F$s < 1). For both tasks, responses were similar across the compatible trials (337 ± 8 ms and 449 ± 10 ms, respectively, for detection and discrimination) and incompatible trials (339 ± 9 and 447 ± 9). Analysis of error data revealed the same pattern, with a main effect of task, $F(1, 26) = 21$, $MSE = .001$, $p < .001$, $\eta_p^2 = .452$; no main effect of compatibility, $F(1, 26) = 1.64$, $MSE = .001$, $p > .1$, $\eta_p^2 = .059$; and no two-way interaction ($F < 1$). Error rates were similar across both compatible trials (2% and 5.4%, respectively, for detection and discrimination) and incompatible trials (1.3% and 4.9%).

The results suggest that finding interference on compatible trials depends on the visual task. The relatively shallow visual processing in target detection did not lead to interference, whereas interference was found with target discrimination. In addition, we did not find facilitation with increased SOA. Instead, the interference effect observed with the concrete concepts seems to disappear when the target is presented after enough delay following cue onset. The null results of Experiment 3 should be interpreted cautiously, because participants were not required to read the cues in order to perform the task successfully. Importantly, we could not rule out the possibility that participants who performed in Experiment 3B did not process the cues as well as those who participated in Experiment 3A. This limits our ability to compare the two experiments and, consequently, discuss the role of SOA, which varied across experiments. In fact, examining the discrimination data across Experiments 3A and 3B did not reveal a statistical interaction between SOA and compatibility. That is, a mixed ANOVA with compatibility (within-subjects) and SOA (between-subjects) as factors revealed only a main effect of compatibility, $F(1, 51) = 6.30$, $MSE = 145.52$, $p = .015$, $\eta_p^2 = .110$, due to slower responses on compatible trials (461 ± 7 ms) than incompatible trials (455 ± 7 ms). The two-way interaction between compatibility and SOA did not reach significance, $F(1, 51) = 2.69$, $p = .107$, $\eta_p^2 = .05$. The main effect of SOA also did not reach significance, $F(1, 51) = 2.19$, $MSE = 5.1 \times 10^3$, $p = .145$, $\eta_p^2 = .041$, which may, again, be due to the fact that participants were not required to read the cues.

It is unclear whether the lack of a two-way interaction between SOA and compatibility reflects (a) low statistical power, (b) not processing the cues, or (c) a genuine but weak interference at long SOAs. We favor the first possibility in light of the findings of the following experiments. Regardless, at this point it is merely important to note that we replicated the basic findings of Estes et al. (2008) using a discrimination task and short cue–target SOA. This, taken together with the previous experiments, suggests that the difference between the effects observed with the two types of concepts was not due to visual task or cue–target delay. Instead, the result may be pointing to the possibility that the sets of words engaged visuospatial mechanisms differently, consistent with the view that the different effects reveal distinct representational properties of the concepts. One possibility is that interference can only be observed when the cues refer to a concrete concept attached to specific perceptual information, whereas facilitation can only be observed when the cues refer to abstract concepts that are, relatively speaking, perceptually nonspecific. In the next experiment we directly tested the possibility that concept type (abstract vs. concrete) is responsible for the direction of the effect.

## Experiment 4

In previous experiments we ruled out task type (detection vs. discrimination) and SOA as factors that determine the direction of the cue–target compatibility effect. Although the combination of short SOA and target discrimination seems necessary for observing interference, facilitation was observed under both of these conditions with abstract concepts of divine and evil (Experiment 1B) and affect (Experiment 2). Thus, the remaining possibility that we tested in this experiment was whether concept type determines the difference in the direction of the effect. We hypothesized that cue–target compatibility can cause facilitation or interference depending on whether the concepts are abstract or concrete, respectively. This notion is based on previous findings of facilitation with numerical concepts (Gevers, Lammertyn, Notebaert, Verguts, & Fias, 2006; Schwarz & Keus, 2004), religious concepts (Chasteen et al., 2010), affect concepts (e.g., happy, sad; Meier & Robinson, 2004), or concepts related to power (Schubert, 2005), and the assumption that these concepts are all metaphorically associated with space. Thus, activating the spatial association would lead to the spatial bias without interfering with perception, causing facilitation. On the other hand, concrete concepts, which evoke perceptual associates of the concepts, lead not only to a spatial bias but to a bias in perception. The perceptual bias may interfere with target processing at the compatible location, because observers are ready to perceive specific objects and not the target letters of the visual task. To test this hypothesis, we used both abstract and concrete categories in the present experiment. If concept type is responsible for the direction of the effect, facilitation and interference should be observed with abstract and concrete concepts, respectively.

It should be noted that concept type (abstract vs. concrete) is not the only remaining difference between the two original studies. As noted earlier (see Table 1), Chasteen et al. (2010) instructed participants to respond based on the cue category, whereas Estes et al. only required their participants to passively view the cues. Recent work on implicit spatial cuing with the abstract concepts of positive and negative valence has shown that attending to the dimension of valence when processing the cues is critical for observing a reliable spatial bias (de la Vega et al., 2012; see also Santiago, Ouellet, Román, & Valenzuela, 2012). Therefore, it is not yet determined whether the different outcomes of the two studies are partially due to different cue treatments (i.e., cue categorization leading to facilitation; passive viewing leading to interference). Thus, to ensure cue treatment does not determine the direction of the effect, it is necessary to present both types of concepts within the same task. We chose cue categorization over passive viewing, because it would allow us to check whether participants process the cues. This method allowed us to also test whether a single direction of effect depends on cue treatment (as indicated in Table 1). As in Experiments 1 and 2, participants responded to the visual target only when the preceding word belonged to a specific category and withheld response otherwise. The category was set at the beginning of each trial, as described below. Although this method is similar to that used by Chasteen et al. (2010), it differs due to the possibility of a category switch after each trial, as Chasteen et al. and other studies used a single category throughout an entire experiment (e.g., Meier & Robinson, 2004; Schubert, 2005). Finally, based on the findings of previous experiments, only a target discrimination task was used in the present experiment, as both facilitation and interference effects were replicated with this task.

### Method

**Participants.** Forty undergraduate students at the University of Toronto participated in the experiment in exchange for course credit. All participants reported normal or corrected-to-normal vision. They were all unaware of the purpose of the study.

**Apparatus and procedure.** Apparatus, stimuli, and procedure were the same as in the previous experiments, unless stated otherwise. Three abstract categories (numbers, religion, mood) and three concrete categories (house, ocean, sky) were used, each assigned to four possible test cues and four unrelated words for catch trials (see Appendix B). Each of the abstract categories has been used in isolation in previous studies that reported facilitation of cue–target compatible trials (e.g., Gevers et al., 2006; Meier & Robinson, 2004; Schwarz & Keus, 2004).

Each trial began with presentation of a fixation cross for 1,000 ms. This was followed by presentation of a category word (e.g., *MOOD*), which remained on the display for 500 ms, and by a second presentation of the fixation cross (lasting for 200 ms), after which the cue word was presented. Following a cue–target SOA that could be either short (200–400 ms) or long (800–1,200 ms), a visual target (*X* or *O*) was presented above or below fixation. On test trials, wherein the cue word belonged to the category word (e.g., *MOOD* followed by *HAPPY*), the target remained on display for 2,000 ms or until a response was made (the *Z* key for *O* or the/ key for *X*). On catch trials, wherein the cue word did not belong to the category word (e.g., *MOOD* followed by *ATTIC*), the visual target remained on the display for 1,000 ms. For test trials, participants received feedback if they responded within the first 100 ms following target presentation (*TOO QUICK*), did not respond within 2,000 ms (*TOO LATE*), or made a response with an incorrect key (*MISTAKE*). For catch trials, participants received feedback if they made a response (*MISTAKE*).

**Design.** Each participant performed one session of the target discrimination task. The session began with 20 practice trials and 386 experimental trials consisting of 193 test trials (matching category and cue) and 193 catch trials (mismatching category and cue). Concept type (i.e., abstract vs. concrete), category (number, religion, mood, house, sky, ocean), target location, and target identity were randomized, and each combination was equally probable. Test trials were grouped based on concept type (abstract vs. concrete), cue–target SOA (short vs. long), and cue–target compatibility (compatible vs. incompatible).

## Results and Discussion

Results showed very low error rates on catch trials (<1%, with none of the participants having a catch-trial error rate higher than 3%), indicating that participants were processing the cues. Response time data from all the correct test trials were trimmed (in the same manner as the previous experiments) and were submitted to a $2 \times 2 \times 2$ repeated measures ANOVA with concept type (abstract vs. concrete), cue–target SOA (short vs. long), and cue–target compatibility as independent factors (see Figure 5). This analysis revealed no main effect of compatibility ($F < 1$); a main effect of concept type, $F(1, 39) = 11.32$, $MSE = 760.45$, $p < .01$, $\eta_p^2 = .225$; and a main effect of SOA, $F(1, 39) = 709.60$, $MSE = 1.77 \times 10^3$, $p < .001$, $\eta_p^2 = .948$. For the main effects, trials with long SOAs had faster responses than those with short SOAs (502 and 626 ms, respectively) and abstract concepts received faster responses than the concrete concepts (559 and 569 ms, respectively). The main effect of concept type, as well as the concept type × SOA interaction, $F(1, 39) = 7.76$, $MSE = 690.91$, $p < .01$, $\eta_p^2 = .166$, is unimportant, especially because the two sets of words were not matched based on psycholinguistic attributes, such as word length and word frequency. On the other hand, the lack of interaction between concept type and cue–target compatibility ($F < 1$) is of great importance. That is, contrary to our hypothesis, the effect of compatibility was not different across concept types. Also of importance was the significant two-way interaction between SOA and compatibility, $F(1, 39) = 11.79$, $MSE = 300.10$, $p < .01$, $\eta_p^2 = .232$. For trials with short SOAs, responses were slower on cue–target compatible trials than incompatible trials (630 and 623 ms, respectively), $t(39) = 2.12$, $SE = 3.16$, $p < .05$. By contrast, for trials with long SOAs, responses were faster on cue–target compatible trials than incompatible trials (498 and 504 ms, respectively), $t(39) = 2.08$, $SE = 2.98$, $p < .05$. Lastly, the three-way interaction was not significant ($F < 1$).

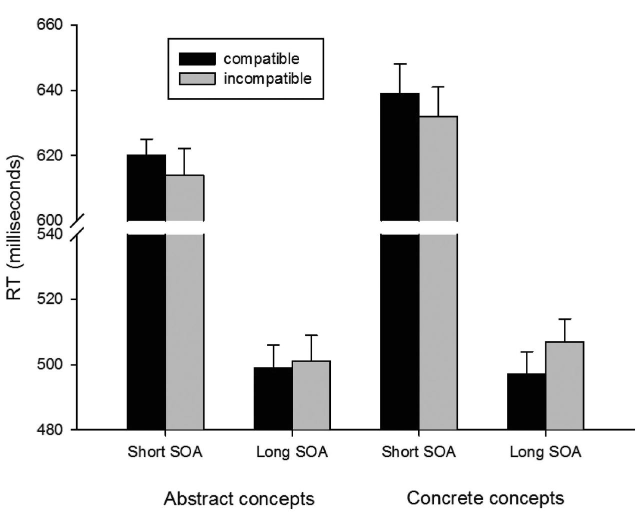


*Figure 5.* Response time (RT) data from Experiment 4 graphed as a function of concept type (abstract vs. concrete), cue–target SOA (short vs. long), and cue–target compatibility. Error bars indicate within-subjects 95% confidence intervals (Cousineau, 2007). SOA = stimulus onset asynchrony.

Error rates on test trials were submitted to a similar ANOVA, which revealed a main effect of concept type, $F(1, 39) = 4.15$, $MSE = .002$, $p < .05$, $\eta_p^2 = .096$; a main effect of SOA, $F(1, 39) = 38.41$, $MSE = .002$, $p < .001$, $\eta_p^2 = .496$; and no main effect of compatibility, $F(1, 39) = 1.54$, $MSE = .003$, $p = .22$, $\eta_p^2 = .038$. Consistent with the RT data, fewer errors were made with long SOAs (3.9%) than with short SOAs (7.1%), and fewer errors were made with abstract concepts (5.0%) than with concrete concepts (6.0%). The two-way interactions between concept type and compatibility, $F(1, 39) = 2.65$, $MSE = .002$, $p = .112$, $\eta_p^2 = .064$; SOA and compatibility ($F < 1$); and concept type and SOA ($F < 1$), as well as the three-way interaction ($F < 1$), were nonsignificant.

The present experiment failed to find a difference between the effects of abstract and concrete concepts. At this point, none of the candidates listed in Table 1 seem to be the key factor whose manipulation would switch the effect from interference or facilitation and vice versa. Facilitation occurred with both short and long cue–target delays and during both visual detection and discrimination of targets (Experiments 1 and 2); interference, however, seems to depend on visual discrimination and can be observed with both abstract and concrete concepts. Moreover, interference can occur regardless of whether participants passively view the cue (Experiment 3A) or categorize it (Experiment 4).

The key question here is why did we observe early facilitation in Experiments 1B and 2 but early interference in the present experiment? If the difference in effects between Estes et al. (2008) and Chasteen et al. (2010) is not due to task type, SOA, or concept type, what is driving the difference? This perplexing issue led us to carefully reexamine the two studies, and in doing so we discovered one additional possible factor. In the Chasteen et al. (2010) study, all the abstract word cues belonged to a single category (religious concepts), whereas in the Estes et al. (2008) study the concrete word cues came from multiple conceptual categories (e.g., clothing, house, animals). Perhaps early interference occurs when multiple categories are used, and there are two possible reasons why this might be the case. First, using multiple categories might lead to a between-trial category switching cost that would not be observed when using a single category. This can be tested with the data from Experiment 4 (see below). Second, multiple categories might prevent task-specific stimulus–response mappings between a subset of the category and a target location (divine–up and evil–down) that may cause facilitation with both short and long SOAs. If so, one could assert that the early facilitated cue–target compatibility is more a product of task (i.e., using a single conceptual category) and does not represent processing in more natural settings (represented by the multiple category designs). This possibility is examined further in Experiments 5 and 6.

Using data from Experiment 4, we first consider the possibility that the consistent interference across both concept types may be associated with category switch between trials. If switching categories between trials is necessary for interference, the interference should be greater on trials in which the category word switches than on trials in which the category word is repeated. Facilitation of cue–target compatible trials, on the other hand, should be greater on trials with repeated categories and smaller on trials with switched categories. To test for this possibility, we ran an additional ANOVA using category repetition (repeat vs. switch), SOA (short vs. long), and compatibility as independent factors (see Figure 6). This ANOVA revealed no main effect of repetition or compatibility ($F$s $< 1$). Neither did the two-way repetition × SOA interaction reach significance, $F(1, 39) = 1.30$, $MSE = 1{,}123.2$, $p = .43$, $\eta_p^2 = .02$. The main effect of SOA, $F(1, 39) = 526.31$, $MSE = 2{,}497.75$, $p < .001$, $\eta_p^2 = .931$; the two-way SOA × compatibility interaction, $F(1, 39) = 28.03$, $MSE = 728.93$, $p < .001$, $\eta_p^2 = .418$; and the three-way repetition × SOA × compatibility interaction, $F(1, 39) = 14.39$, $MSE = 987.32$, $p < .01$, $\eta_p^2 = .270$, were all significant. The significant two-way interaction is similar to what was found in the previous analysis. The three-way interaction, however, is indicative of stronger effects in both directions (interference and facilitation) on the repeat trials ($M \pm SE = -35 \pm 10$ ms and $24 \pm 8$ ms for short and long SOA trials, respectively; note that negative values indicate interference) than on the nonrepeat trials ($-2.7 \pm 3$ ms and $2.6 \pm 3$ ms for short and long SOA trials, respectively), $t(39) = 2.95$, $SE = 10.94$, $p < .005$, for trials with short SOA; $t(39) = 2.33$, $SE = 8.98$, $p < .05$, for trials with long SOA. The main findings of the experiment, therefore, are more pronounced on trials in which the category word is presented for a second time. That is, the interference effect cannot be attributed to between-trial category switching. If anything, this analysis suggests that between-trial category switching can deteriorate both the interference and the facilitation effects, whereas repetition strengthens both effects. These results are inconsistent with the view that the interference observed across both trials is a product of between-trial category switching. Instead, they are consistent with the possibility that facilitation and interference reflect two stages of the same process. We return to this point in the General Discussion.

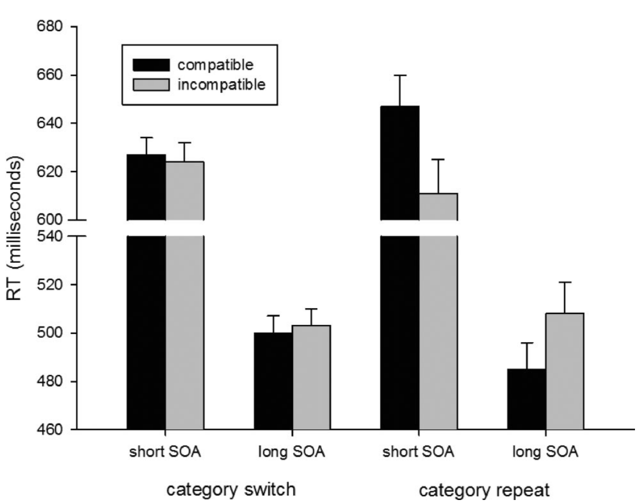


*Figure 6.* Response time (RT) data from Experiment 4 graphed as a function of between-trial category repetition (switch vs. repeat), cue–target SOA (short vs. long), and cue–target compatibility. Error bars indicate within-subjects 95% confidence intervals (Cousineau, 2007). SOA = stimulus onset asynchrony.

It appears, therefore, that interference arises when multiple concept categories are used within the same experimental block, regardless of whether or not they are abstract or concrete. This explanation fits with the characteristics of the two representative studies we have been comparing thus far, but how could the critical role of the number of categories (single vs. multiple) be explained? One explanation comes from the coherent working memory account of cue–target compatibility effects (see Gevers et al., 2006; Santiago et al., 2012; Torralbo, Santiago, & Lupiáñez, 2006). According to this account, when dimensions of stimulus and response (e.g., stimulus: divine/evil; response: visual orienting upward/downward) are both fixed throughout an experiment, values along each stimulus/response dimension become associated to form a coherent representation of individual trials. As a result of this stimulus–response association, processing efficiency is increased whenever associated values must be processed together in a trial, whereas processing efficiency decreases whenever nonassociated values must be processed together. Critically, this view does not discriminate between the effects obtained by abstract and concrete concepts. Therefore, we predicted that using a single category of concrete concepts should replicate exactly the same pattern of findings observed with a single category of abstract concepts. This prediction was tested in the next experiment.

## Experiment 5

If using a single category is required for obtaining facilitation with both SOAs, then whether this category is abstract or concrete should not matter. So far, all our single-category experiments contained abstract concepts. In this experiment, however, we used one concrete category (house-related words) to test whether facilitation can be obtained at both SOAs even if the category is concrete. Did house-related words (e.g., *roof, attic*) lead to both facilitation and interference when they were used in a multiple-category situation? We examined the data from Experiment 4 exclusively for trials wherein *house* was the category word, finding early (short SOA) interference (average RTs = 658 and 622 ms for compatible and incompatible trials, respectively), $t(39) = 3.65$, $SE = 9.93$, $p < .01$, as well as a nonsignificant trend toward late (long SOA) facilitation (average RTs = 496 and 510 ms for compatible and incompatible trials, respectively), $t(39) = 1.50$, $SE = 9.82$, $p = .142$. This made the house category a good choice for testing the role of single versus multiple categories on the direction of the effect. We expected, based on the coherent working memory account of the implicit cuing effect (Santiago et al., 2012; Torralbo et al., 2006), that each house-related concept would be mapped onto the vertical spatial domain. Critically, this task-induced mapping between implicitly upward and downward concepts would be stable and undisrupted, due to the absence of additional categories. Therefore, we predicted that if the house category was used as the only basis for processing concepts throughout an entire experimental block, cue–target compatibility would lead to facilitated responses. Unlike in Experiment 4, this facilitation should be observed with both short and long cue–target SOA.

## Method

**Participants.** Eighteen undergraduate students at the University of Toronto participated in the experiment in exchange for course credit. All participants reported having normal or corrected-to-normal vision. They were all unaware of the purpose of the study.

**Apparatus and procedure.** Apparatus and stimuli were the same as in the previous experiments. Each trial began with a fixation cross presented for 1,000 ms, followed by the cue word. Following a cue–target SOA that could be either short (200–400 ms) or long (800–1,200 ms), a visual target (*X* or *O*) was presented above or below fixation. On test trials, wherein the cue word belonged to the house category (upward cues: *ATTIC, ROOF, CHANDELIER*; downward cues: *BASEMENT, CELLAR, CARPET*), the target remained on display for 2,000 ms or until a response was made (the *z* key for *O* or the */* key for *X*). On catch trials, wherein the cue word did not belong to the category (*TREE, WHALE, DOLPHIN, EAGLE, KEYBOARD, MOUNTAIN*), the visual target remained on display for 1,000 ms. Similar to previous experiments, participants received feedback if they responded too quickly, too late, or incorrectly.

**Design.** Each participant performed one session of target discrimination task. The session began with 20 practice trials and 288 experimental trials consisting of 98 test trials with an upward implicit cue, 98 test trials with a downward cue, and 98 catch/neutral trials. Cue (upward, downward, neutral), target location, and target identity were all randomized, and each combination was equally probable. Test trials were grouped based on cue–target SOA (short vs. long) and cue–target compatibility (compatible vs. incompatible).

## Results and Discussion

Errors on catch trials were low (3.2% on average), indicating that participants were processing the cues. RT data from the correct test trials were trimmed (in the same way as in the previous experiments) and submitted to a 2 × 2 repeated measures ANOVA with SOA (short vs. long) and compatibility used as independent factors (see Figure 7). This analysis revealed a main effect of SOA, $F(1, 17) = 210.50$, $MSE = 310.05$, $p < .001$, $\eta_p^2 = .925$; a main effect of compatibility, $F(1, 17) = 11.82$, $MSE = 178.73$, $p < .01$, $\eta_p^2 = .410$; and no two-way interaction ($F < 1$). Responses were faster on trials with long SOAs ($M \pm SE = 487 \pm 8$ ms) than trials with short SOAs ($548 \pm 10$ ms), and responses were faster on compatible trials ($512 \pm 8$ ms) than incompatible trials ($523 \pm 9$ ms).

Analysis of the error data revealed no main effects of SOA or compatibility (*F*s $< 1$), but it did reveal a two-way interaction, $F(1, 17) = 6.59$, $MSE = .0005$, $p < .05$, $\eta_p^2 = .279$. For trials with short SOA, there was a trend toward reduced errors with cue–target compatibility (2.7% and 4.8% errors for compatible and incompatible trials, respectively), $t(17) = 1.61$, $SE = .013$, $p = .127$, whereas no such trend was observed with long SOA (3.6% and 3.1% errors for compatible and incompatible trials, respectively), $t(17) = .61$, $SE = .008$, $p = .553$. The error data demonstrate clearly that the patterns found in the RT data were not a product of speed–accuracy trade-off.

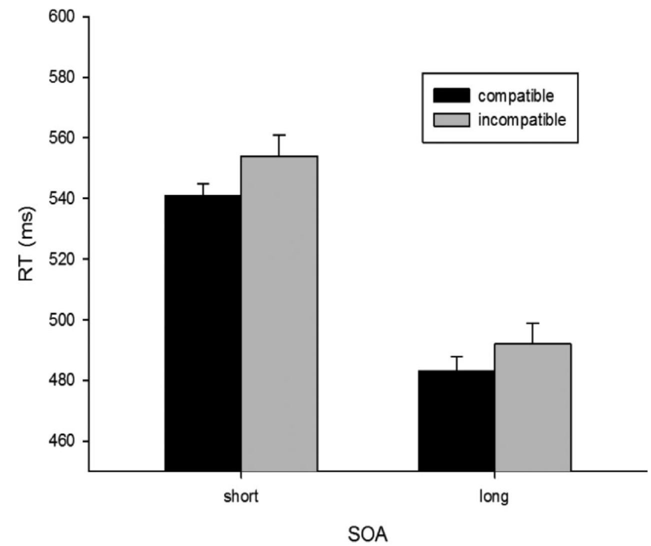


*Figure 7.* Response time (RT) data from Experiment 5 (single concrete category) graphed as a function of cue–target SOA (short vs. long) and cue–target compatibility. Error bars indicate within-subjects 95% confidence intervals (Cousineau, 2007). SOA = stimulus onset asynchrony.

The present results, taken together with the results of the previous experiment, demonstrate the surprising importance of using a single conceptual category for obtaining a facilitatory effect of cue–target compatibility. Whereas the same concrete concepts caused early interference in the previous experiment (multiple categories), they produced both early and late facilitation in the present experiment (single category). Finding both early and late facilitation is consistent with the coherent working memory account of implicit spatial cuing (Santiago et al., 2012; Torralbo et al., 2006), which states that the observer's tendency to form a single representation of a task leads the observer to form associations between a compatible stimulus and response features. Critically, such associations between upward and downward conceptual cues and the visual targets above and below fixation would remain stable whenever only one category is present in the task. Of course, one could see the interpretation based on task-induced mapping as a challenge to interpretations that evoke a task-independent perceptual component for concepts. We address these views in the General Discussion.

## Experiment 6

Thus far, we have reported experiments with a single abstract category (Experiments 1A, 1B, 2), a single concrete category (Experiment 5), multiple concrete categories (Experiment 3), and multiple abstract and concrete categories (Experiment 4). Together, they suggest that implicit spatial cues can cause interference at a short cue–target delay followed by facilitation at a longer cue–target delay, unless a single conceptual category is used, in which case facilitation is caused at both cue–target delays. The missing experiment in confirming this pattern is one with multiple abstract categories. If such an experiment produces the same pattern of results found in Experiment 4, the importance of using multiple categories in observing interference would be confirmed. This was the goal of the present experiment.

Furthermore, this current experiment seems necessary after examining the data from Experiment 4 separately for abstract and concrete concepts. Examining separate cue types was not motivated statistically, because the three-way interaction was not significant. Nonetheless, for our purposes it was necessary to examine whether the SOA × compatibility interaction can be observed with both concept types, before concluding that concept type is not a crucial factor. When we examined the data from Experiment 4, there was no main effect of compatibility with abstract and concrete concepts, when these were examined separately (*p*s $> .50$). More important, the SOA × compatibility interaction did not reach significance with abstract concepts ($p = .141$), but it reached significance with concrete concepts ($p = .007$). Thus, in Experiment 6, we once again attempted to test whether multiple abstract categories can cause early interference followed by late facilitation.

## Method

**Participants.** Twenty-five undergraduate students at the University of Toronto participated in the experiment, in exchange for course credit. All participants had normal or corrected-to-normal vision. They were all unaware of the purpose of the study.

**Apparatus and procedure.** These were identical to those in Experiment 4, except for the following modifications. Category words, which were presented before each cue, consisted of four abstract words (*NUMBER, RELIGION, MOOD,* and *POWER*). Each category word could be followed by a matching cue word (*NUMBER*: *1, 2, 98, 99*; *RELIGION*: *GOD, LORD, SATAN, DEVIL*; *MOOD*: *HAPPY, JOY, SAD, GLOOMY*; *POWER*: *DOMINANT, STRONG, SUBMISSIVE, WEAK*) or a nonmatching word, in the case of catch trials. Participants were instructed to respond to visual targets (i.e., identifying *X* or *O*) whenever the centrally presented cue word belonged to the preceding category word. Otherwise, they were instructed to withhold response.

**Design.** Each participant performed one block of target discrimination task, consisting of 20 practice trials and 256 experimental trials (128 test trials and 128 catch trials). Category (number, religion, mood, or power), cue (upward, downward), target location, target identity, and cue–target SOA were all randomized such that each combination was equally probable. Test trials were divided based on cue–target compatibility and SOA (short vs. long).

## Results and Discussion

After removal of catch trials, error trials (i.e., RT $< 100$ ms or RT $> 2{,}000$ ms; wrong keypress during the discrimination task), and outliers (i.e., responses 2.5 *SD* faster or slower the mean RT), mean RTs were submitted to a 2 × 2 repeated measures ANOVA with cue–target compatibility (compatible vs. incompatible) and cue–target SOA as factors. This analysis revealed no main effect of compatibility ($F < 1$), but there was a main effect of SOA, $F(1, 24) = 262.99$, $MSE = 3.21 \times 10^3$, $p < .001$, $\eta_p^2 = .916$, and a two-way interaction, $F(1, 24) = 4.51$, $MSE = 715.16$, $p = .044$, $\eta_p^2 = .158$. Responses were faster on trials with long SOAs ($M \pm SE = 512 \pm 13$ ms) than trials with short SOAs ($696 \pm 20$ ms). More important, as indicated by the two-way interaction, the compatibility effect depended on SOA. Although with short SOAs, responses were slower on compatible trials ($701 \pm 21$ ms) than incompatible trials ($691 \pm 20$ ms), this difference was not significant, $t(24) = 1.00$, $SE = 10.05$, $p = .326$. On the other hand, with long SOAs, responses were faster on compatible trials ($506 \pm 13$ ms) than incompatible trials ($518 \pm 13$ ms), $t(24) = 3.20$, $SE = 3.95$, $p = .004$.

The reason for the lack of significant interference could be due to possible difficulty in processing one or more categories. Importantly, if responses after a subset of words are largely delayed, then the intended effect of short SOAs will be eliminated. To test this possibility, we examined mean RTs and error rates as a function of the four categories. We found a main effect of category both in RTs, $F(3, 72) = 25.07$, $MSE = 954.89$, $p < .001$, $\eta_p^2 = .511$, and in error rates, $F(3, 72) = 12.48$, $MSE = .001$, $p < .001$, $\eta_p^2 = .342$. These effects were driven by slower and less accurate performance with the POWER category (RT = 649 ms, error rate = 8%) than the other three categories (RT = 591 ms, error rate = 4%). Consequently, to test whether the difficulty with the POWER category might have masked the interference effect, we repeated the original RT analysis without this category (see Figure 8). This analysis revealed no main effect of compatibility ($F < 1$); a main effect of SOA, $F(1, 24) = 173.03$, $MSE = 3.91 \times 10^3$, $p < .001$, $\eta_p^2 = .878$; and a two-way interaction, $F(1, 24) = 12.46$, $MSE = 721.63$, $p = .002$, $\eta_p^2 = .342$. This time, short SOA responses were significantly slower on compatible trials ($687 \pm 22$ ms) than incompatible trials ($665 \pm 21$ ms), $t(24) = 2.21$, $SE = 10.06$, $p = .037$. By contrast, long SOA responses were faster on compatible trials ($503 \pm 13$ ms) than incompatible trials ($519 \pm 14$ ms), $t(24) = 3.54$, $SE = 22.21$, $p = .002$. Overall, it seems that interference with short SOAs can be observed using multiple categories, even when the categories are all abstract.

Finally, error rates were submitted to a similar 2 × 2 ANOVA, which revealed only a main effect of SOA, $F(1, 24) = 21.85$, $MSE = .002$, $p < .001$, $\eta_p^2 = .477$. Consistent with the RT data, there were more errors with short SOA (10.1%) than with long SOA (5.46%). Error rates on catch trials were very low (1.9%),

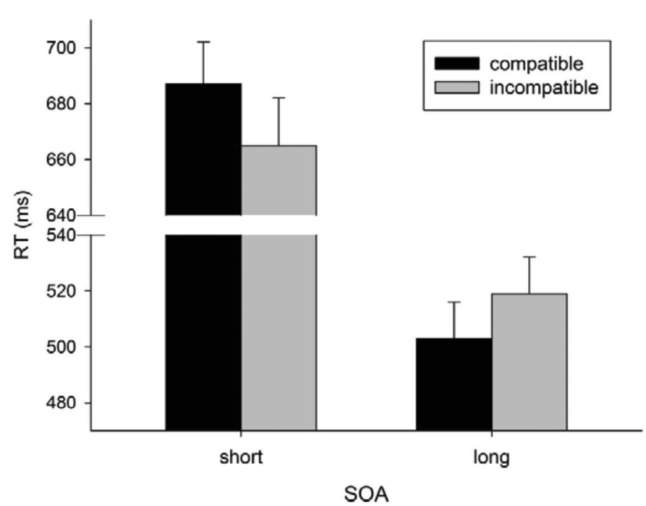


*Figure 8.* Response time (RT) data from Experiment 6 graphed as a function of cue–target SOA (short vs. long) and cue–target compatibility. Error bars indicate within-subjects 95% confidence intervals (Cousineau, 2007). SOA = stimulus onset asynchrony.

indicating that participants correctly withheld response on trials where the category word and the cue word did not match.

## General Discussion

Consistent with the essential role of perceptual features in concept representation, it has been shown that processing concepts referring to objects with typical perceived locations (e.g., HAT, BOOTS) or abstract concepts that are metaphorically associated with locations (e.g., GOD, DEVIL) can either facilitate or interfere with visual processing at the compatible location. In fact, both effects have been taken as support for the visuospatial grounding of concept representation, demonstrating how the current theories of concepts do not predict the specific direction of the effects. Here, replicating and extending the findings of two representative studies that have reported facilitation and interference, we attempted to specify the conditions in which concepts, used as implicit spatial cues, can cause facilitation and interference. First, we examined the findings of Chasteen et al. (2010), who reported facilitated target processing for cue-compatible targets using a single abstract cue category. Experiments 1A, 1B, and 2 demonstrated that this facilitation can occur even with reduced cue–target SOA and in a visual discrimination task. Next, Experiments 3A and 3B replicated the findings of Estes et al. (2008), using multiple concrete cue categories, and found interference on cue–target compatible trials only with a visual discrimination task and with short cue–target SOAs. Finally, Experiments 4–6 revealed no difference between the abstract and concrete concepts in their ability to generate interference and facilitation. Instead, the findings indicate that using multiple concept categories is necessary for observing the complementary effects of early interference and late facilitation in a single experiment. Using a single category, on the other hand, seems to cause both early and late facilitation. Table 2 summarizes these findings.

### Number of Categories

Finding the surprising role of the number of categories has important implications for similar cuing paradigms, because a large portion of studies that have investigated the interaction between conceptual and perceptual representations have implemented experimental designs consisting of one conceptual category and locations along one spatial dimension (horizontal or vertical; e.g., Chasteen et al., 2010; Fischer, Castel, Dodd, & Pratt, 2003; Meier & Robinson, 2004; Pecher et al., 2010; Quadflieg et al., 2011; Schubert, 2005; Zanolie et al., 2012; although see Gevers et al., 2006), perhaps with the implicit assumption that the number of categories is inconsequential. The present findings challenge this assumption, suggesting that the direction of the effect, at least for short cue–target SOAs, is dependent on whether multiple categories or a single conceptual category is used in the entire experimental block. This observation is relevant to the recent disagreements concerning how to interpret the findings of the implicit cuing paradigm (see Lakens, 2011; Louwerse, 2011; Van Dantzig & Pecher, 2011). In particular, reports of facilitation with a single category (e.g., numbers, valence, religion) could be, in part, attributed to a task-induced association between concepts and target locations (Santiago et al., 2012; Torralbo et al., 2006), which results from the observers' tendency to form a coherent representation of the task, instead of treating each event (i.e., cue and target) separately and independently.

If a task-induced association between a single conceptual category and location is responsible for the observed facilitation, how much of this observation can be truly attributed to concept representation? It is, in fact, possible to interpret the facilitated visual processing caused by the cues belonging to one category as a purely task-dependent finding. Such interpretation would be based on the principle of polarity correspondence (PPC; Cho & Proctor, 2003; Proctor & Cho, 2006), according to which binary/polar values of stimuli and responses are mapped onto each other, leading to systematic variations in how efficiently stimulus–response or stimulus–stimulus pairs are processed. For instance, perceptual (up vs. down) or conceptual dimensions (divine vs. evil) have dominant (i.e., salient, default) values that are regarded as the +polar, with the opposite values being the −polar. Consequently, when a target above is paired with the concept "GOD," processing is efficient because both stimuli represent the +polar values. It could be argued, accordingly, that the results of Experiment 1 were due to a stimulus–stimulus mapping between the +polar values (i.e., target above and the divine concept), as well as a mapping between the −polar values (i.e., target below and the evil concept), which caused efficient processing whenever the corresponding values were presented together.

The PPC-based explanation is purely based on task structure, instead of the nature of concept representation. Although recent studies have shown that polarity alignment might play a role in obtaining some compatibility effects (Lakens, 2012; Santens & Gevers, 2008), it would be challenging to apply this principle to the present findings of facilitation for two reasons. First, even with single category concepts, we included a neutral condition that would reduce the tendency to divide the cues into a binary variable. Second, responses were divided based neither on the upward and downward cue categories nor on the target location. Any polarity alignment, therefore, would have been between a task-irrelevant dimension of the cue (spatial meaning) and a task-irrelevant dimension of the target (location). Nonetheless, because interactions between irrelevant stimulus/response dimensions have been shown (Kornblum et al., 1990; Proctor & Cho, 2006) and because the PPC-based account represents a serious alternative to the perceptual grounding account, we consider it in its broadest and most inclusive form. This account would make the following assumptions: target locations above and below are, respectively,

Table 2
*Summary of the Results of Compatibility Effect Divided Based on the Category Number (Single vs. Multiple) and Category Type (Abstract vs. Concrete) of the Cues Used in Each Experiment*

| | | Compatibility effect | |
|---|---|---|---|
| Experiment | Cues | Short SOA | Long SOA |
| 1 | single abstract | facilitation | facilitation |
| 2 | single abstract | facilitation | facilitation |
| 3 | multiple concrete | interference | null |
| 4 | multiple abstract and concrete | interference | facilitation |
| 5 | single concrete | facilitation | facilitation |
| 6 | multiple abstract | interference | facilitation |

*Note.* SOA = stimulus onset asynchrony.

the +polar and −polar values along the spatial dimension; concept cues possessing an upward (divine, happy, etc.) and downward (evil, sad, etc.) spatial connotation happen to also be, respectively, the +polar and −polar values of the semantic dimension; processing efficiency is increased when there is a consistency (or, redundancy) of polarities. That is, faster responses are expected when both +polar (or both −polar) values of the perceptual and semantic dimensions are presented on a trial.

If we had observed facilitation in all of the experiments, a general account of the interaction between concepts and visual target processing, such as PPC, would have been viable. It is, however, difficult to see how PPC can lead to predicting the observed pattern of early interference followed by late facilitation. It is also interesting that the one factor that appears to be most the important requirement in obtaining early interference, (i.e., using multiple conceptual categories within a single experimental block) also eliminates the chances of treating the cues as a single bipolar variable. Indeed, the fact that the nature of the interaction changes with the increased number of categories suggests that single-category experiments might be a special case. With this assumption, we first turn to possible explanations of the observed interference and facilitation emerging at different temporal stages (Experiments 4 and 6). We can then address how this explanation could be modified to account for the consistent facilitation found with a single cue category (Experiments 1, 2, 5).

## Accounting for the Interference and Facilitation

Finding interference and facilitation at different temporal stages of the interaction suggests that the two effects may have a common origin, consistent with the previous attribution of both effects to the activation of the concepts' representation. There have been various explanations as to why the direction of the effect might change with time. Bergen (2007), for example, posited that a semantic task and a perceptual/motor task should interfere with each other if they require a common feature (e.g., the location code UP), unless there is enough delay between the two tasks. The explanation is similar to what is frequently applied in studies of perception and action, indicating that when two distinct processes require a single feature, they interfere with one another. For instance, performing a right-hand keypress impairs perception of rightward arrowheads (Müsseler & Hommel, 1997), or vocally responding "red" impairs perception of a red color patch (Kunde & Wuhr, 2004). More pertinent to the semantic domain, preparing to respond "positive" to a first stimulus can impair perception of a second stimulus associated with positive affect (Eder & Klauer, 2007). These findings have all been explained using the theory of event coding (TEC; Hommel, 2004; Hommel, Müsseler, Aschersleben, & Prinz, 2001). According to TEC, representing a perceptual or action event involves activation of the constituent features, followed by their integration into a single event. Critically, when a feature (e.g., the spatial code "up") is integrated into an action, a separate event that requires the same feature will be at a disadvantage relative to an event that does not involve this feature (e.g., Gozli & Pratt, 2011; Zwickel, Grosjean, & Prinz, 2010). Furthermore, the time interval in which the features are integrated is a subset of the interval in which the features have above-baseline activation (Stoet & Hommel, 1999). Therefore, if Task 2 (visual discrimination) is performed when features required in task 1 are no longer integrated into an event representation but are still active, compatibility should cause facilitation. Based on the arguments introduced in TEC, findings of both interference and facilitation suggest that constructing a linguistic event requires features that are essentially perceptual (Barsalou, 1999), to the extent that these features could be rendered temporarily unavailable for other, concurrent tasks.

To our knowledge, the present study is the first to find interference with a visual task after processing abstract concepts. Compared to the previously observed facilitation effects, this finding suggests a strong association between the concepts and spatial information. That is, the effect of concepts on the spatial task is not a distant by-product. It emerges as early as 300 ms and is in the form of an interference effect, which indicates necessity of the activation of the spatial code. The close association between many abstract concepts and spatial features is consistent with the view that spatial metaphors are essential in many abstract semantic domains (Chatterjee, 2001; Hubbard, Piazza, Pinel, & Dehaene, 2005), as well as with the imaging studies that suggest regions in the posterior parietal lobe, involved in spatial cognition, also underlie cognition of abstract concepts including numeric order, magnitude, and time (Cohen Kadosh & Henik, 2006; Hubbard et al., 2005; Quadflieg et al., 2011; Walsh, 2003).

Our findings, therefore, did not reveal a difference between the effects caused by the abstract or concrete concepts. In contrast, Bergen et al. (2007) compared the influence of hearing sentences such as "the ground shook" (concrete spatial meaning) and "the stocks dropped" (metaphorical/abstract association with space) on visual target processing along the vertical axis. They found that concrete sentences interfered with visual discrimination (presented after a 200-ms SOA) at compatible locations, whereas metaphorical descriptions did not. As they pointed out, it is possible that perceptually simulating metaphorical descriptions just takes longer than perceptually stimulating their concrete counterparts. In the present study, the abstract stimuli were single words, which presumably should lead to a faster activation of the sensorimotor components of the representation. Additionally, our short SOAs were slightly longer (300 ms, on average) than those used by Bergen et al. (2007). Perhaps these factors did not enable us to discriminate between the effects of the two concept types.

## Single-Category Design

How should we account for the special case of single-category experiments? In Experiments 1, 2, and 5, cues belonged to only one category (religious-, affect-, and house-related concepts, respectively), and cue–target compatibility was observed at both short and long SOAs. We have already discussed the coherent working memory account and the possibility of task-induced mapping between stimuli and responses as one possible source of explanation. There are, however, three other possibilities that should be considered. The first has to do with the repeated exposure to a single category. Repeated exposure to a category can cause *semantic satiation*, which correlates with a subjective loss of meaning, inefficiency in semantic judgment tasks, and a reduction in electrophysiological response to semantic content (e.g., Kounios, Kotz, & Holocomb, 2000; Smith & Klein, 1990). Importantly, the problem of repeated exposure to a category would not be eliminated if we increase the number of category members, as we did in Experiment 2. If semantic satiation is solely responsible for turning the early interference to facilitation, the beginning portion of the experiment should contain trials in which interference occurred but was later masked by facilitation. We tested this possibility by analyzing the first 50 trials of Experiments 1, 2, and 5. Only trials from the discrimination task and those with short SOAs were included. These trials represent a portion of the experiments in which participants were exposed to an average of 34 category members (others being neutral cues). This number was chosen because studies on semantic satiation often involve reading a category word about 30 times. Interestingly, in our experiments, facilitation was observed even in these early trials, inconsistent with a role of semantic satiation in causing consistent facilitation. A mixed ANOVA with compatibility as the within-subjects factor and experiment as the between-subjects factor revealed a main effect of compatibility, $F(1, 59) = 8.36$, $MSE = 420.46$, $p = .005$, $\eta_p^2 = .124$, and no two-way interaction ($F < 1$). Responses were faster on compatible trials (544, 577, and 603 ms) than incompatible trials (554, 600, and 619 ms, respectively, for Experiments 1B, 2, and 5).

A second possibility has to do with relying on nonspatial features of the category members in evaluating the cues. Given that evaluating cues belonging to a single category may be easier than evaluating cues belonging to multiple categories, observers may have more control in choosing an optimal processing strategy. Consequently, observers may choose not to use the vertical-spatial domain, which is relevant to the visual discrimination task, and choose other features in evaluating the cues. This means that the spatial features were not integrated into the events of Task 1 but were activated due to their association with the concepts. The activated (but not integrated) spatial information, therefore, might be responsible for the observed facilitation at short SOAs. Further work is required to test this possibility.

A third possibility has to do with an increased efficiency of processing cues and a shift in the time course of processing the concepts. That is, due to high efficiency of processing cues belonging to a single category, our short SOAs were not short enough for interference to be observed. Again, this possibility seems unlikely in light of the pattern observed within the first 50 trials of single-category experiments. Thus, the coherent working memory account (Santiago et al., 2012; Torralbo et al., 2006; see also Gevers et al., 2006) offers the best explanation of why single-category designs lead to both early and late facilitation. Above all, this account undermines the assumption that the processes associated with the cues and the visual targets are independent and that any interaction between them reveals something about their inherent commonality.

## Other Considerations

We argued above that a task-induced mapping between locations and concepts seems to be an implausible explanation for the current findings with multiple-category experiments. Nonetheless, the observed cuing effects might depend on task structure in another way. Coupling of a spatial task and a conceptual task might increase the salience of the spatial dimension of concepts, relative to how these concepts are processed outside this task. Consistent with this view, Santiago et al. (2012) showed how attention to location information modulates the interaction between conceptual and spatial information. For instance, trying to keep track of where the words were presented increased the effect of compatibility between location and spatial meaning of the words. Their findings suggest that the spatial connotation of the words may not always be necessarily activated and that we should consider the flexibility with which different dimensions (spatial, perceptual, linguistic) contribute to conceptual processing depending on the given context (see Barsalou, 1999; Torralbo et al., 2006). In the present paradigm, therefore, we should be cautious in assuming the spatial dimension of the cues is as salient outside the task as it is in the task. Instead, we assume that the systematic interactions (i.e., compatibility effects) between cues and locations simply suggest the very existence of such a spatial dimension.

Another consideration is based on how our abstract categories consisted of polar opposites (e.g., "God" vs. "Devil," "happy" vs. "sad"). Given these within-category semantic oppositions, it is possible that the abstract cues may be more easily mapped to the opposite spatial codes ("up" vs. "down") in the visual task (cf. Lakens, Semin, & Foroni, 2012). For concrete concepts, on the other hand, the polar opposition is either absent or weak (e.g., "basement" and "carpet" are not the opposite of "attic" and "ceiling" in the same way that "sad" and "gloomy" are the opposite of "happy" and "joy"). Accordingly, the contrast among abstract concepts may lead us to predict stronger cuing effects caused by the abstract concepts, compared to the concrete concepts. Although Experiment 4 did not reveal such a finding, we also compared the data from Experiments 2 and 6, which had abstract and concrete concepts, respectively, but were otherwise similar (i.e., both involved randomized SOAs, a single category, and active evaluation of the cues). To compare the cuing effects across the Experiments 2 and 6, we submitted the two sets of RT data to a mixed ANOVA with SOA and cue compatibility as within-subject factors and concept type (abstract vs. concrete) as the between-subjects factor. This analysis revealed main effects of SOA, $F(38) = 187$, $p < .001$, $\eta_p^2 = .831$, and cue–target compatibility, $F(38) = 13$, $p < .001$, $\eta_p^2 = .255$, but no main effect of concept type ($p > .1$) or interaction between concept and compatibility ($p > .7$). Both concepts produced cuing effects of similar magnitude (abstract: 9 ms; concrete: 11 ms). Therefore, as in Experiment 4, these findings revealed no difference between the two concept types. This can mean either (a) the concrete concepts were also treated as members of opposite subcategories (via their semantic-spatial relation) or (b) the polar opposition did not modulate the spatial cuing effects caused by the abstract concepts. The latter possibility seems more likely in light of the fact that we intermixed abstract concepts with neutral cues, reducing the contrastive relation in representation the two abstract subcategories (Duscherer, Holender, & Molenaar, 2008). Consistent with this possibility is the recent findings of Lakens et al. (2012, Experiment 5), who showed that presenting neutral concepts together with positive and negative affect concepts can reduce the metaphorical mapping between brightness (light vs. dark) and valence. This reduced mapping was attributed to a reduced ability in representing the concepts as a dichotomous variable. Similarly, perhaps the cuing effects caused by the abstract and concrete concepts were similar because the neutral (filler) words discouraged observers from treating the cues as a dichotomous variable.

Although some factors that predict the nature of the interaction between conceptual and perceptual processes are determined (e.g., temporal proximity), the important role of the context in which these interactions are studied should also be carefully considered (e.g., with the presence of more than one category, the nature of the visual task). A recent study by Pecher and Boot (2011) illustrated how conceptual processing of magnitude might be more likely to engage visuospatial mechanisms when the concept of magnitude is embedded within the context of a concrete situation than during a simple numerical comparison. Pecher and Boot instructed participants to evaluate relative magnitude in a particular and concretely described situation (e.g., "The man had two books in his bookcase"), whereas in a separate condition, they instructed participants to evaluate the magnitude of numbers relative to a given quantity (e.g., "50"). Results showed reliable upward and downward (or rightward and leftward) visual biases only after evaluation of magnitude in concrete situations. Because the present experiments relied on the method of presenting concepts in isolation and out of context, the effects found might be underestimating the engagement of the visuospatial mechanism in conceptual processing within more natural situations.

## Conclusion

The present study found further support for the participation of visuospatial features in conceptual processing. In particular, we reason that visuospatial features not only are activated by concepts but are also temporarily bound to other linguistic features to form an integrated conceptual event (cf. Hommel, 2004; Hommel, Müsseler, et al., 2001). With this assumption, the opposite patterns of interaction (facilitation and interference) between conceptual and visuospatial tasks are reconciled and viewed as two stages of the same kind of processes. We found, in addition, the same time course of interaction for both abstract and concrete concepts. The present study also revealed an important distinction between single-category and multiple-category designs, the awareness of which is important for future research.

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## Appendix A

### Mean (*SE*) RT Data Grouped Based on SOA, Cue Type, and Target Location

| Experiment | Target location | Short SOA Upward cue | Short SOA Downward cue | *p* | Long SOA Upward cue | Long SOA Downward cue | *p* |
|---|---|---|---|---|---|---|---|
| 1 | target above | 507 (9) | 516 (10) | .04 | 501 (15) | 511 (16) | .02 |
| | target below | 513 (12) | 500 (11) | .001 | 504 (17) | 492 (16) | .08 |
| 2 | target above | 568 (15) | 572 (15) | .70 | 505 (11) | 514 (14) | .21 |
| | target below | 573 (14) | 559 (13) | .06 | 516 (13) | 507 (10) | .25 |
| 3 | target above | 475 (10) | 461 (10) | .01 | 448 (12) | 448 (9) | .99 |
| | target below | 466 (11) | 472 (11) | .26 | 446 (10) | 450 (10) | .40 |
| 4 | target above | 635 (12) | 618 (11) | .001 | 500 (12) | 506 (12) | .25 |
| | target below | 627 (11) | 623 (11) | .40 | 503 (12) | 497 (12) | .14 |
| 5 | target above | 542 (10) | 569 (13) | .004 | 482 (9) | 491 (9) | .10 |
| | target below | 540 (11) | 541 (11) | .89 | 494 (10) | 484 (8) | .10 |
| 6 | target above | 674 (22) | 651 (23) | .11 | 501 (13) | 526 (16) | .004 |

*Note*. The *p* values express the significance level of the response time (RT) change at a fixed target location and stimulus onset asynchrony (SOA), depending on the cue type. *SE* = standard error.

## Appendix B

### Cues in Experiments 3A, 3B, and 4

The following cues were presented in capital letters in Experiments 3A and 3B. Words that were treated as filler words in the present study are denoted with an asterisk. Without their context words (Estes et al., 2008; Experiment 1 and 2), their spatial meaning was either ambiguous or opposite to their designated category.

**Upward cues.** snout, curtains, seat*, eye, cap, handle*, windows, steeple, tower, tree, stalk*, hat, lamp, collar, ear, lamp, petal*, mane, roof, attic, peak, cap, surface, cloud, laces, spout, light, cloth, leaves, buckle*

**Downward cues.** claw, carpet, tire, talon, coaster, bristles*, wheels, pew, radio*, milk*, seed, boot, drawer, paw, foot, rug, stem, hooves, lobby*, cellar, base, stalk*, floor, puddle, soles, drain, corner, leg, roots, hem

**Neutral/filler words.** bear, bedroom, bicycle, house, bottle, broom, car, church, clock, coconut, corn, cowboy, desk, pencil, hand, cabin, flower, horse, hotel, home, table, mushroom, key, rain, truck, shower, street, tennis, football, trouser

The following cues were presented in capital letters in Experiment 4. For catch trials, four cue words were assigned to each category to minimize any categorization ambiguity that might have resulted from random assignment (e.g., religion + star).

**Test trials.** *Numbers:* 1, 2, 98, 99 *Religion:* god, lord, satan, devil

*Mood:* happy, joy, sad, gloomy *House:* attic, roof, basement, cellar

*Sky:* bird, star, cloud, helicopter *Ocean:* whale, shark, dolphin, submarine

**Catch trials.** *Numbers:* whale, shark, dolphin *Religion:* 1, 2, 98, 99

*Mood:* attic, roof, basement, cellar *House:* happy, joy, sad, gloomy

*Sky:* Banana, flower, story *Ocean:* shoes, table, desk, pencil

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