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Long-term facilitation of return: A response-retrieval effect

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Abstract

The current study used a target-target procedure to examine the extent to which perceptual and response factors contribute to inhibition of return (IOR) in a visual discrimination task. When the target was perceptually identical to the previous target, and the required response was the same, facilitation was observed for both standard and long-term target-target stimulus onset asynchronies (SOAs). When the color of the previous target differed from the current target but the response remained the same, facilitation was reduced in both the standard SOA and long-term SOA conditions. Finally, IOR was observed for both standard and long-term SOAs only in the condition in which there was a change in response. This pattern of inhibition and facilitation provides new evidence that the responses previously associated with a location play an important role in the ability to respond to a stimulus. We interpret this finding as consistent with a framework in which the involuntary retrieval of bound stimulus-response episodes contribute to response compatibility effects in visual stimulus discrimination.

Long-term facilitation of return: A response-retrieval effect

When presented with simple stimuli, the efficiency of reporting attributes of the stimuli (their presence, location, appearance) is often affected by stimuli and responses that have previously occurred. Examples include negative priming (Tipper, 1985), priming of pop-out (Malkovic & Nakayama, 1994), and spatial cuing effects (Posner, 1980). Although often explained with recourse to attentional mechanisms, such priming effects may also arise from the retrieval of bound stimulus-response episodes from memory (Niell, Valdes, Terry, & Gorfein, 1992; Hommel, 1998; Kahneman, Triesman, & Gibbs, 1992). Such episodic memory accounts predict that (1) the stimulus-response compatibility between the current trial and previous trials is a critical determinant of performance, and (2) the influence of previous episodes on the current trial should be detectable over relatively long periods of time if interference is sufficiently controlled. In such accounts, responses are slowed when the stimulus-response bindings in the current trial do not match the stimulus-response bindings from the previous trial, and may be speeded when stimulus-response bindings are repeated. The core idea is that a new stimulus automatically retrieves the previously associated response; if the response required by the task is congruent with the retrieved response, facilitation occurs, but when the response required by the task conflicts with the retrieved response, responses will be slowed. Attentional and memory-based accounts of such inter-trial effects make similar predictions regarding (1), however demonstration of (2) which we shall refer to as “long-term” effects, can serve as positive evidence for a contribution of memory processes to visual performance. Long-term effects have been demonstrated in negative priming (Tipper et al., 1991; DeSchepper & Triesman, 1996), priming of pop-out (Thomson & Milliken, 2012), and visual search (Chun & Jiang, 1998).

Long-term effects have also been demonstrated with respect to another priming effect: inhibition of return. Briefly, inhibition of return is the finding of slowed responses to stimuli appearing in a previously attended location (Posner, Rafal, Choate & Vaughan, 1985; Klein, 2000). The term IOR can refer to both an empirical finding (slowed responding to a location previously attended) as well as an attentional mechanism; in this paper, “IOR” will henceforth refer to the empirical finding unless otherwise specified. The existence of long-term IOR was discovered by Tipper, Grison, and Kessler (2003); their study used complex visual stimuli (faces) and showed that long-term IOR responses could last up to 13 minutes after cue presentation if the visual context was sufficiently complex. The authors explained this effect by proposing that inhibitory states from a preceding cue were retrieved and re-established, causing slowed responding. In contrast, an episodic retrieval account would attribute slowed responses to the conflict between the location-response bindings created by the cue and the required response for a target when it appears in the same location as the cue.

Wilson, Castel, and Pratt (2006) produced similar evidence for long-term IOR by providing only spatial context for simple, colored stimuli. Using a go/no-go task, Wilson et al. examined the impact of perceptual and response changes on IOR for both standard (1,500 ms) and long-term (10,500 or 13,500 ms) SOAs. In their second experiment, one of three coloured circle stimuli (red, blue, or green) appeared briefly in one of four positions (above, below, left, or right of fixation) every 1,500ms. The participant’s task was to make a response to two of the coloured stimuli, and withhold a response to the third. Blocks of 6 or 8 trials in which the circle stimulus could only appear in the top or bottom positions were used to assess IOR at a standard cuing SOA of 1,500 ms. Between each block of standard trials a single long-term trial was presented in which the circle stimulus would appear in the left or right position. The SOA

between each long-term trial was then 10,500 or 13,000 ms and were used to assess long-term cuing effects. Using this paradigm the authors were able to examine the contribution of appearance and response changes on spatial cuing. The authors found that a change in a perceptual feature was not sufficient to produce IOR; IOR was only produced when there was a change in both the location *and* response. Furthermore, because this response-based IOR effect was present for both the standard and long-term SOAs, the authors suggested that the same memory retrieval mechanism may underlie both standard and long-term IOR. However, instead of attributing IOR to the retrieval of an inhibitory attentional state (Tipper et al., 2003), Wilson et al. proposed that IOR was due to retrieval of the response associated with its location from the previous trial. This account can be seen as a type of memory-based event-file account (Hommel, 2004), identifying stimulus location-response bindings as a critical factor in determining response time (RT). In this context, the results of Wilson et al. demonstrate (1) that conflicts in location-response bindings result in slowed responses, whereas other feature-location binding conflicts do not, and (2) that such bindings survive the presentation of intervening stimuli. It is worth noting that Wilson et al. and Tipper et al. (2003) used discrimination tasks which may rely more on memory processes than a simpler detection task. We will return to this issue in the discussion section.

The present study tests the memory-based response conflict account of Wilson et al. (2006) by using a discrimination task in which all stimuli are associated with one of two responses. If response-conflict is the basis of the long-term IOR effect of Wilson et al., this task should lead to long-term IOR when a different response is required for a stimulus appearing in the same location as a preceding stimulus. In contrast, if long-term IOR results from retrieval of an inhibitory state (Tipper, Grison, & Kessler, 2003), then because responses are never withheld,

no long-term IOR should be found. Anticipating our results, IOR only occurred when the required response changed, supporting Wilson et al.'s memory-based response conflict account. In addition, we showed that a location-based response-repetition benefit emerges at both standard and long-term SOAs. Several studies using target-target paradigms have shown that when a response repeats, facilitation occurs for successive stimuli appearing in a single location (Taylor & Donnelly, 2002; Pratt & Castel, 2001; Roggeveen, Prime, & Ward, 2005).

Methods

Participants

Sixty-three undergraduate students from Queen's University participated in the study in exchange for course credit or five dollars. All had normal or corrected-to-normal vision. Participants were naive to the purpose of the experiment.

Apparatus

The experiment was conducted on a personal computer in a dimly-lit, sound-attenuated room. Participants viewed stimuli on a 16" CRT monitor at a distance of 50 cm. Viewing distance was ensured using a chin rest. Experimental stimuli were presented using Matlab version 7.04 with the Psychophysics Toolbox version 3.0.8 (Brainard, 1997).

Design and Procedure

The overall trial sequence is depicted in Figure 1. The initial display consisted of two white diamond-shaped placeholders and two square-shaped placeholders (each 1.8° in width and height, each 4.8° from a fixation cross) presented on a dark background with a central fixation cross (0.35°). Stimuli took the form of filled-in circles of four different colors: blue, green, red,

and purple (radius of 0.5°). Participants were instructed to respond by pressing the *Z* key with the left index finger when a green or purple stimulus appeared on the screen and with the *M* key with the right index finger when a red or blue stimulus appeared. Colors and locations of the stimuli were randomized at the start of each trial, with the exception that, on standard trials, stimuli could only appear in the top or bottom square, and on long-term trials, stimuli could only appear in the left or right diamond. The stimuli were presented in the following pattern: (a) six or eight stimuli in the vertically aligned square placeholders (colors and up/down locations randomized), (b) one stimulus presented in one of the horizontally aligned diamond placeholders (left/right location randomized). This pattern would then repeat. Because of concern that stimulus-location based effects, such as the Simon effect, might contribute to the long-term trials but not the standard trials, the mapping of location and trial type was reversed for approximately half of the participants ($n = 33$) such that standard trials were presented in the horizontally aligned diamond placeholders and long-term trials were presented in the vertically aligned square placeholders. The experiment consisted of four blocks of trials, within which participants received 25 sets of 6 or 8 standard trials followed by a long-term trial. The SOA between each stimulus remained constant at 1,500 ms; therefore the SOA was 1,500 ms in standard IOR trials. In long-term IOR trials, the SOA was either 10,500 ms (7 stimuli \times 1,500 ms) or 13,500 ms (9 stimuli \times 1,500 ms). The participants were instructed to: (1) stay fixated on the fixation cross, and (2) press the appropriate key as quickly as possible upon detecting a stimulus.

Results

Of the 63 participants, 5 were excluded because they made response errors on more than 25% of trials. For the remaining 58 participants, mean accuracy was 90.5%. Only RTs for correct responses were analysed. The mean RTs are presented in Table 1. Mean RTs were

analyzed with a 2 (Trial mapping: standard vertical or standard horizontal) X 2 (SOA: standard, long-term) x 2 (Target Location: Same or Different) X 3 (Target Condition: Same-Color/Same-Response, Different-Color/Same-Response, Different-Color/Different-Response) mixed model analysis of variance (ANOVA). Long-term trials with 6 and 8 intervening trials were collapsed together because there were not enough observations per condition to analyze separately.

Our primary concern in the analysis of response-time data was whether the pattern of location-based priming effects associated with different target conditions are consistent for standard and long-term trials, as well as for different trial mappings (a comprehensive list of F ratios and Mean Square Errors (MSEs) are provided in Table 2). We therefore first concentrate our analyses on interactions involving SOA and Trial mapping. Trial mapping interacted only with SOA, $F(1, 56) = 5.17, p = .027$, partial $\eta^2 = .08$, but no three- or four-way interactions involving Trial Mapping reached significance, $F_s < 2.33, p_s > .10$, suggesting that the priming-based RT effects of interest did not differ for vertically and horizontally mapped stimuli. The critical three-way interaction between SOA, Target Location and Target Condition was observed, $F(2, 112) = 9.50, p < .001$, partial $\eta^2 = .145$. For both standard- and long-term SOAs, Target Location and Target Condition interacted, $F(2, 112) = 125.92, p < .001$, partial $\eta^2 = .69$, $F(2, 112) = 5.27, p = .006$, partial $\eta^2 = .09$.

The interactions between Target Location and Target Condition show that location-based priming effects did occur in our data, for standard- and long-term SOAs. To determine whether the repetition of stimulus location led to response facilitation or IOR for a given SOA and Target Condition, we conducted six planned, paired-samples t -tests for each Target Condition separately for each SOA. For standard SOAs, location-repetition speeded responses for Same-Color/Same-Response trials, $t(57) = -12.33, p < .001$ (see Table 1 for means and standard errors), and for

Different-Color/Same-Response trials, $t(57) = -9.46, p < .001$, but slowed responses for Different-Color/Different-Response trials, $t(57) = 8.90, p < .001$. For long-term SOAs, location repetition again speeded responses for Same-Color/Same-Response trials, $t(57) = -2.14, p = .037$, but not for Different-Color/Same-Response trials, $t(57) = 0.06, p = .96$. As in standard-SOA trials, location repetition slowed responses in the Different-Color/Different-Response condition, $t(57) = 2.07, p = .043$. This set of comparisons demonstrates similar priming effects for standard- and long-term SOAs. One exception to this trend is that facilitation was absent at long-term SOAs for the Different-Color/Same-Response condition, but present for the standard SOAs. However, the magnitude of facilitation did decline between the Same-Color/Same-Response condition and the Different-Color/Same-Response condition in the standard SOA, as demonstrated by a paired-samples t -test comparing the RT difference (Different Location – Same Location) between these two conditions, $t(57) = 2.41, p = .019$. Therefore, for both SOAs, a change in stimulus color led to a decrease in location-based response facilitation. To summarize, for both standard- and long-term conditions, facilitation of responding occurred for repeated locations when the stimulus appearance and response repeated, but inhibition for a repeated location occurred when the stimulus appearance and response changed. Changing stimulus appearance, but not the response, reduced the amount of location-based facilitation for both SOAs.

No speed-accuracy trade-offs were observed in our data. Running the same analysis for accuracy as for response time revealed a complimentary effect. Trial Mapping did not interact with any key effects, $F_s < 0.89, p_s > .41$, and a three way interaction between SOA, Target Condition, and Target Location again emerged, $F(1, 112) = 4.13, p = .02$, partial $\eta^2 = .07$. Standard and long-term trials alike produced an interaction between Target Condition and Target

Location, $F(2, 112) = 61.56, p < .001$, partial $\eta^2 = .54$, and $F(2, 112) = 4.75, p = .01$, partial $\eta^2 = .08$, respectively. Six planned, paired-sample t -tests complimented the RT findings. In standard SOA trials, location-repetition improved accuracy in the Same-Color/Same-Response condition, $t(57) = 5.87, p < .001$, and in the Different-Color/Same-Response condition, $t(57) = 4.82, p < .001$, but reduced accuracy in the Different-Color/Different Response condition, $t(57) = -9.56, p < .001$ (see Table 1 for means and standard errors). For long-term SOAs, repetition of location did not modulate accuracy in the Same-Color/Same-Response condition, $t(57) = 0.46, p = .646$, improved accuracy in the Different-Color/Same-Response condition, $t(57) = 2.09, p = .041$, and reduced accuracy in the Different-Color/Different-Response condition, $t(57) = -2.26, p = .028$. Overall, location-based facilitation in response time was accompanied by increases in accuracy, and location-based suppression of response time was accompanied by decreases in accuracy.

Discussion

The current study sought to determine whether a conflict between two responses was sufficient to elicit IOR in a target-target paradigm, and whether such IOR would emerge at long SOAs. When both the location-feature binding and the location-response binding stayed the same (Same-Color/Same-Response conditions) response times were facilitated in both the standard- and long-term conditions. If the location-feature binding changed but the location-response binding stayed the same (Different-Color/Same-Response), the facilitation was reduced in both the standard and long-term conditions and was actually eliminated in the latter condition. Finally, when the location-response binding changed (Different-Color/Different-Response conditions), rather than facilitation, IOR was observed for both the standard and long-term conditions. The finding of response repetition-based facilitation is consistent with previous research that has demonstrated facilitation when response and location repeat (Terry, Valdes, &

Neill, 1994; Hommel, 1998; Taylor & Donnelly, 2002; Taylor & Ivanoff, 2005). Critically, we further demonstrated that this effect persists for SOAs of over 10s, after multiple stimuli had appeared, implicating memory as a basis for this effect. Taken together, these results show that the spatial, perceptual, and response bindings on previous trials influence the speed of target discriminations similarly at standard- and long-term intervals.

The current study, when considered in conjunction the results of Wilson et al. (2006), provides converging evidence that at least some amount of the response cost associated with repeating a stimulus location stems from a conflict in location-response bindings. In both studies, IOR always occurred and only occurred when the response changed from the previous trial. It is crucial to note that this does not appear to generalize to simple localization or detection tasks (Maylor & Hockey, 1985; Pratt & Castel, 2001). For example, Maylor and Hockey used a procedure in which the target stimulus appeared above, below, left and right of fixation. Participants responded with a single, speeded key-press as soon as a target appeared. Despite constant response repetition, the authors found that responses were consistently slower to a target appearing in the location of a previous target. It is possible that perceptual decisions based on stimulus location or stimulus presence, requiring less stimulus analysis, might not be influenced by the automatic memory retrieval of responses and may be primarily determined by attentional processes (for a related framework regarding differential process contributions to detection versus discrimination tasks, see Lupiáñez, 2010). Another possible interpretation is that a response cost emerges only when all attributes except location (i.e., appearance and response) change, and that it is not the location-response mismatch per se that causes slowed responses. Although our paradigm does not allow for the differentiation of these two hypotheses, it is worth noting that the paradigm of Hommel (1998) does. His data show that when response switches,

but stimulus appearance does not, response is slowed at a repeated location. This finding supports the notion that it is location-response compatibility that drives whether facilitation or inhibition will be observed, at least at a standard SOA (500ms). Whether the same finding emerges when longer SOAs are tested is a question that remains open. However, given that the current study and the Wilson et al. study show a similar pattern of results across standard- and long-term SOAs, we would expect that a long-term version of Hommel's paradigm would also support a response-compatibility interpretation.

It is interesting that Wilson et al. (2006) did not find a location-based facilitation effect when the response repeated, but that we did here. The current results provide additional evidence that response compatibility can produce location-based facilitation when the response repeats and location-based inhibition when the response changes. It is possible that, because Wilson et al. used a go/no-go task, withholding a response nullified the benefits of repeated responses. Another possibility is that the response-repetition benefit may simply be more difficult to detect in their study. The go/no-go task used in Wilson et al. led to average response times of 378ms, whereas our two-alternative response choice task led to average response times of 531ms; it is always more difficult to detect response benefits when responses are already very fast as in their study.

Can episodic retrieval accounts explain IOR in general? The robustness of response costs for repeated locations in detection or localization tasks suggests that an attentional IOR mechanism is a core visual process. IOR has successfully been found in discrimination tasks at longer SOAs (Lupiáñez et al., 1997), although it has been shown to decay shortly thereafter (measured at 1,300ms; an order of magnitude less than our long-term SOA). However, in order to account for the present data, the inhibition produced by the IOR mechanism would need to

persist for as long as 10 seconds. We are not aware of any IOR studies that have tested SOAs beyond 10 seconds that do not invoke a memory component as an explanatory mechanism. We also know of no predictions regarding the duration of attentional inhibition at such long SOAs. Although it remains possible that attentional inhibition may persist for this duration, an episodic retrieval mechanism can comfortably accommodate long-lasting effects. Further work is necessary to more clearly distinguish between these possibilities.

The possibility then emerges that both episodic retrieval and an attentional IOR mechanism determine response times. Parallel mechanisms of IOR and memory-based response facilitation have been proposed before to account for unexpected performance changes; for example, Christie & Klein (2001) proposed that an additional memory-based mechanism could explain why response facilitation emerged when targets repeated in a negative priming experiment. The specific contributions of each process await experimental clarification. What is clear is that a pure episodic retrieval framework cannot account for the findings in detection and localization tasks (see Maylor & Hockey, 1985), but in discrimination tasks, the pattern of data that emerges is compatible with a contribution of episodic retrieval processes to performance. There are evidently reductions in the magnitude of the priming effects (both facilitation and inhibition) from standard- to long-term SOAs in our study. This may reflect memory decay or interference, which increases with time and intervening stimulus presentation. However, it may also reflect the contribution of additional, non-mnemonic processes operating at the standard SOA which do not affect performance at the long-term SOA. Nonetheless, the primary goal of our work has been to continue to provide evidence for a contribution of memory retrieval to response efficiency in simple perceptuo-motor tasks; further research will be required to disentangle the specific contributions of memory and of attentional processes to performance.

In conclusion, this research provides novel evidence of a memory-based response-repetition benefit and additional evidence for a memory-based response-change cost. Using a novel paradigm, the current study demonstrated facilitation for both standard and long-term SOAs when a stimulus appearing at a repeated location required a repeated response. Our results are consistent with an event-file account wherein location-response bindings stored in memory are used to integrate perceptual data with previous perceptuo-motor binding (Hommel, 2004; Milliken et al., 2000).

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Table 1.

Mean response times (ms) and response accuracy (%) by SOA, Target condition, and Target Location.

		<i>Target Location</i>			
		<i>Same</i>		<i>Different</i>	
<i>SOA</i>	<i>Target Condition</i>	<i>RT</i>	<i>Accuracy</i>	<i>RT</i>	<i>Accuracy</i>
Standard	Same-Color/Same-Response	452 (3)	96.8 (0.5)	495 (2)	94.4 (0.5)
	Diff.-Color/Same-Response	530 (3)	88.5 (0.6)	562 (4)	84.0 (0.8)
	Diff.-Color/Diff.-Response	555 (2)	86.3 (0.6)	537 (2)	91.9 (0.3)
Long	Same-Color/Same-Response	533 (5)	91.7 (1.0)	546 (5)	91.0 (1.0)
	Diff.-Color/Same-Response	537 (5)	93.1 (0.9)	536 (5)	90.3 (0.9)
	Diff.-Color/Diff.-Response	547 (4)	88.5 (0.8)	537 (3)	90.1 (0.6)

Note. All RTs are displayed in milliseconds. Standard error of the means are reported in parentheses.

Table 2.

Results of Analyses of Variance for Response Time and Accuracy.

<i>Source</i>	<i>Response Time</i>		<i>Accuracy</i>	
	<i>F ratio</i>	<i>MSE</i>	<i>F ratio</i>	<i>MSE</i>
(1) SOA	50.84**	925.60	1.70	27.19
(2) Target Location	23.72**	739.55	0.73**	43.13
(3) Target Condition	104.65**	970.30	37.40**	37.24
(4) Trial Mapping	4.62*	17,612.18	4.47*	289.20
(1)x(2)	12.29**	897.66	0.01	39.99
(1)x(3)	98.11**	981.79	37.44*	37.26
(1)x(4)	5.17*	925.60	7.77**	27.19
(2)x(3)	42.43**	696.42	32.23**	27.73
(2)x(4)	0.43	739.55	0.11	43.13
(3)x(4)	0.11	970.30	0.49	37.24
(1)x(2)x(3)	9.50**	679.26	4.13*	27.30
(1)x(2)x(4)	0.51	897.66	0.01	39.99
(1)x(3)x(4)	0.032	981.79	0.892	37.26
(2)x(3)x(4)	2.24	696.42	0.88	27.73
(1)x(2)x(3)x(4)	2.33	679.26	0.80	27.29

* indicates significance at the $p < .05$ level** indicates significance at the $p < .01$ level

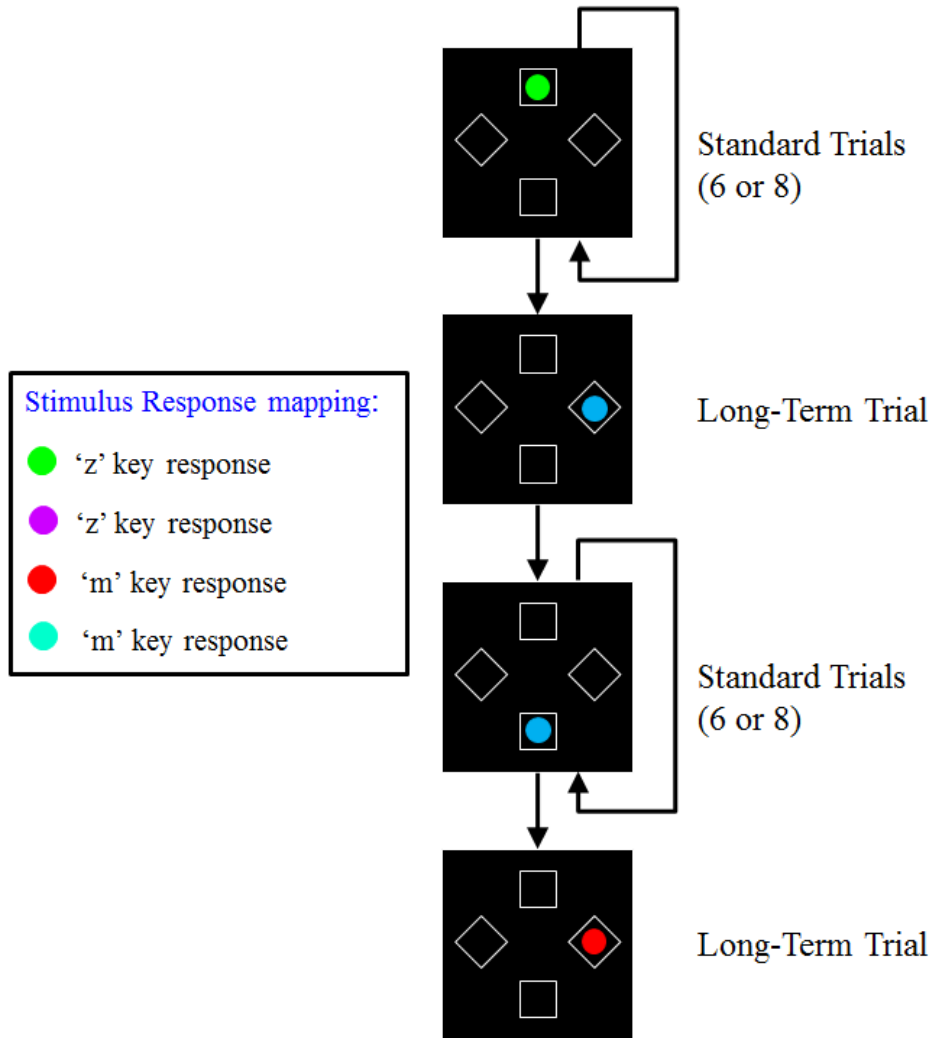


Figure 1. Sequential structure of trials. Stimulus-response mappings are depicted in the legend.

The SOA between successive stimulus presentations was 1500 ms.

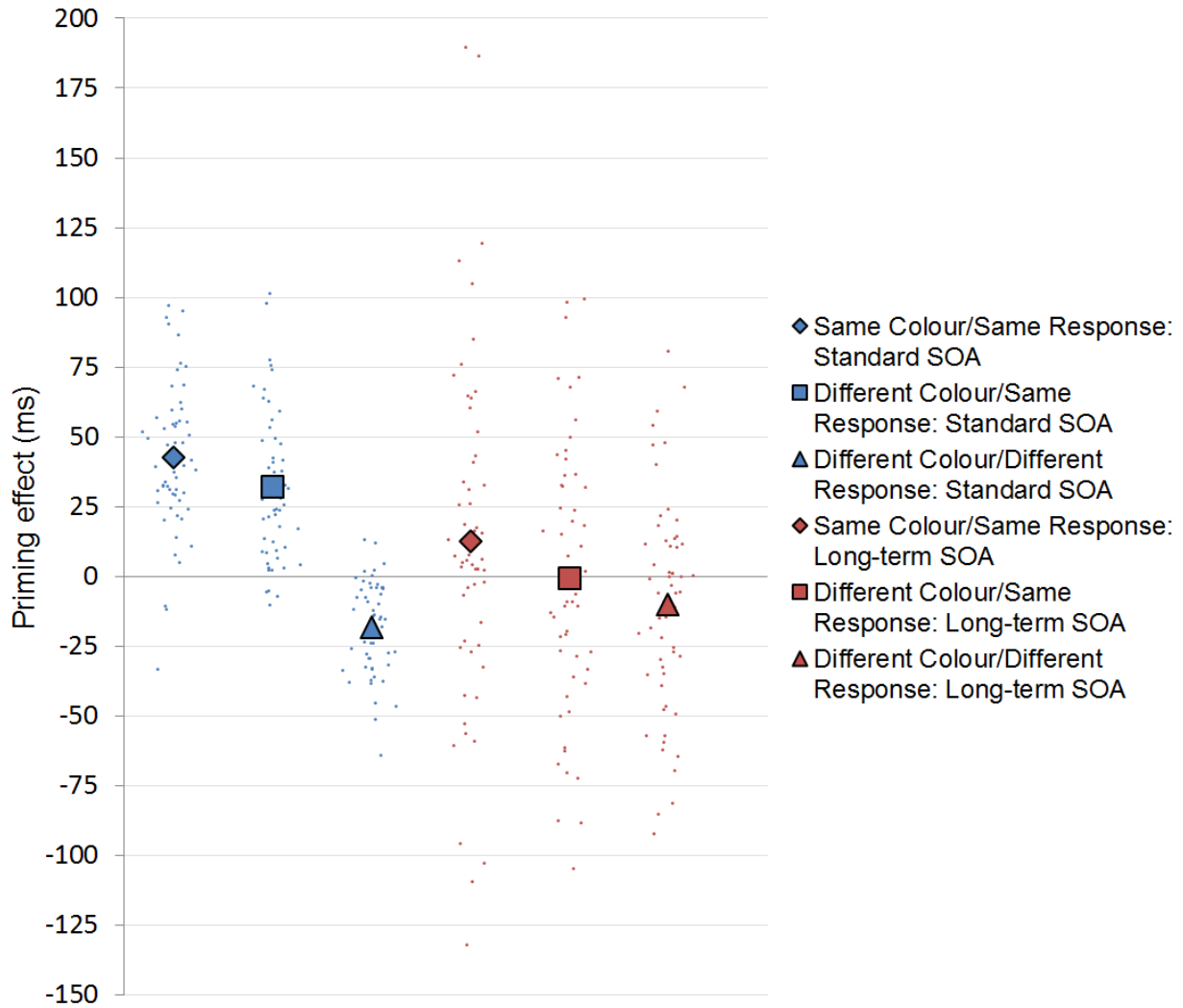


Figure 2. Priming effects for standard and long-term SOA durations in milliseconds. Positive numbers on the vertical axis indicate facilitation and negative numbers indicate inhibition. The data of individual subjects are plotted as filled circles, where condition means are depicted with symbols indicated in the legend to the right of the figure. Note that for display purposes only (i.e., to allow better visualization of individual samples), the horizontal position of each observation was randomized.