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# Modulation of motor-meaning congruity effects for valenced words

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**Abstract**

We investigated the extent to which emotionally valenced words automatically cue spatio-motor representations. Participants made speeded button presses, moving their hand upward or downward while viewing words with positive or negative valence. Only the color of the words was relevant to the response; on target trials, there was no requirement to read the words or process their meaning. In Experiment 1, upward responses were faster for positive words, and downward for negative words. This effect was extinguished, however, when words were repeated. In Experiment 2, participants performed the same primary task with the addition of distractor trials. Distractors either oriented attention toward the words' meaning or toward their color. Congruity effects were increased with orientation to meaning, but eliminated with orientation to color. When people read words with emotional valence, vertical spatio-motor representations are activated highly automatically, but this automaticity is modulated by repetition and by attentional orientation to the words' form or meaning.

**Keywords:** Automaticity, Metaphor, Motion, Space, Valence

## Introduction

Do some abstract concepts depend, in part, on mental representations of physical space? According to theories of metaphorical mental representation, linguistic metaphors like 'a *rising* price', 'a *sliding* scale, or 'a *long* engagement' suggest that many of our abstract ideas are grounded in representations of *motion* and *space*. These are, in turn, grounded directly in perceptuo-motor experiences (e.g., Clark, 1973; Lakoff & Johnson, 1999; Talmy, 1988). Although initial arguments for metaphor theory were based on descriptive linguistic data, psychological experiments provide evidence for important links between spatio-motor representations and mental representations in more abstract domains like *power* (Schubert, 2005), *happiness* (Meier & Robinson, 2004), *time* (Boroditsky, 2000), *number* (Dehaene et al., 1993), and *similarity* (Casasanto, 2008). Yet researchers are just beginning to specify what roles spatial representations may play in abstract thought.

Debates about metaphorical representation have focused on two theoretical possibilities outlined by Murphy (1996), which were impossible to distinguish based on observational linguistic data, alone. On the Strong View, representations in metaphorical source domains (e.g., space) are necessary for conceptualizing target domains (e.g., time). According to Lakoff and Johnson (1999), activating source-target mappings is obligatory: without them, "abstract thought is virtually impossible." On the Weak View, however, source domain representations make an optional contribution to people's understanding of target domains. Boroditsky (2000) tested whether spatial representations are necessary for understanding temporal language, and concluded that "spatial schemas are *useful*, but *not necessary*" (italics added).

Framing experiments in terms of the necessity of source domain representations for understanding target domains (and for understanding target-domain language in particular) helped to transform a question that was long the province of linguists and philosophers into a question that is tractable using the psychologist's toolkit. Yet continuing to test a Strong-Weak dichotomy seems unlikely to lead to further new discoveries.

On nearly any theory of metaphor, source domain representations are hypothesized to be *part* of a more complex mental representation or word meaning: on the Strong View, a necessary part. The idea that there are *necessary parts* (i.e., features) of concepts or word meanings, however, is difficult to maintain. Wittgenstein (1953) famously exploded the notion that even a simple, relatively concrete word like *game* has any features that are necessarily present in all of its instantiations. It seems unlikely that more abstract words like *value* or *justice*, whose meanings are notoriously fluid, would have any necessary parts. This suggests the necessity question should be reframed in terms of functionality: What causes source domain representations to be activated, and what functional roles do they play in understanding target domains?

Psychologists have also raised a related question about metaphor (e.g., Meier & Robinson, 2004; Meier, et al., 2007): Are source domains activated *automatically* when people understand target domains? Automaticity is of interest because it is taken as evidence against the possibility that source-domain representations are only activated strategically (perhaps consciously) when people need to communicate about abstract ideas, or in response to task demands (Meier, et al., 2007). Curiously, however, automaticity has been treated as binary; source domains either *are* or *are not* activated automatically. Yet for most aspects of concepts and word meanings, it seems unlikely that activation is fully automatic − not in the same sense that people automatically perceive the lines in the Müller-Lyer illusion to be of different lengths. As classic studies of 'semantic flexibility' suggest, context can modulate the activation of even those aspects of a word's meaning that might seem to be indispensable (e.g., Barclay, et al., 1974). Notions of automaticity that are well-suited for characterizing aspects of perceptual and motor processes may not be appropriate for characterizing aspects of meaning: meaning is not a reflex.

Traditional notions of necessity and automaticity must be tailored to fit questions about metaphor (and about meaning, more broadly). Rather than asking whether source domains are necessary for understanding target domains, it may be more fruitful to ask 'what functional roles do source-domain representations play in understanding target domains?' Rather than investigating *whether* source domain representations are activated automatically, it may be useful to ask '*to what extent* is their activation automatic, and *under what conditions* is their activation increased or diminished?' We take up these latter questions of automaticity here, assuming automaticity to be a continuum.

Emotional valence is an abstract domain that people often talk about using metaphors from space and motion: when people are optimistic they're *looking up*, and when they're sad they're *feeling down*; hopes can *rise*; morale can *drop*; spirits can *soar* or *plummet.* Behavioral studies suggest these linguistic metaphors correspond to mental metaphors: non-linguistic associative mappings from representations of motion or space to the representations of emotional valence. Stroop-like experiments show these mappings are activated when people process language with positive or negative valence, even when they're not using any linguistic metaphors.

In one study (Meier & Robinson, 2004), participants were faster to judge words like *polite* and *rude* as having positive or negative valence when positive words were presented at the top and negative words at the bottom of a computer screen (Experiment 1). Furthermore, judging words to be positive directed attention to the top of the computer screen, and judging them to be negative directed attention to the bottom (Experiment 2). Yet based on these experiments it would be premature to conclude that space-valence associations are 'automatic'. For one thing, the spatial variation from trial to trial was highly salient in Meier & Robinsons' experiments (in fact, impossible to ignore), and for another, participants made explicit judgments about the valence of the words. Thus, the tasks strongly focused attention on both the source and target domains.

To address these concerns, Casasanto (2008) adapted a spatial interference task of Zwaan & Yaxley's (2003) for use with valenced words. Participants saw pairs of words, one above and the other below fixation, and made speeded synonym-antonym judgments. Target word pairs were antonyms, one with positive and the other with negative valence. Participants were fastest to classify the pairs as antonyms when the positive word appeared above the negative (e.g., *wealthy* above *poor*). In a second experiment, participants were faster to make lexical decisions on positive-valence words (e.g., *brave*, *ethical*) when they were presented above non-word distractors, and on negative-valence words (e.g., *failure*, *hate*) when presented below non-word distractors. This was true even though neither the spatial position of the words, nor their valence, nor any other part of their meaning was relevant to the task.

In a third experiment, Casasanto (2008) presented positive and negative words in the center of a screen, in either red or blue letters. On the right and left of the screen there were three large boxes. The top box was red and the bottom box was blue (or vice versa). The middle box was white, and was filled with marbles. Participants were instructed that as soon as each word appeared, they should move one marble with each hand into the box corresponding to the color of the word's font, as quickly as possible. They moved marbles fastest when the direction of movement was congruent with the spatial schema suggested by the word's valence. This was true even though movements were cued only by the words' colors: not only was their meaning irrelevant, the tasks did not even require participants to process the words *as words.*

These Stroop-like congruity effects suggest that spatial representations are activated with a considerable degree of automaticity when people read valenced words. The goal of the present study was to test the limits of this automaticity. In Experiment 1, we tested whether repeating stimuli modulated the magnitude of the space-valence congruity effect. Casasanto's (2008) marble-moving task was adapted for use with button presses, to automate response coding. Stimuli were presented twice, in successive blocks, and reaction times were compared across blocks. In Experiment 2, we tested whether attentional orientation influenced the magnitude of space-valence congruity effects. We used a Task Set Inertia manipulation (Allport & Wylie, 2000). Distractor trials oriented attention during the target trials toward either semantic or perceptual aspects of the target words.

## Experiment 1: Does repetition modulate motor-meaning congruity effects?

Experiment 1 tested whether motor-meaning congruity effects observed in previous studies would be modulated by repetition of the same stimulus words.

### Methods

**Participants** Native English-speaking UC Berkeley students (N=20) participated in exchange for course credit or payment.

#### Materials

Two lists of 48 English words were created, one with positive and the other with negative valence (e.g., *wealthy*, *poor*, *virtuous*, *evil*, *joy*, *disgust*, etc.), totaling 96 stimuli. The words were nouns and adjectives that have no literal spatial meaning, but which subjects in a previous norming study spatialized consistent with their metaphorical associations (e.g., placing *wealthy* above *poor*; *virtuous* above *evil*, etc.) Positive and negative words did not differ in frequency (p=0.70), number of syllables (p=0.60), or number of letters (p=0.12), by two-tailed t-tests.

Stimuli were presented on a CRT monitor with a refresh rate of 60 Hz. A standard QWERTY keyboard was mounted vertically directly underneath the monitor, and participants responded using three of the keys: top (the A key), bottom (the apostrophe key), and middle (the H key). The top and bottom keys were colored green and purple, and the assignment of colors to keys was counterbalanced across participants. The middle key was always colored white.

**Procedure** All 96 words were presented one at a time in random order in block 1, and again in a new random order in block 2. Half of the words were in green letters and half in purple letters. The assignment of colors to words was the same for both blocks within-subjects, and counterbalanced between subjects.

Participants began each trial by holding down the middle (white) key with the pointer or middle finger of the dominant hand. A fixation cross appeared for 1000ms-1500ms on a rectangular distribution (to prevent anticipatory releases of the middle key). When the fixation disappeared, a word appeared in the center of the screen for 2000 ms in lowercase, bold 28-point Arial font (purple or green), on a black background. Participants were instructed to release the white key and press the key matching the color of the text as quickly as possible. Only the color of the word was relevant to the response: the word's meaning was irrelevant, and the direction of the response was incidental. But because the purple and green keys were positioned vertically, one above the other, each key press required the participant to make either an upward or a downward movement. After pressing the colored key, participants returned their finger to the white key. Pressing the white key initiated the next trial.

The color of the words was orthogonal to their valence. Therefore, for half of the trials the direction of the correct response was congruent with the valence of the word (e.g., if the word *joy* appeared in green and the green key was on top), and for the other half of the trials direction and valence were incongruent (e.g., if the word *joy* appeared in purple and the purple key was on bottom).

Participants received warning messages, displayed for 2500 ms, if they released the middle key too early (less than 200 ms after word onset) or too late (more than 1000 ms after word onset). Participants performed 16 practice trials prior to the first block. Halfway through each block, they were given a rest, and chose when to continue.

## Results and Discussion

### Accuracy

Participants pressed the correct button for over 99% of trials. Accuracy did not differ as a function of congruity or block (t-values<1).

### Reaction Times

We collected two reaction times: Release Time (measured from the onset of the word to the release of the middle white key), and Press Time (measured from the onset of the word to the press of the colored key). From these we computed Travel Time (Press Time - Release Time). Trials for which Press Time was more than two standard deviations from the participant's mean were excluded from further analysis (143 out of 3840 trials, 3.7%).

**Release Times** Mean Release Times are given in fig 1a-b. Omnibus 2 × 2 × 2 ANOVAs showed a 3-way interaction of Direction (upward, downward), Valence (positive, negative), and Presentation (first, second), both by subjects ($F_1(1,19)=5.95$, $p=.03$) and by items ($F_2(1,94)=5.83$, $p=.02$). The predicted motor-meaning congruity effect would be indicated by a 2-way interaction of Direction × Valence. There were no significant 2-way interactions in the data from both presentations, combined (all $F$'s<1), so separate 2-way ANOVAs were conducted to test for this effect within each block.

Presentation 1 showed the predicted Direction × Valence interaction ($F_1(1,19)=4.67$, $p=.04$; $F_2(1,94)=3.26$, $p=.07$). Presentation 2 showed a slight trend in the opposite direction, but the Direction × Valence interaction did not approach significance ($F_1(1,19)=1.60$, *ns*; $F_2(1,94)<1$, *ns*).

**Press Times** Mean Press Times are given in Figure 1c-d. Omnibus 2 × 2 × 2 ANOVAs showed a 3-way interaction of Direction (upward, downward), Valence (positive, negative), and Presentation (first, second), by subjects and by items ($F_1(1,19)=9.17$, $p=.007$; $F_2(1,94)=3.72$, $p=.06$).

Presentation 1 considered alone showed the predicted Direction × Valence interaction ($F_1(1,19)=4.43$, $p=.05$; $F_2(1,94)=3.32$, $p=.07$). Presentation 2 showed a slight trend in the opposite direction, but the Direction × Valence interaction did not approach significance ($F_1(1,19)=2.84$, *ns*; $F_2(1,94)<1$, *ns*).

Overall, there was a strong main effect of direction for Press Times ($F_1(1,19)=131.62$, $p=.0001$; $F_2(1,94)=764.76$, $p=.0001$), which was not present for Release Times. This effect appears to be an artifact of kinematic differences between top and bottom key presses, which used different muscle groups due to the positioning of the keyboard. This main effect is not relevant to the predicted motor-meaning congruity effect.

**Travel Times** Neither the omnibus 3-way ANOVAs nor the separate 2-way ANOVAs testing relationships between Direction and Valence in Presentation 1 and Presentation 2 showed any interactions that approached significance. This suggests that congruity effects arise during action planning rather than action execution.

In summary, we found the predicted Direction × Valence interaction only during the first presentation of the stimulus words. This motor-meaning congruity effect was absent when words were presented a second time (in Block 2). To test the effect of repetition directly, we compared the magnitude of the congruity effect (incongruent trials -

congruent trials) across blocks, both for Release Times ($t_1(19)=2.46$, $p=.02$; $t_2(95)=2.37$, $p=.02$) and Press Times ($t_1(19)=3.02$, $p=.007$; $t_2(95)=1.95$, $p=.05$). Repetition significantly reduced the effect of congruity between movement direction and valence.

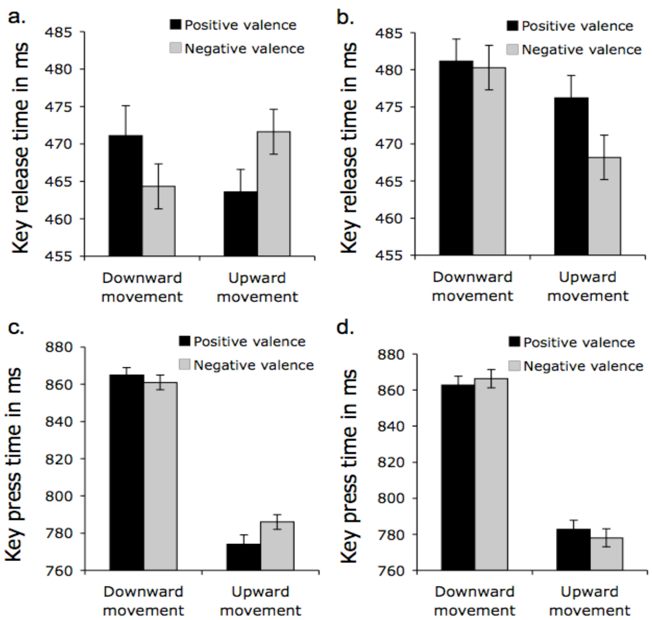


**Figure 1.** Results of Experiment 1. Top: RT measured from the release of the middle key for Presentation 1 (1a) and Presentation 2 (1b). Bottom: RT measured from the press of the colored key for Presentation 1 (1c) and Presentation 2 (1d). Error bars indicate s.e.m.

## Experiment 2: Does attentional orientation modulate motor-meaning congruity effects?

What accounts for the disappearance of the congruity effect when words are repeated? On one possibility, participants may have become so efficient at performing the task that there was no opportunity to detect any interference from irrelevant dimensions of the stimuli: a ceiling effect. Yet an increase in efficiency should result in an overall decrease in reaction times from Presentation 1 to Presentation 2. Since we found no main effect of Presentation, this explanation is not well supported.

Alternatively, it may be that with practice, participants are better able to attend to the relevant dimension of the stimuli (their color) as opposed to irrelevant dimensions (their valence, and more generally their meaning). To test this explanation, for Experiment 2 we adapted Allport & Wylie's (2000) Task Set Inertia paradigm. Target trials were the same as in Experiment 1, but distractor trials were added. For one group of participants, the distractor trials oriented attention toward the meanings of the target words. For the other group, distractors oriented attention toward the target words' colors. We compared reaction times across groups to determine whether attentional orientation modulates the magnitude of space-valence congruity effects.

## Methods

**Participants** Native English-speaking UC Berkeley students (N=48) participated for course credit or payment.

### Materials and Procedure

The experimental apparatus for Experiment 2 was the same used in Experiment 1. The primary task was identical to Presentation 1 of Experiment 1, except that 48 distractor trials were added, randomly intermixed with the 96 target trials, for a total of 144 trials. Participants were assigned to perform one of the two versions of the task, one with distractors designed to orient attention to the Meaning of target words, and the other to the Color of target words. Responses to these distractors were not recorded.

Stimuli in the Meaning Orientation condition were 24 concrete nouns, half referring to animate and half to inanimate objects. Whereas target words were shown in purple or green letters, distractors were in white letters. Participants performed a go/no-go animacy judgment, releasing and then re-pressing the middle white button to indicate the distractor word named something animate. In the Color Orientation condition, a 2×2 grid of grey squares appeared. On half of the trials the grid was empty, and on the other half an unsaturated red "X" appeared in one of the squares, balanced across the 4 positions. Participants performed a go/no-go X-detection judgment, re-pressing the middle white button to indicate that a red X was present.

Only one block of trials was performed, and brief rests were provided twice, after the first 48 trials and then after the next 96 trials.

Initially, 16 participants were assigned to each of the distractor conditions. Upon preliminary analyses, the predicted congruity effect was present in the Meaning Orientation condition but not in the Color Orientation condition. Sixteen new participants were added to the Color Orientation condition, to ensure that the absence of a congruity effect was not due to lack of statistical power. Since results for the second cohort did not differ from results in the first, data from both cohorts were combined for the analyses reported here.

## Results and Discussion

### Accuracy

Participants correctly pressed the button corresponding to the color of the word for 100% of target trials. Performance on distractor trials was not analyzed.

### Reaction Times

Omnibus 2 × 2 × 2 ANOVAs showed no significant 3-way interaction of Direction (upward, downward), Valence (positive, negative), and Distractor Type (Meaning, Color). The Press Time data showed the predicted 2-way interaction of Direction and Valence in the Meaning Orientation condition ($F_1(1,15)=6.12$, $p=.03$; $F_2(1,94)=4.23$, $p=.04$), but not in the Color Orientation condition ($F_1(1,31)=.11$, *ns*; $F_2(1,94)=.55$, *ns*). A slight trend toward the same Direction × Valence interaction in the Meaning Orientation condition was found for Release Times ($F1(1,15)=1.61$, $p=.22$; $F2(1,94)=1.57$, $p=.21$) and Travel Times ($F1(1,15)=4.81$, $p=.05$; $F2(1,94)=.82$, $p=.37$). The absence of a significant effect on Release Times was unexpected, given the results of Expt. 1. This may have been the result of noise introduced into the early phase of target responses when participants were required to task-switch following distractor trials.

To test the predicted effect of attentional orientation on Press Times directly, we compared the magnitude of the congruity effect (incongruent trials - congruent trials) across conditions. According to a Wilcoxon signed rank test, the congruity effect was greater in the Meaning Orientation condition (15.1 ms) than in the Color Orientation condition (1.7 ms; difference of means=13.4 ms, W=176, $p=.04$, one-tailed). Orienting attention toward Meaning or toward Color during distractor trials modulated the size of the motor-meaning congruity effect observed during target trials.

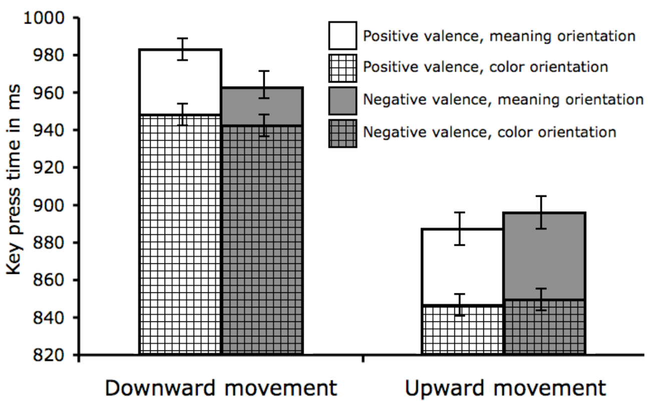


**Figure 2.** Results of Experiment 2. Space-valence congruity effects were found for target trials when distractors oriented attention to word meaning but not to word color. Error bars indicate s.e.m.

## General Discussion

In two experiments, we show effects of congruity between the valence of a word and the spatial direction of the response it cued. In both experiments participants responded only to the color of the target words, pressing the button that matched in color. The spatial directions of the responses were task-irrelevant, as were the meanings of the words. Still, participants responded fastest when the direction of the response and the valence of the word were in agreement: upward movements for positive-valence words, and downward for negative-valence words. The presence of space-valence congruity effects even during shallow, incidental processing of both space and valence suggests that the spatial component of the words' meanings was activated with a high degree of automaticity.

Both experiments also illustrate that automaticity has its limits. In Experiment 1, the motor-meaning congruity effect was found only during the first presentation of the stimuli, but not upon their repetition. Since there was no overall reduction in response times between Presentation 1 and Presentation 2, the extinction of the congruity effect does not appear to be a ceiling effect.

Experiment 2 tested an alternative explanation for the effect of repetition: perhaps with practice, participants became more adept at focusing on the task-relevant dimension of the stimuli (their color) rather than the task-irrelevant dimension (their meaning). Consistent with this proposal, when distractor trials oriented participants to the meaning of the target words, a strong congruity effect was found. By contrast, when distractor trials oriented participants to the color of the target words the congruity effect disappeared.

It is possible to interpret both the repetition effect (in Expt. 1) and the Task Set Inertia effect (in Expt. 2) as effects of attention. During the initial presentation of the words in Expt. 1 and in the Meaning Orientation condition of Expt. 2, participants failed to fully disregard the task-irrelevant meanings of the target words, one component of which is a spatial (or spatio-motor) representation with a certain direction. During the second presentation in Expt. 1 and the Color Orientation condition of Expt. 2, participants more successfully attended to the target words' colors. In Expt. 1, this was because the participants became better at restricting attention to the task-relevant dimension of the stimuli, as a result of practice. In Expt. 2, this was because of attentional 'inertia' from the colored-letter-detection distractor task.

Although this standard interpretation may be valid, there is a potential alternative that does not rely on the construct of attention ("psychology's Weapon of Mass Explanation", according to Vincent Walsh (2003). Implicit in the attentional account is an assumption that reading a word activates *its meaning.* On standard psycholinguistic theories, *the meaning* of a word is retrieved from the mental lexicon, much the way a definition can be looked up in a dictionary. Then attention determines how strongly the word's meaning is activated, and which aspects of the meaning are highlighted.

On alternative accounts of the mental lexicon, however (e.g., Elman, 2004), words don't have meanings; rather, words are cues to activate stored information. The particular constellation of information that gets activated in any instance depends both on the cue, *per se*, and on the context in which the cue is encountered. As a consequence, a word's meaning is unlikely to ever be the same over successive experiences (see James, 1892/2001). 'Meaning', then, is nothing more (or less) than the effect that the word-in-context has on the representations formed in the mind of its reader (or hearer).

On this dynamic view of word meaning, our stimulus words cued the activation of spatio-motor representations in some contexts more than in others. The results of the first block of Expt. 1 suggest that the target words typically cue upward or downward spatio-motor representations such that these representations were activated even though they are irrelevant to the task at hand. But the same words serve as weaker cues for activating such task-irrelevant representations in contexts where the participant's experience (either with the preceding block of target trials or with the intermixed distractor trials) has adjusted the cue validity of the words' color relative to validity of other pieces of information associated with the words, such as their valence.

Ordinarily, for the words we used as stimuli, valence has high cue validity and the color of the ink has low cue validity: reading that someone is *a hero* is normally a valid cue that the reader should construe the referent positively, regardless of the color *hero* is printed in. But the typical cue validity of words' color and valence is reversed in our tasks, because of the tasks' goals. Seeing a word in green letters is a valid cue that the item should be construed as a member of the category of "up-words" (or "down-words"), regardless of the word's valence or other aspects of its meaning. The weights that participants assign to Color and Meaning as cues, it seems, can be adjusted by the experience of doing the primary task repeatedly, or by the addition of distractor trials that require either color processing or meaning to be processed exclusively.

The present data may be equally consistent with the first proposed account (that words have meanings and attention determines which parts of their meanings get activated) and with the second (that words are cues, and the same cues activate different sets of information depending on the contexts in which they are encountered). Arguably, the second view is preferable on grounds of parsimony: the appearance and disappearance of space-valence congruity effects can be explained based on contextual modulation of retrieval cue weights, alone, rather than on retrieval dynamics *and* the intervention of attention. Distinguishing these accounts definitively will require further experiments.

## Conclusions

Some versions of metaphor theory propose that source domain representations are activated automatically when people process words or concepts in target domains (Lakoff & Johnson, 1999). Experimental results have been interpreted as evidence for this automaticity (e.g., Meier & Robinson, 2004). Here we show that, indeed, spatio-motor representations are activated with a surprising degree of automaticity when people read words with positive or negative emotional valence. Space-valence congruity effects are found even when both space and valence are processed shallowly and incidentally.

The present results make clear that automaticity has its limits. The magnitude of space-valence congruity effects was modulated both by repetition of the valenced words and by a Task Set Inertia manipulation (Allport & Wylie, 2000). Spatio-motor representations may be activated by default when people read valenced words, but their activation is also context-dependent. These results are consistent with dynamic views of mental metaphor and of meaning construction, more broadly (Elman, 2004; Evans, 2009; Feldman, 2006).


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