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ORIGINAL ARTICLE

Biasing spatial attention with semantic information: an event coding approach

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Abstract We investigated the influence of conceptual processing on visual attention from the standpoint of Theory of Event Coding (TEC). The theory makes two predictions: first, an important factor in determining the influence of event 1 on processing event 2 is whether features of event 1 are bound into a unified representation (i.e., selection or retrieval of event 1). Second, whether processing the two events facilitates or interferes with each other should depend on the extent to which their constituent features overlap. In two experiments, participants performed a visual-attention cueing task, in which the visual target (event 2) was preceded by a relevant or irrelevant explicit (e.g., "UP") or implicit (e.g., "HAPPY") spatial-conceptual cue (event 1). Consistent with TEC, we found relevant explicit cues (which featurally overlap to a greater extent with the target) and implicit cues (which featurally overlap to a lesser extent), respectively, facilitated and interfered with target processing at compatible locations. Irrelevant explicit and implicit cues, on the other hand, both facilitated target processing, presumably because they were less likely selected or retrieved as an integrated and unified event file. We argue that such effects, often described as "attentional cueing", are better accounted for within the event coding framework.

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Introduction

Perceptual events are coded in a distributed fashion. Features of a single visually perceived object are, for example, coded separately such that each feature is coded by a different set of neural populations in the cortex. According to the Theory of Event Coding (TEC; Hommel, Müsseler, Aschersleben, & Prinz, 2001), the distributed features of an event are linked to one another through the generation of a short-lived, unified representation that consists of the integrated activity of all the relevant event features (e.g., Hommel, 1998, 2004; Kahneman, Treisman, & Gibbs, 1992; Treisman, 1998).

Important refinements to TEC have come from observing how processing two consecutive events influence one another when the two share common features. Depending on the specific characteristics of the task and the events, overlap of features can result in facilitation or interference (e.g., Frings, Moeller, & Rothermund, 2013; Frings & Rothermund, 2011; Frings, Rothermund, & Wentura, 2007; Gozli, Goodhew, Moskowitz, & Pratt, 2013c; Gozli & Pratt, 2011; Hommel, 1998, 2005; Moeller & Frings, 2014; Rothermund, Wentura, & De Houwer, 2005). For example, in an experimental task in which visual items can vary in their location and shape, repeating both features across consecutive trials tends to facilitate processing. Repeating only one of these features (partial repetition), however, can have the opposite effect, as it demands separating the feature from the old event file and incorporating it into a new event file. Partial repetition can produce a cost even

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compared to when the two events share no features at all, supporting the notion that a given feature can be integrated into one event file at a time (e.g., Hommel, 1998; Moeller, Hommel, & Frings, 2015; Müsseler & Hommel, 1997; Rothermund et al., 2005; Stoet & Hommel, 1999; see also Thomaschke, Hopkins, & Miall, 2012).

Although TEC has been used extensively in studying perception and action, it is relatively less explored in relation to conceptual processes (although see Frings et al., 2013; Gozli, Chasteen, & Pratt, 2013a; Moeller et al., 2015). What makes the theory pertinent to the conceptual domain is the strong association between concepts and sensorimotor codes (e.g., Barsalou, 1999; Gallese & Lakoff, 2005). Many authors have argued that comprehending a spatial word (e.g., "UP" or "DOWN") can involuntarily activate the associated visuospatial features, resulting in a spatial bias in processing an upcoming target (e.g., Gibson & Kingstone, 2006; Gibson, Scheutz, & Davis, 2009; Gozli, Pratt, Martin, & Chasteen, 2016; Ho & Spence, 2006; Hommel, Pratt, Colzato, & Godijn, 2001). For example, Hommel et al. (2001b) demonstrated that when a spatial word, such as "ABOVE" or "BELOW", precedes a target in a visual detection task, it results in relatively faster responses to a target at the compatible location. Similarly, concepts that are metaphorically associated with spatial features, e.g., affective concepts "HAPPY" or "SAD", or religious concepts "GOD" or "DEVIL", have been shown to activate spatial codes, and bias visuospatial attention (e.g., Chasteen, Burzdy, & Pratt, 2010; Gozli et al., 2013a; Gozli, Chow, Chasteen, & Pratt, 2013b; Meier & Robinson, 2004; Marmolejo-Ramos, Montoro, Elosúa, Contreras, & Jiménez- Jiménez, 2014; Sasaki, Yamada, & Miura, 2016; Taylor, Lam, Chasteen, & Pratt, 2015; Zanolie et al., 2012; Xie et al., 2014, 2015). Meier and Robinson (2004), for example, showed that words with a positive (e.g., "HAPPY" and "BRAVE") or negative (e.g., "SAD" and "BITTER") valence are categorized faster when they are presented in metaphorically congruent locations on the screen (i.e., top for positive and bottom for negative), suggesting that these words are conceptually represented in a physical (vertical) dimension (see also Gozli et al., 2013b). Taken together, these studies suggest that sensorimotor codes play a role in conceptual understanding. The assumptions of TEC, therefore, may be applied to the interaction between conceptual and sensorimotor performance, when the two types of tasks are coupled together. As such, we would expect to see performance differences depending on the extent of the overlap between conceptual and sensorimotor processes.

Previously, the effect of congruence or incongruence between a spatial concept and responses to a subsequent visual target has been interpreted as attentional orienting (e.g., Chasteen et al., 2010; Gozli et al., 2016; Santiago & Lakens, 2015; Taylor et al., 2015), or in terms of task-specific alignment of stimulus–response polarities (i.e., the extent to which conceptual polarities are mapped onto the task-relevant spatial dimension; see, e.g., Lakens, 2012; Lynott & Coventry, 2014; Pecher, Dantzig, Boot, Zanolie, & Huber, 2010; Proctor & Xiong, 2015). However, both spatial orienting and polarity alignment can explain only a subset of findings in which the congruence between the cue (event 1) and the target (event 2) facilitates performance. By contrast, TEC would predict that, in some instances, feature overlap (i.e., cue-target congruence) should interfere with performance. This is because the number of features activated and integrated from any event varies with the features associated with that event. Here, we use the word "feature" to refer to the set of sensorimotor, affective, and introspective activity across various modalities that accompany the encounter with, or remembering of, an event (Barsalou, 1999, 2008; Connell & Lynott, 2014). While climbing a rock, or even encountering words referring to rock climbing, for example, the set of activated and integrated features could include the tactile and proprioceptive sensations of the grip, the temperature of the rock, the exerted force, the current movement, and the sense of enjoyment or fatigue.

With regard to the number of features associated with a concept, we can dissociate between explicitly spatial words, such as "ABOVE" and "BELOW", and implicitly spatial concepts, such as "HAPPY" and "SAD". It is important to note that by "implicitly spatial words", we refer to words associated with perceptual objects that have a typical location (e.g., "SKY") and abstract concepts that are metaphorically associated with space (e.g., "HAPPY"). Explicitly spatial concepts would activate relatively fewer non-spatial features and, therefore, their corresponding event file would include fewer non-spatial features. By contrast, implicitly spatial concepts would activate a relatively larger number of non-spatial features, such as interoceptive and introspective features. Therefore, the event file corresponding to an implicitly spatial concept would include a larger number of non-spatial features. Following the assumptions of TEC, the impact of spatial meaning on visuospatial bias should depend on whether their meaning is completely spatial (explicit cue) or partially spatial (implicit cue). The key point is that because there are a greater number of non-overlapping features that are activated by implicit spatial cues, their spatial congruence with another visual event should yield a different outcome compared to the congruence of explicit cues, which possess relatively fewer non-overlapping features with the target. Specifically, larger overlap between the cue and a visual target, i.e., in the case of explicit cues, should result in facilitation, whereas fewer overlap between the two, i.e., in the case of implicit cues, should result in interference (similar arguments, although not based on TEC, have been recently put forth by Estes, Verges, & Adelman, 2015, and Ostarek & Vigliocco, 2017). These studies are consistent with our assumption that separate event files are generated in response to the cue and the target; that is, the separation between the event files does not require a separate manual response to each stimulus. On the basis of this assumption, we could predict that manipulating cue-target feature overlap can change the pattern of their interaction.

Besides the potential role of feature-overlap, a second assumption of TEC is that the interaction between processing of two consecutive events depends on whether their shared features are integrated into event files (e.g., Frings & Rothermund, 2011; Hommel, 2004; Memelink & Hommel, 2013; Moeller, Frings, & Pfister, 2015). At present, there does not seem to be a clear consensus with regard to how most effectively manipulate feature integration, though manipulating task-relevance of a stimulus seems to be one method for doing so (e.g., Frings & Rothermund, 2011; Giesen & Rothermund, 2014; Hommel, 1998, 2005; Moeller & Frings, 2014; see also Kiss, Grubert, & Eimer, 2013). Across different experiments, for example, Hommel (1998) varied the task relevance of the shape or color of a stimulus and reported evidence for the inclusion of the task relevant, but not the task-irrelevant, feature in the event file. Similarly, Moeller and Frings (2014) reported evidence for distractor-response binding when the distractor locations were attended, but not when they were unattended. These findings suggest that task-relevance is necessary for the inclusion of a feature into the event file (but see Giesen et al., 2012 and Hommel, 2005 for evidence that task-irrelevant features can bind into event files in some circumstances). Alternatively, feature integration, irrespective of task relevance, might occur spontaneously when encountering an event, and relevance might instead influence which features are more likely to be retrieved as a unified event file when encountering a second related event. That is, both task-relevant and -irrelevant features are automatically bound into an event file at encoding, but attention control settings might increase the weight or potency of task relevant features at retrieval such that only the relevant features are part of the retrieved event file (Hommel, Memelink, Zmigrod, & Colzato, 2014). Critically, in both cases, and for the purposes of the current study, task relevance should impact which features are bound into an event file when encountering a second event.

It is, therefore, conceivable that if spatial cues are task-irrelevant, then spatial features could be activated (but not bound into the event file) and, consequently, lead to the facilitation of congruent targets. This is consistent with the facilitation found under masked conditions (e.g., Ansorge, Khalid, & König, 2013; Ansorge, Kiefer, Khalid, Grassl, & König, 2010). If so, then in the case of irrelevant implicit spatial cues in particular, active, but not bound, spatial features will result in a larger effect compared to relevant cues (i.e., bound features) because the spatial feature that is responsible for cueing remains available in the former case.

The goal of the present study was, for the first time, to examine the predictions of TEC with regard to the relationship between conceptual and visual processing using the cueing paradigm. More specifically, our investigation focuses on the potential role of three factors. First, in two separate experiments, we test how a cue's explicit or implicit spatial meaning differently biases visual attention. Let us first consider task-relevant cues. We expected the implicit cues to activate additional features relative to explicit cues, and thus cause interference. That is, in addition to their well-established association with physical space (e.g., Chasteen et al., 2010; Gozli et al., 2013b; Meier & Robinson, 2004; Zanolie et al., 2012), words with implicit spatial meaning will activate other non-spatial features. For example, the word "HAPPY" could recruit several features, other than up, into an event file (these additional features could include motor features related to posture or facial expressions of oneself, perceptual features related to positive expressions of others, etc.). As a result, the partial overlap between the cue and the target is more prominent with implicit spatial cues, which means interference is more likely with such cues. Explicit cues, on the other hand, are expected to evoke features associated with location and are more likely to facilitate congruent target stimulus processing, because there are a fewer number of non-overlapping features between explicit cues and the visual targets.

The second factor aims to test the effects of the two types of cues when they are task-irrelevant. Little research has examined the influence of task-relevance of cues on subsequent visual processing, rendering the interaction difficult to predict. If we assume that attentional selection increases the likelihood of binding, then we should predict different effects with explicit and implicit irrelevant cues. Although a task-relevant implicit cue may interfere with compatible target processing due to the formation of a partially overlapping integrated event file, without the binding of its spatial features, it should facilitate visual processing for compatible visual targets. That is, when an implicit cue is presented as task-irrelevant, cue-target compatibility should result in facilitated performance. With respect to task-relevant explicit cues, if they can facilitate processing of compatible targets, then it is also likely that when they are not selected (i.e., are task-irrelevant), they would continue to yield the same kind of effect (Ansorge et al., 2010). Thus, we predicted that task-relevance would not reverse the effect of explicit cues (see Fig. 1 for a summary of the first two factors).

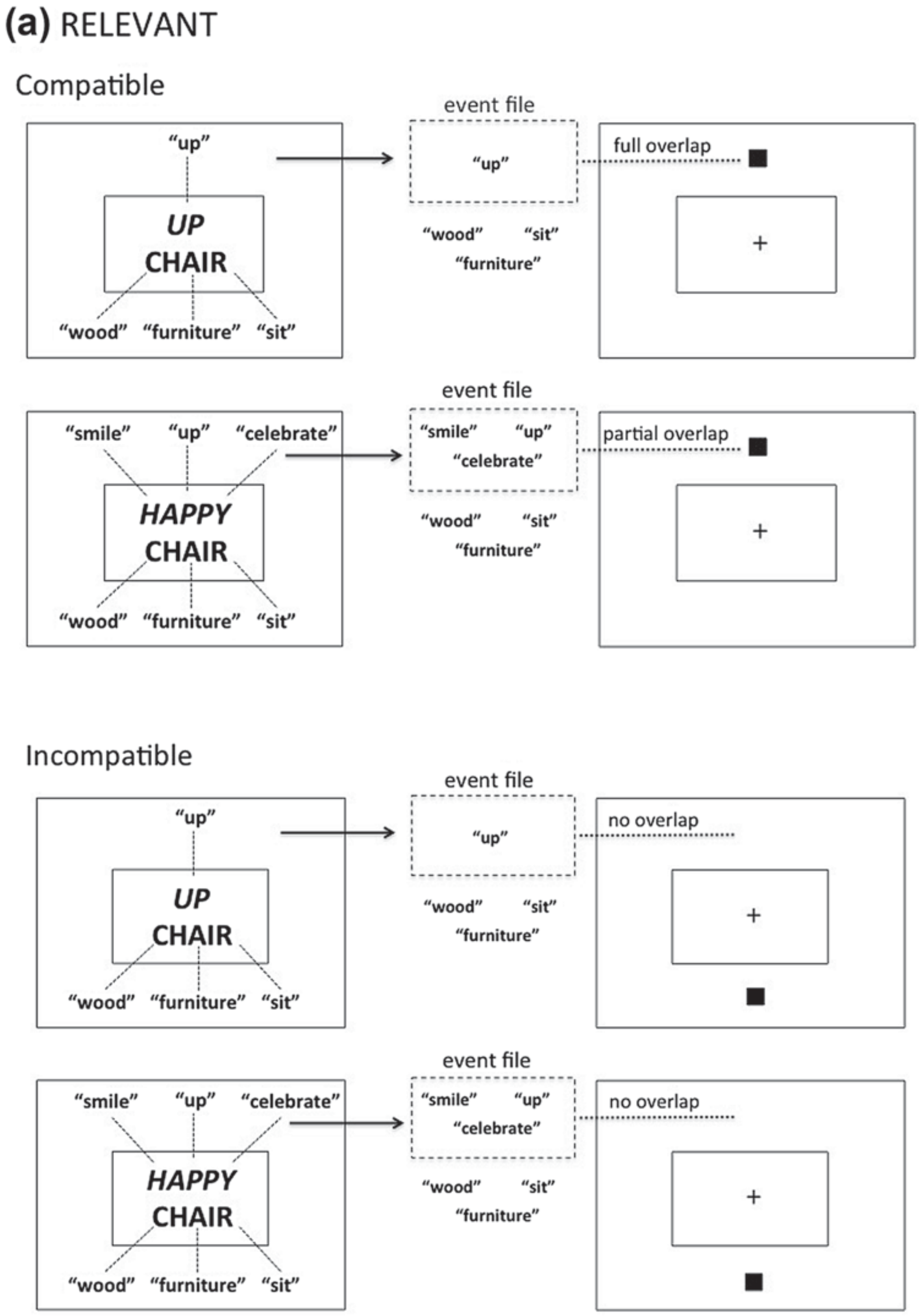
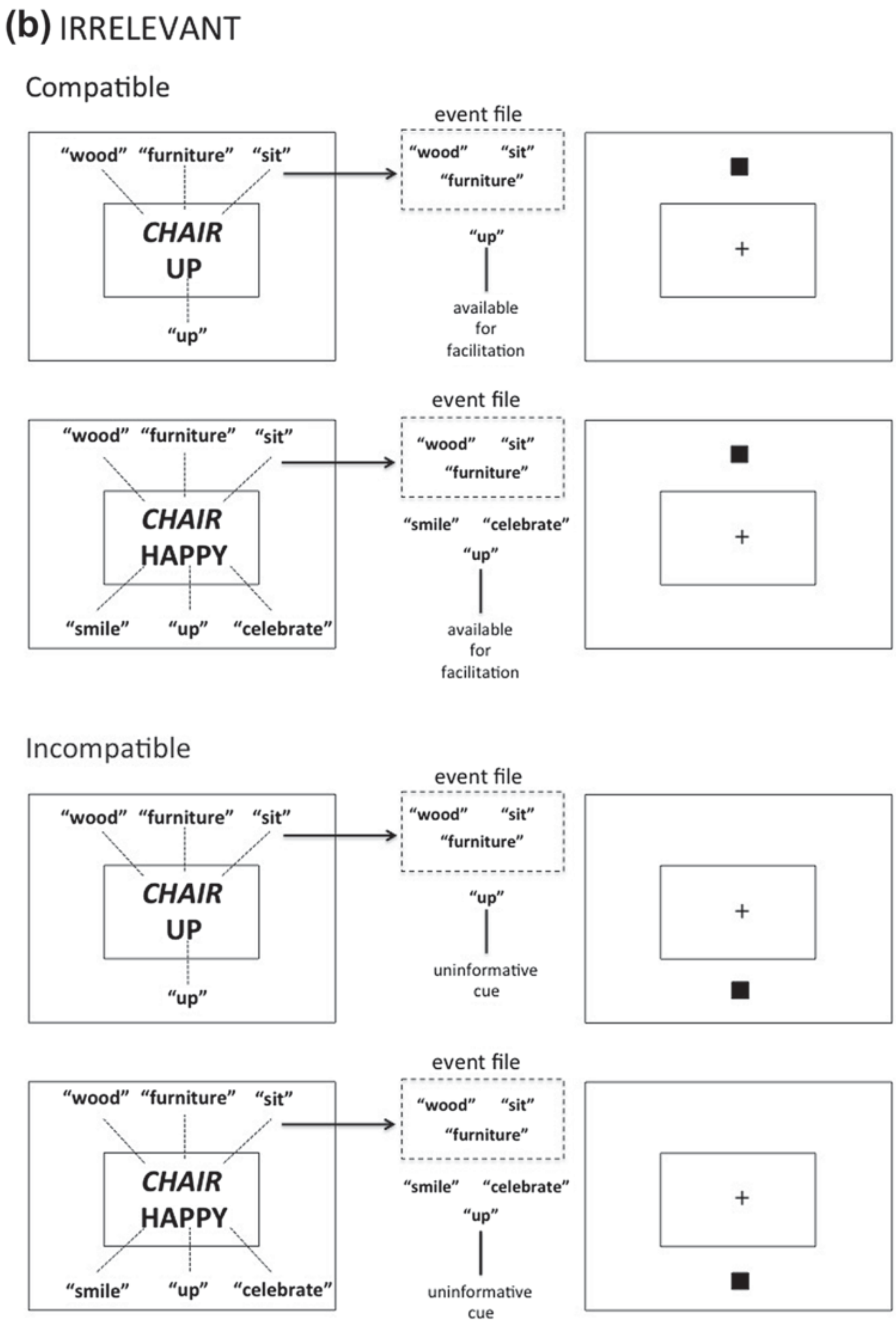


Fig. 1 Summary of how words with explicit or implicit spatial meaning and their task-relevance might influence subsequent visual cueing. In the (**a**) relevant cue condition, spatial features are bound into an event file and lead to facilitation or interference of processing a compatible upcoming target based on the extent of the overlap between the features of the generated event file and the visual target (full overlap = facilitation; partial overlap = interference). When incompatible, the features do not overlap with the upcoming target. In the (**b**) irrelevant cue condition, spatial features are generally activated but not bound into an event file, which allows them to be available to facilitate the processing of subsequent compatible visual targets. The features are uninformative and do not impact performance when incompatible

Third, we examined the effects of the delay between the presentation of the cue and the visual target (or cue-target stimulus onset asynchrony; SOA) on target processing, given its importance in predicting whether the cue will facilitate or interfere with subsequent visual processing (Gozli et al., 2013a). With respect to TEC, event codes are considered to not be stable in time and go through three stages (initial activation, integration, and final activation; Hommel et al., 2001a; Stoet & Hommel, 1999). It is possible then that any interference effects might be transient (confined to the second stage) and will disappear after enough delay (third stage of event coding). Hence, we varied SOA in our study, while keeping in consideration that timing is not the only factor that determines feature integration and the effect of subsequent target processing.

It is important to emphasize that our predictions rest on the assumption that separate event files are generated when encountering the cue and when encountering the visual target. Of course, the issue of what defines an event remains

Fig. 1 continued



controversial, and some authors may dispute our conception in favor of a definition that includes the entire cue-target-response sequence. However, based on previous research (see Hommel, 2004; Kahneman, Treisman & Gibbs, 1992), we assume that the separation of event files does not require separate overt/manual responses and, as such, separate event files are generated for the cue and the target. Consistent with TEC, in the following two experiments we find

[1] Making this assumption a priori might seem problematic. The alternative assumption, namely that both words could be selected at once and to the same degree, seems defensible if we entertain the possibility that the vertically arranged words are grouped into a single perceptual object. However, this assumption gives rise to the prediction that cue Relevance should have no impact on performance (Duncan, 1984), which is disconfirmed in both Experiments 1 and 2. Hence, our assumption that the relevant word is selected with a higher likelihood at the expense of the irrelevant word was confirmed by the findings.

that concepts with explicit and implicit spatial meaning have similar effects in visual task when they are not selected during the task (i.e., task-irrelevant), whereas they have opposite effects when they are selected for task performance (i.e., task-relevant). These findings confirm (a) the association between concepts and sensorimotor codes, and (b) the assumptions of TEC regarding the consequences of feature integration and feature overlap.

Experiment 1

In a first experiment, we tested the effect of task-relevant and -irrelevant explicit spatial cues on detection of a target stimulus in a spatial cueing paradigm. Unlike previous studies that typically only test the influence of task-relevant cues on target processing (e.g., Gibson & Kingstone, 2006), we included both task-relevant and -irrelevant spatial cues (each presented together with a neutral word) to test how the effect of spatial concept would change depending on the selection of the cue. On every trial, a direction word (e.g., "ABOVE") and a neutral furniture word not associated with directionality (e.g., "COUCH") were presented. The two words were vertically aligned, which reduces the likelihood of grouping them into a single item (Frings & Rothermund, 2011). Thus, we assumed that only one of the two words could be selected at any given time.[1] The two words were further distinct in their physical feature, the relevant word always italicized, whereas the irrelevant word was always in normal font. Following the presentation of the words, a visual target (a small dot) was presented above or below fixation. In one session, participants were asked to respond to the presence of the visual target only if the relevant (italics) word was a direction word ("Relevant Cue" condition), and in another session they were asked to perform the respond to the visual target when the relevant word was a furniture word (i.e., the direction word was irrelevant; "Irrelevant Cue" condition). Thus, the Cue conditions (Relevant or Irrelevant) were labeled on the basis of the task-relevance of the direction words only as we were primarily interested in how attention is modulated by the relevance of words with spatial features.

If the event file corresponding to the relevant word only includes the features associated with that word, then the direction words will facilitate detecting the visual target at the compatible location when task-relevant. We make this prediction for the relevant cues, on the basis of previous research (e.g., Hommel et al., 2001b). The effect of irrelevant cues is, however, less clear. It is plausible that the irrelevant spatial words could produce the same kind of visual bias, though with a weaker magnitude. A main prediction, however, is that explicit spatial cues would not interfere with visual target detection at a location that is compatible with their meaning, because they activate relatively fewer number of non-spatial features.

Method

Participants

Twenty University of Toronto undergraduate students participated in this experiment in exchange for course credit. The sample size for the present experiment (along with Experiment 2) was determined based on the average effect sizes of facilitation and interference effects previously reported in detection tasks of visual cuing paradigms (e.g., Gozli et al., 2013a). The participants reported normal or corrected to normal vision, and were unaware of the purpose of the study. The Research Ethics Board of the University of Toronto approved all experimental protocols.

Apparatus and stimuli

Participants performed the task in dimly lit rooms. The experiment was programmed in Matlab (MathWorks, Natick, MA, USA), using the Psychophysics toolbox (Brainard, 1997; Pelli, 1997; version 3.0.8). Stimuli were presented on 19" CRT monitors set at 1024 × 768 resolution and 85 Hz refresh rate. Using a head/chin-rest, participants' distance from the display was fixed at about 45 cm. All stimuli were presented in white against a black background. Words were presented inside a central rectangle that subtended 8° × 5.6° of visual angle. Words either belonged to the explicit directional words category ("UP", "DOWN", "ABOVE", "BELOW") or to the furniture category ("CHAIR", "TABLE", "COUCH", "SHELF"). On a given trial, the target and distractor words were defined as the word presented in Italic and normal Arial font, respectively. The visual target was a small dot (0.4° × 0.4° in size, deviating by 8° from fixation) presented above or below the display center.

Procedure

The display structure and the sequence of events are shown in Fig. 2. Each trial began with the presentation of the central rectangular frame and a central fixation cross (0.6° × 6°), remaining on display for 1000 ms. Next, the word stimuli were presented for 200 ms. The two words were always inside the rectangular frame, always vertically aligned, centered with respect to the vertical midline and deviating by ±1.5° with respect to the horizontal midline. One of the words was always a direction word, while the other word was always a furniture word. In addition, one of

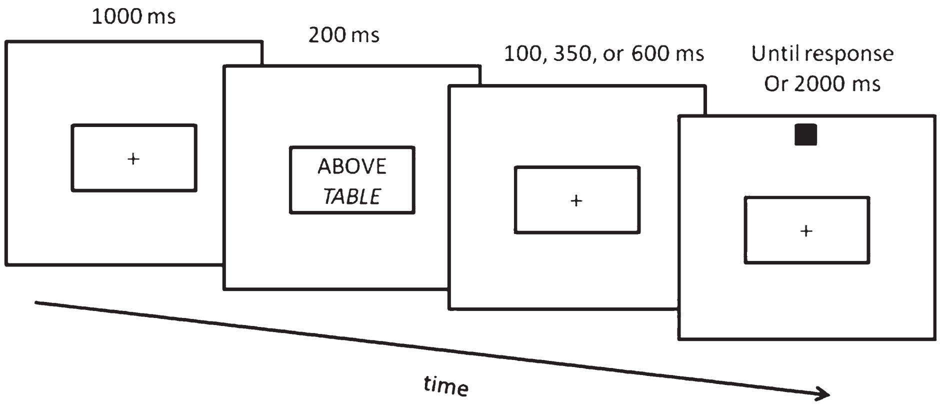


Fig. 2 Example of Experiment 1 procedure. Participants attended only to the relevant word in *italics*, and following a variable delay (300, 550, or 800 ms), performed a visual detection task

the words was presented in italics (relevant word), while the other word was presented in normal font (distractor word). Next, the fixation cross reappeared and remained for 200 ms. Following a variable delay (100, 350, or 600 ms, which respectively correspond to cue-target SOAs of 300, 550, and 800 ms), the visual target was presented above or below the center. As previously noted, we varied SOA due to its importance in predicting whether conceptual processing will lead to facilitation or interference in subsequent visual processing (see Gozli et al., 2013a), and to minimize expectation of when the visual target will appear. One could reasonably assume that for the longest SOA (i.e., no target appearing at SOA = 550 ms), participants could predict when the target will appear, although they still cannot predict where it will appear. Participants were asked to press the spacebar (using their dominant/preferred hand) as soon as the visual target appeared. In the Relevant Cue condition, participants were instructed to perform the visual detection task only when the italic word referred to a direction, and otherwise withhold response. In the Irrelevant Cue condition, participants were instructed to perform the detection task only when the italic word referred to a furniture word (the direction words were irrelevant in this condition). Participants received a visual feedback if their response time was faster than 100 ms ("TOO QUICK!"), if no response was recorded in 2000 ms ("TOO SLOW!"), or when a response was recorded on trials in which the italic word belonged to the irrelevant category, i.e., no-go trial ("MISTAKE!").

Design

Each participant completed two separate blocks (the Relevant Cue and Irrelevant Cue conditions), with each block consisting of 20 practice trials and 192 experimental trials. The order of the two blocks was counterbalanced across participants. Any given trial was equally likely to be a test trial (i.e., a trial in which the italic word belonged to the relevant category) or a no-go trial (i.e., a trial in which the italic word belonged to the irrelevant category). The relevant word was equally likely to appear above or below the irrelevant word. The four possible direction words, the four furniture words, the three possible cue-target SOAs (300, 550, and 800 ms), and the possible location of the visual detection target (above vs. below) were all randomized and equiprobable. Trials were coded as "compatible" or "incompatible" depending on the relationship between the meaning of the spatial cue word (regardless of whether it was task-relevant or irrelevant) and the location of the visual target. In addition, since the cue could also vary in eccentricity, cue-target distance varied randomly (near vs. far) from trial to trial. We included another factor, cue-target distance, which could take the value "near" when the cue and the target were both above or both below fixation, or otherwise it would take the value "far". Explicit and implicit cues were varied between experiments due to concerns of the length of the testing session and effects of fatigue and loss of concentration (other variables associated with cue type, such as relevance, compatibility, and cue-target SOA had to be varied within subjects instead).

Results and discussion

Error rates on test and no-go trials were $M = 8.7\%$ (SE = 1.4%) and $M = 8.8\%$ (SE = 1.3%), respectively, indicating that participants complied with task instructions. Before analyzing response time (RT), we conducted an RT outlier-detection/exclusion procedure described by Cousineau and Chartier (2010), consisting of a square root transformation of RT values and normalizing the distribution. This procedure has the advantage of bringing symmetry to the RT distribution and increasing the likelihood of detecting both low- and high-outlier values. We then excluded values that fell 2.5 SD above or below the total mean of the transformed distribution, which resulted in the exclusion of 3.2% of the total number of trials. In addition, in the analysis of RT data, we excluded incorrect trials and trials that immediately followed an incorrect trial, due to potential post-error slowing effects (see, e.g., Dutilh et al., 2012). In the Appendix, we report RT analyses without the application of outlier-exclusion for the sake of comparison. The results of those analyses matched the results with outlier-exclusion.

Mean RTs were submitted to a 2 × 2 × 2 × 3 repeated measures ANOVA with factors being cue Relevance (relevant vs. irrelevant), cue-target Compatibility, cue-target Distance (near vs. far), and cue-target SOA (300, 550, and 800 ms). This analysis revealed both a main effect of SOA ($F[2, 38] = 124.34$, $p < 0.001$, $\eta_p^2 = 0.867$) and a main effect of Compatibility ($F[1, 19] = 10.58$, $p = 0.004$, $\eta_p^2 = 0.358$)—see Fig. 3 for the Compatibility effect. We did not find an interaction between Compatibility and Relevance ($F[1, 19] = 2.32$, $p < 0.144$, $\eta_p^2 = 0.109$), and none of the other main effects or interactions reached significance (F values <1.62, p values >0.21). The main effect of SOA indicates faster responses with longer cue-target delays. Most importantly, the main effect of Compatibility indicates faster detection when the meaning of the cue was compatible with target location ($M \pm SE = 367 \pm 19$ ms), relative to when the two were incompatible (380 ± 19 ms).

Given that our task required visual detection, there are only two kinds of potentially informative errors on test trials. These include anticipations (defined as responding before, or within the first 100 ms after, visual target onset), and missed trials (defined as failing to respond within the first 2000-ms after target onset). A third type of error would result from mistakenly pressing a key other than the designated spacebar. This type of error was infrequent ($M \pm SE = 1.3 \pm 0.02\%$) and, we can presume, occurred whenever participants temporarily misplaced their responding finger on any key other than the spacebar (i.e., its analysis would not be informative). Thus, we separated anticipations and missed trials and submitted each to the same ANOVA.

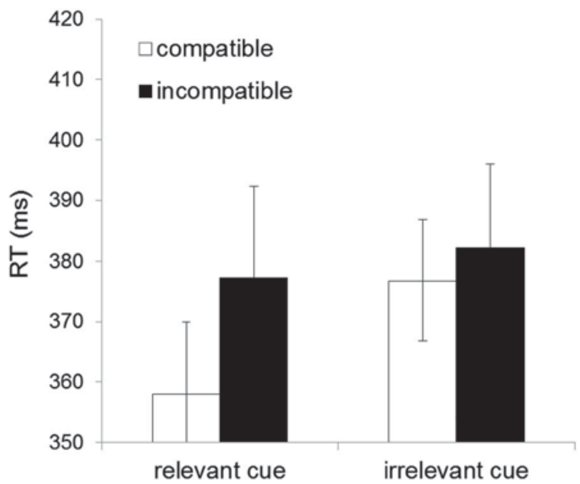


Fig. 3 Mean reaction time (RT) on the visual detection task from compatible and incompatible trials in the "Relevant Cue" and "Irrelevant Cue" conditions of Experiment 1. *Error bars* represent within-subject confidence intervals (Cousineau, 2005; Morey, 2008)

Analysis of anticipation errors revealed a main effect of SOA ($F[1, 19] = 6.58$, $p = 0.004$, $\eta_p^2 = 0.257$). Anticipation errors increased with larger SOA, with a gradual increase from $M = 0.6\%$ (SE = 0.3%), to $M = 3.2\%$ (0.5%), to $M = 5.1\%$ (1.5%), respectively, with SOA = 300, 550, and 800 ms. This suggests that at longer SOAs participants' responses were made, relatively speaking, less on the basis of detecting the visual target and more on the basis of their own temporal prediction. Furthermore, we found a marginal effect of Relevance on anticipation errors ($F[1, 19] = 4.34$, $p = 0.051$, $\eta_p^2 = 0.186$). Complementary to this finding, the analysis of missed trials revealed only a main effect of cue Relevance ($F[1, 19] = 7.41$, $p = 0.014$, $\eta_p^2 = 0.281$). Percentage of anticipation errors was larger with task-relevant ($M = 3.6 \pm 0.7\%$) than with irrelevant ($M = 2.3\% \pm 0.6\%$) cues, whereas percentage of missed trials were smaller with relevant ($M = 3.5 \pm 1.2\%$) than with irrelevant ($M = 6.1 \pm 1.0\%$) cues. This pattern of results could mean that spatial words served as better (perhaps, less ambiguous) go-signals, compared to the alternative category (furniture words). Most important for our purpose, we did not find a main effect of Compatibility on anticipations ($F[1, 19] = 0.88$) or missed trials ($F[1, 19] = 1.07$, $p = 0.314$, $\eta_p^2 = 0.053$), which means the effect of cue-target compatibility, in RT, is most likely not a product of a speed-accuracy trade-off.

Consistent with previous reports (e.g., Gibson & Kingstone, 2006; Gibson et al., 2009; Ho & Spence, 2006; Hommel et al., 2001b), the present findings suggest that direction words with explicit spatial meaning (e.g., "ABOVE") bias visuospatial processing in the direction of their meaning, as revealed by facilitated detection of a subsequent stimulus appearing in that location. In addition, the findings also suggest that even when these direction words are task-irrelevant, they continue to bias performance in a similar manner. To examine how words with implicit spatial meaning bias attention in the same visual-attention cueing paradigm, we conducted Experiment 2.

Experiment 2

In this experiment, we tested the effect of task-relevant and -irrelevant words with implicit spatial meaning (such as "HAPPY" or "SAD") on target detection in the same paradigm. Again, the novelty of the present experiment is the inclusion of both task-relevant and -irrelevant implicit spatial cues to examine whether their influence on target detection, based on feature overlap, is consistent with TEC. Because implicit spatial cues are associated with more features relative to explicit cues, we expected to see a different pattern of facilitation and interference depending on the cues' relevance to the task (i.e., based on whether their features are bound into the initially selected or retrieved event files) from that found in Experiment 1. In particular, we expected an interference effect when the implicit cues are relevant due to the binding of additional features into an event file that partially overlaps with the subsequent target. It is, of course, possible to argue that there is a partial overlap of cues and targets even in Experiment 1 and that the explicit-implicit distinction, with regard to the number of non-overlapping features, is a matter of degrees. However, we assume that the number of non-overlapping features is more in the case of implicit cues and that the non-overlapping features increase the probability of interference. Two recent studies motivate this prediction (Estes et al., 2015; Ostarek & Vigliocco, 2017). Both studies manipulated the featural overlap between semantic cues (e.g., bird) and targets (e.g., an image of a bird vs. an image of a cloud) and found that a cue-target featural congruence (in addition to spatial congruency) results in facilitation, whereas featural incongruence results in interference. Thus, although the featural overlap was not complete, and cues and targets differed in several respects (e.g., cues being centrally presented words and targets being peripherally presented images), increasing cue-target overlap resulted in a positive compatibility effect. The same rationale applies to the present study, with implicit spatial cues, respectively, sharing fewer features with the target, relative to explicit cues.

As before, it is difficult to make a specific a priori prediction for the irrelevant cues. On the one hand, it is possible that irrelevant implicit cues are simply ignored, resulting in no spatial bias. On the other hand, it is possible that irrelevant cues activate the spatial code without including this feature in an integrated event file. If so, then irrelevant implicit cues should facilitate spatial processing at the congruent location.

Method

The methods were identical to Experiment 1, with the exception that implicitly directional valence words ("HAPPY", "JOY", "SAD", and "SORROW") were used instead of explicitly directional words. As noted earlier, words with positive valence ("HAPPY" and "JOY") activate upward spatial features, while words with negative valence ("SAD" and "SORROW") activate downward spatial features (e.g., Gozli et al., 2013b; Meier & Robinson, 2004). Accordingly, with relevant cues, participants were instructed to perform the visual detection task when the italic word is related to an emotion or mood, and otherwise withhold response. Twenty University of Toronto undergraduates with normal or corrected-to-normal vision participated in exchange for course credit. They were all unaware of the purpose of the study.

Results and discussion

Percentages of error on test and no-go trials were $M = 7.8\%$ (SE $= 1.3\%$) and $M = 13.5\%$ (SE $= 3.1\%$), respectively, indicating that participants complied with task instructions. Again, before analyzing RT data, we excluded outliers using the procedure described in Cousineau and Chartier (2010), using 2.5 SD as the cut-off criterion (2.9% of all trials). In the RT analysis, we also excluded errors and trials immediately after an error.

Mean RTs were submitted to a $2 \times 2 \times 2 \times 3$ repeated measures ANOVA, with factors being cue Relevance, cue-target Compatibility, cue-target Distance, and cue-target SOA. This analysis revealed both a main effect of SOA ($F[2, 38] = 214.04$, $p < 0.001$, $\eta_p^2 = 0.918$) and a three-way interaction between Relevance, Distance, and Compatibility ($F[1, 19] = 8.20$, $p = 0.010$, $\eta_p^2 = 0.302$). As shown in Fig. 4, on trials in which cue and target appeared *near* each other, we observed a two-way interaction between Relevance and Compatibility ($F[1, 19] = 11.103$, $p = 0.004$, $\eta_p^2 = 0.369$), but we did not find the same Relevance x Compatibility interaction when cue and target appeared *far* from each other ($F[1, 19] = 0.92$). In cue-target near trials, relevant and irrelevant cues, respectively, resulted in interference ($t[19] = 2.06$, $p = 0.054$, Cohen's

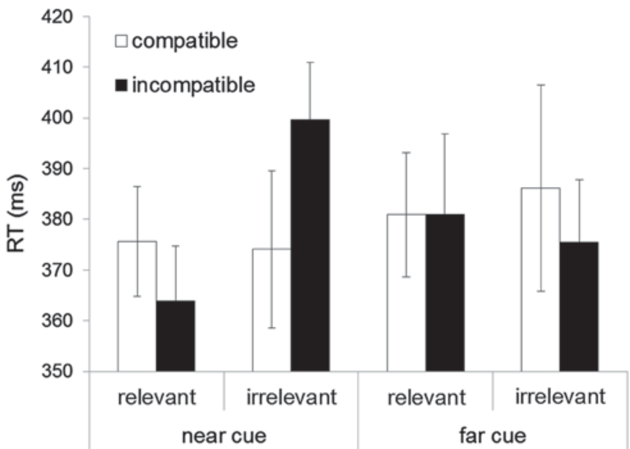


Fig. 4 Mean reaction time (RT) on the visual detection task from compatible and incompatible trials in the "Relevant Cue" and "Irrelevant Cue" conditions of Experiment 2. *Error bars* represent within-subject confidence intervals (Cousineau, 2005; Morey, 2008)

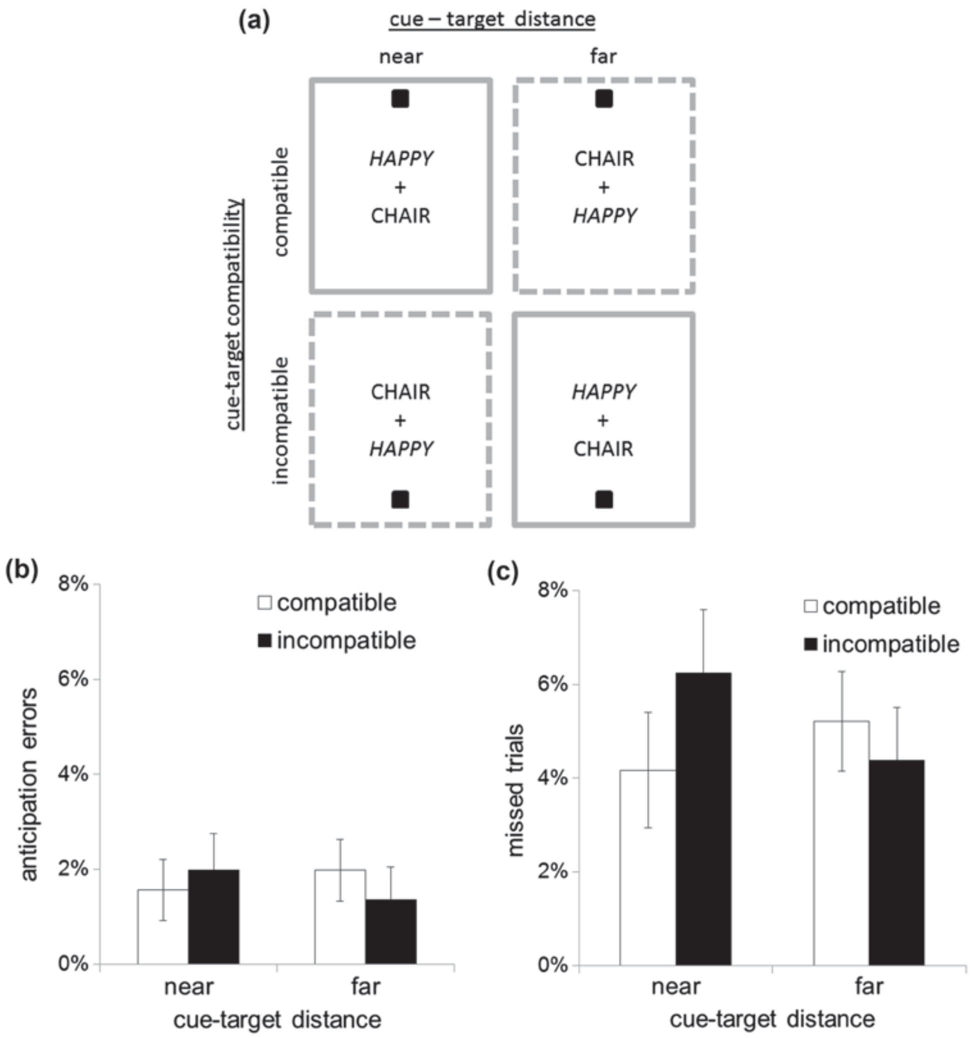


Fig. 5 Congruency between cue meaning and cue location is determined by the combined values of cue-target compatibility and cue-target distance (**a**). Cue meaning-location is congruent for near-compatible and far-incompatible trials (*solid frames*), incongruent for near-incompatible and far-compatible trials (*dashed frames*). For meaning-location congruent cues, both anticipation errors (**b**) and missed trials (**c**) were higher, relative to incongruent cues. *Error bars* represent within-subject confidence intervals (Cousineau, 2005; Morey, 2008)

$d = 0.46$) and facilitation ($t[19] = 2.50$, $p = 0.022$, Cohen's $d = 0.56$). None of the other main effects or interactions were significant.

Errors on test trials were divided into anticipations (RT < 100 ms) and missed trials (RT >2000 ms), and were separately submitted to the same ANOVA. Analysis of anticipations revealed a main effect of SOA ($F[2, 38] = 10.73$, $p < 0.001$, $\eta_p^2 = 0.361$). Matching the results of Experiment 1, this main effect was driven by higher percentage of anticipation errors with longer SOA ($M = 0.1 \pm 0.1\%$, $M = 2.2 \pm 0.3\%$, and $M = 3.1 \pm 0.7\%$, respectively for SOA = 300, 550, and 800 ms). Furthermore, we found a two-way interaction between Compatibility and Distance ($F[1, 19] = 5.00$, $p = 0.038$, $\eta_p^2 = 0.208$), and a three-way interaction between SOA, compatibility, and distance ($F[2, 38] = 8.86$, $p < 0.001$, $\eta_p^2 = 0.318$).

Interpreting the compatibility–distance interaction is possible by reformulating the two factors in terms of a single variable, namely the congruency of the cue location and cue meaning (e.g., if "HAPPY" is presented above fixation, then its meaning and its location are compatible). The congruency between the location and meaning of a cue is fixed based on the combined values of Compatibility and Distance (Fig. 5). In the case of compatible-near and incompatible-far, cue location is necessarily congruent with cue meaning. By contrast, in the case of compatible-far and incompatible-near, cue location is necessarily incongruent with cue meaning (Fig. 5). Thus, the interaction between Compatibility and Distance can be expressed in terms of cue location-meaning congruency. Anticipation errors were higher with cue location-meaning incongruent ($M = 2.0 \pm 0.3\%$) compared to congruent trials ($M = 1.5 \pm 0.3\%$). The three-way interaction between SOA, Compatibility, and Distance indicated that the Compatibility x Distance interaction just described, was reliable at SOA = 550 ms ($t[19] = 3.58$, $p = 0.002$, Cohen's $d = 0.80$), whereas it was absent at the other two SOAs ($t[19] < 1.4$, $p > 0.19$, Cohen's $d < 0.23$).

Analysis of missed trials, using the same ANOVA, only revealed a two-way interaction between Compatibility and Distance ($F[1, 19] = 5.63$, $p = 0.028$, $\eta_p^2 = 0.229$). Matching the findings in anticipation errors (Fig. 5), the two way interaction was driven by a higher percentage of missed trials when cue location was congruent with cue meaning (i.e., compatible-near and incompatible-far, $M = 4.3 \pm 1.1\%$), compared to when cue location was incongruent with cue meaning (i.e., compatible-far and incompatible-near, $M = 5.7 \pm 1.2\%$). No other main effect or interaction was found in the analysis of missed trials. In short, the incongruence between cue location and cue meaning increased both types of errors (missed trials and anticipations).

Role of valence

An additional analysis of RT data from Experiment 2 was motivated by the possible role of valence (positive vs. negative). Previous research has shown that positive valence can not only cause bias toward a location (e.g., Gozli et al., 2013b; Meier & Robinson, 2004), but also the influence the scope of attention (e.g., Rowe, Hirsh, & Anderson, 2007). In the present study, if the positive words broadened the scope of attention, then they should reduce the consequence of attentional orienting. By contrast, with a narrower scope of attention (presumably after reading negative words) orienting should matter more. That is to say, we expected to find an interaction between cue Valence and cue-target Compatibility, driven by a larger compatibility effect with negative words. This analysis was separated from the main analysis, because (a) it was not derived from the primary purpose of the study and (b) including all factors in a single analysis would have reduced the number of trials-per-cell down to 4. So in this analysis, we replaced the factor SOA with the factor Valence, because the main finding of the previous RT analysis (three-way interaction between Relevance, Compatibility, and Distance) did not involve, and did not interact with, SOA. Thus, we submitted mean RT data to a $2 \times 2 \times 2 \times 2$ repeated measures ANOVA, which included cue Valence (positive vs. negative), cue Relevance, cue-target Compatibility, and cue-target Distance as factors. Confirming the previous analysis, we found a two-way interaction between Relevance and Compatibility ($F[1, 19] = 6.52$, $p = 0.019$, $\eta_p^2 = 0.256$), qualified by a three-way interaction between Relevance, Compatibility, and Distance ($F[1, 19] = 5.33$, $p = 0.032$, $\eta_p^2 = 0.219$). The interaction between Relevance and Distance also reached significance ($F[1, 19] = 5.07$, $p = 0.036$, $\eta_p^2 = 0.211$). In addition, we found a main effect of Valence ($F[1, 19] = 5.19$, $p = 0.035$, $\eta_p^2 = 0.214$), and a three-way interaction between Valence, Relevance, and Compatibility ($F[1, 19] = 6.80$, $p = 0.017$, $\eta_p^2 = 0.264$).

The main effect of Valence indicates faster responses with positive cues ($M = 374 \pm 13$ ms), compared to negative cues ($M = 385 \pm 13$ ms). The three-way interaction that included Valence is consistent with the idea that positive and negative valence are associated, respectively, with wider and narrower spatial selection. Specifically, as demonstrated in Fig. 6, the valence × compatibility interaction was reliable only with negative cues ($t[19] = 3.38$, $p = 0.003$, Cohen's $d = 0.76$), whereas it was far from reliable with positive cues ($t[19] = 0.55$, $p = 0.59$, Cohen's $d = 0.12$). These results do not change the main interpretation of the study. Instead, the reliable cueing effect with negative words confirms the idea that reliability of factors that influence attentional orienting, e.g., symbolic cueing, depend on a narrow scope of attention to some degree.

Analysis of both experiments

In order to examine the different effects of implicit versus explicit cues on subsequent visual processing in one analysis, we submitted both data sets to a mixed ANOVA with cue Relevance, cue-target Compatibility, and cue-target Distance as within-subjects factors, and with Cue Type (explicit vs. implicit) as the between-subjects factor. The analysis revealed a significant three-way interaction between Relevance, Compatibility, and Cue Type ($F[1,38] = 8.09$, $p = 0.007$, $\eta_p^2 = 0.176$). Moreover, this analysis did not show a main effect of Cue Type ($F[1,38] = 0.05$) or any other interaction between Cue

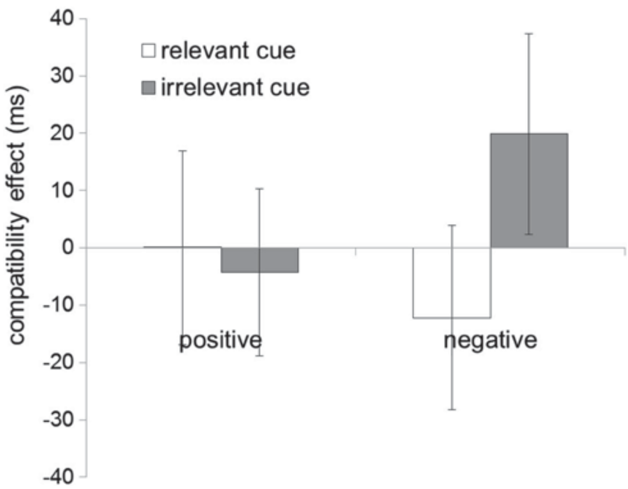


Fig. 6 Compatibility effect ($RT_{incompatible} - RT_{compatible}$) in Experiment 2, graphed as a function of cue valence and cue relevance. *Error bars* represent within-subject confidence intervals (Cousineau, 2005; Morey, 2008)

Type and other variables. This confirms that explicit and implicit spatial cues, when task-relevant, have a different impact on subsequent visual attention due to their different number of associated features that influence the extent of the overlap with compatible visual targets.

We must be cautious in comparing the results from Experiments 1 and 2, particularly if we consider whether the difference between the two experiments can be accurately described in terms of explicit vs. implicit spatial association. Although we did find a modulation of Compatibility with cue Relevance in Experiment 2, this two-way interaction was itself modulated by cue-target Distance. Not finding an effect of Distance (or its interaction with other factors) in Experiment 1 points to other potentially important differences between the two set of cues. The role of Distance in Experiment 2, and not in Experiment 1, could indicate that attention was more reliably oriented to the relevant cue location in the case of implicit cues. It is possible, for instance that the explicit cues were more easily processed peripherally, requiring little or no attentional orienting away from fixation, or that attention was more efficiently disengaged from such cues, compared to the implicit cues. Both scenarios could explain the absence of the role of Distance in Experiment 1. Regardless, the divergent results with regard to cue—target distance adds to the difficulty of comparing the two experiments and interpreting their difference in terms of explicit vs. implicit spatial meaning of the cues.

In sum, contrary to the results seen with explicit cues, and consistent with TEC, cue-target compatibility only facilitates performance when the cues were irrelevant (i.e., did not have to be selected for task performance). Indeed, we observed an interference pattern with relevant cues. In terms of event coding, interference can be interpreted as unavailability of the spatial code due to its integration into the event that represents the cue (Hommel et al., 2001a; Müsseler, 1999; Müsseler & Hommel, 1997). The facilitation effect, on the other hand, can be interpreted as activation-without-binding, and thus as availability of, the spatial feature of the cue.

General discussion

The interaction between concepts and sensorimotor mechanisms, as revealed by visual-attention cueing paradigms, has previously been explained in terms of attentional orienting in space. Within the orienting framework, conceptual cues have been categorized as "push" cues, distinguished from the peripheral, "pull" cues (e.g., Logan, 1995). The purpose of this study, however, was to examine this interaction within the framework of Theory of Event Coding (TEC; Hommel, 2004, 2009; Hommel et al., 2001a). Specifically, we examined how the overlap between features associated with symbolic spatial cues and subsequent visual targets affects visual attention. To this end, we manipulated the extent of the feature overlap between a spatial cue (event 1) and an ensuing visual target (event 2) in a cueing paradigm by using words with implicit (e.g., "HAPPY"; evoking many features in addition to space) or explicit (e.g., "UP"; evoking primarily the spatial features) spatial meaning. In addition, we manipulated the relevance of those words to the task to examine how spatial meaning biases attention based on the selection of the cue word. Attentional selection of an item is thought to enable, or at least increase the likelihood of, feature binding (e.g., Treisman & Gelade, 1980; Treisman & Schmidt, 1982), which, according to TEC, results in a temporary unavailability of those features for other concurrent processes.

According to TEC, the interaction between two event files depends on (a) whether they share common features and (b) whether the features are bound. For TEC, an event file does not necessarily consist of a single entity, to which all features are bound. Instead, an event file is a set of—possibly independent—bindings that are formed within an episode (Hommel, 1998, 2004). Processing facilitation or interference occurs as a result of a complete or partial overlap of the features, respectively. We reasoned that there would be relatively fewer featural overlap in the case of implicit cues, because these concepts are associated with more non-spatial features. In support of TEC, we observed an interference effect with (relevant) implicit cue, and a facilitation effect with (relevant) explicit spatial cues and the target.

In addition, we distinguished between relevant and irrelevant spatial cues in terms of their likelihood of selection and, in turn, the likelihood that cue features are bound into an event file when the file is selected or retrieved. We reasoned that, on average, the higher likelihood of selecting the relevant word in favor of the irrelevant word would result in higher likelihood of feature binding in the case of relevant cues, and relatively lower likelihood of feature binding in the case of irrelevant cues. For implicit cues, this leads to the prediction that the same cue that can result in interference can result in in facilitation when it is irrelevant to the task, presumably because its spatial feature is not occupied by an event file. Consistent with that interpretation, we observed a facilitation effect when implicit spatial cues were task-irrelevant. Finally, we saw a weak facilitation effect when explicit cues were task-irrelevant, suggesting that, although the spatial features were ignored and not bound into the event file, their availability nonetheless resulted in a weak visual bias. In sum, our study, for the first time, provides compelling evidence of a TEC-based explanation of biases in visuospatial attention based on feature overlap between two subsequent events and feature binding.

An important difference in the findings of the two experiments had to do with the role of cue-target distance. Whereas cue-target distance modulated the compatibility effect with implicit cues (Fig. 4), it had no effect in the case of explicit cues. This disparity suggests that spatial orienting to words may have occurred more reliably in the case of implicit cues, which could be explained by assuming that processing explicit cues either did not require much attentional orienting away from fixation or that attention disengaged from them fast enough to eliminate any effect of cue-target distance. Yet another explanation rests on the assumption that explicit spatial features of the same event must be sequentially processed. Luo and Proctor (2016) recently reported that two explicit spatial features of a single stimulus affected response by only one feature at any given time. That is, control of response by the semantic feature of the stimulus accompanied an absence of effect from stimulus location, and vice versa. The authors argued that processing spatial features occurs sequentially, starting from stimulus location and ending with semantic spatial feature. Alternatively, attention to semantic feature could reduce processing weight given to stimulus location (Memelink & Hommel, 2013). Even if we accept the sequential-processing assumption, we still need to explain why it applies to explicit, but not implicit, cues (given that both spatial features affected performance in Experiment 2). Regardless, the different role of cue-target distance across our two experiments makes it difficult to provide a simple comparison of the present findings merely on the basis of cue type (explicit vs. implicit).

The effect of irrelevant implicit cues is interesting in light of recent research on the effect of masked primes. Ansorge et al. (2013) found that although masked (i.e., subliminally processed) direction words facilitated processing of compatible valence words, masked valence words did not facilitate processing of compatible direction words. Their findings are consistent with the notion that without attentional selection valence words would fail to evoke their associated spatial feature. The present study, however, demonstrates that the spatial feature associated with valence concepts is activated without attentional selection, although selection can alter the way in which the two processes interact.

The present results with the relevant explicit cues represent a replication of previous studies, including the study by Hommel et al. (2001b) which showed that explicitly spatial cues (e.g., “UP”, “DOWN”, “LEFT”, “RIGHT”) facilitate detection of subsequent targets in compatible locations. Our results with irrelevant explicit cues, furthermore, represent a conceptual replication of previous findings in which the cues were masked (e.g., Ansorge et al., 2010, 2013; Goodhew, Visser, Lipp, & Dux, 2011). Although the findings of Hommel et al. (2001b), and similar findings of facilitated performance with cue-target compatibility (e.g., Chasteen et al., 2010; Gozli et al., 2016; Meier & Robinson, 2004; Zanolie et al., 2012; Xie et al., 2014, 2015) could also be explained using a spotlight model of attention, or feature priming, such an account cannot predict conditions in which cue-target compatibility results in interference (e.g., Estes et al., 2008, 2015; Gozli et al., 2013a; Lachmair, Fernandez, Gerjets, 2016; Ostarek & Vigliocco, 2017). Most notably, the differences between explicit and implicit, in the relevant-cue conditions in the present study, cannot be accounted for using a spotlight model. In contrast to the ineffectiveness of the spotlight model, TEC provides a possible account of the data by proposing a role for cue-target feature overlap (e.g., explicit vs. implicit cues), as well as assuming a role for attentional selection of the cue (e.g., relevant vs. irrelevant cues). TEC also easily incorporates an important assumption we make; cognitive spatial code associated with a concept is shared with those activated in sensorimotor tasks (Barsalou, 1999; Gallese & Lakoff, 2005; Pulvermüller, 1999).

By taking into account the notions of feature binding and feature overlap, TEC is able to explain how symbolic cues with spatial meaning impacts visuospatial attention. Furthermore, by assuming that conceptual, perceptual, and action-related processes rely on the same representational resources (cf., Barsalou, 1999; Casasanto, 2010; Fischer & Zwaan, 2008), TEC-based explanations preserve the same form, regardless of whether the two events are two actions (Eder, Müsseler, & Hommel, 2012; Fournier, Wiediger, Taddese, 2015; Stoet & Hommel, 1999), a concept and a percept (Gozli et al., 2013a), a concept and an action (Gozli et al., 2013b), or an action and a percept (Eder & Klauer, 2007, 2009; Gozli & Pratt, 2011; Kunde & Wühr, 2004; Müsseler & Hommel, 1997). Interestingly, research investigating the impact of actions with affective connotations on affective perceptions has demonstrated analogous findings showing that the relevance of emotion during action preparation results in interference or facilitation effects, respectively, depending on whether the emotion is relevant and bound to an event file that partially overlaps with affective features of the following stimulus, or is irrelevant and facilitates processing of overlapping features due to its lingering activity (Eder & Klauer, 2009).

Unlike the spotlight model of attentional orienting, TEC can account for instances in which cue-target compatibility interferes with performance. However, there are a few findings whose assimilation in TEC presents a challenge. On one hand, Estes et al. (2008) found an interference effect with cue-target compatibility when participants did not perform a categorization task on implicit cues, which rendered them task-irrelevant. More drastically, Dudschig et al. (2014) found interference even with masked implicit cues. On the other hand, Meier and Robinson (2004) and a series of similar studies (e.g., Chasteen et al., 2010; Ouellet, Santiago, Funes, & Lupiánez, 2010; Zanolie et al., 2012) found a facilitation effect with cue-target compatibility when participants did perform a categorization task on the implicit cue before encountering a visual target. These results might not directly challenge the assumptions of TEC regarding the importance of feature integration, but they do highlight TEC's current limitation in outlining a clear set of conditions in which feature integration will and will not occur.

A partial resolution of the current discrepancy can be attempted on the basis of two additional factors: (1) the time-course of cue processing (see, e.g., Gozli et al., 2013a; Stoet & Hommel, 1999; Wühr & Musseler, 2001) and (2) the possibility of task-induced polarity correspondence in at least a subset of studies. First, assuming that feature integration is followed by a phase in which the features are unbound, but still active, we can attribute the empirical discrepancy to differences in cue-target SOA. Designs with relatively shorter SOA tend to result in interference, whereas designs with relatively longer SOA tend to result in facilitation (Lachmair et al., 2016; Gozli et al., 2013a). Considering cue-target SOA is an important step in explaining the discrepancy between findings of facilitation and interference, because it is an additional factor that determines whether the cue features are integrated or not.

Another potentially important factor is whether participants view concepts from a single conceptual category throughout the experimental session (valence, power, time, etc.) or from a mixed set of multiple categories. Using a single category can increase the likelihood of task-induced mapping between concepts and target locations, or polarity correspondence, which in turn increases the likelihood of finding facilitation (see, Lakens, 2011, 2012; Lynott & Coventry, 2014; Pecher et al., 2010; see also, Gozli et al., 2016; Santiago & Lakens, 2015). Thus, Dudschig et al. (2014), who used masked cues, found interference perhaps because they used a mixed set of categories. In contrast, studies with unmasked cues from a single category of valence (Meier & Robinson, 2004), divinity (Chasteen et al., 2010), time (Ouellet et al., 2010), power (Zanolie et al., 2012), and self-esteem (Taylor et al., 2015) have consistently found facilitation.

The validity of our assumptions about these factors (task-relevance, visibility, timing, single vs. multiple of categories, etc.), and how they might interact, requires further investigation. Even the acceptance of all our assumptions would not eliminate all empirical anomalies. For instance, we would still not be able explain why the interaction between congruent conceptual and perceptual events can facilitate and interfere with performance, respectively, with visible and masked concepts (Goodhew et al., 2011). Thus, additional factors will most likely need to be considered.

A final remark on the conditions of feature-integration is necessary. Hommel (2004) lists three processing characteristics of the brain that could support binding: correlation (neural synchrony), indexing (which would presumably determine what codes would participate in the correlation), and convergence (as in the case of "grandmother cell", or perhaps more plausibly, Hebbian cell assemblies, which have been constructed due to long-term correlations, and would serve as functional unit, e.g., Pulvermüller, 1999). In the case of our task-relevant words, because these words are selected for performance, their corresponding features would more probably be activated (indexing) across a wider range of the cell assembly that corresponds to the concept (convergence); and since they correspond to a single perceptual object, the activated features would enjoy well-timed pattern of neural firing (correlation). It is important to note, however, that TEC is underspecified with regard to the mechanisms that enable, enhance, or prevent feature integration.

The relatively unique contribution of TEC here comes from the assumptions of (1) commensurability of cognitive codes, such as UP or DOWN across perception and action, which could be extended to situations in which those same codes are evoked via conceptual processing, (2) the idea that a set of bound features—not necessarily fully integrated—perhaps in the form of dyads, result from encountering each event, and (3) the idea that interactions between two consecutive event files depends on feature integration and featural overlap.

Our main opponent position, in the present context, is the simple attentional orienting (spotlight metaphor), which characterizes the interaction between concepts and attention in terms of the movement of the attentional spotlight and, consequently, can only predict target processing facilitation. We believe TEC is a richer and more comprehensive framework against that simple view. However, further distinctions (e.g., including how many bindings can occur at the same time, or how many mechanisms support feature binding, etc.) fall beyond the scope of the present study, some of which require additional specification in TEC.

Our findings may also be interpreted within signal detection or differential-weighting models which do not assume uniform variations in processing efficiency for all stimuli (i.e., spotlight), but instead propose that the selection of each potential stimulus should depend on a distinct spatial probability map (e.g., Eckstein, Drescher, & Shimozaki, 2006; Palmer, Ames, & Lindsey, 1993; Palmer, Verghese, & Pavel, 2000). Accordingly, in the current experimental design, we could presume that the cues created spatial probability maps that were featurally specific (e.g., an upward bias, accompanying the expectation to see a smile). An implicit cue that is supposed to be selected might have increased feature-specific expectation at the compatible location that mismatched our target feature. The same cue, when it was supposed to be ignored, might have created featurally non-specific expectation at the compatible location (cf., Estes, Verges, Adelman, 2015). Regardless, the efficiency with which that target was processed, or the speed of its detection, was ultimately determined by the extent of its feature overlap with the preceding cue, as well as the selection of the cue. Importantly, this observation could be derived from the event coding theory.

When an implicitly spatial word is attended to due to its relevance (integrated features), the unavailability of the spatial code will temporarily slow down target processing at the compatible location. Our findings with the implicit relevant cues replicate the findings of Estes et al. (2008), who showed that words with spatial meaning (e.g., "TOWER", "HAT", "CARPET", "CELLAR") interfere with visual target processing at compatible locations. Estes et al. interpreted their findings in terms of perceptual simulation, which can be described as an internally generated "masking" effect. Critically, the account based on perceptual simulation does not predict the opposite effect, found in the present study, with the irrelevant implicit cues. Our interpretation, based on TEC, is based on feature integration and the unavailability of the spatial features and, therefore, accommodates the effects of both relevant and irrelevant implicit cues.

Contrary to the earlier findings of Gozli et al. (2013a), we did not observe a facilitation effect at longer cue-target SOAs in the task-relevant implicit cue condition of the current study (i.e., the interference effect was not modulated by SOA). The discrepancy between the results can be attributed to two differences between the studies. First, Gozli et al. (2013a) used cue-target SOAs of up to 1200 ms, while the longest SOA in the current study was 800 ms. We could not increase the SOA beyond 800 ms due to the simple nature of our detection task and ceiling effects reached at that SOA (participants were detecting targets in nearly 330 ms). Second, the differences between the tasks used in both studies can further explain the inconsistent findings. Facilitation effects with longer SOAs in Gozli et al. (2013a) were observed with a letter discrimination task, which generally results in longer response times than a detection task, and provides a greater opportunity for features evoked by the cue to unbind from the formed event file and facilitate visual processing at the cued location due to their availability. Although using a discrimination task would have allowed easier comparisons between the two studies, we utilized a simpler detection task due to the complexity of the preceding cueing phase (participants first had to discriminate between fonts, then determine if the cue belonged to the relevant category, and finally respond as soon as the target appeared).

It is worth noting that there are a few limitations to the scope of what can be concluded from our study. One of our important assumptions has been that, in performing the task, participants selected the italicized word first, and then judged the category of the selected word. We made this assumption because, first, it should be more efficient to make the initial selection based on a physical feature than a semantic feature (e.g., Cho et al., 2006), particularly when the selection criteria remains consistent. Second, it would be reasonable to expect the instructions to influence the participants' strategy for initial selection of items, particularly because it has been shown that participants adopted such strategies even when they are less efficient than an alternative (e.g., Rajsic, Wilson, & Pratt, 2015). Third, the opposite pattern of compatibility effect found with relevant and irrelevant implicit cues (Experiment 2) would be interpretable only under the assumption that participants treated the relevant and irrelevant cues differently. However, aside from this indirect confirmation, we cannot more directly rule out the possibility that participants, at least on a subset of trials, might have adopted a different strategy. In the most dramatic case, participants could have always selected the cue words, based on semantic category—regardless of their task-relevance—and then judged whether the word was italicized. The strongest confirmation of this possibility would come from a main effect of cue-target Distance (faster responses on cue-target near trials), just as the strongest confirmation of our assumption would come from a two-way interaction between cue-target Distance and cue Relevance. Given that neither of these effects reached statistical significance, we cannot make a confident statement about performance strategy, although we would emphasize that there is no positive evidence that participants used the semantic categories as the basis of their initial selection, and that such a strategy would not fit the different pattern of results in the relevant and irrelevant conditions.

A second limitation has to do with the difference between explicit and implicit cues. Is it safe to assume that, as we have, that the two sets of concepts differ primarily with regard to their number of non-spatial features (and consequently, the extent of overlap with a spatially compatible visual target)? This question requires further work. The most important potential confound comes from the possibility that direction words might be more easily processed, or perhaps even attended, when they appear in the periphery (due to factors such as higher word frequency). If the ease of selection from the periphery, and not the number of features, is the decisive difference between the two sets of concepts, then our argument has to be revised accordingly. There is, however, sufficient ground for the assumption that the ease of peripheral selection is not the crucial difference. Studies that have used explicit spatial concepts have regularly reported facilitation effects, even when the words were task-irrelevant or masked (e.g., Ansorge et al., 2010; Gibson & Kingstone, 2006; Ho & Spence, 2006; Hommel et al., 2001b). By contrast, studies that have used implicit spatial concepts include reports of interference (e.g., Estes et al., 2008, 2015; Gozli et al., 2013a; Lachmair et al., 2016), including reports in which masking implicit spatial concepts eliminates or inverses the facilitation effect (Ansorge et al., 2013; Sasaki et al., 2016). In short, the difference between the two types of concepts does not seem to be accounted for solely in terms of the ease of processing.

A third limitation is with regard to the comparison between the two types of concepts in the present study. One could argue that a within-subject manipulation of cue type could have been more informative. However, such a design might have undesired consequences. First, participants might begin treating implicit cues in spatial terms, because of having encountered the explicit cues, which means the spatial dimension of the implicit concepts would be given more weight (Memelink & Hommel, 2013). Moreover, because of the inclusion of implicit cues, explicit cues might also become associated—within the context of the experiment—with more non-spatial features, e.g., features associated with the metaphorically compatible concepts. This might then result in the same pattern of findings with implicit cues, which would be difficult to interpret. Examining the two types of concepts in separation, therefore, seems like the optimal strategy. If a difference between the two sets of concepts exists, then it has to emerge when they are varied between-subjects.

In conclusion, we provide strong evidence that some attentional cueing effects can be explained in terms of event coding, extending the scope of TEC into the conceptual domain. More importantly, examining cueing from the standpoint of event coding connects attentional cueing to a wide variety of topics that relate to the interaction between two events as a function of their feature overlap. This framework is particularly useful for explaining findings in which congruence between a cue and a subsequent target leads to interference (Estes et al., 2008; Gozli et al., 2013a). More importantly, this framework is crucial for further exploring the relationship between concepts and sensorimotor mechanisms.

Compliance with ethical standards

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Conflict of interest Tarek Amer declares that he has no conflict of interest. Davood Gozli declares that he has no conflict of interest. Jay Pratt declares that he has no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

Appendix

In this section, we report analyses of RT data from both experiments, without the exclusion of RT outliers. Here, we excluded the incorrect trials and trials immediately following an incorrect response. Response times, therefore, could take any value up to 2000 ms, which was the cut-off built-in of the procedure.

Experiment 1

Mean RTs from Experiment 1 were submitted to a $2 \times 3 \times 2 \times 2$ repeated measures ANOVA, with factors being cue Relevance, cue-target SOA, cue-target compatibility, and cue-target distance. This analysis revealed a main effect of SOA ($F[2,38] = 71.84$, $p < 0.001$, $\eta_p^2 = 0.791$). As SOA increased, RTs decreased (484, 377, and 340 ms, respectively, for SOAs = 300, 550, and 800 ms). We also found a main effect of Compatibility ($F[1,19] = 6.10$, $p = 0.023$, $\eta_p^2 = 0.243$), driven by faster responses with cue-target compatible than incompatible trials (respectively, 391 ± 27 and 409 ± 31 ms). Both of these results matched the findings reported in the main text after outlier-exclusion. The only other significant finding was a two-way interaction between Relevance and SOA ($F[2,38] = 4.04$, $p = 0.026$, $\eta_p^2 = 0.176$). The effect of SOA was more pronounced with irrelevant cues (514, 400, and 345 ms, respectively, for SOAs = 300, 550, and 800 ms), compared to relevant cues (453, 355, and 335 ms). No other main effect or interaction reached statistical significance. Most importantly, we found no interaction between Relevance x Compatibility ($F[1,19] < 0.48$). In short, the main results of Experiment 1 (i.e., the main effect of cue-target Compatibility) persist in the absence of the RT outliers-detection/exclusion procedure.

Experiment 2

Mean RTs from Experiment 2 were submitted to the same repeated measures ANOVA. This analysis also revealed a main effect of SOA ($F[2,38] = 122.29$, $p < 0.001$, $\eta^2_p = 0.866$). As SOA increased, RTs decreased (491, 381, and 352 ms, respectively, for SOAs = 300, 550, and 800 ms). We also found a two-way interaction between relevance and distance ($F[1,19] = 7.56$, $p = 0.013$, $\eta^2_p = 0.285$), driven by faster responses when the target appeared near the relevant (i.e., selected) word compared to when the target appeared near the irrelevant (i.e., not selected) word (401 vs. 419 ms). Finally, we found a three-way interaction between relevance, compatibility, and distance ($F[1,19] = 4.65$, $p = 0.044$, $\eta^2_p = 0.197$). Matching the results reported in the main text, we found the same pattern of Relevance x Compatibility interaction—i.e., facilitation with cue-target compatibility when the cue is irrelevant, but an inverse compatibility when the cue is relevant—only with cue-target near trials (39 ± 22 ms, Cohen's $d = 0.39$), but no such interaction when the target and cue appear far from each other (−5 ± 12 ms, Cohen's $d = 0.09$). No other main effect or interaction reached significance. Thus, the central result of Experiment 2 (i.e., the three-way interaction between relevance, compatibility, and distance) remains the same without the application of the RT outliers-detection/exclusion procedure.

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