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Valence and vertical space: Saccade trajectory deviations reveal metaphorical spatial activation

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Concepts of positive and negative valence are metaphorically structured in space (e.g., happy is *up*, sad is *down*). In fact, coupling a conceptual task (e.g., evaluating words as positive or negative) with a visuospatial task (e.g., identifying stimuli above or below fixation) often gives rise to metaphorical congruency effects. For instance, after reading a positive concept, visual target processing is facilitated above fixation. However, it is possible that tasks requiring upwards and downwards attentional orienting artificially strengthen the link between vertical space and semantic valence. For this reason, in the present study the vertical axis was uncoupled from the response axis. Participants made eye movements along the horizontal axis after reading positive or negative affect words, while their saccade movement trajectories were recorded. Based on previous research on saccade trajectory deviation, we predicted that fast saccade trajectories curve *towards* the salient segment of space, whereas slow saccade trajectories would curve *away* from the salient segment. Examining saccadic trajectories revealed a pattern of deviations along the vertical axis consistent with the metaphorical congruency account, although this pattern was mainly driven by positive concepts. These results suggest that semantic processing of valence can automatically recruit spatial features along the vertical axis.

Keywords: Embodied semantics; Conceptual metaphors; Saccade trajectory.

Our sense of space provides metaphorical structure for our understanding of abstract concepts such as valence, power, and divinity (Lakoff & Johnson,

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1980, 1999; Meier & Robinson, 2005). An examination of language use supports this claim as we, for instance, tend to regard the positive, good, strong, and happy as up in space, whereas the opposite category members are described as down (e.g., "he is down", "he needs to cheer up", etc.). Recent evidence suggests that the link between abstract concepts and space is so intimate that a conceptual task (e.g., reading single words) can bias performance on a concurrent visual or motor task (Chasteen, Burdzy, & Pratt, 2010; de la Vega, de Filippis, Lachmair, Dudschig, & Kaup, 2012; Gozli, Chasteen, & Pratt, in press; Meier & Robinson, 2004; Schubert, 2005; Zanolie et al., 2012). A strong interpretation of the current evidence would be that semantic processes require visuospatial representations and, therefore, engage spatial attention in an automatic and necessary manner (see Gallese & Lakoff, 2005; Meteyard & Vigliocco, 2008). Thus far, however, studies that have addressed the interaction between valence and space have used experimental designs wherein locations of interest (e.g., up/down) are relevant to task performance. Consequently, given the flexibility and context sensitivity of conceptual processing, it is possible that the interaction between valence and space is largely dependent on the relevance of the spatial domain (Santiago, Ouellet, Román, & Valenzuela, 2012; Torralbo, Santiago, & Lupiáñez, 2006). In other words, the mapping of positive/negative with up/down, for example, may be at least partially the product of task demands. In the present study, we ask whether semantic valence can generate a spatial bias at metaphorically congruent locations when those locations are task irrelevant. First, to provide a better context for the present study, a brief overview of previous work is necessary.

The hypothesis that semantic processing of valence activates spatial information has been supported using two kinds of tasks. The first set of tasks requires participants to respond to word stimuli that are presented at a metaphorically congruent or incongruent location (e.g., "HAPPY" presented above/below fixation). Meier and Robinson (2004, Exp. 1) employed this task, and found faster responses when word meaning and word location were metaphorically congruent, compared to when they were incongruent. The generality of this finding, however, was recently questioned in a study by Santiago et al. (2012), who highlighted the importance of specific task characteristics. For instance, in the original experiment by Meier and Robinson, a spatial cue precedes and signals the upcoming target word, perhaps also making location a salient feature of the task. Not presenting this cue was shown to eliminate the metaphorical congruency effect (Santiago et al., 2012, Exp. 2) unless participants were motivated to monitor location information (Exp. 3). Santiago et al., thus, argued for a more flexible view of the link between semantic valence and space, wherein activation of spatial information is not strictly necessary for semantic processing of valence (also see de la Vega et al., 2012; Tourangeau, Couper, & Conrad, 2013).

The evidence from the word evaluation task, therefore, does not conclusively establish whether semantic valence can automatically and necessarily activate the metaphorically congruent spatial information. Even if the space–valence interaction found in such a task were robust, interpreting the interaction would not be straightforward. As argued by Lakens (2012), for example, the congruency effect could also be partly attributed to asymmetries in processing efficiency that exist separately within each domain. In other words, the possible processing advantage of up over down, and positive over negative, should be taken into account while examining the metaphorical congruency advantage. Even assuming a genuine valence–verticality interaction, driven by metaphorical congruency, the issue of task relevance remains unresolved. The necessity of attentional orienting above/below fixation coupled with word reading opens the possibility that the valence–verticality association is artificially emphasized within the task. In other words, valence words may have been processed differently because of the salience of the vertical axis (see Torralbo et al., 2006).

A second type of task that has been used to test the valence–space interaction involves presenting a word at fixation, followed by a visual target (e.g., X/O) presented above/below fixation, to which participants perform a response (Chasteen et al., 2010; Estes, Verges, & Barsalou, 2008; Gozli et al., in press). Meier and Robinson (2004, Exp. 2) employed this task and found faster responses to the visual targets appearing at locations that are metaphorically congruent with the preceding word (e.g., "HAPPY" followed by a target above fixation). Again, vertical axis, though independent of word evaluation, remains relevant within this task. It is, therefore, possible that the relevance of vertical spatial domain affects the way in which the words are processed such that the space–valence association is artificially strengthened in the task.

One way to overcome the problem of task relevance in tests of metaphorical congruency is to present one of the two critical features subliminally. In a recent study, Ansorge, Khalid, and Koenig (2013) found that masked, subliminally processed valence words fail to generate a metaphorical congruency effect. However, as the authors pointed out, by masking the words both the awareness and the extent of processing are reduced and, therefore, the absence of a congruency effect could be attributed to weaker spread of activation from valence to spatial codes. Furthermore, Ansorge et al. did not test the effect of valence on visuospatial orienting, but on speed of processing semantic space (e.g., words "ABOVE", "BELOW"). The conceptual metaphor theory posits a direct link between semantic valence and perceptual space (Gallese & Lakoff, 2005; Meier & Robinson, 2005), but this does not necessarily imply a direct link between semantic valence and semantic space. Thus, in the present study we addressed the problem of task

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relevance without manipulating awareness of valence, and without using semantic representation of space. That is, we used a spatial orienting task, in which the axis of the response was uncoupled from the axis of the spatial metaphor. Instead, in these experiments, we examined the effect of a vertically oriented metaphor on eye movement trajectories along the horizontal axis. Without the relevance of the vertical axis to the task, any attentional bias along the vertical axis can no longer be attributed to an artificially emphasized association between valence and vertical space.

Saccade trajectories provide a very sensitive measure of attentional bias (Van der Stigchel, 2010; Van der Stigchel, Meeter, & Theeuwes, 2006), sensitive to both stimulus-driven and cognitive sources of salience (e.g., Godijn & Theeuwes, 2002, 2004), and more informative than manual or saccadic response time (e.g., Al-Aidroos & Pratt, 2010; West, Al-Aidroos, & Pratt, 2013). Specifically, when an irrelevant location becomes salient, trajectory of a target-directed saccade can deviate towards or away from the salient location (Van der Stigchel, 2010; Van der Stigchel et al., 2006). The direction of deviation, in part, depends on saccade latency (McSorley, Haggard, & Walker, 2006; Walker & McSorley, 2008; see also, Godijn & Theeuwes, 2002; Van Zoest, Donk, & Theeuwes, 2004). Fast saccades are affected by simultaneous activity at the target and distractor locations, which result in an averaging effect, causing saccades to deviate towards the distractor location. By contrast, slow saccades are affected by top-down processes that maintain activity at the target location, but suppress activity at the distractor location, causing deviation *away* from the salient distractor (Tipper, Howard, & Paul, 2001; Van der Stigchel et al., 2006).

In the present study, two alternative outcomes are conceivable. First, the metaphorical congruency effects (e.g., Gozli et al., in press; Meier & Robinson, 2004) might completely rely on the task relevance of both domains of semantic valence and vertical space. If so, saccade trajectories should not systematically vary based on semantic valence. Second, the metaphorical congruency effect might be observed despite the irrelevance of the vertical axis. If so, positive and negative valence should increase the salience *above* and *below* fixation, respectively. This induced salience, in turn, is expected to induce a pattern of deviations towards (fast saccades) and away (slow saccades) from the metaphorically congruent locations.

EXPERIMENT 1

In this experiment, participants first read a single word, henceforth referred to as the *cue*, at fixation. They were instructed to perform a horizontal saccade if the cue was related to a feeling/mood (e.g., "HAPPY") and withhold response if the cue referred to a piece of furniture (e.g., "TABLE").

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The saccade goal could appear at either the left or right periphery. Critically, simultaneous with the saccade target onset, two distractors appeared above and below fixation. Distractors were equally distant from fixation and, therefore, were not expected to create a stimulus-driven bias along the vertical axis (McSorley, Haggard, & Walker, 2004). Instead, the salience of a distractor might be modulated because of a cue-induced attentional bias (e.g., the above distractor being more salient than the one below after reading "HAPPY").

In addition to being equidistant from fixation, the two distractors had the same colour (both being either black or white). We varied the colour of the distractors because of previous evidence suggesting a metaphorical congruency effect between brightness and valence (Meier, Robinson, & Clore, 2004). In a semantic evaluation task, Meier et al. (2004) found faster responses to positive words printed in white, and faster responses to negative words printed in black, compared to when the colour and valence were metaphorically incongruent. In light of those findings, it is conceivable that *up* may become more salient if white distractors follow a positive cue, and *down* may become more salient if black distractors follow a negative cue. Contrary to this prediction, Lakens, Semin, and Foroni (2012) have recently demonstrated the necessity of attending to the colour dimension for obtaining the colour–valence congruency effect. In accordance with Lakens et al., given that distractor colour is task irrelevant in the present study, it is likely that distractor colour will not affect performance at all.

In short, this experiment will test valence-induced attentional bias along the vertical axis by monitoring saccade trajectory deviations. According to the metaphorical activation account, processing positive valence increases the salience of the space above fixation, resulting in upwards and downwards deviations in fast saccades and slow saccades, respectively. On the other hand, processing negative valence increases the salience of the space below fixation, resulting in downwards and upwards deviations in fast and slow saccades, respectively. In other words, the metaphorical activation account predicts the impact of cue valence to be modulated by saccade speed; whereas fast saccades are expected to deviate towards the salient location (e.g., upwards after a positive cue), slow saccades are expected to deviate away from the salient location (e.g., downwards after a positive cue). Furthermore, this valence–space interaction might also interact with distractor colour (e.g., more upwards salience with positive cues and white distractors).

Method

Participants. Twelve undergraduate students (age range = 18–26) at the University of Toronto took part in the experiment in exchange for course

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credit. They all reported normal or corrected-to-normal vision and they were all unaware of the purpose of the experiment. All experimental protocols were approved by the Ethics Committee at the University of Toronto.

Apparatus. Eye movements were monitored using a camera based eye-tracker (SR Research Eyelink 1000) with a temporal resolution of 1000 Hz and an RMS spatial resolution of 0.01° of visual angle. The start and end of a saccade were defined using the velocity and acceleration thresholds of 30°/s and $8000°/s^2$, respectively. A 9-point calibration and validation procedure was used to determine location of fixations on the screen. Eye position was monitored using the right eye, and the calibration-validation procedure was repeated until an average measurement error below 0.5° was obtained. Stimuli were displayed on a 19-inch flat-screen CRT set at a refresh rate of 85 Hz and 1024 × 768 pixels resolution. A head/chinrest was used to keep the participants' heads at the fixed distance of 60 cm from the screen.

Stimuli. Cues consisted of three categories of positive (JOY, BLISS, POSITIVE, CHEER, HAPPY, SMILE), negative (SAD, SORROW, CRY, GLOOMY, DESPAIR, FROWN), and neutral (TABLE, CHAIR, COUCH, SHELF, DESK, BED) words. Cues were presented at fixation in Arial font (font size = 24 pixels). The visual target was a circle presented laterally at the left or right side of fixation (diameter = 0.4°, eccentricity = 6°). Distractors were two squares presented laterally above and below fixation (side = 0.4°, eccentricity = 6°). Cues and targets were both presented in yellow colour (~50 Cd/m^2), distinct from the colour of the distractors, which were both black (~2 Cd/m^2) or white (~50 Cd/m^2). All stimuli were presented against a grey (~10 Cd/m^2) background and the stimuli had equal contrast relative to the grey background, (contrast ratio ~5:1). Figure 1 shows one possible sequence of events during a trial.

Procedure. Each trial was initiated by the participant, by looking at the centre of the screen (at the drift correction stimulus: a white ring with an outer diameter of 0.35° and an inner diameter of 0.16°) and pressing the spacebar. When the keypress and participant's gaze at the centre were both detected, the trial would begin. First, a yellow fixation cross (0.4° × 0.4°) appeared at the centre of the display for 1000 ms. Next, the cue word replaced the fixation cross and remained for 400 ms. Then, the fixation cross reappeared, remaining for another 200 ms. Next, the saccade target appeared at the left or right periphery. Participants were instructed to make a speeded saccade response to the precise location of the target only when the cue word related to an affect/mood concept (test trials), while maintaining central fixation when the cue referred to a piece of furniture (catch trials), in order to ensure semantic processing of the cue. Regions of interest (ROIs; radius = 1.5°) were defined around the central fixation (central ROI) and the peripheral target locations (peripheral ROIs) to detect performance errors. On catch trials, an error was defined as gazing outside the central ROI. On

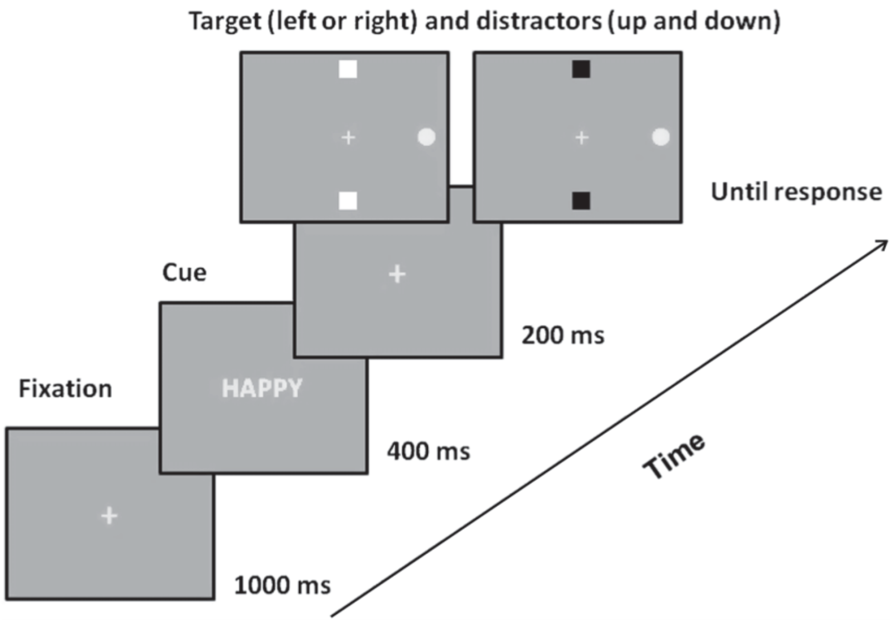

Figure 1. Sequence of events in a sample trial of Experiment 1. Participants performed speeded saccadic response to the peripheral target onset (left or right), unless the cue referred to a piece of furniture (e.g., "TABLE"), while ignoring the white/black distractors above and below fixation.

test trials, correct performance was defined as performing a saccade to the correct peripheral ROI (without ever moving into the nontarget peripheral ROI).

With both presentations of the central fixation cross, position of the gaze was monitored to ensure central fixation. If a saccade was detected prior to cue or target onset, participants received an auditory error signal (200 Hz, 100 ms) and the trial was recycled (presented again at a randomly chosen point in the experiment). A saccade to the target on a catch trial would also elicit the error signal and recycling of the trial.

Design and analysis. Participants performed one practice block of 20 trials and two experimental blocks of 108 trials. Trial characteristics, cue type (positive, negative, or neutral), target location (left vs. right), and distractor colours (black vs. white) were all pseudorandomized and equiprobable. Curvatures of saccade trajectories were calculated using the quadratic method introduced by Ludwig and Galchrist (2002). This method involves rescaling all saccade paths along a fixed horizontal distance (between -1 and $+1$) and then finding the best-fitting quadratic function for each path (i.e., $y = ax^2 + bx + c$, wherein y and x represent positions along the vertical and horizontal axes). Parameter "a", the quadratic coefficient, indicates the magnitude of curvature for each saccade, with $a = 0$ representing a linear trajectory. Positive and negative values of the quadratic coefficient represent upwards and downwards curvatures, respectively. Furthermore, to investigate

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the time course of deviation, responses were divided into two equal bins of slow and fast based on each participant's median saccadic response time (RT). Thus, in the following analysis of saccade curvatures, we divided trials based on cue valence (positive vs. negative), saccade speed (fast vs. slow), and distractor colour (black vs. white).

Results and discussion

Saccade curvatures. After excluding anticipatory saccades (RT < 100 ms, 1% of trials), late saccades (RTs above Mean $+ 2.5$ *SD*, 4% of trials), and incorrectly performed saccades (i.e., saccades that did not land on the target ROI, 9% of trials), missed trials (i.e., blinks or failures to record, 5% of trials), trials were binned into two equal groups of fast (Mean $\pm SE = 228 \pm 8$ ms) and slow (300 ± 13 ms) based on the median RT of each participant. Mean saccade curvatures (quadratic coefficients) were then submitted to a $2 \times 2 \times 2$ ANOVA, with cue (positive vs. negative), saccade speed (slow vs. fast), and distractor colour (white vs. black) as the three factors. None of the main effects or interactions reached significance ($F < 1$), except for the two-way interaction between cue and saccade speed, $F(1, 11) = 15.21$, $p < .01$, $\eta_p^2 = .580$. The two-way interaction revealed different patterns of change from fast to slow saccades across positive and negative cues (Figure 2). With positive cues, there was a 0.020° decrease in curvature from fast to slow saccades, which significantly differed from zero, $t(11) = 2.25$, $SE = .009$, $p <$ .05; with negative cues, by contrast, there was a 0.003° increase in curvature

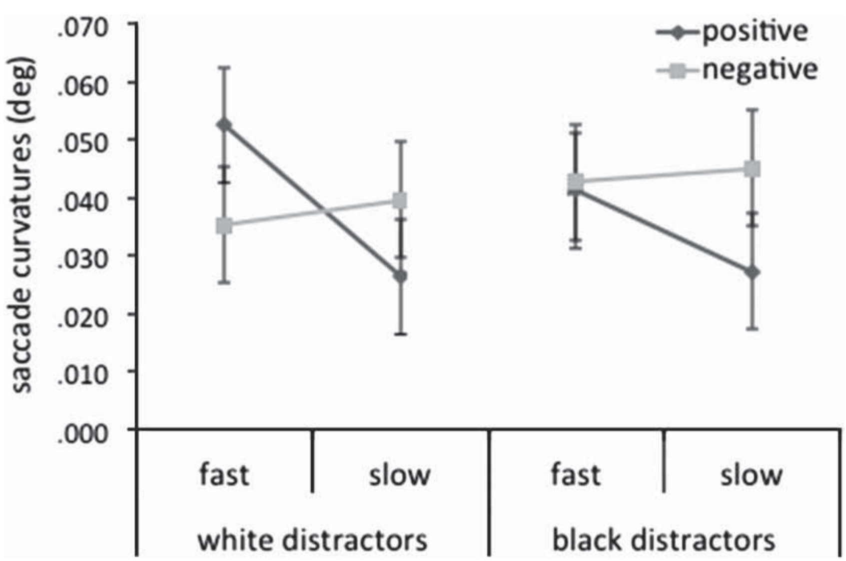

Figure 2. Saccade trajectory deviations (calculated using the quadratic method; Ludwig & Gilchrist, 2002) in Experiment 1 graphed as a function of distractor colour, cue type (positive vs. negative), and saccade speed. Error bars represent within-subject standard errors (Cousineau, 2005).

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from fast to slow saccades, which did not differ significantly from zero ($t < 1$). Assuming that fast saccades deviate towards the salient location, whereas slow saccades (reflecting top-down inhibitory processes) deviate away from the salient location, the pattern of interaction is consistent with higher salience of *above* after positive cues. Thus, the pattern of interaction seems to be mainly driven by positive cues.

It is worth noting that saccades were, on average, curved upwards (Mean $= 0.039°$). It is commonly observed that, in the absence of any salient distractors, saccades continue to deviate upwards (for horizontal saccades) or rightwards (for vertical saccades). A nonzero baseline for saccade curvatures likely indicates a baseline asymmetry in the salience of one hemifield over the other. We will return to this issue in Experiment 2.

Saccade RT and errors. To test whether the valence–space interaction in trajectory deviations were accompanied by changes in saccade RTs or errors, we submitted both RT data and percentage errors to a $2 \times 2 \times 2$ ANOVA, using speed, cue, and distractor colour as independent factors. For RT data, the analysis revealed only the obvious effect of speed, $F(1, 11) = 131.88$, $p < .001$, $\eta_p^2 = .923$. Not finding an effect of cue or distractor colour on RTs supports the assumption that the variable saccade speed could be treated as orthogonal to the other two variables (cue type and distractor colour).

Analysis of errors was performed, using the same ANOVA as before, separately for proportion of missed trials (i.e., blinks or failures to record) and for incorrectly performed saccades. First, unsurprisingly, in analysing the proportion of missed trials none of the main effects or interactions reached significance (Fs < 1). Second, in analysing the proportion of incorrect saccades (i.e., saccades towards the distractors), a main effect of colour was found, $F(1, 11) = 14.50$, $p = .003$, $\eta_p^2 = .569$, revealing more incorrect saccades with white distractors ($M \pm SE = 11\% \pm 4\%$) compared to black distractors ($7\% \pm 3\%$). Although the distractors were equated with regard to contrast ratio, the white distractors were more similar to the saccade targets in brightness, which might have given a top-down benefit to white distractors compared to black distractors (Becker, Folk, & Remington, 2010). No other main effect or interaction reached significance, although there was a trend towards a two-way interaction between colour and saccade speed, $F(1, 11) = 3.13$, $p = .105, \eta_p^2 = .222$. Examining this trend, we found that a higher proportion of errors with white distractors was only observed in slow saccades (errors with white and black distractors (12% vs. 6%), $t(11) = 3.27$, $SE = .019$, $p = .007$, and not in fast saccades (errors with white and black distractors: 9% vs. 9%), $t(11) < 1$. An increase with time in the effect of distractor colour also suggests that the source of this difference may be a top-down benefit for white distractors (Theeuwes, Atchley, & Kramer, 2000).

A final step in analysing incorrect saccades involved a direction-specific analysis. Namely, upwards and downwards incorrect saccades were coded as $+1$ and -1, respectively. With this method, an equal number of upwards and downwards errors in a condition would result in 0% direction-specific error, and a higher proportion of downwards errors would result in a negative score. Most importantly, analysis of direction-specific proportion of incorrect saccades revealed no main effect of cue, $F(1, 11) = 1.58$, $p > .2$. Nor did cue interact with other factors (Fs < 1.4, ps $> .2$). That is, positive and negative cues did not systematically produce saccades landing on incorrect (e.g., metaphorically congruent) locations. Among other effects, only the two-way interaction between speed and distractor colour approached significance, $F(1, 11) = 3.27$, $p = .10$, $\eta_p^2 = .229$. This trend does not seem particularly informative given the purpose of the present study.[1]

Testing left/right asymmetry. Previous work suggests that the distribution of attention along the horizontal axis might also be sensitive to conceptual processing (e.g., Chasteen et al., 2010; de la Vega et al., 2012). If so, we should see a pattern of interaction between target location (left vs. right) and cue type (positive vs. negative) in RT data. The metaphorical connection between colour judgement and semantic valence also predicts a congruency effect between distractor colour (white vs. black) and cue types. To test these possibilities, mean RTs were submitted to a repeated measures ANOVA with distractor colour, cue type, and target location as factors. None of the main effects or interactions reached significance, although the main effect of target location approached significance, $F(1, 11) = 3.22$, $p = .100$, $\eta_p^2 = .226$, indicative of faster leftwards saccades ($M \pm SE = 255 \pm 9$ ms) compared to rightwards saccades ($M \pm SE = 265 \pm 12$ ms). Neither the Cue $\times$ Target location interaction, nor the Cue $\times$ Colour interaction were significant (F-values < 1). The three-way interaction also did not reach significance, $F(1, 11) = 1.27$, $p = .294$.

Overall, the results of the first experiment revealed a baseline upwards tendency in saccade trajectory deviations. More importantly, positive cues further increase the salience of the segment above fixation. That is, from fast to slow saccades, the upwards deviations decreased significantly, suggesting the involvement of top-down processes that inhibit salient, but irrelevant locations (van Zoest et al., 2004; Walker & McSorley, 2008).

[1] With black distractors, we found that fast incorrect saccades tended to be more upwards than slow incorrect saccades, direction-specific proportion of errors for fast and slow saccades: 3% vs. –1%, $t(11) = 2.17$, $SE = 0.02$, $p = .052$. By contrast, with white distractors, slow incorrect saccades tended to be more upwards than fast incorrect saccades, although this pattern was not significant, direction-specific errors: 0% vs. 2%, $t(11) = 1.12$, $SE = 0.024$, $p = .28$

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EXPERIMENT 2

Although the up/down locations were task irrelevant in Experiment 1, they were part of the display in the form of distractors. Participants, therefore, had the option of allocating attention to a distractor location, despite the fact that those locations were consistently irrelevant. The next step in testing the robustness of the metaphorical congruency effect is by removing those distractors. If the valence-induced salience along the vertical axis depends on the presence of distractor objects, we should not observe the same pattern of trajectory deviations in this experiment. On the other hand, if the valence-induced change in visual salience does not require the presence of distractors, a similar pattern of deviations should be observed in the present experiment. This finding would confirm the status of the conceptual processes as a factor in modulating visuospatial salience.

Method

This experiment was identical to Experiment 1 in all regards, except for the removal of the peripheral distractors above and below fixation. Twelve new undergraduate students (age range = 18–22) at the University of Toronto took part in the experiment in exchange for course credit. They all reported normal or corrected-to-normal vision and they were all unaware of the purpose of the experiment. Participants performed one practice block of 20 trials and two experimental blocks of 108 trials. Trial characteristics, cue type (positive, negative, or neutral), and target location (left vs. right) were pseudorandomized and equiprobable.

Results and discussion

After excluding anticipatory saccades (RT $<$ 100 ms, 1% of trials), late saccades (RTs above Mean + 2.5 *SD*, 4.1% of trials), incorrectly performed saccades (i.e., saccades that did not land on the target ROI, 6% of trials), and missed trials (i.e., blinks and failures to record, less than 1% of trial), trials were binned into two equal groups of fast (Mean $\pm$ SE = 201 $\pm$ 6 ms) and slow (257 $\pm$ 8 ms) based on the median RT of each participant. Mean saccade curvatures were then submitted to a 2 $\times$ 2 ANOVA, with cue (positive vs. negative) and saccade speed (slow vs. fast) as factors (Figure 3). The main effects of speed, $F(1, 11) = 1.07$, $p = .32$ and cue type ($F < 1$) did not reach significance, but the interaction did, $F(1, 11) = 5.07$, $p = .046$, $\eta_p^2 = .316$. Similar to Experiment 1, with positive cues there was a 0.020° reduction in curvatures from fast to slow saccades, which was significantly greater than zero, $t(11) = 3.04$, $SE = 0.008$, $p = .011$. By contrast, with negative cues, there was a nonsignificant (less than 0.001°) reduction in curvatures from fast to slow saccades ($t < 1$). Assuming that fast saccades deviate towards the salient

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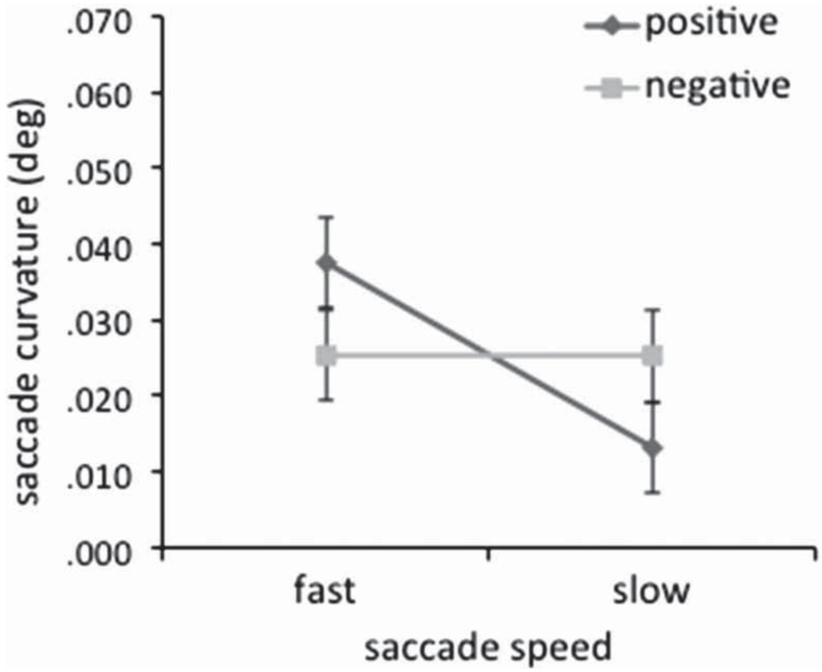

Figure 3. Saccade trajectory deviations in Experiment 2 graphed as a function of cue type (positive vs. negative), and saccade speed. Error bars represent within-subject standard errors (Cousineau, 2005).

location, and slow saccades deviate away from the salient location, the pattern of interaction is consistent with higher salience of the segment above fixation after positive cues.

Saccade RTs and errors. To test whether the valence-space interaction in trajectory deviations was accompanied by changes in saccade RTs or errors, we submitted both RT data and proportion of incorrect saccades to the same 2×2 ANOVA as before. Given that missed trials (i.e., blinks and failures to record) constituted a small portion of trials (less than 1%), we confined error analysis to the analysis of incorrect saccades. First, for RT data, the analysis revealed only the obvious effect of speed, $F(1, 11) = 37.52$, $p < .001$, $\eta_p^2 = .773$. For incorrect saccades, the main effect of speed approached significance, $F(1, 11) = 3.31$, $p = .096$, $\eta_p^2 = .231$ indicating more errors with fast saccades (7%) than with slow saccades (5%). Finally, incorrect saccades were coded in a direction-specific manner (upwards and downwards incorrect saccade were coded as $+1$ and -1, respectively) and were submitted to the same 2×2 ANOVA. This analysis revealed no significant main effect or interaction (Fs < 1). We should note that the average direction-specific error scores were particularly low, though reflecting an upwards tendency ($M \pm SE = 2\% \pm 1\%$).

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Testing left/right asymmetry. To test the possible congruency effects of positive-right and negative-left, mean RTs were submitted to a 2×2 repeated measures ANOVA with cue type (positive vs. negative) and target location (left vs. right) as factors. None of the main effects or interactions reached significance, although the main effect of target location approached significance, $F(1, 11) = 3.11$, $p = .10$, $\eta_p^2 = .220$. Unlike Experiment 1, leftwards saccades ($M \pm SE = 226 \pm 6$ ms) were slightly slower than rightwards saccades ($M \pm SE = 220 \pm 6$ ms). To ensure that the absence of the metaphorical congruency effect along the horizontal axis was not due to low statistical power, we collapsed the data from both experiments and reanalysed the data. We also added saccade speed as an additional factor, since the interaction along the horizontal axis may also be sensitive to saccade speed (e.g., Khalid & Ansroge, 2013, showed that the congruency effect between irrelevant direction words, "LEFT", "RIGHT", and saccade direction was strongest in fast saccades). A $2 \times 2 \times 2$ ANOVA with cue type, speed, and target location as factors revealed only the expected main effect of speed, $F(1, 23) = 214.69$, $p < .001$, $\eta_p^2 = .903$. Neither the interaction between cue and target location, $F(1, 23) = 1.67$, $p = .21$, $\eta_p^2 = .068$, nor the three-way ($F < 1$) interaction reached significance.

Results of Experiment 2 (no distractors) replicated those of Experiment 1 (distractors above and below fixation). The interaction between saccade speed and cue valence, which was mainly driven by positive cues, suggests higher salience of the segment above fixation after processing positive valence. Importantly, this finding was still present in the absence of distractors along the vertical axis. These results support a metaphorical congruency effect that does not rely on task relevance of the vertical axis.

Given the overall tendency of saccades to have upwards deviation, regardless of cue valence, we were concerned with the possibility that our findings were a product of this overall upwards tendency. To examine this possibility, we combined the two data sets from Experiments 1 and 2, and split the data based on the direction of saccade deviation (upwards vs. downwards), and repeated the 2×2 ANOVA on each subset. As Figure 4 shows, when isolating the saccades with downwards deviation, the same two-way interaction between speed and cue remained present, $F(1, 23) = 9.91$, $p = .005$, $\eta_p^2 = .301$. Neither the main effect of speed, nor the effect of cue, reached significance (F-values < 1).

When isolating saccades with upwards deviation, the original two-way interaction also remained significant, $F(1, 23) = 12.26$, $p = .002$, $\eta_p^2 = .348$. In addition, the main effects of speed, $F(1, 23) = 16.83$, $p < .001$, $\eta_p^2 = .423$ and cue, $F(1, 23) = 15.67$, $p = .001$, $\eta_p^2 = .405$ also reached statistical significance, when examining upwards deviations in isolation. The upwards deviation was larger with fast saccades ($0.21 \pm 0.03°$) compared to slow saccades ($0.10 \pm 0.01°$). The upwards deviation was also larger after positive cues ($0.20 \pm 0.03°$)

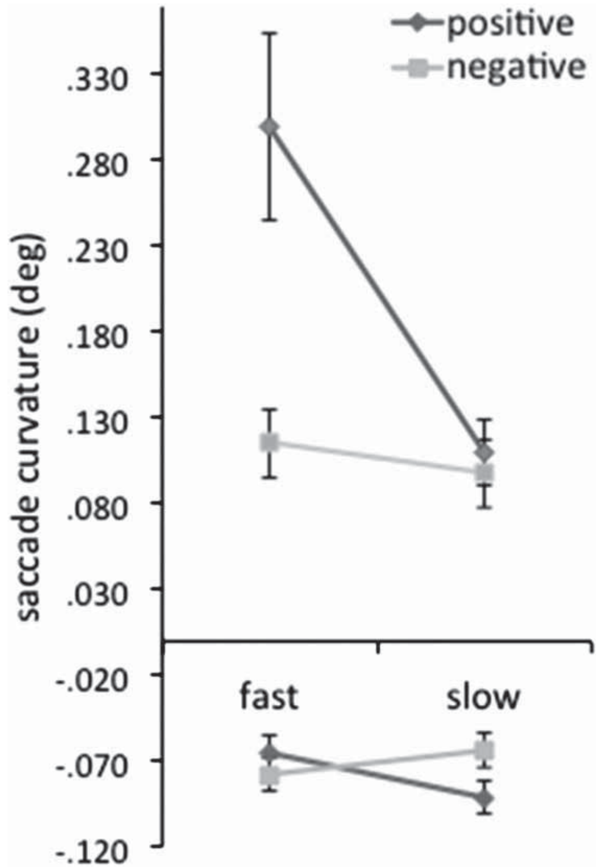

Figure 4. Saccade trajectory deviations collapsed across both experiments graphed as a function of the direction of deviation, cue type (positive vs. negative), and saccade speed. Error bars represent within-subject standard errors (Cousineau, 2005).

compared to negative cues ($0.11 \pm 0.01°$). The main effect of speed is likely indicative of the higher salience of the upper spatial hemifield, compared to the lower hemifield. Even if that is the case, it is important to note that the Speed $\times$ Cue interaction did not seem to depend on the baseline tendency for upwards deviations, because the same pattern of interaction is present for upwards and downwards saccades when examined separately.

GENERAL DISCUSSION

Concepts of positive and negative valence are metaphorically structured in space (e.g., to be happy is to be up in space), and previous evidence suggests that semantic processing of valence can, indeed, bias visual attention towards the metaphorically congruent location (Meier & Robinson, 2004; see also, Ansorge et al., 2013; Gozli et al., in press; Lakens, 2012; Santiago et al., 2012). The present study tested this metaphorical congruency effect in a context wherein up/down locations were completely task irrelevant. That is, participants

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produced eye movements along the horizontal axis after reading a single word referring to a positive or negative concept. Based on previous research on saccade trajectory deviation, we predicted that fast saccade trajectories deviate *towards* the salient segment of space, whereas slow saccades deviate *away* from the salient segment (Van der Stigchel et al., 2006; Walker & McSorley, 2008). Across two experiments, saccade trajectory deviations were consistent with the metaphorical congruency account, although this pattern was mainly driven by positive concepts. These findings support the notion that semantic processing of valence automatically recruits spatial features along vertical space regardless of the task relevance of the vertical axis.

Our findings converge with recent evidence that valence priming can result from viewing simple geometric shapes that convey vertical direction, such as a downwards pointing "V" (Larson, Aronoff, & Steuer, 2012) or from viewing displays that create illusory upwards or downwards self-motion (Seno, Kawabe, Ito, & Sunaga, 2013). In particular, Seno et al. (2013) observed that participants tend to recollect memories whose valence metaphorically match the direction of perceived self-motion (e.g., more positive memories with upwards motion). These observations suggest that spatial processing can not only bias semantic processing, but can also bias the way we recollect autobiographical memories.

In examining the perceptual foundation of concepts, the experimental context and task characteristics should be carefully considered (e.g., Gozli et al., in press; Lakens, 2011, 2012; Lakens et al., 2012; Santiago et al., 2012). The role of relevance of particular features within the experiment has recently been highlighted in a number of studies. Yee, Ahmed, and Thompson-Schill (2012) reported a robust interaction between perceptual colour (e.g., *green*) and word meaning (e.g., "cucumber") only when participants perform one block of a colour-naming task first. By contrast, no interaction was found without the initial exposure to the colour-naming task, suggesting that the initial task strengthened the association between semantic information and perceptual colour features (Yee et al., 2012). Similarly, reading words with positive and negative meaning within the context of tasks that continually demand attentional orienting to up/down locations might overestimate how spatial information can, in general, be primed through valence. Torralbo et al. (2006) made a similar argument with respect to the metaphorical association between the concepts of time (e.g., past and future) and space. Torralbo et al. found different patterns of time–space interaction (one consistent with time progressing left-to-right, the other consistent with time progressing back-to-front) depending on whichever spatial axis was task relevant.

Given the importance of task characteristics, it seems reasonable to consider the possibility that the link between semantic valence and spatial features might be artificially strengthened due to task characteristics. Indeed, two recent studies suggest that the valence–space interaction depends on

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participants' attention to both dimensions (de la Vega et al., 2012; Santiago et al., 2012). If participants engage in a lexical decision task, instead of valence judgement, semantic valence may no longer activate the metaphorically associated spatial feature (de la Vega et al., 2012). Similarly, reduced salience of the spatial features (e.g., up/down) within the task may weaken or eliminate the association (Santiago et al., 2012). Given that the vertical axis was completely task irrelevant in the present study, the metaphorical congruency effect reflected in saccade trajectory deviations supports the strong link between the two domains. It is especially worth comparing the present findings to those reported by Santiago et al. (2012) given that those authors did not find any sign of valence–verticality interaction once attention was not allocated to one of the two dimensions. The most likely reason for this divergence is that RT-based measures (keypress or vocal responses) are less sensitive than measures of spatial representation and spatial salience (e.g., Al-Aidross & Pratt, 2010; Gozli & Pratt, 2012). If so, then the null findings of Santiago et al. could be due to weaker metaphorical activation rather than the complete absence of such activation.

It is worth noting that, although the effect of metaphorical activation is here recorded in a measure of attentional bias (i.e., overt orienting of attention), it does not necessarily follow that semantic valence engages visual attention directly. That is, by causing patterns of sensorimotor activation that underlies representation of semantic valence, the cues may indirectly influence attention. A similar argument could be made regarding the neural basis of the present finding. The changes in saccade trajectories suggest a modulation of activity in the superior colliculus (SC), the structure that is thought to maintain the saliency map of space for oculomotor action (e.g., McPeek, Han, & Keller, 2003; McPeek & Keller, 2004). Since SC receives input from several preoculomotor maps of space (Wurtz, 1996), the present findings cannot determine the neural source of the valence-induced modulation. An important candidate, however, is the inferior parietal cortex and, in particular, areas surrounding the intraparietal sulcus (IPS). This structure has long been thought to contribute to spatial representation (Colby & Goldberg, 1999), with possible contribution to conceptual processing of numbers and magnitude (Hubbard, Piazza, Pinel, & Dehaene, 2005). More recently, IPS has been implicated in semantic valence judgement (Quadflieg et al., 2011). Thus, it seems likely that the initial deviations in saccade trajectory (i.e., fast saccades) were caused by the input from the IPS to the SC, which is then inhibited, resulting in deviations away (i.e., slow saccades) from the metaphorically congruent location.

The present experiments did not reveal a space–valence interaction along the horizontal axis (e.g., faster rightwards saccades after positive valence). Previous studies have suggested that to obtain this interaction participants must explicitly categorize words based on valence (de la Vega et al., 2012).

Furthermore, the association between valence and left/right locations seems to be driven by the asymmetry in manual motor fluency (Casasanto & Chrysikou, 2011; de la Vega, Dudschig, De Filippis, Lachmair, & Kaup, 2013). Since we did not require participants to perform manual left/right action towards target locations, or to explicitly evaluate the words, the null effect is consistent with the previous findings. Although this issue goes beyond the scope of the present study, semantic valence might indeed be associated with vertical space more robustly than horizontal space.

Although the present study found evidence in support of the automatic valence-induced activation of spatial features, this evidence was mainly driven by the positive concepts (see also, Lakens, 2012). The possible asymmetry in the strength of the connection between valence and spatial features merits further examination. Although a cumulative body of evidence suggests semantically induced activation in perceptual domains, the flexible nature of these associations, and how such flexibility serves specific tasks, should be further examined.

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