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Flowers and Spiders in Spatial Stimulus-Response Compatibility:

Does Affective Valence Influence Selection of Task-Sets or Selection of Responses?

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Abstract

The present study examined the effect of stimulus valence on two levels of selection in the cognitive system, selection of a task-set and selection of a response. In the first experiment, participants performed a spatial compatibility task (pressing left and right key according to the locations of stimuli) in which stimulus-response mappings were determined by stimulus valence. There was a standard spatial stimulus-response compatibility (SRC) effect for positive stimuli (flowers) and a reversed SRC effect for negative stimuli (spiders), but the same data could be interpreted as showing faster responses when positive and negative stimuli were assigned to compatible and incompatible mappings, respectively, than when the assignment was opposite. Experiment 2 disentangled these interpretations, showing that valence did not influence a spatial SRC effect (Simon effect) when task-set retrieval was unnecessary. Experiments 3 and 4 replaced keypress responses with joystick deflections that afforded approach/avoidance action coding. Stimulus valence modulated the Simon effect (but did not reverse it) when the valence was task-relevant (Experiment 3) as well as when it was task-irrelevant (Experiment 4). Therefore, stimulus valence influences task-set selection and response selection, but the influence on the latter is limited to conditions where responses afford approach/avoidance action coding.

Keywords: Affective valence; stimulus-response compatibility; response selection; task-set retrieval; hierarchical control.

Human behaviour is adaptive. It can be adjusted in response to abrupt changes in the environment or in anticipation of a future event (Braver, 2010). These adaptive behaviours reflect the ability to select an appropriate action from many possible alternatives according to the demands of a task or the environment (Hick, 1952; Luce, 1959), but selection can take place at different levels of cognitive processes (Norman & Shallice, 1986; Proctor, Yamaguchi, Dutt, & Gonzalez, 2013; Yamaguchi, Logan, & Li, 2013). For instance, in a typical cognitive task, the actor would need to select an appropriate set of task instructions (or task-set) that specifies mappings between particular stimuli and responses (Meiran, 1996; Rogers & Monsell, 1995). This task-set selection should be followed by selection of an individual response to a stimulus according to the task instructions. Factors that influence these selection processes have been of interest to psychologists for many decades (e.g., Fitts & Seeger, 1953; Hick, 1952; Lu & Proctor, 1995; MacLeod, 1991). The present study investigated one such factor, *affective valence*, which has been shown to influence performance in a variety of task settings (e.g., Chen & Bargh, 1999; Eder & Rothermund, 2010; Greenwald, McGhee, & Schwartz, 1998; Solarz, 1960). In particular, the present study focused on the influence of affective valence on two levels of selection, selection of task-sets and selection of individual responses.

Valence is one of the basic dimensions of emotion, or *affect*, which varies along a continuum between pleasant and unpleasant (Osgood, 1952; Russell, 2003) or positive and negative (Greenwald et al., 1998). The valence of stimuli can influence several types of cognitive functions. For instance, positive or negative stimuli tend to capture attention more strongly than do neutral stimuli (Hansen & Hansen, 1988; Öhman, Flykt, & Esteves, 2001; Yamaguchi & Harwood, 2017). Emotional stimuli or events are also remembered better than non-emotional ones (Anooshian & Hertel, 1994; Ayçiçeği & Harris, 2004). Stimulus valence

causes automatic reaction of facial muscles (Neumann, Hess, Schulz, & Alpers, 2005) and shapes actions so that it is faster to approach positive stimuli than negative stimuli, whereas it is faster to move away from negative stimuli than from positive stimuli (Chen & Bargh, 1999; Solarz, 1960). Certain objects may form implicit associations with valence and interfere with performance (Greenwald et al., 1998; Meissner & Rothermund, 2013). Affective valence also influences the ability to regulate cognitive processes (Botvinick, Cohen, & Carter, 2004; van Steenbergen, Band, & Hommel, 2010). Of most relevance to the present study, stimulus valence has been claimed to reverse a robust psychological phenomenon, the *spatial stimulus-response compatibility (SRC) effect* that emerges from spatial correspondence between stimuli and responses (Conde et al., 2011, 2014).

In studies of Conde et al. (2011, 2014), Brazilian university students rated four soccer teams for their preferences and then performed a spatial compatibility task. Stimuli in the latter task were soccer players who wore the uniform of the participant's favourite team or that of the rival team. These stimuli occurred on the left or right side of the screen. Participants were required to press a key that was spatially compatible or incompatible with the positions of the soccer players, according to the uniform they wore. In one condition, participants pressed a key on the same side as the position of the soccer player if the uniform was of their favourite team, and a key on the opposite side of the position of the soccer player if the uniform was of their rival team. In another condition, participants pressed a key that was on the opposite side of the soccer player if the uniform was of their favourite team, and a key on the same side of the soccer player if the uniform was of their rival team. Previous studies reported that approaching positive stimuli is faster than avoiding them, whereas avoiding negative stimuli is faster than approaching them (Chen & Bargh, 1999; De Houwer, Crombez, Baeyens, & Hermans, 2001; Solarz, 1960).

Conde et al. suggested that spatially compatible responses (e.g., pressing a left key to stimuli on the left) are equivalent to approaching, whereas spatially incompatible responses are equivalent to avoiding. Therefore, compatible responses would be faster than incompatible responses to positive stimuli, resulting in a standard spatial SRC effect, but incompatible responses would be faster than compatible responses to negative stimuli, reversing the SRC effect. Consistent with this idea, their study showed a standard spatial SRC effect when stimuli were the favourite team (positive stimuli), but a reversed effect when stimuli were the rival team (negative stimuli). Cavallet et al. (2016) replicated these results with ADHD patients.

However, another interpretation of Conde et al.'s (2011) results is possible (Proctor, 2013). In the task, participants were not informed of the relevant stimulus-response (S-R) mapping (as to whether they were to make a spatially compatible or incompatible response) until the soccer player appeared on the screen. Thus, on each trial participants first selected a relevant task-set and then selected an appropriate response after a stimulus onset. In the SRC literature, this experimental setting is known to be a *mixed mapping* condition, in which the spatial SRC effect is eliminated (Shaffer, 1965; Vu & Proctor, 2004) or significantly reduced (Yamaguchi & Proctor, 2006). In fact, when Conde et al.'s data are inspected according to the assignment of stimulus valence to S-R mappings (favourite-compatible/rival-incompatible vs. rival-compatible/favourite-incompatible, which were separated between blocks) rather than the team uniforms, there appears to be no spatial SRC effect in each block (Proctor, 2013). Instead, the data suggest that certain assignments of S-R mappings to the team uniforms were preferred over other assignments; namely, responses were faster in general if the compatible S-R mapping was assigned to the favourite team and the incompatible S-R mapping to the rival team than if these mappings were assigned to the opposite teams. Therefore, the findings might reflect the

influence of stimulus valence on selection of appropriate task-sets (i.e., S-R mapping) rather than selection of particular responses.

Consequently, there are two plausible interpretations of the influence of stimulus valence on the spatial SRC effect. The present study distinguished these possibilities. Experiment 1 used the spatial SRC task with mixed compatible and incompatible mappings as in Conde et al.'s (2011) study. Stimuli were photographs of flowers and spiders that appeared on the left or right of the screen, which are often used as positively and negatively valenced stimuli (e.g., Greenwald et al., 1998; Öhman et al., 2001). Participants responded by pressing left and right keys, and the S-R mapping was specified by stimulus valence, flowers (positive) or spiders (negative). We assessed whether Conde et al.'s results could be generalized beyond the soccer team uniforms to another commonly used set of valence stimuli.

In Experiment 2, participants responded to the same flower and spider stimuli by pressing the same response keys, but the valence determined particular responses rather than S-R mappings. Participants pressed one response key if stimuli were flowers and the other if stimuli were spiders, regardless of the locations of the stimuli. This rendered stimulus valence relevant to response selection but irrelevant to task-set selection. Also, spatial compatibility between stimulus and response locations became task-irrelevant, which should still produce a variant of the spatial SRC effect (the *Simon effect*; Lu & Proctor, 1995). If the stimulus valence influences selection of individual responses, flower stimuli should produce a standard Simon effect, but spider stimuli should reverse the Simon effect.

Experiment 3 was the same as Experiment 2, but instead of pressing a left or right key, participants moved a visual cursor on the screen by deflecting a joystick to the left or right. This response mode would afford a more explicit sense of “approach” and “avoidance” actions to

stimuli. Previous studies suggest that for flowers, approach responses would be faster than avoidance responses, but for spiders, avoidance responses would be faster than approach responses. Note that approach responses correspond to spatially compatible responses whereas avoidance responses correspond to spatially incompatible responses. Hence, the Simon effect should be larger for flowers (where approach/avoidance advantages are consistent with spatial compatibility) than for spiders (where approach/avoidance advantages are inconsistent with spatial compatibility). If the negative valence reverses the spatial SRC effect, there should be a reversed Simon effect for spiders but a standard Simon effect for flowers. Experiment 4 followed up the results of Experiment 3 and examined whether stimulus valence had an effect on response selection when the valence was rendered irrelevant to response selection.

Experiment 1

Experiment 1 examined the generality of Conde et al.'s (2011) finding that the spatial SRC effect was reversed for negative stimuli when participants had to select relevant task-sets (compatible or incompatible mapping) according to the stimulus valence. Instead of the soccer team uniforms used in the original study, whose valences are personal to individual participants, we used stimuli that are more common in the studies of affect, flowers and spiders (e.g., Greenwald et al., 1998; Öhman et al., 2001; Yamaguchi & Harwood, 2017). Use of the flower and spider stimuli for which affective valence effects have been found in other paradigms allowed us to verify that the results obtained by Conde et al. were indeed due to valence and not some other factor specific to their stimuli.

Flowers and spiders appeared on the left or right of the screen randomly and equally often (see Figure 1A). In one block, participants pressed a key on the same side as the stimulus if it was a flower but on the opposite side if it was a spider (*flower-compatible/spider-*

incompatible block). In another block, participants pressed a key on the same side of the stimulus if it was a spider but on the opposite side if it was a flower (*spider-compatible/flower-incompatible block*). The experiment aimed to replicate the findings of Conde et al. (2011), which is necessary before its theoretical implication is examined more closely. Thus, responses should be faster with the compatible mapping than with the incompatible mapping when stimuli are flowers (i.e., standard SRC effect), but responses should be faster with the incompatible mapping than with the compatible mapping when stimuli are spiders (reversed SRC effect). When the same data are analysed according to the blocks with different assignments of mappings and stimulus valence, responses should be faster in the flower-compatible/spider-incompatible block than in the spider-compatible/flower-incompatible block, with no spatial SRC effect in either block (Proctor, 2013).

Method

Participants. Forty-one students (27 female; mean age = 19.9 years, SD = 2.7) from introductory psychology courses at New Mexico State University participated for experimental credits¹. The present and subsequent experiments were reviewed and approved by the Institutional Review Board at New Mexico State University.

Apparatus and stimuli. The apparatus consisted of a 19-in LCD monitor and a personal computer. The stimuli were images of 10 flowers and 10 spiders (14 cm wide × 8 cm high; see Appendix A). They were presented at the left or right side of the screen, 13 cm from the screen centre. Responses were registered by pressing the “z” (left) and “/” (right) keys on a standard desk-top QWERTY keyboard.

Procedure. The experiment was conducted individually. Participants were seated

¹ For all four experiments, all factors were within-subject variables. To attain statistical power of at least .80 with a medium effect size, each experiment required a sample size of 34.

approximately 60 cm in front of the computer monitor. They placed the left and right index fingers on the left and right keys. Instructions emphasized the speed and accuracy of responding. Each participant performed two mapping conditions in separate blocks. One of the conditions required participants to respond to flowers by pressing a spatially compatible response key and to spiders by pressing a spatially incompatible response (*flower-compatible/spider-incompatible block*). In the other condition, the response mapping was reversed (*spider-compatible/flower-incompatible block*). Within each mapping block, participants first performed 16 practice trials, followed by two blocks of 120 trials each. The order of the blocks was counterbalanced across participants.

Each trial started with a central fixation ($0.5 \text{ cm} \times 0.5 \text{ cm}$) for 500 ms, followed by a photograph on the left or right side of the screen. The photograph was either a flower or a spider, and it stayed on the screen until a response key was pressed. A response was followed by the message “Correct” or “Incorrect,” which appeared for 1000 ms, depending on the response accuracy. Response time (RT) was defined as the interval between stimulus onset and a depression of a response key.

Results

Trials with $RT < 200 \text{ ms}$ or $> 3000 \text{ ms}$ were discarded (0.47% of all trials). Mean RT for correct responses and percentages of error trials (PE) were computed for each participant (see Table 1).

The data were analysed in two ways. First, following Conde et al. (2011), RT and PE were submitted to a 2 (Valence: positive vs. negative) \times 2 (Spatial Compatibility: compatible vs. incompatible) analysis of variance (ANOVA). Second, following Proctor’s (2013) interpretation, the same data were submitted to a 2 (Mapping: flower-compatible/spider-

incompatible vs. spider-compatible/flower-incompatible) x 2 (Spatial Compatibility: compatible vs. incompatible) ANOVA. The results are summarized in Table 2². Note that these ANOVAs are different ways of organizing the same data, so they yield the same *F* ratios, just associated with different terms.

For RT, consistent with Conde et al.'s results, the first ANOVA revealed a significant interaction between Valence and Spatial Compatibility. The SRC effect was 28 ms for positive stimuli (*M*s = 595 ms vs. 623 ms for compatible and incompatible trials) but -24 ms for negative stimuli (*M*s = 621 ms vs. 597 ms for compatible and incompatible trials). No other effects were significant. Also, consistent with Proctor's interpretation, the second ANOVA revealed that the significant term was now the main effect of Mapping: RT was shorter for the flower-compatible/spider-incompatible mapping (*M* = 596 ms) than for the spider-compatible/flower-incompatible mapping (*M* = 622 ms). No effect involving spatial compatibility was significant.

For PE, the first ANOVA showed that there was a main effect of Spatial Compatibility. PE was less for incompatible (*M* = 2.32%) than for compatible trials (*M* = 3.83%), reversing the SRC effect. The interaction between Valence and Spatial Compatibility was marginal, and it is noteworthy that the SRC effect was eliminated for positive stimuli (*M*s = 3.45% vs. 3.01% for compatible and incompatible trials) and reversed for negative stimuli (*M*s = 4.20% vs. 1.63% for compatible and incompatible trials). For the second ANOVA, the main effect of Spatial Compatibility was significant, and it was now the main effect of Mapping that showed a nonsignificant trend, with the outcomes in the correct direction (*M*s = 2.54% and 3.61% for flower-compatible/spider-incompatible and spider-compatible/flower-incompatible).

Discussion

² In addition to these main analyses, we have also analysed the results by including an additional factor, Mapping Order, which are reported in Appendix B.

The present results are consistent with Conde et al.'s (2011) finding as well as Proctor's (2013) reinterpretation of the finding (also see Conde et al., 2014). When analysed in terms of stimulus valence, there was a standard SRC effect for positive stimuli, but the effect was reversed for negative stimuli. When reanalysed in terms of task assignment, there was no SRC effect, but RT was shorter for the flower-compatible/spider-incompatible mapping than for the spider-compatible/flower-incompatible mapping. Therefore, the present experiment extended the previous finding to stimuli that were more commonly used in studies of affective processing (e.g., Öhman et al., 2001; Yamaguchi & Harwood, 2017).

Experiment 2

The outcomes of Experiment 1 can be interpreted in two ways. The first is that compatible responses in the present task are equivalent to approach actions, whereas incompatible responses are equivalent to avoidance actions (Conde et al., 2011). Approach actions are faster to positive stimuli than to negative stimuli, but avoidance actions are faster to negative stimuli than to positive stimuli (Solarz, 1960). Thus, compatible responses are faster than incompatible responses (i.e., the standard SRC effect) for positive stimuli; but incompatible responses are faster than compatible responses (reversed SRC effect) for negative stimuli. This interpretation implies that the effect of stimulus valence rests in response selection. The second is that mixing spatially compatible and incompatible mappings in a single block required two types of selection processes, task-set (S-R mapping) selection and response selection. Task-set selection is faster when positive and negative stimuli are assigned, respectively, to compatible and incompatible mappings than when they are assigned to opposite mappings (Proctor, 2013), whereas mixing two mappings eliminated the spatial SRC effect at response selection (Shaffer,

1965). This interpretation implies that stimulus valence has an effect on task-set selection. Experiment 2 dissociated these possibilities.

To examine the effect of stimulus valence on response selection, as opposed to task-set selection, participants in this experiment selected a left or right response according to stimulus valence; that is, participants pressed one response key for flowers and the other key for spiders (see Figure 1B). Stimulus valence and spatial compatibility were both randomized within the same block, and consistent S-R mappings were used throughout a session. Hence, any influence of stimulus valence could not be attributed to task-set selection. It was expected that, if stimulus valence only influenced task-set selection in Experiment 1, there would be no effect of stimulus valence in the present experiment because task-set selection was not involved. If stimulus valence influenced response selection, the outcomes of Experiment 1 should be replicated; that is, there should be a standard SRC effect (or, Simon effect) for positive stimuli but a reversed effect for negative stimuli.

Method

Participants. A new group of 40 students (26 female; mean age =19.8, SD =2.1) were recruited in the same manner as in Experiment 1.

Apparatus, stimuli, and procedure. The same apparatus and stimuli as those of Experiment 1 were used. A major difference was that participants were instructed to press one of the two response keys if the stimulus was a flower and the other key if it was a spider. The mapping between stimuli and responses was counterbalanced across participants, and each participant used the consistent mappings throughout a session. The total number of trials was the same (4 blocks of 120 test trials) as in Experiment 1. Participants had 16 practice trials before the test blocks. The procedure was the same as Experiment 1 in other respects.

Results

Trials were filtered in the same manner as in Experiment 1, discarding 0.54% of all trials. Mean RT for correct responses and PE were computed for each participant (see Table 1). They were first submitted to a 2 (Valence: positive vs. negative) x 2 (Spatial Compatibility: compatible vs. incompatible) x 2 (S-R Mapping: spider-left/flower-right vs. flower-left/spider-right) ANOVA, but no effect involving S-R Mapping was significant, so this variable was excluded. The data were then submitted to a 2 (Valence: positive vs. negative) x 2 (Spatial Compatibility: compatible vs. incompatible) ANOVA (see Table 3).

For RT and PE, only the main effect of Spatial Compatibility was significant. RT was faster for compatible ($M = 617$ ms) than for incompatible trials ($M = 635$ ms); and PE was less for compatible ($M = 0.99\%$) than for incompatible trials ($M = 2.42\%$). Valence did not modulate these effects.

Discussion

There was a standard Simon effect, but the effect did not depend on stimulus valence, suggesting that stimulus valence did not influence response selection. This outcome corroborated Proctor's (2013) proposal that stimulus valence influenced task-set selection, not response selection. Therefore, positive stimuli facilitated retrieval of compatible mapping, whereas negative stimuli facilitated retrieval of incompatible mapping. Although Conde et al. (2014) have already agreed with this interpretation, the present experiment provides the first empirical evidence that directly supported the interpretation.

And yet, the lack of influence of stimulus valence on the Simon effect is noteworthy. Previous studies have shown effects of valence on response selection (e.g., Chen & Bargh, 1999). Because compatible trials require participants to press keys on the same side as stimuli,

and incompatible trials required them to press keys on the opposite side, compatible and incompatible responses could be considered, respectively, as approach and avoidance actions. If so, the compatible and incompatible responses should be facilitated for positive and negative stimuli, respectively, and this influence of valence would have resulted in a smaller Simon effect for negative stimuli than for positive stimuli. The lack of such modulation of the Simon effect in Experiment 2 implies that participants did not code the left-right keypress responses as approach and avoidance actions. Experiment 3 aimed to verify that, with the current task setting and stimuli, stimulus valence could still influence the Simon effect when responses are coded more explicitly as “approach” and “avoidance” actions (Eder & Rothermund, 2008).

Experiment 3

Experiment 3 was designed to create an unambiguous sense of “approach” and “avoidance” actions. The experiment was essentially the same as Experiment 2, but participants now used a joystick to control a visual cursor that appeared on the screen (see Figure 1C). Participants were presented with the same flower and spider stimuli that appeared on the left and right of the screen. They moved the cursor to the left or right from the screen centre to flowers or spiders, with a corresponding joystick movement. In past studies, researchers defined the physical movement of a hand or a finger as approach and avoidance actions (e.g., moving a lever with the hand toward or away from a computer screen; e.g., Chen & Bargh, 1999). Similar results were obtained when participants were instructed to move a manikin toward or away from a word at the screen centre (De Houwer et al., 2001) or to move a positive or negative word toward or away from a target object by deflecting a joystick (Solarz, 1960; Zhang, Proctor, & Wegener, 2012). In the present experiment, participants controlled a visual cursor on the screen that moved toward or away from stimuli on the left and right with a left-right joystick movement.

The visual cursor provided a strong sense of lateral movement toward or away from stimuli (e.g., Guiard, 1983). Thus, on compatible trials participants moved the cursor toward the stimulus location, producing an approach action; on incompatible trials they moved the cursor away from the stimulus location, producing an avoidance action.

Note that this design allowed us to manipulate spatial stimulus-response compatibility and approach/avoidance advantages for valenced stimuli orthogonally. For positive stimuli, there should be an advantage of “moving-toward” (spatially compatible) responses as opposed to “moving-away” (spatially incompatible) responses. For negative stimuli, there should be an advantage of moving-away (spatially incompatible) responses, as opposed to “moving-toward” (spatially compatible) responses. Thus, the Simon effect should be enhanced for positive stimuli but reduced for negative stimuli. If the valence of stimuli actually reverses spatial compatibility, as in the original explanation of Conde et al.’s (2011) findings, then the Simon effect would not only be smaller but would be reversed to favour spatially incompatible trials for negative stimuli.

Method

Participants. Another 40 participants (25 female; mean age = 19.1, SD = 2.6) were recruited in the same manner as in the preceding experiments.

Apparatus, stimuli, and procedure. The experiment was essentially identical to Experiment 2, except that responses were made by deflecting a joystick (Logitech Attack™ 3 Joystick) to move a visual cursor (0.4 cm × 0.4 cm). Participants used their dominant hand (37 right-handed and 3 left-handed). In this experiment, trials ended with a text “Faster!” presented on the screen if participants did not make response within 2000 ms, and these trials were excluded from the analysis. Participants were instructed to deflect the joystick all the way to the left or right on each trial. RT was defined as the interval between stimulus onset and a deflection

of the joystick by 7° to the left or right, which corresponded to the cursor displacement of 20 pixels from the screen centre.

Results

Trials with RT < 200 ms or with no response were excluded from the analyses (1.12% of total trials). Mean RT and PE (see Table 1) were submitted to a 2 (Valence: positive vs. negative) x 2 (Spatial Compatibility: compatible vs. incompatible) ANOVA³ (see Table 3).

For RT, the main effect of Spatial Compatibility and the interaction between Spatial Compatibility and Valence were significant. The Simon effect was 43 ms for positive stimuli ($M_s = 551$ ms vs. 594 ms for compatible and incompatible trials) and was 23 ms for negative stimuli ($M_s = 565$ ms vs. 589 ms for compatible and incompatible trials). Thus, the Simon effect was smaller for negative stimuli than for positive stimuli, but evident for both ($p_s < .001$).

For PE, only the main effect of Spatial Compatibility was significant. PE was less for compatible trials ($M = 2.25\%$) than for incompatible trials ($M = 4.11\%$). The Simon effect was larger for positive stimuli ($M = 2.29\%$) than for negative stimuli ($M = 1.44\%$), but this difference was not statistically significant.

Discussion

The present experiment showed that with more obvious approach/avoidance actions with the joystick that controlled a visual cursor on the screen, stimulus valence did modulate the Simon effect. For positive stimuli, compatible trials were consistent with the advantage of approach over avoidance responses, whereas for negative stimuli, incompatible trials were consistent with an advantage of avoidance over approach responses; consequently, the Simon effect was smaller for negative stimuli than for positive stimuli. These results are in agreement

³ See Appendix B for supplemental analyses including S-R mapping.

with previous studies that showed the approach/avoidance advantages for positive and negative stimuli (Chen & Bargh, 1999; De Houwer et al., 2001; Solarz, 1960; Zhang et al., 2012). The outcome implies that the lack of the influence of stimulus valence in Experiment 2 was due to participants not representing keypress responses as approach/avoidance actions. This is perhaps not too surprising, since keypresses are discrete responses at distinct locations on a keyboard and do not involve movement of a limb or a visual stimulus controlled by a limb that could be conceived of as approaching or avoiding a stimulus. Nevertheless, the present results also showed that the influence of negative stimuli on the Simon effect was not sufficiently strong to reverse spatial compatibility entirely. Thus, even with a response mode that can be coded as approach/avoidance actions, the influence of affective valence on response selection is not sufficiently strong to explain the reversed SRC effect for negative stimuli in Experiment 1. This result provides further evidence that the influence of stimulus valence when responding with keypresses in that experiment was not on response selection but on task-set selection.

Experiment 4

A notable difference between Experiments 1 and 3 was that stimulus valence was relevant to response selection in Experiment 3 but was irrelevant in Experiment 1. The present experiment examined whether stimulus valence could affect response selection when it is irrelevant to response selection. The present task was similar to that of Experiment 3, but coloured frames were added to stimuli (see Figure 1D), and participants responded to the colour by deflecting the joystick and moving the cursor to the left or right. The same images of flowers and spiders were presented within the coloured frames, but the contents were irrelevant to the task. This experimental setting assessed whether stimulus valence could modulate the Simon effect when stimulus valence was irrelevant to response selection.

Method

Participants. A new group of 41 undergraduate students (35 females; average age = 18.5, SD = 0.8) were recruited from the same subject pool as in the preceding experiments.

Apparatus, stimuli, and procedure. The apparatus and stimuli were identical with those in Experiment 3, except that there were frames coloured in blue or red around the images of flowers and spiders. Half of the participants moved the cursor to the left if the frame was red and to the right if it was blue; the others did the opposite. The procedure closely followed that of Experiment 3 in other respects. Participants used their dominant hand to operate the joystick (39 right-handed, and 2 left-handed).

Results

Trials were filtered in the same way as in Experiment 3, discarding 0.88% of trials. Mean RT and PE (see Table 1) were submitted to 2 (Valence: positive vs. negative) x 2 (Spatial Compatibility: compatible vs. incompatible) ANOVAs (see Table 3).

For RT, there were significant main effects of Spatial Compatibility and Valence. Responses were faster for compatible trials ($M = 630$ ms) than for incompatible trials ($M = 670$ ms), producing a 40-ms Simon effect. Responses were also faster for positive stimuli ($M = 647$ ms) than for negative stimuli ($M = 654$ ms). These two factors also interacted: the Simon effect was larger for positive stimuli ($M = 46$ ms) than for negative stimuli ($M = 33$ ms).

For PE, only the main effect of Spatial Compatibility was significant. PE was less for compatible trials ($M = 1.75\%$) than for incompatible trials ($M = 3.49\%$). The Simon effect was not statistically larger for positive stimuli (1.70%) than for negative stimuli (1.79%).

Discussion

Although stimulus valence was task-irrelevant, the present experiment also demonstrated

the influence of stimulus valence on the Simon effect. This outcome is consistent with the results of Experiment 3⁴, and it does suggest that valence automatically influences cursor-movement/joystick responses regardless of task instructions. It is noteworthy that some previous studies have found the advantages of approach/avoidance actions to positive and negative stimuli even when the valence was irrelevant to the task (e.g., Chen & Bargh, 1999; Krieglmeyer, Deutsch, De Houwer, & De Raedt, 2010), although a recent meta-analysis on the approach/avoidance advantages indicated that explicit instructions on the affective aspects of stimuli is an important factor for the effect to be observed (Phaf, Mohr, Rotteveel, & Wicherts, 2014). The present experiment suggests that the approach/avoidance advantages do not always require explicit instructions; the advantages likely depend on how strong a given response mode provides a sense of moving toward or away from valenced stimuli.

General Discussion

The present study dissociated the two possible interpretations of the reversed SRC effect found in previous studies (Conde et al., 2011, 2014). Experiment 1 extended the finding of the reversed SRC effect when S-R mappings were determined by the valence of stimuli. We found a standard SRC effect for positive stimuli but a reversed SRC effect for negative stimuli as in Conde et al.'s (2011) study, but using flower and spider stimuli of the type often used for positive and negative valence. However, as in the original study, the same data can also be considered from a view that responses were generally faster if positive and negative stimuli were assigned, respectively, to compatible and incompatible mappings than if the mapping assignment was reversed (Proctor, 2013). The first interpretation suggests that valence modulated the SRC effect at response selection, whereas the second interpretation suggests that valence modulated

⁴ See Appendix B for supplemental analyses comparing Experiments 3 and 4.

the SRC effect at task-set selection. To dissociate these interpretations, Experiment 2 examined the effect on response selection in the absence of a need to select task-sets by having participants make one keypress to flowers and another to spiders. The results showed no influence of stimulus valence on a spatial compatibility effect (the Simon effect), providing evidence that valence influenced task-set selection, not response selection, in Experiment 1.

From the results of Experiments 1 and 2, it is tempting to suggest that stimulus valence has no influence on response selection. However, previous studies have suggested that stimulus valence can also influence response selection (e.g., Chen & Bargh, 1999; Eder & Rothermund, 2010), so we further examined possible valence effects on response selection in more detail. Experiment 3 used the same task setting as Experiment 2 but with a response mode (movement of a cursor/joystick toward or away from stimuli) that more clearly conveyed a sense of approach/avoidance actions. The results showed that there were advantages of approach/avoidance responses to positive/negative stimuli, respectively, which influenced the Simon effect but not strong enough to reverse the SRC effect. Experiment 4 further made stimulus valence irrelevant to response selection, as in Experiment 1, but with the joystick/cursor-movement response mode as in Experiment 3. The results demonstrated that the approach/avoidance advantages for valenced stimuli modulated the Simon effect but did not reverse the Simon effect as in Experiment 3.

Altogether, the present study indicates that stimulus valence does influence selection of task-sets or responses, depending on whether selection is made based on the attribute. However, the influence of valence on response selection is sizeable only when the responses are coded as approach or avoidance actions (Eder & Rothermund, 2008), which in the present case required toward and away joystick/cursor movements. Even in that case, though, the negative valence did

not reverse spatial compatibility. Instead, valence and spatial compatibility influence response selection simultaneously, and the tendency to make the avoidance response to negative stimuli is weaker than the tendency to make the spatially compatible response, reducing but not reversing the Simon effect.

The evidence that the mixed mapping results of Conde et al. (2014) occurred in task-set selection is consistent with a hierarchical model of response selection, in which the appropriate task-set (or S-R mapping) is determined first, followed by application of the task-set to select a response (Kleinsorge & Heuer, 1999; Proctor et al., 2013; Shaffer, 1965, 1966; Yamaguchi & Proctor, 2006). The basic idea is that the positive stimulus is more compatible with a task-set that involves spatially compatible S-R mapping and the negative stimulus with a task-set that involves spatially incompatible S-R mapping. This leads to faster selection of the mapping rule when the assignment of valence to task-set retains this relation than when it is counter to it. After selection of the mapping rule, it is then applied to the location stimulus when spatially compatible and incompatible mappings are mixed (Shaffer, 1965; Vu & Proctor, 2004). Shaffer's (1965) study also included conditions in which the mapping rule was precued in advance of the location stimulus. He showed that the advantage for the spatially compatible mapping was re-introduced with precues, suggesting that preparation for that mapping could occur in advance. No similar advantage for the spatially compatible mapping was evident when it was signalled by positive stimuli and the incompatible mapping by negative stimuli in the present study. This result implies that although the time at which the rule could be applied was influenced by the valence mapping, the faster rule selection did not allow for advance preparation of the designated spatial mapping.

The locus of the approach/avoidance advantages was also examined by Eder and Rothermund (2008). In their Experiment 4, participants responded to positive and negative words by moving a joystick toward or away from the computer monitor. The mapping between valenced stimuli and approach/avoidance responses was signalled by a neutral cue (display colour). Their results showed that although the approach/avoidance advantages for valenced words were obtained, the temporal delay between the mapping cue and the valenced words had little impact on these advantages. These outcomes suggest that the approach/avoidance advantages were not mediated by memory retrieval (i.e., task-set selection). This conclusion is consistent with the hierarchical model we proposed above, which predicts selective influences of factors that affect task-set selection and response selection. In Eder and Rothermund's study, stimulus valence was relevant to selecting a toward- or away-response as in Experiment 3 of the present study, but it was irrelevant to selecting an S-R mapping; thus, valence would affect response selection but not task-set selection in their study. Therefore, Eder and Rothermund's finding reinforces the hierarchical model of response selection, and Experiment 4 of the present study (also see Chen & Bargh, 1999; Krieglmeier et al., 2010) further adds that stimulus valence can automatically influence response selection. The present study provided little evidence supporting that stimulus valence automatically influences task-set selection, but further investigations are required to scrutinize the possibility.

The present results suggest that the findings of Conde et al. (2011) and our Experiment 1 were due to task-set selection, but the mechanism underlying the facilitated task-set selection remains to be resolved. A possible explanation is that mapping rules are coded as positive or negative, which creates affective compatibility with valenced stimuli. Recent studies have suggested that conflicts in cognitive processes trigger aversive signals and result in a negative

emotion (Botvinick, 2007; Fritz & Dreisbach, 2013; van Steenbergen et al., 2009). Thus, a spatially compatible mapping may be coded as positive affect, whereas an incompatible mapping may be coded as negative affect, which then would produce affective compatibility with positive and negative stimuli (e.g., Lavender & Hommel, 2007). An alternative, proposed by Proctor (2013), is that there is correspondence between non-affective polarities of stimuli and mappings (Proctor & Cho, 2006). The polarity correspondence principle proposes that binary categories are coded as “+” and “-” in many cases. In the present tasks, positive and negative stimuli may be coded as “+” and “-” so were compatible and incompatible mappings. Then, positive stimuli correspond to compatible mapping, and negative stimuli correspond to incompatible mapping. These correspondences may have facilitated the retrieval of these mappings. As with affective compatibility, polarity correspondence was originally proposed as a principle for response selection, and the present results cannot distinguish the two possibilities. Regardless, the study suggests that similar mechanisms are at work at different levels of selection processes. This has significant implications for theories that assume hierarchically structured control processes (e.g., Logan & Crump, 2011; Norman & Shallice, 1986).

The lack of the influence of valence on response selection in Experiment 2 provides evidence that stimulus valence did not modulate spatial compatibility at response selection in Experiment 1. Previous studies have reported effects of valence in similar task settings, but they have typically used movements of joysticks toward or away from the participant him/herself, which can be more clearly conceived of as approach/avoidance, rather than stimuli to which they respond (e.g., Chen & Bargh, 1999; De Houwer et al., 2001; Solarz, 1960). Experiment 3 did show the influence of stimulus valence on the Simon effect (although it did not reverse the effect) when responses were made by moving a visual cursor and a joystick toward or away from

stimuli, confirming that the lack of effect of stimulus valence in Experiment 2 was due to the keypress mode of responding. Keypress responses might not have been coded as approach/avoidance actions because participants had already placed their fingers on keys, so there was no movement of own hands or a consequential cursor movement toward or away from stimuli. It is also possible that the influence of affective valence appears when responses require extended movements (Buetti, Juan, Rinck, & Kerzel, 2012), although only a small deflection of the joystick was required in the present Experiments 3 and 4. Alternatively, it has been shown that the consequence of action (or action effect) exerts a strong influence on response selection (a phenomenon known as the *response-effect compatibility*; Kunde, 2001). It may be the anticipated effect of the joystick deflection (i.e., the movement of a cursor on the screen) that produces the approach/avoidance advantage at response selection. The design of our study only allows us to speculate about these possibilities, and it would be interesting to disentangle the effects of valence on response selection and response execution in future investigations.

To conclude, the present study demonstrated separate effects of affective valence on task-set selection and response selection, whereby the latter depended on the type of action. Whereas many studies have suggested the importance of the congruity between affective value of stimuli and actions, the importance of the congruity between affective value of stimuli and task-sets has not been considered much in previous studies. In everyday settings, there are many occasions in which people switch between tasks that are valenced positively (e.g., enjoyable hobbies) and tasks that are valenced negatively (tedious chores). Strong biases for positively valenced tasks would lead to addiction, whereas strong biases against negatively valenced tasks would result in procrastination. The present findings are suggestive of the influence of affective processing in such situations, and it will be informative to determine in future studies whether similar

congruency effects between affective stimuli and valenced tasks can be observed in other task settings.

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Table 1. Mean response time (in milliseconds), percentage of error trials, and the stimulus-response compatibility (SRC) or Simon effect in Experiments 1-4 (values in parentheses are standard errors of the means).

Expt	Mapping/Valence	Response Time				Percentage Error					
		Compatible		Incompatible		Compatible		Incompatible		SRC/Simon Effect	
1	Flower-compatible/ Spider-incompatible	595	(20.61)	597	(22.43)	2	3.45	(.58)	1.63		(.28)
	Spider-compatible/ Flower-	621	(23.38)	623	(24.32)	2	4.20	(.71)	3.01	(.79)	-1.19
	incompatible										
	Positive	595	(20.61)	623	(24.32)	28	3.45	(.58)	3.01	(.79)	-0.44
	Negative	621	(23.38)	597	(22.43)	-24	4.20	(.71)	1.63	(.28)	-2.57
2	Positive	617	(25.46)	633	(24.58)	17	1.05	(2.54)	0.21	(.55)	-0.84
	Negative	617	(26.43)	637	(26.56)	20	0.92	(2.30)	0.30	(.46)	-0.63
3	Positive	551	(12.49)	594	(12.08)	43	2.21	(.53)	4.49	(.60)	2.29
	Negative	565	(12.71)	589	(12.43)	23	2.28	(.39)	3.72	(.49)	1.44
4	Positive	631	(14.25)	677	(16.51)	46	1.83	(.28)	3.53	(.38)	1.70
	Negative	630	(15.96)	663	(17.28)	33	1.66	(.25)	3.45	(.48)	1.79

Table 2: ANOVA results on response time (RT) and percentage of error trials (PE) in Experiment 1

Factors	<i>df</i>	<i>MSE</i>	<i>F</i>	<i>p</i>	η_p^2
<i>Conde et al.'s (2011) interpretation: RT</i>					
Valence (V)	1,40	387.72	< 1	.977	< .001
Spatial Compatibility (SC)	1,40	1376.09	< 1	.698	.004
V x SC	1,40	4129.93	6.69	.013	.143
<i>Proctor's (2013) interpretation: RT</i>					
Mapping (M)	1,40	4129.93	6.69	.013	.143
SC	1,40	1376.09	< 1	.698	.004
M x SC	1,40	387.72	< 1	.977	< .001
<i>Conde et al.'s (2011) interpretation: PE</i>					
V	1,40	3.17	1.26	.268	.031
SC	1,40	6.47	14.38	< .001	.264
V x SC	1,40	14.68	3.17	.083	.073
<i>Proctor's (2013) interpretation: PE</i>					
M	1,40	14.68	3.17	.083	.073
SC	1,40	6.47	14.38	< .001	.264
M x SC	1,40	3.17	1.26	.268	.031

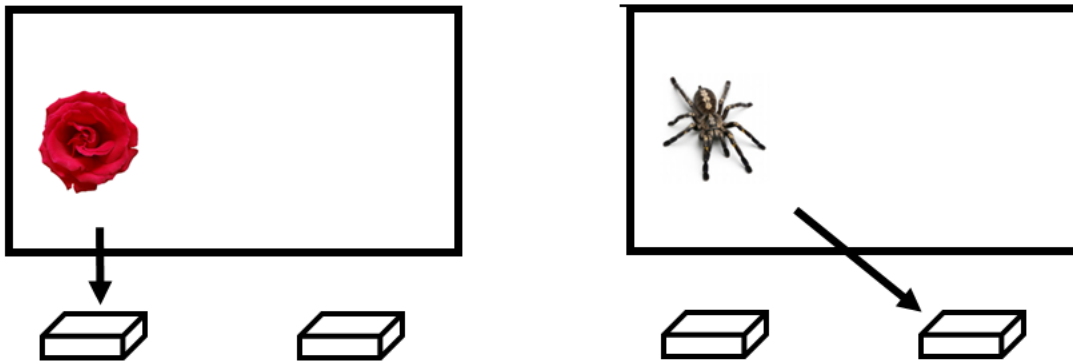
Table 3. ANOVA results on response times (RT) and percentage of error trials (PE) in Experiments 2-4.

Factors	<i>df</i>	<i>MSE</i>	<i>F</i>	<i>p</i>	η_p^2
<i>Experiment 2: RT</i>					
Valence (V)	1,39	2955.36	< 1	.825	.001
Compatibility (C)	1,39	702.56	18.94	< .001	.327
V x C	1,39	647.52	< 1	.685	.004
<i>Experiment 2: PE</i>					
V	1,39	1.16	1.16	.289	.029
C	1,39	3.62	22.70	< .001	.368
V x C	1,39	1.10	< 1	.726	.003
<i>Experiment 3: RT</i>					
V	1,39	2174.86	< 1	.527	.010
C	1,39	1290.97	33.92	< .001	.465
V x C	1,39	423.06	9.31	.004	.193
<i>Experiment 3: PE</i>					
V	1,39	7.75	< 1	.436	.016
C	1,39	5.00	27.76	< .001	.416
V x C	1,39	2.86	2.51	.121	.061
<i>Experiment 4: RT</i>					
V	1,40	363.12	5.43	.025	.120
C	1,40	1798.55	36.01	< .001	.474
V x C	1,40	329.72	5.49	.024	.121
<i>Experiment 4: PE</i>					
V	1,40	2.04	< 1	.602	.007
C	1,40	4.94	25.26	< .001	.387
V x C	1,40	1.78	< 1	.837	.001

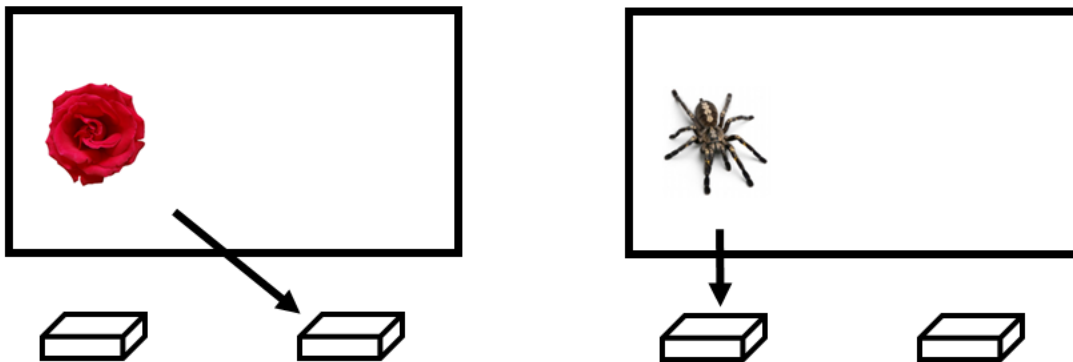
Figure 1. Examples of the experimental conditions in Experiments 1-4. Note that these images are only for an illustrative purpose, and the sizes of stimuli and display are not scaled to those used in the actual experiments. These examples are representative, but not an exhaustive list of all conditions in the respective experiments. The stimulus features in the parentheses are task-irrelevant features in a given condition (compatible = spatially compatible; incompatible = spatially incompatible; positive = flower; negative = spider). In Experiments 3 and 4, the central circle represents a cursor that moved from the centre to the left or right side of the screen when a joystick was deflected.

A. Experiment 1

Positive → Compatible mapping **Negative → Incompatible mapping**

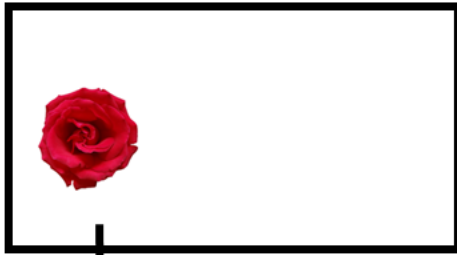


Positive → Incompatible mapping **Negative → Compatible mapping**

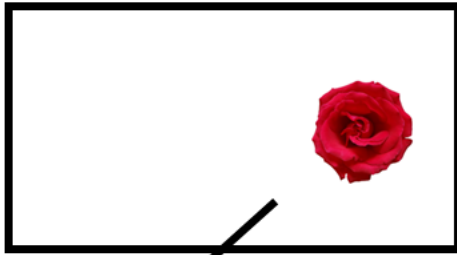


B. Experiment 2

Positive → Left response
(compatible)



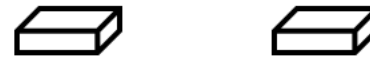
Positive → Left response
(incompatible)



Negative → Right response
(incompatible)

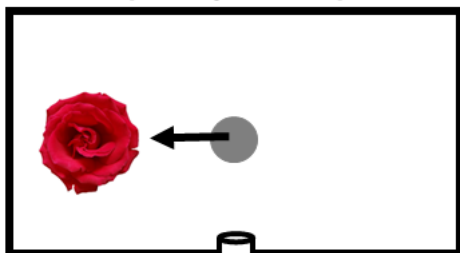


Negative → Right response
(compatible)

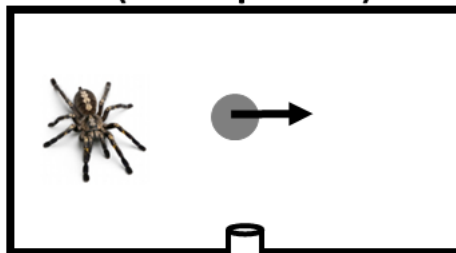


C. Experiment 3

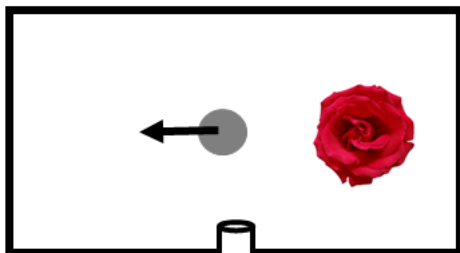
Positive → Left response
(compatible)



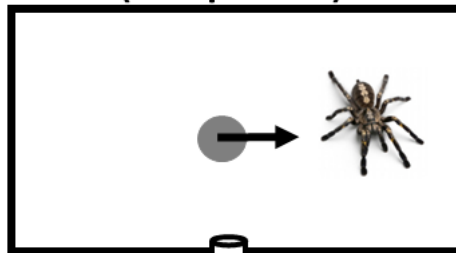
Negative → Right response
(incompatible)



Positive → Left response
(incompatible)

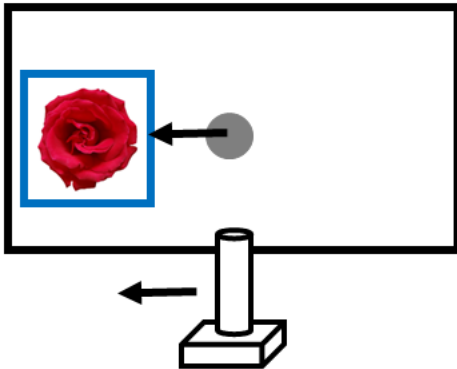


Negative → Right response
(compatible)

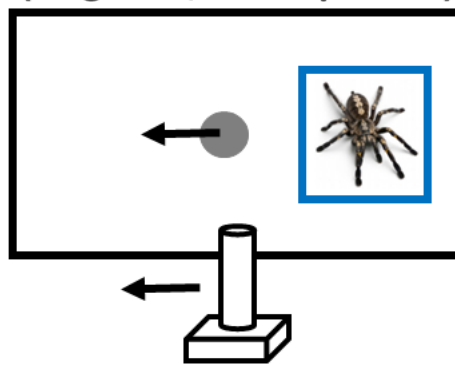


D. Experiment 4

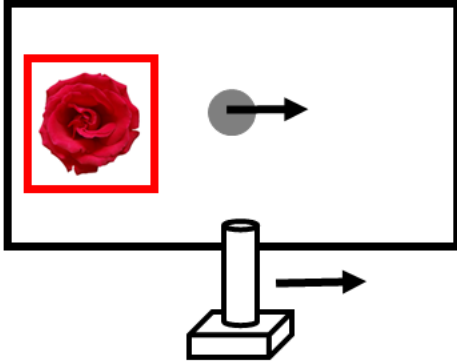
Blue frame → Left response
(Positive, compatible)



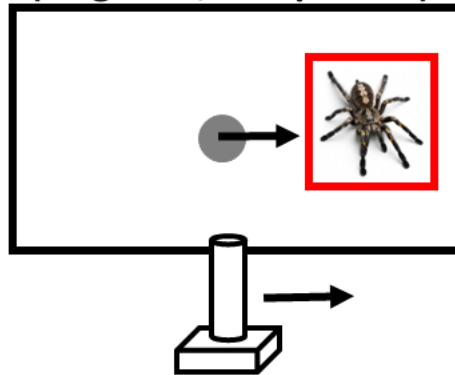
Blue frame → Left response
(Negative, incompatible)



Red frame → Right response
(Positive, incompatible)



Red frame → Right response
(Negative, compatible)



Appendix A
Flowers and Spiders

Flowers



Spiders



Appendix B

Supplemental Analyses

Experiment 1

In addition to the two analyses reported in the main texts of Experiment 1, we also performed two analyses with an additional factor, Mapping Order (flower-compatible/spider-incompatible first vs. spider-compatible/flower-incompatible first). For PE, no effects involving Mapping Order, $F_s < 1.7$, $p_s > .2$. For RT, there was a significant interaction between Mapping Order and Valence in Conde et al.'s (2011) analysis, which corresponded to the 3-way interaction among Mapping Order, Mapping, Spatial Compatibility in Proctor's (2013) analysis, $F(1, 39) = 5.85$, $MSE = 345.83$, $p = .020$, $\eta_p^2 = .130$.

According to Conde et al.'s (2011) analysis, RT was longer for positive valence ($M = 594$ ms) than for negative valence ($M = 587$ ms) when the flower-compatible/spider-incompatible assignment was performed first, but RT was longer for negative valence ($M = 632$ ms) than for positive valence ($M = 625$ ms) when the spider-compatible/flower-incompatible assignment was performed first. In other words, RT was generally longer for valence that was first assigned to compatible mapping than for valence that was assigned to incompatible mapping first.

According to Proctor's (2013) analysis, when the flower-compatible/spider-incompatible assignment was performed first, RT was longer with compatible mapping ($M = 586$ ms) than with incompatible mapping ($M = 580$ ms) for the flower-compatible/spider-incompatible assignment, but RT was shorter with compatible mapping ($M = 593$ ms) than with incompatible mapping ($M = 602$ ms) for the spider-compatible/flower-incompatible assignment. When the spider-compatible/flower-incompatible assignment was performed first, RT was shorter with compatible mapping ($M = 604$ ms) than with incompatible mapping ($M = 615$ ms) for the flower-

compatible/spider-incompatible assignment, but RT was longer with compatible mapping ($M = 649$ ms) than with incompatible mapping ($M = 645$ ms) for the spider-compatible/flower-incompatible assignment. In other words, the SRC effect was negative ($M_s = -5$ ms and -4 ms) for the valence-compatibility assignment that was performed first, but the SRC effect was positive ($M_s = 9$ ms and 11 ms) for the valence-compatibility that was performed second. These results could be understood as showing that the SRC effect was negative or eliminated in the first block but was reinstated in the second block, or that the SRC effect was eliminated with the first valence-compatibility assignment but was reinstated because of switching to a different valence-compatibility assignment. In either case, these outcomes are interesting in their own rights, but, unfortunately, our study is not designed to distinguish between these possibilities, so further investigations are required to examine them in more detail.

Experiment 3

As in Experiment 2, the data were first submitted to 2 (Valence: positive vs. negative) x 2 (Spatial Compatibility: compatible vs. incompatible) x 2 (S-R Mapping: spider-left/flower-right vs. flower-left/spider-right) ANOVA.

For RT, S-R Mapping interacted with Valence, $F(1, 38) = 9.37$, $MSE = 1790.42$, $p = .004$, $\eta_p^2 = .198$. With the spider-right/flower-left mapping, RT was shorter for flowers ($M = 560$ ms) than for spiders ($M = 575$ ms); with the flower-right/spider-left mapping, RT was shorter for spiders ($M = 569$ ms) than for flowers ($M = 595$ ms). In other words, left responses were generally faster than right responses, which likely reflects the fact that the majority (37 out of 40 participants) operated the joystick with the right hand, so it was faster to deflect to the left side.

For PE, there was a main effect of S-R Mapping, $F(1, 38) = 5.97$, $MSE = 23.14$, $p = .019$, $\eta_p^2 = .136$. PE was smaller with the flower-left/spider-right mapping ($M = 2.29\%$) than with the

spider-left/flower-right mapping ($M = 4.15\%$). In both cases, there were no significant interactions involving S-R Mapping and Spatial Compatibility.

Comparison between Experiment 3 and Experiment 4

As a supplemental analysis, an ANOVA was conducted on RT to compare the influence of valence on the Simon effect between Experiments 3 and 4. It involved Valence, Spatial Compatibility, and Experiment, with the first two variables being within-subject factors and the last being a between-subject factor. Nevertheless, the only significant effect involving Experiment was its main effect, $F(1, 79) = 15.26$, $MSE = 30380.02$, $p < .001$, $\eta_p^2 = .162$, and the 3-way interaction was not significant, $F(1, 79) < 1$, $p = .449$.