Responding to feature or location: a re-examination of inhibition of return and facilitation of return

Jay Pratt *, Alan D. Castel

Department of Psychology, University of Toronto, 100 St. George Street, Toronto, Ont., Canada M5S 3G3

Abstract

It was found [Vision Res. 36 (1996) 2125] that reaction times for repeated targets were longer in detection and location discrimination tasks (inhibition of return; IOR) and shorter in color and orientation discrimination tasks (facilitation of return; FOR). The present experiment, using a more detailed analysis, shows that both IOR and FOR can be found in the discrimination tasks. Overall, the results are inconsistent with the notion that IOR and FOR effects reside in separate visual pathways. Rather, the results are accounted for by repetition priming and IOR that occur with specific combinations of target features and task demands. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Reaction time; Inhibition of return; Facilitation; "Where vs. what"

1. Introduction

There is neurophysiological evidence that there are two separate visual processing pathways. One pathway, the dorsal–parietal pathway, has been characterized as the "where" pathway (e.g. Ungerleider & Mishkin, 1982) or the "action" pathway (e.g. Goodale & Milner, 1992). This pathway is used to process visual information about spatial locations. The other pathway, the ventral–temporal pathway, has been characterized as the "what" pathway (e.g. Ungerleider & Mishkin, 1982), and is used to process visual information about various object features, such as color and orientation.

In a series of experiments, Tanaka and Shimojo (1996, 2000) suggest that the behavioral consequences of these two separate visual pathways can be seen from the results in a spatial cueing paradigm. It has long been known that reaction times (RTs) for a detection target are longer if the target appears at the location of a prior cue. This increase in RT, termed inhibition of return (IOR), generally occurs when the cue precedes the target by more than 300 ms (e.g. Posner & Cohen,

1984). Although IOR has been repeatedly demonstrated with targets that require detection or location responses (e.g. Maylor, 1985; Ro, Pratt, & Rafal, 2000), there is evidence both for and against IOR occurring for responses based on non-spatial target features (e.g. Kwak & Egeth, 1992; Pratt, Kingstone, & Khoe, 1997).

In reviewing the literature at the time, Tanaka and Shimojo (1996) hypothesized that IOR occurs for location-based tasks, such as detection and location discrimination, whereas IOR does not occur for feature-based tasks. Such feature-based tasks would involve the discrimination of some non-spatial attribute of a target, such as color or orientation. To examine this hypothesis, they conducted a series of four experiments that used the exact same methodology and differed only in the nature of the task, and the type of response required by the subjects. Unlike the traditional cue–target procedure commonly used in IOR experiments (e.g. Posner & Cohen, 1984), Tanaka and Shimojo used a target–target procedure where every stimulus served as a target. Thus, instead of comparing targets at cued and uncued locations, the RTs to targets were based on whether the preceding target was at the same location (i.e. a cued trial) or at the opposite location (i.e. an uncued trial). The targets consisted of rectangles that were randomized in terms of peripheral

* Corresponding author. Tel.: + 1-416-978-0676; fax: + 1-416-946-3981.

E-mail address: pratt@psych.utoronto.ca (J. Pratt).

location (left or right), color (red or green), and orientation (vertical or horizontal). In addition, four response–stimulus intervals (RSI) were used (100, 300, 500, and 1200 ms). The only difference between the four experiments was the type of response made to the target. In the detection experiment, observers were instructed to make a simple detection response to the appearance of the target, regardless of the location, color, and orientation of the target. In the location experiment, observers were instructed to make a choice response based only on the location of the target. Likewise, the color experiment required a choice response based only on the color of the target, and the orientation experiment required a choice response based only on the orientation of the target, regardless of the other features of the target.

The results of the four experiments confirmed Tanaka and Shimojo's (1996) hypothesis that IOR occurs for location-based tasks and not for feature-based tasks. In both the detection and location tasks, they found IOR (slower RTs for targets at the same location as the previous target). In addition, they found faster RTs for targets at the same location as previous targets for both the color and orientation tasks. They termed this effect facilitation of return (FOR), and suggested that FOR occurs for feature-based discrimination tasks while IOR occurs for location-based detection and discrimination tasks. Moreover, they suggested that these opposing effects are due to the visual pathway used for each task. Specifically, IOR occurs for tasks that use the dorsal–parietal ("where") pathway, whereas FOR occurs for the tasks that use the ventral–temporal ("what") pathway.

There are reasons to believe, however, that the data collected by Tanaka and Shimojo (1996) might not lend itself to such a straightforward interpretation. In reporting the results from the series of four experiments, they report location main effects for all four experiments, and it is these main effects (slower repeated locations for detection and location, faster repeated locations for color and orientation) that they use as support for their conclusion of IOR and FOR in separate visual pathways (see their figure 2, which plots RT by RSI for targets at repeated and non-repeated locations from subject AI). Importantly, this figure collapses across color and location, providing the impression that there were no location by color or location by orientation interactions. This was, in fact, not the case as the color discrimination experiment yielded a location by color interaction and the orientation discrimination experiment yielded a location by orientation interaction. The nature of these interactions, which potentially compromise the notion of IOR and FOR in different visual pathways, are not reported or discussed.

The present study sought to re-examine the findings of Tanaka and Shimojo (1996) to determine if the location by color and location by orientation interactions are problematic for the notion of IOR for location tasks (via the "where" pathway) and FOR for feature-based tasks (via the "what" pathway). To do so, a close replication of the four Tanaka and Shimojo experiments was conducted.

2. Method

2.1. Subjects

Eight subjects, undergraduate students from the University of Toronto, participated in the study in exchange for course credit. All reported normal or corrected to normal acuity and color vision, and all were naïve to the purposes of the study.

2.2. Apparatus and procedure

The experiment took place in a dimly illuminated sound attenuated room. Subjects were seated 44 cm in front of a computer monitor. The viewing distance was held constant with the use of an adjustable head/chin rest. The computer keyboard was directly in front of the subject, and was used as the response device. Subjects were asked to fixate on a central fixation cross (0.1° by 0.1°) in order to prevent eye movements.

The experiment and sequence of events were modeled after Tanaka and Shimojo (1996). The subjects engaged in four tasks in separate blocks. The four tasks were simple detection, location discrimination (left/right), color discrimination (red/green), and orientation discrimination (vertical/horizontal). In the detection task, subjects were asked to press the space bar on the keyboard as soon as target appeared. In each of the three discrimination tasks, subjects were asked to make a two alternative forced choice (2AFC) by pushing labeled keys on the keyboard (either "z" or "/") that corresponded to the two choices (location: left = z, right = /; color: red = z, green = /; orientation: vertical = z, horizontal = /). The subject was asked to respond to the target as quickly and as accurately as possible by pressing the appropriate key. If the subjects pressed the incorrect key, or responded faster than 100 ms or slower than 1000 ms, a short tone (400 Hz, 100 ms) was presented.

A single rectangle (0.6° × 0.4°) served as both the target for the current trial, and the cue for the following trial. Throughout the set of trials, the fixation cross remained on the center of the screen. The initial target appeared at one of two locations on the horizontal meridian, either to the left or to the right of the fixation cross, and the distance between the target and the

fixation point was 6°. The target was randomized in terms of location (left or right), color (red [17 cd/m^2] or green [22.5 cd/m^2]) and orientation (vertical or horizontal). The background was black with a luminance of 0.5 cd/m^2. The interval between the key-press response and the presentation of the next target (the response stimulus interval: RSI) was also randomized across trials (either 100, 300, 500, or 1200 ms). Thus, the interval between the previous target and the next target was the sum of the RSI and the reaction time to respond to the target. Reaction time was measured as the time between the onset of the target and the onset of the response. As soon as the subject responded to the target, it disappeared. After a randomized RSI, the next trial began.

2.3. Design

The entire session consisted of four blocks with 800 trials in each block. Subjects were told that the experiment consisted of four sections, and that they would be given specific instruction at the beginning of each section. Subjects were given short breaks at intervals of 200 trials, as well as longer breaks in between blocks. The order in which subjects engaged in each block was randomized according to a 4 by 4 Latin-square design. The stimuli and trial sequence was exactly the same for the four conditions, with the only difference being the instructions given to the subject and the nature of the task. Subjects completed each block in less than 20 min, and the entire session was completed in a single 90-min session.

3. Results

The mean RTs for all four experiments were analyzed using a 4 (RSI: 100, 300, 500, or 1200 ms) $\times 2$ (location: same or different) $\times 2$ (color: same or different) $\times 2$ (orientation: same or different) ANOVA. With regards to the location factor, "same" refers to when a target occurred in the same location as the previous target, and "different" refers to when a target occurred in the opposite location to the previous target. Similarly, "same" in the color condition refers to when the preceding target was the same color, and in the orientation condition refers to when the preceding target had the same orientation.

To begin with, the present study replicates Tanaka and Shimojo's main effects for location in all four tasks [$Fs(1, 7) > 13.5$, $Ps < 0.01$]. The mean main effect data is shown in Fig. 1, plotted in the same manner as Tanaka and Shimojo plotted their main effect data from subject AI. Examining the main effect data in Fig. 1 clearly indicates that IOR was found across all RSIs in the detection and location tasks, whereas FOR was found across all RSIs in the color and orientation tasks. Thus, at this level of analysis, the present results confirm Tanaka and Shimojo's disassociation of location-based and feature-based tasks. As noted earlier, it is this level of analysis that Tanaka and Shimojo based their conclusions on.

In addition to the main effects for location, present study also replicated the location $\times$ color interaction in the color task [$F(1, 7) = 117$, $P < 0.0001$] and the location $\times$ orientation interaction in the orientation task
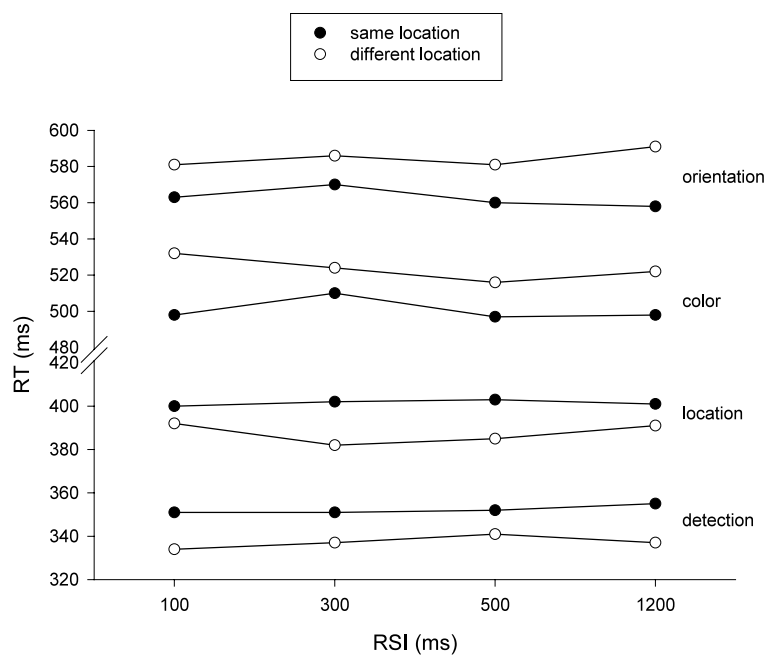

Fig. 1. Results from the four tasks (detection, location, color, and orientation) plotted for same and different locations, on repeated trials, as a function of RSI. As presented by Tanaka and Shimojo (1996), the RTs are collapsed across the target dimensions of color and orientation.
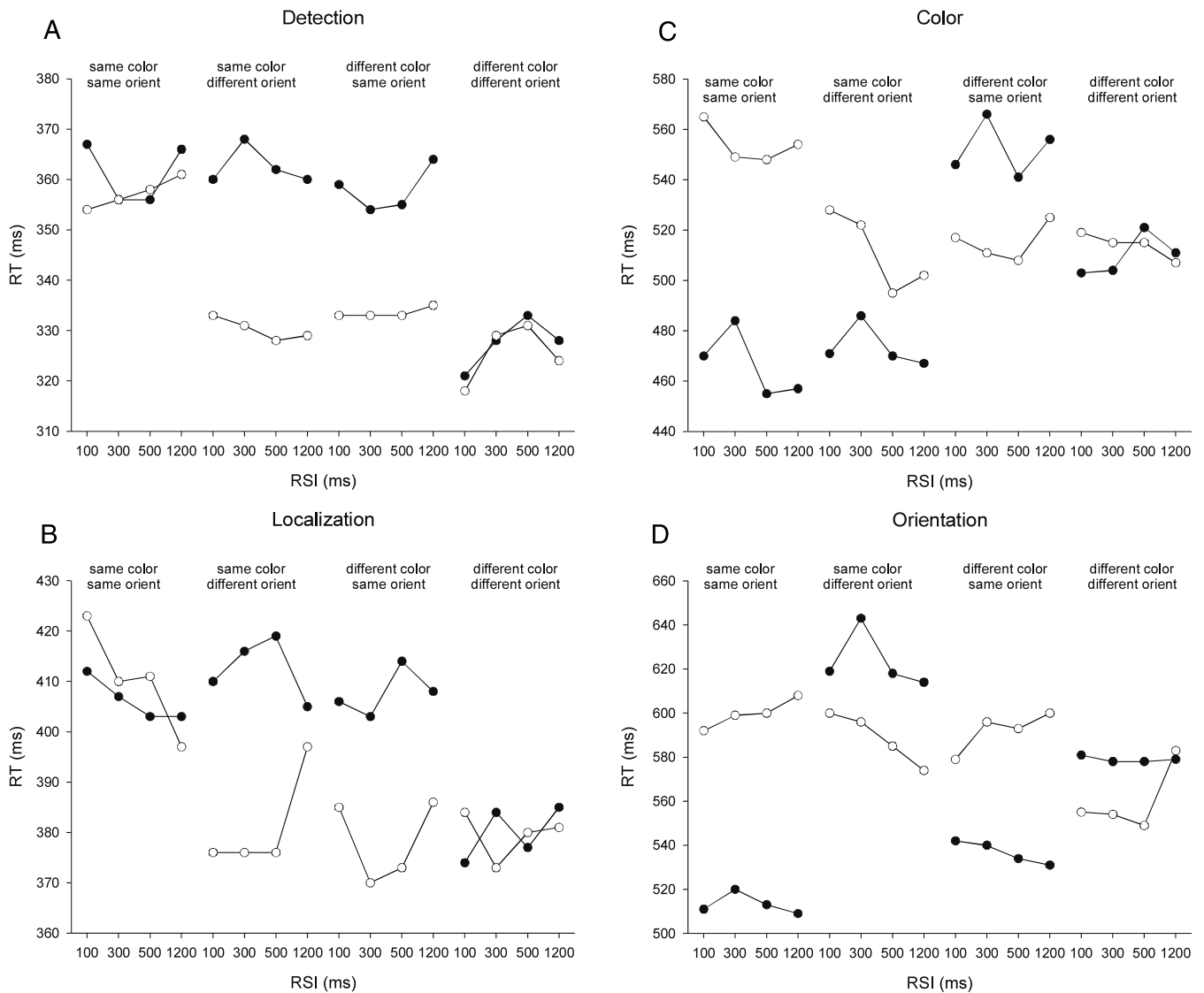
Fig. 2. The RTs for each task, plotted for same and different locations, as a function of RSI and the relationship between successive target attributes. The filled-in circles are the same locations, and the empty circles are different locations.

$[F(1, 7) = 161, \; P < 0.0001]$ found by Tanaka and Shimojo (1996). To discover the source of these interactions, the data are plotted separately for each task. Moreover, the mean RTs are not only separated by location (as in Fig. 1), but also by color and orientation. This level of analysis provides new information regarding the notion of separate pathways for IOR and FOR.

The mean RTs for the detection task are shown in Panel A of Fig. 2. As can be seen from this figure, and confirmed by planned comparisons ($P < 0.05$), robust IORs were found for the target combinations for same color + different orientation and same orientation + different color. The planned comparisons also indicated that no differences between same and opposite locations, at any RSI, were found for the target combinations of same color + same orientation and different color + different orientation.

The mean RTs for the location discrimination task are shown in Panel B of Fig. 2. This figure shows the same pattern of results as found for the detection task, and planned comparisons (Ps < 0.05) confirmed that the only significant effects were the IOR found in the same-color + different orientation and same orientation + different color target combinations. Thus, the results from the detection and location conditions indicated that IOR does not occur for all spatially-based responses, but rather that the attributes of the targets affect the RTs.

The mean RTs for the color discrimination task are shown in Panel C of Fig. 2. Facilitation of return was found in this task, but only for the two conditions in which the color of the preceding target was the *same* as the probe target. When orientation remained the same, but the color of the preceding and probe trials *differed*, IOR was found. Planned comparisons confirmed that

both the FOR and IOR effects at each RSI were significant (Ps < 0.05). As before, an inconsistent and non-significant pattern of results was found when the target differed on both color and orientation.

The mean RTs for the orientation discrimination task are shown in Panel D of Fig. 2. Once again, FOR was found in this task, but only in the conditions where the orientation of the preceding target was the same as the orientation of the probe target (Ps < 0.05). For the later three RSIs, IOR was also found in the task when the orientation differed between the preceding and probe targets, and the color remained the same (Ps < 0.05). Once again, an inconsistent pattern of results was found as the target differed on both color and orientation. However, as indicated by planned comparisons, this time the pattern was significant IOR at the shortest three RSIs, and significant FOR at the longest RSI (Ps < 0.05).

The percentage of error trials appears in Table 1, and these data were also analyzed with a 4 (RSI) × 2 (location) × 2 (color) × 2 (orientation) ANOVA. No main effects or interaction effects were found with the detection and location tasks (Ps > 0.05). A color by location interaction was found in the color task [$F(1, 7) = 10.2$, $P < 0.02$], and an orientation by location interaction was found in the orientation task [$F(1, 7) = 24.7$, $P < 0.002$], with no other significant main effects or interaction effects (Ps < 0.05) in these tasks. In both these cases, more errors were made in the conditions that

produced longer RTs, indicating that the subjects were not trading off speed for accuracy.

4. Discussion

Although the main effects from the four conditions in the present study replicated those found by Tanaka and Shimojo (1996), a closer examination of data reveals that IOR did not occur only in location-based tasks and FOR only in feature-based tasks. Rather, the presence or absence of IOR and FOR was dependent on the type of task and the specific attributes of the preceding and probe targets. Thus, the notion that IOR occurs for tasks that use the dorsal–parietal visual pathway and FOR occurs for tasks that use the ventral–temporal visual pathway does not appear to be tenable.

The pattern of results from the present study does, however, suggest a new theory regarding the circumstances in which facilitation and inhibition will be found. The first assertion of this notion is that FOR will be found when the task-relevant non-spatial feature remains the same between preceding and probe targets. When this "critical feature" is the same, FOR will occur. The mechanism underlying this assertion is likely some type of repetition priming that facilitates responses when a critical feature is repeated between successive targets. The second assertion is that IOR will

Table 1
Mean percentage errors for each condition (see the text for details)

RSI	Same location				Different location			
	100	300	500	1200	100	300	500	1200
Detection								
Same color, same orient	0.4	0.5	0	0	0	0.6	1.0	0
Same color, diff orient	0.5	0	0	0	0	0	0	0.4
Diff color, same orient	0.8	0	0.5	0.4	0.5	1.1	0.6	0
Diff color, diff orient	0.4	0.5	0	0	0	1.3	0	0
Location								
Same color, same orient	1.5	2.0	0.5	0	1.0	0.5	0	0.9
Same color, diff orient	0.4	0	0.9	1.2	0.7	2.3	1.7	1.3
Diff color, same orient	0	0.5	1.3	0.4	1.0	2.3	0.5	0.4
Diff color, diff orient	0.8	1.5	0.9	0.6	1.1	1.3	1.4	0
Color								
Same color, same orient	2.1	1.3	5.0	3.3	9.4	6.7	9.4	12.7
Same color, diff orient	3.8	4.3	2.1	6.2	6.6	9.6	9.9	8.2
Diff color, same orient	7.8	6.4	9.7	10.6	3.5	4.9	3.8	4.7
Diff color, diff orient	7.8	9.7	7.8	10.5	7.3	4.7	4.1	2.7
Orientation								
Same color, same orient	4.2	6.2	7.4	4.9	16.6	13.7	16.7	11.8
Same color, diff orient	23.2	19.4	15.5	16.5	15.7	7.9	9.5	7.9
Diff color, same orient	4.3	3.7	3.4	7.6	20.7	12.3	16.4	14.5
Diff color, diff orient	12.9	15.3	15.2	14.4	10.8	6.6	10.0	14.1

be found if the task-relevant non-spatial feature is different between the preceding and probe targets. The mechanism underlying this assertion is interference arising from the change in the critical feature between successive targets. The third assertion is that IOR will be found if the non-spatial features are irrelevant to the task (e.g. detection or location tasks). The mechanism underlying this assertion is the traditional notion of IOR where spatially directed responses are slowed for targets at repeated locations. Of the 16 task–target combinations (i.e. task: detection, location, color, orientation; target: same color + same orientation, same color + different orientation, same orientation + different color, different orientation + different color), these three assertions account for the results of ten such combinations. The fourth assertion is that neither consistent FOR nor IOR effects will be found when all of the non-spatial features differ between preceding and probe targets. The appearance of an entirely different object in the visual field from the previous object may cause a resetting of any FOR and IOR that might otherwise be present. This assertion accounts for four of the remaining six task–target combinations.

The two task–target combinations that are not accounted for by this hypothesis are the same color + same orientation combination from the detection and location conditions. It is not immediately clear why these two combinations did not show IOR as did the combinations where only one non-spatial feature differed in the detection and location tasks. It is possible that repetition priming arising from the repeated features of the targets masked any IOR arising from the repeated target location. Such modulation of IOR effects have previously been reported by Pratt and Abrams (1999).

Overall, the combination of repetition priming, repetition interference, and spatially based inhibition accounts for the results of the present experiment. Moreover, the notion of isolated IOR and FOR effects in separate visual pathways suggested by Tanaka and Shimojo (1996) cannot account for the present findings. Finally, it should be noted that the target–target paradigm used by Tanaka and Shimojo and the present study is considerably different from the cue–target paradigm commonly used to examine IOR (e.g. Posner & Cohen, 1984; Pratt et al., 1997; Rafal, Calabresi, Brennan, & Sciolto 1989). The difference in the two methods may not be trivial. Indeed, there is little or no evidence for repetition priming effects from studies using identical stimuli for cues (that are not responded to) and targets (that are responded to) (e.g. Maylor & Hockey, 1985; Pratt, Hillis, & Gold, in press). Thus, the new hypothesis forwarded in the present study may be limited or restricted to situations is which responses are made to all presented stimuli.

To summarize, although Tanaka and Shimojo's assertion of isolated IOR and FOR effects in separate visual pathways is compelling and consistent with some aspects of the data, a detailed examination of the results calls this notion into question. Rather, the present findings indicate that the role of repetition priming and interference based on critical features of the target, as well as inhibition of spatial locations, must be considered in future work that seeks to examine the mechanisms that lead to IOR and FOR in location-based and feature-based tasks.

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