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BRIEF REPORT

Attention Goes Both Ways: Shifting Attention Influences Lexical Decisions

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Spatial components of concepts can influence the speed with which peripheral targets are responded to (e.g., the word *God* speeds responses to targets presented above fixation; *devil* speeds responses to targets presented below fixation). The basic premise underlying these conceptual cueing effects is that thinking of a spatial metaphor activates an internal spatial representation which in turn influences the allocation of attention in the visual field. An important step forward in understanding conceptual cues is determining whether the underlying process is bidirectional: Do shifts of attention facilitate activation of corresponding conceptual information? To test this, a peripheral cue was used to induce shifts of attention to a peripheral location, and the effect of this shift on concept processing was measured with a standard lexical-decision task in which participants made word/nonword responses to a letter string presented at fixation (Experiments 1 and 3), or with a modified lexical-decision task in which participants made English/Dutch judgments of a word presented auditorily (Experiment 2). If shifts of attention activate spatially compatible concepts, then shifting attention to a peripheral location should speed lexical decisions for spatially compatible concepts such that leftward shifts lead to faster lexical decisions of left relative to right concepts (and likewise for rightward, upward, and downward shifts). Our results support this prediction, suggesting that behaviors in the visual field can influence the activation of internal representations.

Keywords: spatial attention, conceptual cueing, congruency effects, embodied cognition

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Conceptual cueing of visual attention refers to an effect of conceptual processing on the allocation of attention in the visual field. The most concrete example of this is the use of explicit directional cues. For example, Hommel, Pratt, Colzato, and Godijn (2001) presented a centrally located directional arrow ($<$, $>$) or word (*left*, *right*) which was followed by a peripheral target requiring a simple detection response. Targets were detected faster when appearing at locations indicated by the cue (compatible condition) than at another location (incompatible condition). This occurred even though these cues were entirely irrelevant to the detection task and observers were explicitly told that the cues did not predict the location of the target, suggesting that processing concepts involves automatic activation of corresponding sensorimotor spatial components. Similar results have been observed for a myriad of concepts, including those with implicit spatial meaning such as valenced concepts (e.g., *polite, rude*; Meier & Robinson, 2004), time-related concepts (e.g., *tomorrow, yesterday*; Weger & Pratt, 2008), concepts of number (Fischer, Castel, Dodd, & Pratt, 2003) and letter (Dodd, Van der Stigchel, Adil Leghari, Fung, & Kingstone, 2008), words referring to concrete concepts with a typical location in space (e.g., *hat, boot*; Estes, Verges, & Barsalou, 2008), as well as abstract religious (e.g., *god, devil*; Chasteen, Burdzy, & Pratt, 2010) and political (e.g., *liberal, conservative*; Mills, Smith, Hibbing, & Dodd, 2015) concepts.

The implicit assumption underlying these studies is that conceptual cues invoke shifts of visual attention. That is, the processing of a concept activates a corresponding internal spatial representation that in turn causes attention to be oriented to the spatially compatible region of the visual field. An important step forward in understanding conceptual cues is examining the directionality of their association with space. So far, studies of conceptual cueing have been unidirectional: A conceptual cue is centrally presented and the effect of that cue on some measure of peripheral attention is examined. If, however, concepts cause shifts of attention, then it may be possible for shifts of attention to activate spatially compatible concepts (e.g., shifting attention up should activate upper regions of the visual field, which in turn should facilitate lexical access to concepts explicitly or implicitly associated with up). That is, the relationship between conceptual cues and space in the visual field may be bidirectional. If so, then moving attention leftward should improve processing for spatially compatible concepts in much the same way as processing a concept improves attentional performance.

Experiment 1

To test whether the relationship between conceptual cues and space in the visual field is bidirectional, a classic peripheral cue (i.e., flash of light) is used to induce shifts attention to a peripheral

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location in the visual field, and the effect of this shift on concept processing is measured with a standard lexical-decision task. Thus, participants oriented to a peripheral cue and then performed a word/nonword judgment of a letter string presented at fixation. If shifts of attention activate spatially compatible concepts, then shifting attention to a peripheral location should lead to faster word/nonword judgments of spatially compatible concepts. For example, leftward shifts of attention should lead to faster word/nonword judgments of left relative to right concepts (and likewise for rightward, upward, and downward shifts).

Method

Participants. Participants were required to be English-first speakers and to have normal or corrected-to-normal vision. During data collection, however, we discovered that although all participants were English-first speakers, more than half were multilingual. As such, we doubled our target sample size to evaluate multilingualism as a potential between-subjects covariate. Accordingly, 48 undergraduates from the University of Toronto participated in exchange for course credit (see Table 1 for demographics), each of which was naïve to the purpose of the experiment and was informed of their rights of participation according to the Research Ethics Board at the University of Toronto.

Apparatus. Testing took place in a dimly lit, sound attenuated room. Participants were seated 48 cm from a 60-Hz CRT monitor (1,024 × 768 resolution), with chin/forehead rests to maintain their viewing position and distance. An IBM compatible Pentium-equipped PC running Experiment-Builder 1.10.1241 (SR Research Ltd., Mississauga, Ontario, Canada) controlled stimulus presentation. All stimuli were displayed on a black background (1.25 cd/m^2).

Stimuli and procedure. Appendices A and B lists the word and nonword lexical decision stimuli, respectively. Figure 1 illustrates the procedure. Each trial started with a gray fixation cross (45.6 cd/m^2, 1° × 1° with 0.04° thickness) in the center of the display along with two gray peripheral placeholders (45.6 cd/m^2, 4° × 4° with 0.04° thickness) for 750, 1,000, or 1,250 ms. The distance between fixation and the center of each placeholder was 8° of visual angle. Subsequently, one of the placeholders was brightened and thickened (87.7 cd/m^2 with 0.32° thickness). Participants were instructed to fixate the location of this peripheral cue, which could appear along either the vertical or horizontal axis. Vertical and horizontal cues were blocked, with block order counterbalanced across participants. After 100 ms, the display was cleared and a lexical decision stimulus was presented in the center of the display. Lexical decision stimuli were letter strings and consisted of pronounceable nonwords (e.g., *jur, ryped, scrorched*) and four different conceptual word categories: words associated with up (e.g., *bird, lord, ceiling*), down (e.g., *ants, hell, basement*), left (e.g., *enter, birth, before*), and right (e.g., *exit, death, after*).[1] Letters were capitalized (Times New Roman font), gray in color (45.6 cd/m^2), and measured 0.80° of visual angle. By pressing the "F" or "J" key on a keyboard, participants made speeded word/nonword judgments (response key mappings were counterbalanced across participants). Letter strings were presented for 4,000 ms or until a response was registered, after which the display was cleared. The intertrial interval was 1,500 ms.

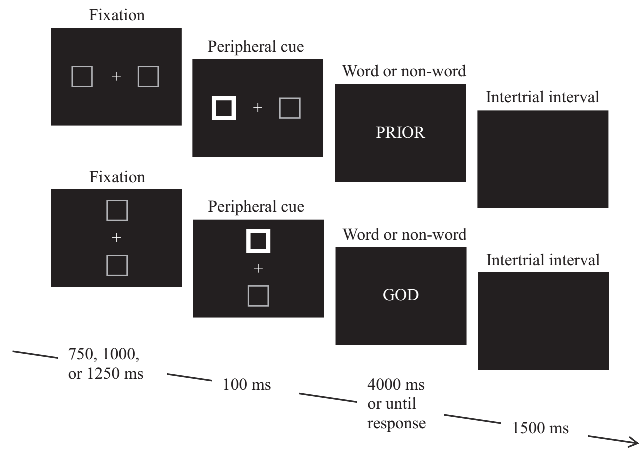

Figure 1. Example trial sequence for horizontal and vertical cue conditions.

Design. Each participant completed two blocks of 200 trials. One block contained vertical peripheral cues and up/down conceptual words, whereas the other contained horizontal peripheral cues and left/right conceptual words. Within each block there were 100 nonwords and 100 conceptual words (50 conceptual words per dimension). In each trial within a block, the peripheral cue location (above, below/left, right) and type of letter string (word, nonword) were equally likely. Within the word condition, each word category (up, down/left, right) was equally likely.

Table 1
Participant Characteristics in Experiments 1–3

Characteristic	Experiment 1 *n*	Experiment 1 %	Experiment 2 *n*	Experiment 2 %	Experiment 3 *n*	Experiment 3 %
Participants	48	100.0	22	100.0	100	100.0
Language						
Unilingual	21	43.7	5	22.7	37	37.0
Multilingual	27	56.3	17	77.3	63	63.0
Gender						
Male	19	39.6	9	40.9	34	34.0
Female	28	58.3	12	54.6	66	66.0
Other	1	2.1	1	4.5	0	.0
Handedness						
Left	4	8.4	2	9.1	2	2.0
Right	44	91.6	20	90.9	98	98.0

[1] Pronounceable nonwords were generated as follows. First, Medler and Binder's (2005) online tool *MCWord* was used to compute the word length (number of characters in a letter string), number of orthographic neighbors (number of different words that can be generated by changing only a single letter), and summed frequency of orthographic neighbours (how often an orthographic neighbor is used in speech/text per 1,000,000 words) for each conceptual word. Next, Rastle, Harrington, and Coltheart's (2002) *ARC Nonword Database* was used to generate pronounceable nonwords that matched the conceptual words on the parameters above. Thus, words and nonwords were matched on word length (M = 5.8 +/− 2.1 letters), number of orthographic neighbors (M = 4.2 +/− 5.6 neighbors), and summed frequency of orthographic neighbors (M = 176.4 +/− 2007.1 occurrences).

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Results and Discussion

Incorrect responses (5.12%) and responses less than 250 ms or greater than 2,000 ms (1.17%) were discarded. Correct response times (RTs) were analyzed with a 2 (block: vertical, horizontal) × 3 (cue-word compatibility: compatible, incompatible, nonword) × 2 (language: unilingual, multilingual) linear mixed effects model with crossed random intercepts for subjects and words and random subject slopes for the effects of block, cue-word compatibility, and their interaction (Barr, Levy, Scheepers, & Tily, 2013; Hoffman, 2014). Effect size was assessed using pseudo-R^2 statistics (Singer & Willett, 2003), which express the proportion of variance reduced in a given variance component after inclusion of a relevant fixed effect.

Figure 2 shows the mean RTs, collapsing across the multilingualism factor. Critically, there was a significant main effect of cue-word compatibility, $F(2, 123.4) = 18.77$, $p < .001$, pseudo-$R^2 = 19.2\%$, where responses were faster in the compatible ($M = 661$ ms) than in the incompatible ($M = 680$) condition, $t = 2.00$, $p = .049$. This is the predicted cue-word compatibility effect. Responses were also faster in the compatible and incompatible conditions than in the nonword ($M = 727$ ms) condition, ts > 4.34, ps $< .001$, which is the typical lexical decision result. The main effect of block was not significant, $F(1, 96.0) = 1.96$, $p = .165$, pseudo-$R^2 = 1.5\%$, and did not interact significantly with cue-word compatibility, $F(2, 173.2) = .30$, $p = .743$, pseudo-$R^2 < 1.0\%$.[2] Looking at Figure 2, however, it is somewhat surprising that the main effect of block was not significant given that responses appear to be consistently faster in the vertical relative to horizontal block. A post hoc power analysis conducted with *GPower 3.1* software (Faul, Erdfelder, Lang, & Buchner, 2007) indicated that the statistical power of this test was .69, which is slightly less than ideal and thus may reflect a type II error.

In sum, Experiment 1 investigated whether the processes underlying conceptual cueing effects are bidirectional. Specifically, if conceptual processing activates internal spatial representations that in turn influence behaviors in the visual field, do behaviors in the visual field also influence the activation of internal representations? The results suggest this is the case: lexical decisions were speeded when preceded by a spatially compatible behavior (e.g., the word *up* preceded *by an up behavior*) than an incompatible one (e.g., the word *up* preceded by a down behavior).

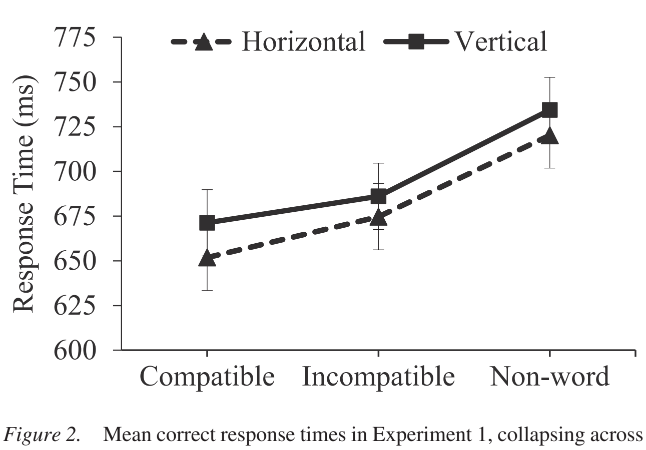

Figure 2. Mean correct response times in Experiment 1, collapsing across the language factor. Error bars represent +/− 1 standard error.

Experiment 2

Before we can reasonably conclude that shifts of attention modulated lexical access, one potential alternative must be addressed. Specifically, because lexical decision stimuli were presented at fixation, participants had to shift attention to the cued location then back to fixation. As such, it is unclear whether the speeding of lexical decisions is attributable to a spatially compatible behavior. Our interpretation, however, is not that the shift of attention per se was responsible for activating spatially compatible concepts but rather that selection of a particular region of space—via a shift of attention—was responsible. To rule out the possibility that a shift of attention from a peripheral location back to fixation was somehow responsible for the cue-word compatibility effect, a second experiment was conducted in which a shift back to fixation was not required. This was achieved by presenting lexical decision stimuli auditorily. Thus, rather than responding to lexical decision stimuli at fixation (Experiment 1), responses were to auditory stimuli (Experiment 2), which obviates the need to shift attention back to fixation. In addition, because of difficulty in generating nonwords that a computer program could pronounce, rather than word/nonword responses to letter strings non-Dutch speakers instead discriminated whether auditory stimuli were English or Dutch words.

Method

Participants. Participation criteria were the same as Experiment 1 with the addition that participants were non-Dutch speakers (effectively making Dutch words 'nonwords'). An a priori power analysis conducted with *GPower 3.1* software (Faul et al., 2007) indicated that with an alpha level of .05 and a power level of .80, a sample size of 24 would be necessary to observe an effect size of pseudo-$R^2 = 19.2\%$ (i.e., the size of the cue-word compatibility effect in Experiment 1). Because of this, and the fact that multilingualism did not influence the size of the cue-word compatibility effect in Experiment 1 and therefore was not considered in this experiment, 24 undergraduates from the University of Toronto participated in exchange for course credit. Two participants were excluded from analysis for responding incorrectly on >75% of trials. The error rate for each of the 22 remaining subjects was <18% (see Table 1 for demographics). All participants were naïve to the purpose of the experiment and were informed of their rights of participation according to the Research Ethics Board at the University of Toronto.

Apparatus, stimuli, procedure, and design. Auditory stimuli were presented binaurally with iCAN headphones in the range of 60–70 dB (peak volume). English words were the same con-

[2] A possible moderating role of multilingualism was examined given the reliance of the present experiment on linguistic ability. This turned out to be a rather inconsequential factor, however. There was a significant language by block interaction, $F(1, 46.6) = 4.23$, $p = .045$, pseudo-$R^2 = 7.2\%$, such that the effect of block (horizontal minus vertical) was larger for multilinguals ($M = -33.23$, $t = -2.52$, $p = .014$) than unilinguals ($M = 3.19$, $t = .22$, $p = .827$), but no other effects were significant (Fs $<$ 1, pseudo-R^2s $<1.0\%$). Thus, multilinguals were significantly faster to respond in the horizontal versus vertical condition, whereas unilinguals did not differ in speed of response between horizontal and vertical conditions. Uni- and multilinguals, however, did not differ on the size of the cue-word compatibility effect.

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ceptual words as in Experiment 1. Appendix C lists the Dutch words used in place of nonwords for the modified lexical-decision task. As participants did not speak Dutch, English and Dutch words were matched only on spoken duration ($M_{English}$ = 712 +/− 136 ms; M_{Dutch} = 739 +/− 158 ms). Auditory stimuli were generated using developer tools within Google Translate (https://translate.google.ca). All other aspects were the same as Experiment 1.

Results and Discussion

Response times were defined as the time interval between the onset of the auditory stimulus and the response.[3] Incorrect responses (6.45%) were omitted from analysis. Correct RTs (see Figure 3) were analyzed with the linear mixed effects model of Experiment 1, but omitting multilingualism. There was a significant main effect of cue-word compatibility, $F(2, 58.8) = 11.35$, $p < .001$, pseudo-$R^2 = 16.0\%$, where responses were faster in the compatible ($M = 901$ ms) than in the incompatible ($M = 925$) condition, $t = 2.09$, $p = .040$; this replicates the effect from Experiment 1 with slightly different stimuli, suggesting a robust effect. Responses were also faster in the compatible and incompatible conditions than in the Dutch word ($M = 983$ ms) condition, $ts > 3.32$, $ps < .001$, which is similar to the typical lexical decision result. The main effect of block was not significant and did not interact significantly with cue-word compatibility ($Fs < 1$, pseudo-R^2s $< 1.0\%$).

Experiment 3

Two concerns warrant further consideration.[4] First, there are legitimate concerns about replication in areas related to conceptual cueing (e.g., Doyen, Klein, Pichon, & Cleeremans, 2012; Meier, Fetterman, & Robinson, 2015). Indeed, effect size estimates for conceptual cueing effects can change drastically when sample sizes are increased. For example, Meier et al. (2015) conducted a replication of one of their earlier studies and found that the effect size in the high-powered study was about half of that in their earlier study. It seems prudent, therefore, to conduct a high-powered replication. Second, there is concern that the nature of a concept—whether concrete or abstract—may differentially affect the relationship between space and concepts. Experiments 1 and 2 examined the relationship between conceptual cues and space without regard to the specific nature of the concept—that is, whether the concept was abstract (e.g., God) or concrete (e.g., roof) in nature was not directly considered. Accordingly, the purpose of Experiment 3 was to conduct a high-powered replication with better control over the specific nature of the concept. To that end, 100 subjects participated in Experiment 3, in which abstract and concrete concepts associated with vertical space were tested.

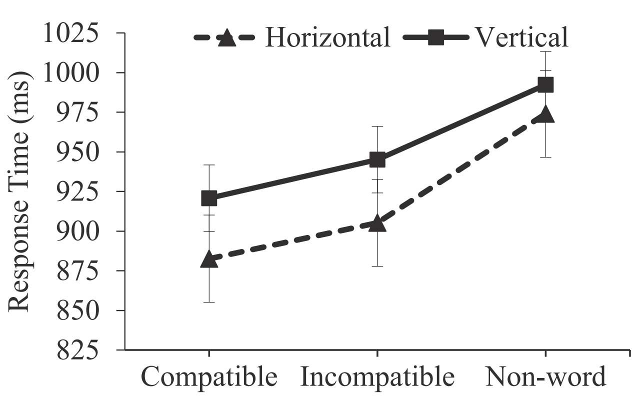

Figure 3. Mean correct response times in Experiment 2. Error bars represent +/− 1 standard error.

Method

Participants. Participation criteria were the same as Experiment 1. The initial sample consisted of 115 undergraduates from the University of Toronto who participated in exchange for course credit. Fifteen of these were not English-first speakers and were discarded, resulting in a sample size of 100 (see Table 1 for demographics). All participants were naïve to the purpose of the experiment and were informed of their rights of participation according to the Research Ethics Board at the University of Toronto.

Apparatus. Testing took place in a dimly lit, sound attenuated room, with participants seated 57 cm from a 144-Hz LCD monitor (2,560 × 1,440 resolution). Chin/forehead rests were used to maintain viewing position and distance. An IBM compatible Pentium-equipped PC running Experiment-Builder 1.10.1241 (SR Research Ltd., Mississauga, Ontario, Canada) controlled stimulus presentation. All stimuli were displayed on a black background (1.25 cd/m^2).

Stimuli and procedure. These were the same as in Experiment 1 with two exceptions. First, only the vertical dimension was used. The horizontal dimension was not included here because most of the horizontal word items were abstract and therefore did not permit strict control over the balance of concrete versus abstract items. Second, the word and nonword lexical decision stimuli were only a subset of those used in Experiment 1 rather than the full set. Again, this was necessary to ensure balance in the number of concrete and abstract items. There were 20 up words (concrete: SKY, CLOUD, BIRD, HEAD, EYES, ROOF, HAT, HELICOPTER, CHIMNEY, ATTIC; abstract: ALMIGHTY, GOD, HEAVEN, CREATOR, LORD, JOYOUS, HAPPY, JOLLY, GLAD, CHEERFUL) and 20 down words (concrete: GROUND, FISH, ROOTS, TOES, FLOOR, BOOTS, BASEMENT, SUBMARINE, RUG, TIRES; abstract: DEVIL, HELL, SATAN, LUCIFER, DEMON, MELANCHOLY, SORROW, DEPRESSED, SAD, UNPLEASED).[5] Words and nonwords were matched on word length ($M = 5.6$ +/− 1.9 letters), number of orthographic neighbors ($M = 5.9$ +/− 6.7

[3] We also analyzed response times defined as the time interval between the offset of the auditory stimulus and the response. This analysis yielded identical inferential statistics as those reported in the text.

[4] We thank an anonymous reviewer for bringing these concerns to our attention.

[5] Nonwords were as follows: ERV, BLEAF, ROUN, PUNK, PSAB, PRAP, NUP, PHREIGHTHS, SHROUND, WROUL, SKEAGUED, JUR, KIMPED, SPAGUED, CUNK, GNEGGS, DULTS, WUMPS, PEUM, PHLARLED, FROUSE, JUMB, KNUSH, GUDE, CLIFE, BROUT, SPRIMPED, GHEIGHTHS, VOM, RIKES, JEBBS, LYPE, SMOOF, SHRALTS, CLETT, STREIGHTHS, TEIGNS, THROURSED, ZAV, SHRILCHED.

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neighbors), and summed frequency of orthographic neighbors (M = 42.9 +/− 102.8 occurrences).

Design. Each participant responded to each of 80 unique lexical decision items (20 concrete words, 20 abstract words, and 40 nonwords) twice, once with an above peripheral cue and once with a below peripheral cue, for a total of 160 trials. In each trial, the peripheral cue location (above or below fixation) and type of letter string (word or nonword) were equally likely. Within the word condition, the nature of the concept (abstract or concrete) was equally likely.

Results and Discussion

Incorrect responses (3.0%) and responses less than 250 ms or greater than 2,000 ms (<1%) were discarded. Correct RTs were analyzed with a 3 (cue-word compatibility: compatible, incompatible, nonword) × 2 (word group: abstract, concrete) nested linear mixed effect model (the effect of word group was nested within the compatible and incompatible conditions of cue-word compatibility given that nonwords are neither abstract nor concrete) with crossed random intercepts for subjects and words and random subject slopes for the effect of cue-word compatibility and its interaction with word group.

Figure 4 shows the mean RTs. Once again, there was a significant main effect of cue-word compatibility, $F(2, 119.0) = 22.15$, $p < .001$, pseudo-R^2 = 34.3%, where responses were faster in the compatible (M = 631 ms) than in the incompatible (M = 650 ms) condition, $t = 3.05$, $p = .003$. This is the predicted cue-word compatibility effect. Responses were also faster in the compatible and incompatible conditions than in the nonword (M = 716 ms), which is the typical lexical decision result. Notice that the effect size for the cue-word compatibility effect was nearly twice as large as in Experiments 1 and 2, likely owing to the reduced set of word items. Critically, the nested effect interaction of cue-word compatibility (compatible, incompatible) and word group (abstract, concrete) was not significant, $F(2, 96.1) = .47$, $p = .627$, pseudo-R^2 < 1.0%, indicating the magnitude of the cue-word compatibility effect did not reliably differ between abstract (M = 22 ms) and concrete (M = 16 ms) conceptual word groups. These results replicate and extend Experiments 1 and 2 by demonstrating that the nature of the internally represented concept—whether concrete or abstract—does not differentially impact the relationship between space and concepts.

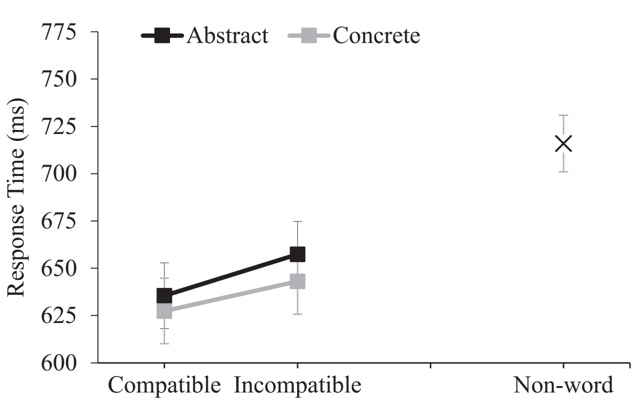

Figure 4. Mean correct response times in Experiment 3. Error bars represent +/− 1 standard error.

General Discussion

Direct experience with the physical dimension of space is thought to structure our understanding of concepts for which direct sensory experience is unavailable (e.g., to be divine is to be up in space; to be conservative is to be right in space), and previous evidence suggests that conceptual processing indeed biases visual attention toward spatially compatible locations (e.g., Chasteen et al., 2010; Dodd et al., 2008; Estes et al., 2008; Fischer et al., 2003; Hommel et al., 2001; Meier & Robinson, 2004; Mills et al., 2015; Weger & Pratt, 2008). The present study examined whether the processes underlying these conceptual cueing effects are bidirectional: can shifts of attention to a particular location in the visual field facilitate the processing of corresponding concepts? Experiment 1 observed a cue-word compatibility effect such that lexical decisions were speeded when preceded by a spatially compatible cue (e.g., the word *up* preceded by an up cue) than an incompatible one (e.g., the word *up* preceded by a down cue) on both vertices. Thus, just as activated internal representations are capable of influencing behaviors in the visual field, behaviors in the visual field can also influence the activation of internal representations.

Because Experiment 1 required a shift of attention to the location of the peripheral cue then back to fixation, it is unclear whether the speeding of lexical decisions is attributable to a spatially compatible behavior. To rule out this possibility, Experiment 2 presented lexical decision stimuli auditorily, thus removing the need to shift attention back to fixation. Again, a cue-word compatibility effect was observed. Our interpretation, therefore, is not that the shift of attention per se was responsible for activating spatially compatible concepts but rather that selection of a particular region of space—via a shift of attention—was responsible.

The present work contributes to the conceptual metaphor and embodied cognition literature (Barsalou, 1999, 2008; Gozli, Chasteen, & Pratt, 2013; Lakoff & Johnson, 1980, 1999; Landau, Meier, & Keefer, 2010) by demonstrating how visual positioning of information along the vertical or horizontal dimension can affect accessibility of conceptual representations. In the literature, two interrelated mechanisms are discussed as underlying these language-space associations (compatibility effects): (a) metaphorical mapping and (b) automatic reactivation of experiential traces during language understanding. Conceptual metaphor theory (Lakoff & Johnson, 1980, 1999; Landau et al., 2010) focuses on how people perceive and represent items that have no direct sensory experience. It proposes that the human cognitive system is structured around a set of concepts that emerge directly from experience. The general principle of conceptual metaphor theory—that less concrete concepts can be understood metaphorically in terms of more concrete ones—implies a unidirectional nature to compatibility effects. Indeed, as remarked by Landau et al. (2010), "metaphorical mappings between dissimilar concepts tend to go in the direction of a concrete source concept to a relatively more abstract target concept, but not the other way around" (pp. 1052).

Support for the metaphor account (i.e., unidirectional mapping) is found in Meier and Robinson (2004; Experiment 3). Their participants first responded vocally as to whether a spatial prime appeared above or below fixation. Immediately afterward, a pos-

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itively or negatively valenced word was presented at fixation and participants determined as quickly and as accurately as possible whether the word conveyed positive or negative meaning. In contrast to the present findings, Meier and Robinson failed to observe a compatibility effect between the location of the prime and the meaning of the word such that participants were no faster to evaluate positive words when preceded by a prime appearing above fixation than when the prime appeared below fixation (and likewise for negative words—participants were no faster to evaluate negative words when preceded by a prime appearing below fixation than when the prime appeared above fixation). Thus, whereas the present results suggest a bidirectional relationship between concepts and space, the Meier and Robinson study suggests a unidirectional one whereby affective judgments activate spatial attention, but this does not prime evaluations. According to Meier and Robinson (2004), this was attributable to the asymmetrical nature of affective metaphor. Individuals can use their sensory system to determine the location of an item in space and, as such, do not need to borrow metaphor to achieve an understanding of vertical position. The present study questions the general validity of the metaphor view, as the findings suggest that perception and cognition may have a common neuronal basis, thereby allowing for a bidirectional relationship between the two.

This common neuronal basis is consistent with notions that action and perception share representations. In this perspective, conceptual processing is thought to automatically activate perceptual features associated with the meaning of the concept (i.e., simulation; Barsalou, 1999, 2008). Thus, activating a concept representation also activates a corresponding spatial representation stored during experience of the concept's referent, which in turn causes attention to be shifted to the spatially compatible region of space. The implication is that conceptual processing invokes brain activity associated with the processing of spatial information (Barsalou, 1999, 2008). If so, then the relationship between conceptual and perceptual representations should be bidirectional: activating a spatial representation (e.g., via shift of spatial attention) should also activate corresponding conceptual representations, which in turn should facilitate access to conceptually compatible concepts. This is precisely what was found in the present study—shifting attention facilitated lexical access when the spatial aspects of the behavior and the lexical item matched (e.g., the word *up* followed by a behavior that activates upward space).

The present findings are in line with a recent study by Berndt, Dudschig, and Kaup (2016). They examined bidirectionality between space and concepts using perceptual cues in which anagram problems (e.g., *dolphin* = "dplhion" or *cloud* = "cdulo") were presented at different locations in the visual field (top or bottom of the display). They found that anagrams were solved faster when the position of the anagram was compatible with the typical location of the solution's referent in the real world (*cloud* is top; *dolphin* is bottom). Importantly, however, this effect depended on the presence of a background ocean-sky picture, suggesting that experiential traces can activate associated concepts only within a supporting context. Berndt et al. (2016) therefore interpret these findings as reflecting a mixture of automatic activation processes and the integration of the context information provided by the background picture. It is unclear why a supporting context was not necessary to obtain a compatibility effect in the present studies. A likely possibility may have to do with the difference between studies in how attention was shifted to peripheral locations. Specifically, the manner by which attention is shifted (either via endogenous task-goals in Berndt et al. or exogenous stimulation in the current study) may impact the relationship between space and concepts.

Despite all this evidence that activating experiential traces indeed activates related concepts, there is a remaining possibility that language use might account for concept-space mappings, such that conceptual cueing effects are driven by the frequent use of spatial terms with target concepts (e.g., *God above*; Goodhew, McGaw, & Kidd, 2014; Louwerse, 2008). Thus, participants may shift their attention upward upon processing *God* because they have frequently and systematically been exposed to the term in conjunction with *above* and *up*, such that this spatial information has become associated with the concept itself. Such accounts predict that the magnitude of conceptual cueing effects is explained by linguistic collocations of the concept word and spatial words (i.e., frequency of use of the words together). The present study cannot rule out this account; however, it seems that such an account requires two associations (upper space with the word *above*, and the word *above* with the word 'God'), whereas our interpretation requires only one (that upper space be associated with the word 'God') and is therefore more parsimonious and thus preferred, at least for the time being.

Context of the Research

Spatial representation is critical for perceiving and acting on objects in the world given that identifying and/or acting upon an object usually requires that the object first be located in space. Recent work indicates that spatial representations continue to influence higher cognition, such as conceptual understanding. This is evident in studies demonstrating that processing concepts referring to objects with typical locations in space (e.g., head, foot) or abstract concepts that are metaphorically associated with locations in space (e.g., God, Devil) influence where attention is allocated in the visual field. Consistent with the essential role of perceptual (spatial) features in concept representation, the present studies found that cueing location (up, down, left, and right) influenced the processing of semantically related concepts. This work helps establish boundary conditions in embodied cognition as it challenges explanations that have been offered for conceptual cueing, such as conceptual metaphor theory, which assume a unidirectionality of this effect.

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Appendix A

List of Conceptual Words Used in Experiments 1 and 2

Horizontal		Vertical	
Left words	Right words	Up words	Down words
BAD	BIG	UP	BED
MR.	END	CAP	RUG
DUSK	JR.	GOD	SAD
LEFT	OLD	HAT	ANTS
MRS.	SR.	HOT	BASE
PAST	DAWN	JOY	DARK
TINY	EAST	SKY	DEEP
WEST	EXIT	TOP	DOWN
ZERO	FAIR	ATOP	FISH
BIRTH	GOOD	BIRD	FOOT
EARLY	JUST	EYES	HELL
ENTER	LAST	GLAD	SEED
FALSE	LATE	GROW	TOES
FIRST	LIFE	HEAD	WEAK
PRIOR	NEXT	HIGH	BELOW
SMALL	OPEN	LORD	BOOTS
START	TRUE	PEAK	DEPTH
WRONG	AFTER	ROOF	DEVIL
YOUNG	DEATH	STAR	DRAIN
ARRIVE	DRIVE	TREE	EMPTY
BEFORE	GREAT	ABOVE	FLOOR
CLOSED	LARGE	ANGEL	FROWN
CLUMSY	LATER	ATTIC	ROOTS
REJECT	LEAVE	CLOUD	SATAN
SIMPLE	MORAL	CROWN	SHOES
SUNSET	OLDER	HAPPY	SOLES
AWKWARD	RIGHT	JOLLY	SOUTH
DUBIOUS	ACCEPT	LIGHT	TIRES
EARLIER	ATTEND	NORTH	UNDER
LEFTIST	BIGGER	SMILE	UPSET
LIBERAL	FUTURE	TOWER	BOTTOM
NEGLECT	LATEST	COLLAR	CARPET
REVERSE	BIGGEST	HEAVEN	CELLAR
SMALLER	COMPLEX	JOYOUS	GLOOMY
WESTERN	EASTERN	LEAVES	GROUND
YOUNGER	FORWARD	STRONG	HOOVES
DEMOCRAT	SUNRISE	CEILING	SHRINK
EARLIEST	FAIRNESS	CHMINEY	SORROW
LEFTWARD	POSITIVE	CREATOR	SUBWAY
NEGATIVE	PROGRESS	PLEASED	WHEELS
PREVIOUS	TOMMOROW	STEEPLE	FALLING
SINISTER	AFTERHAND	ALMIGHTY	LUCIFER
SMALLEST	CLOCKWISE	CHEERFUL	UNHAPPY
TERRIBLE	IMPORTANT	DOMINANT	BASEMENT
BACKWARDS	RIGHTWARD	ELEVATED	DEPRESSED
COMMUNISM	REPUBLICAN	HIGHRISE	SUBMARINE
SOCIALISM	SUBSEQUENT	EVAPORATE	UNPLEASED
YESTERDAY	APPROPRIATE	EXCITEMENT	MELANCHOLY
BEFOREHAND	TRADITIONAL	HELICOPTER	SUBMISSIVE
ANTICLOCKWISE	CONSERVATIVE	SKYSCRAPER	UNDERGROUND

(*Appendices continue*)

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Appendix B

List of Non-Words Used in Experiment 1

Horizontal			Vertical		
SKU	MENGE	BLEENED	EK	VAUGE	KNAFED
KIB	GWETT	SCOURTS	KEL	GNEEK	CRUICE
SKO	GWILL	GWUSQUE	JUR	WROUL	CLOAMS
ONG	GNASP	BROGGED	NUP	BLEAF	FROUSE
DWA	WUILD	SMOLFED	CEB	SILED	BLOWNS
URB	RYPED	GWUGGED	NUD	DULTS	NEAVES
OMP	SHUBS	SPLEIGNS	ERV	WUMPS	TEIGNS
PROG	MENTS	SCRASSED	WUD	COVED	PSULTS
ALLS	SLAWN	THWOURNS	ZOF	PLENT	PSOOMS
NEPH	SHUSS	SHRAMPED	VOM	DAWLS	BRAWNED
FOLS	LALKS	GAUNCHED	ZAV	CLOWS	SHROUND
YEMS	RAMES	PRUNCHED	SMOO	TWOOR	SPAGUED
WOBS	PLOOST	THWEALED	ROUN	BROUT	MOOTHED
ZAMN	DWERBS	NAUNCHED	PSAB	CLETT	WHARMED
PABE	YEERED	GNERCHED	PEUM	JEBBS	TERB
LUNK	RHOPSE	DWINCHED	MAFT	KIRTH	SHRALTS
SKOD	MEEVED	GREETHED	PUNG	PHUMF	SPLOONS
NOMB	HOLLED	THREPPED	TULP	CLIFE	SKEAGUED
VAZE	SWIEGE	THAUNCHED	CUNK	MERKS	PHLARLED
POUL	HARMTH	SPLERCHED	YABS	KNUSH	STRILMED
SPLY	KNYMES	SCROOTHED	PRAP	SMOOF	SCRILLED
BAMS	DONKED	SHRITCHED	SNAB	PASKS	DWEAGUES
NAMS	BOATHE	PHRANCHED	WOBE	RULLS	SPRIMPED
DINC	STERKS	PHREACHED	PERB	MOAMS	KNAUNCHED
VOED	KNARGED	SCRORCHED	BRAM	RIKES	THROURSED
GUKE	STRORTS	FREIGHTHS	KUGS	DWIPE	GHEIGHTHS
WOUTS	PHLAINT	THRAUNCHED	FUMS	GHYPT	SHRILCHED
NOIDS	CLOOVED	STRAUNCHED	TWED	DRIKES	SHRAUNCHED
SPONK	SWEILED	THREIGHTHS	JUMB	KIMPED	PHREIGHTHS
VIQUE	FLURVES	BREIGHNDGED	TADS	GNEGGS	SHREIGHTHS
GNULB	WOOCHED	SCKREIGHTHS	LYPE	PRAWLS	STREIGHTHS
PLISK	BLOULED	GHLOUGHPHTHS	YOND	THREWS	SCKRAUNCHED
SMIME	PHLUNCH	SCKREIGHNDGED	GUDE	FRENES	SPROARPHTHS
HOOTH			PEEF		

(*Appendices continue*)

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Appendix C

List of Dutch Words Used in Experiment 2

Horizontal			Vertical		
DAK	LOPEN	BEWEGEN	NA	KWAAD	ZONDER
HUN	KOPEN	BETALEN	MOE	NAAST	HUIDIG
ALS	HOREN	GROEIEN	VAN	BOVEN	LEKKER
DUS	WETEN	BLIJVEN	BIJ	ONDER	SCHOON
DOEN	LEREN	ZWANGER	WIT	TEGEN	LELIJK
OOIT	LEZEN	VANDAAG	DIK	ANDER	DONKER
SOMS	HALEN	GEDRAGEN	DUN	BETER	ORANJE
MEER	LENEN	GENIETEN	DOM	ENIGE	GELIJK
DOOD	KUNNEN	VERKOPEN	LUI	VROEG	ZELFDE
MIJN	VOELEN	SCHIJNEN	NOG	JUIST	VROLIJK
HAAR	VOLGEN	GOEDKOOP	ERG	KLAAR	VERRAST
ZIJN	HOUDEN	VOLGENDE	BOOS	GROOT	BENEDEN
GEEN	KENNEN	ALGEMEEN	BLIJ	KLEIN	BEROEMD
VAAK	VINDEN	VERGETEN	NAAR	LICHT	EENZAAM
VLAK	WILLEN	GEBEUREN	ROND	ZWAAR	KRIJGEN
TAAI	HEBBEN	BEDOELEN	KORT	ZACHT	SPREKEN
ZWAK	WORDEN	PROBEREN	LANG	GROEN	WACHTEN
OOST	VRAGEN	UITGEVEN	LAAT	BLAUW	VERVELEN
ZUID	KIJKEN	GEBRUIKEN	VRIJ	PAARS	ONRUSTIG
GAAN	PRATEN	VERTELLEN	ECHT	ZWART	OPGEWEKT
ETEN	ZEGGEN	ONTMOETEN	LEEG	GRIJS	TEVREDEN
ZIEN	DENKEN	AANBIEDEN	VIES	BRUIN	MOGELIJK
LATEN	WERKEN	LUISTEREN	MOOI	BREED	VERKEERD
MAKEN	BELLEN	SCHRIJVEN	SAAI	BEIDE	VERVELEND
NEMEN	REGENEN	BESLISSEN	RIJK	RECHT	DUIDELIJK
KOMEN	HAGELEN	VERLIEZEN	SNEL	DROOG	MAKKELIJK
GEVEN	BEWOLKT	VERTREKKEN	KOUD	STERK	BIJZONDER
HATEN	VRIEZEN	VERWACHTEN	DUUR	AARDIG	CHAGRIJNIG
DELEN	DRAAIEN	HERINNEREN	HOOG	ZIELIG	VERDRIETIG
NIETS	GELOVEN	ONDUIDELIJK	ROOD	ACHTER	ONGEDULDIG
ALLES	BRENGEN	VOORZICHTIG	GEEL	TUSSEN	BELANGRIJK
BIJNA	SLUITEN	GEBRUIKELIJK	ROZE	BINNEN	ANTWOORDEN
MEEST	SNIJDEN	TELEURGESTELD	PLAT	BUITEN	BESCHIKBAAR
NOORD			DRUK		

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