

Saliency, Perceptual Dimensions, and the Diversion of Attention

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Parallel and automatic processing is evidenced in visual search by what is commonly called popout. An object of search (a target) that differs widely from all other display objects on some simple visual dimension is commonly called a singleton; an example is search for a red circle when all other displayed circles are green. A singleton attracts attention to the degree that it is salient, and highly salient singletons produce search that is almost independent of display size. The present research examines the way this attraction of attention can be diverted by the presence of singletons on 1 or 2 nontarget perceptual dimensions (e.g., search for a red circle among green ones, when one of the green circles is larger than the others, and another might be green but square). The results establish that distraction occurs rarely but strongly, that 2 distractors produce more distraction than 1, and that the degree of distraction depends not only on saliency but also on dimension similarity. These findings occurred in 2 different tasks: The observer either reported the orientation of a Gabor embedded in the target or reported the presence and absence of the target.

In life there are constant demands for attention from numerous sources, many occurring at roughly the same time. Therefore, it is important to understand how the attention system adjudicates multiple and close-to-simultaneous attention demands. The present research explores this issue with a task that requires that attention be devoted closely to one particular aspect of the environment, which is easy enough that it always succeeds, and that uses distractors that are irrelevant to the task but demand attention automatically. To take an example from everyday experience, one is driving and needs to brake when a stoplight turns red, but at that moment a dog in the back seat barks loudly. Will reaction time increase?

This issue is often explored when the primary task is novel, is carried out in working memory, and requires full attention. In such cases it is not surprising that diversion of attention causes a loss of performance measured by accuracy or response time. It is important to explore this issue also when the primary task is well learned and carried out with automatic processing (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). One of the hallmarks of automatic processing is its lack of demand for (much) attention and its resistance to unlearning (see a summary in Shiffrin (1988)). Yet, as we shall see in this article, automatic processing can be hampered by strong competing demands for attention even in situations where those demands

are task irrelevant and optimally should be ignored. These are cases where the competing demands are also automatically induced. The issue is important for everyday activities because much of what we do is well learned and at least partly automatic, and distraction could have severe consequences (e.g., failing to brake at a red light because of a dog barking).

Many researchers, using a variety of techniques, have explored this issue. We borrow a paradigm that has been used with great success by Jan Theeuwes (Hickey & Theeuwes, 2011; Theeuwes, 1991, 1992, 1994). In a typical study, N visual stimuli, perhaps circles, are presented in a circular configuration surrounding a fixation. All stimuli are identical save one that is a target designated before the trial. For example, the observer might look for one red circle in a ring of green ones. The unique target is usually called a singleton because it differs from all other stimuli on some salient dimension. In one version of the paradigm all the circles *contain* another stimulus that can take either of two values randomly arranged from circle to circle (e.g., a vertical or horizontal line), and the observer must find the target circle (e.g., the red one) and report the orientation of the embedded stimulus. In a number of studies Theeuwes and colleagues have shown that response time is longer when the display contains a nontarget stimulus that calls for attention automatically, typically a singleton on another dimension. For example, the target might be a red circle among green circles, but when a second circle is replaced by a green square, response time is longer. We use two versions of this paradigm to ask and answer two questions: How do multiple but task-irrelevant demands for attention combine to distract attention to the relevant task? What aspect of a distracting singleton diverts attention: its salience, its dimension, or some combination of both?

We seek to examine distraction when the main task is as easy and automatic as possible. To ensure this, we use targets that are perceptual singletons and a consistent mapping paradigm. Much research shows that visual search is easy and shows little effect of display size when the target of search differs from all other display objects (foils) on some highly discriminable perceptual dimension, such as color, shape, size, motion, or contrast. The parallel, automatic, easy perceptual search and slower, attention demanding, difficult perceptual search distinction is explained by Jeremy Wolfe with his guided search

model (Wolfe, 1994, Wolfe, Cave, & Franzel, 1989). *Consistent mapping* refers to tasks in which the target being sought is the same for all trials in a session. Schneider and Shiffrin (1977) and Shiffrin and Schneider (1977) presented extensive evidence (verified in numerous later studies) that varied mapping (in which targets on some trials are foils on another) is highly attention demanding and highly effortful, but consistent mapping greatly reduces attention demands and effort. One might therefore expect that distraction of attention would have far greater negative consequences when the primary task requires attention than when the primary task is carried out automatically. Generally this is the case, but distraction does have negative consequences even when automatic processing results from perceptually salient singletons and a task using consistent mapping (as in the present studies).

Distraction under such conditions has been the subject of much prior research, particularly by Theeuwes (Hickey & Theeuwes, 2011; Theeuwes, 1994). He and others have looked at cases in which a single foil calls for attention because it is a singleton on an irrelevant dimension. Because we are often faced in life with more than one distracting event, we ask in the present research what type of distraction occurs when there are two such irrelevant singletons, on two different irrelevant dimensions. Will the two popout foils inhibit each other, reducing the cost, or operate separately and add to the cost? Because we use foils on different dimensions, we can also examine dimensional interactions: Is the distraction observed simply because of salience of the foils or also because of an interaction of the dimension of the target and those of the foils?

The basic design is modeled after those used by Theeuwes. In a condition called embedded report (Experiment 1) a circular array of 12 circles is presented. Most circles are of identical size and are green. On every trial for an entire session, the same target is identified as the object of search. In one session, the target is a red circle, in another session the target is a larger green circle, and in another session the target is a green square. These conditions therefore use consistent mapping and easy perceptual distinctions to produce popout: Accuracy is uniformly high, and response time is used to assess performance. Inside each display object is a Gabor oriented vertically or horizontally. The observer finds the target object and

reports the orientation of the Gabor. On some trials there are task-irrelevant singletons (foils) on the other dimensions (e.g., a larger green circle when a small red circle is the target). There are either no foils, one foil, or two foils. Example displays with a red target are shown in Figure 1: The display on the left has no foils, and the one on the right has two. The observer knows foils should be ignored (although this is not always possible). A second study (Experiment 2) is called “presence/absence”; it was carried out with a different set of observers. It uses identical displays, but the observer merely reports the presence or absence of a target; in this condition the number of different displays is roughly doubled because each trial type must be matched with one without a target.

EXPERIMENT 1

In Experiment 1 a group of six observers looked for the target object (which was always present) and reported the orientation of the embedded Gabor. (In Experiment 2, a different group of seven observers reported the presence or absence of the target object; for this group, only half the trials had the target.) All observers were Indiana University students with normal vision, ages 18 to 30 years, and were paid for their participation. Each of three sessions took about 1 hour to complete. Observers were instructed to be fast and accurate.

METHODS

Each display was presented on a 60-Hz CRT monitor and consisted of 12 objects centered at fixation and in a circle with a spread of about 12° of visual angle at the usual viewing distance. Most objects in the display were green circles of the same size (about 1.25°). All objects contained a Gabor of a fixed frequency (5 Hz) oriented randomly vertically or horizontally (as in Theeuwes, 1991). A different target was defined for and used throughout each of three sessions (target order was permuted across observers): a green square roughly of regular size, a larger green circle, and a red circle of regular size. These three targets were made perceptually salient so that popout occurred: Finding the target was easy, and accuracy was always very high. However, we allowed the three target stimuli to have different saliences in order to examine and assess the interaction of salience and target dimension. The red and green colors were #FF0000 and #00FF00. The size of the square side was 1.25°. The

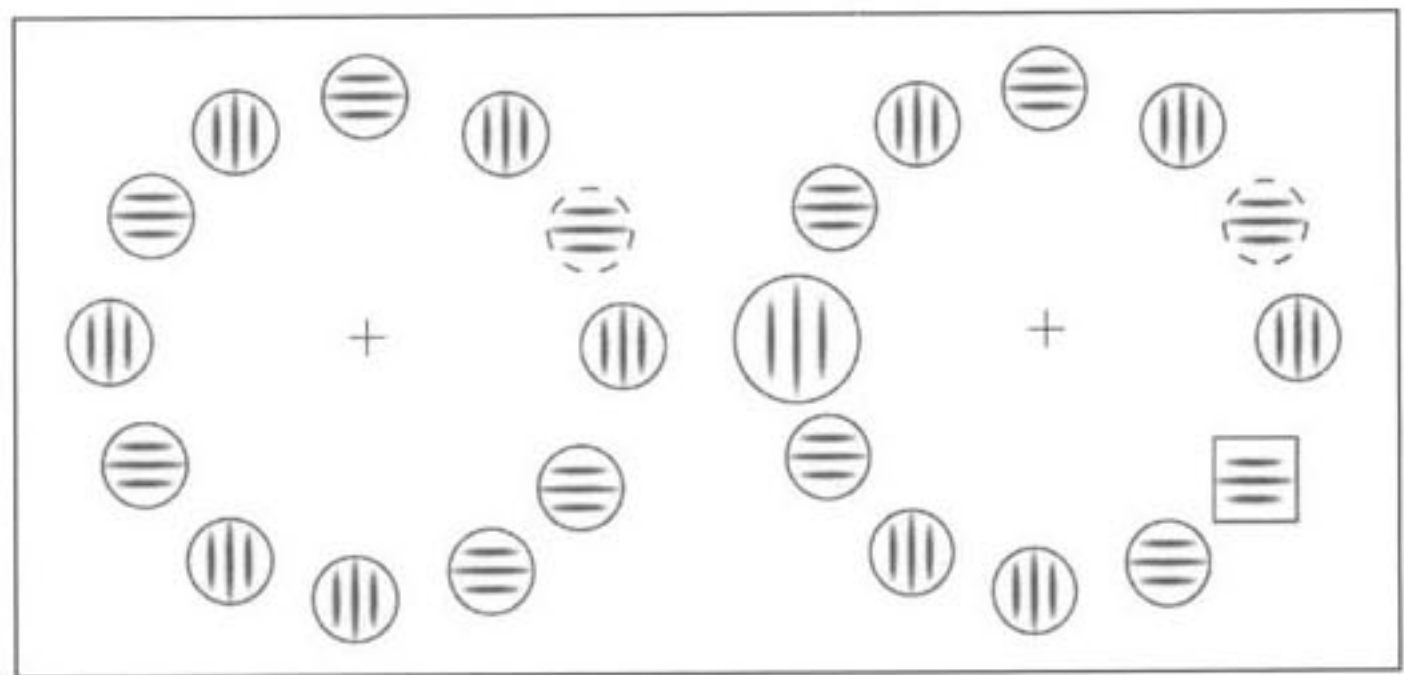


FIGURE 1. Examples of displays when search is for a red target, Experiment 1. *Left*, No foil is present. *Right*, 2 foils are present. Other displays contained just 1 foil. (Note. Red target is depicted here with dotted lines; in the experiment the circle was complete)

large circle was twice the size of the small circle, at 2.5°. The Gabor patches were centered in each object, generated with a Gaussian with standard deviation of .8, phase of zero, frequency of 5 Hz, and an amplitude of 10. Two example displays are shown in Figure 1 (these examples also applied for red target present trials in Experiment 2).

The two objects not used as a target for a given session served as popout foils, each of which tended to attract attention. In Experiment 1, 17% of the trials had no foil, 33% had one foil (split equally between the two foils), and 50% had two foils. Target and foil positions were randomly chosen on each trial.

A given trial started with a fixation cross displayed for 1,500 ms. The fixation cross then stayed on while the 12 objects appeared around the fixation cross, as in Figure 2. The display stayed on until a response was made with designated keys on the keyboard. The response was followed by visual feedback (correct or incorrect), and the next trial was initiated with a press of the spacebar. Each subsequent daily session provided a new target for the search, and the foils therefore included previous targets.

RESULTS

The number of trials completed per session ranged from about 1,250 to 1,350 (the study termination each day was determined by the time taken in a session, ending at about 55 min). Accuracy was uniformly high, about 96% to 97%, and did not differ appreciably across conditions (Table 1).

The main data of interest were the response times. Figure 3 shows the median RTs for conditions defined by number of foils, averaged across sessions and observers. The observers individually showed

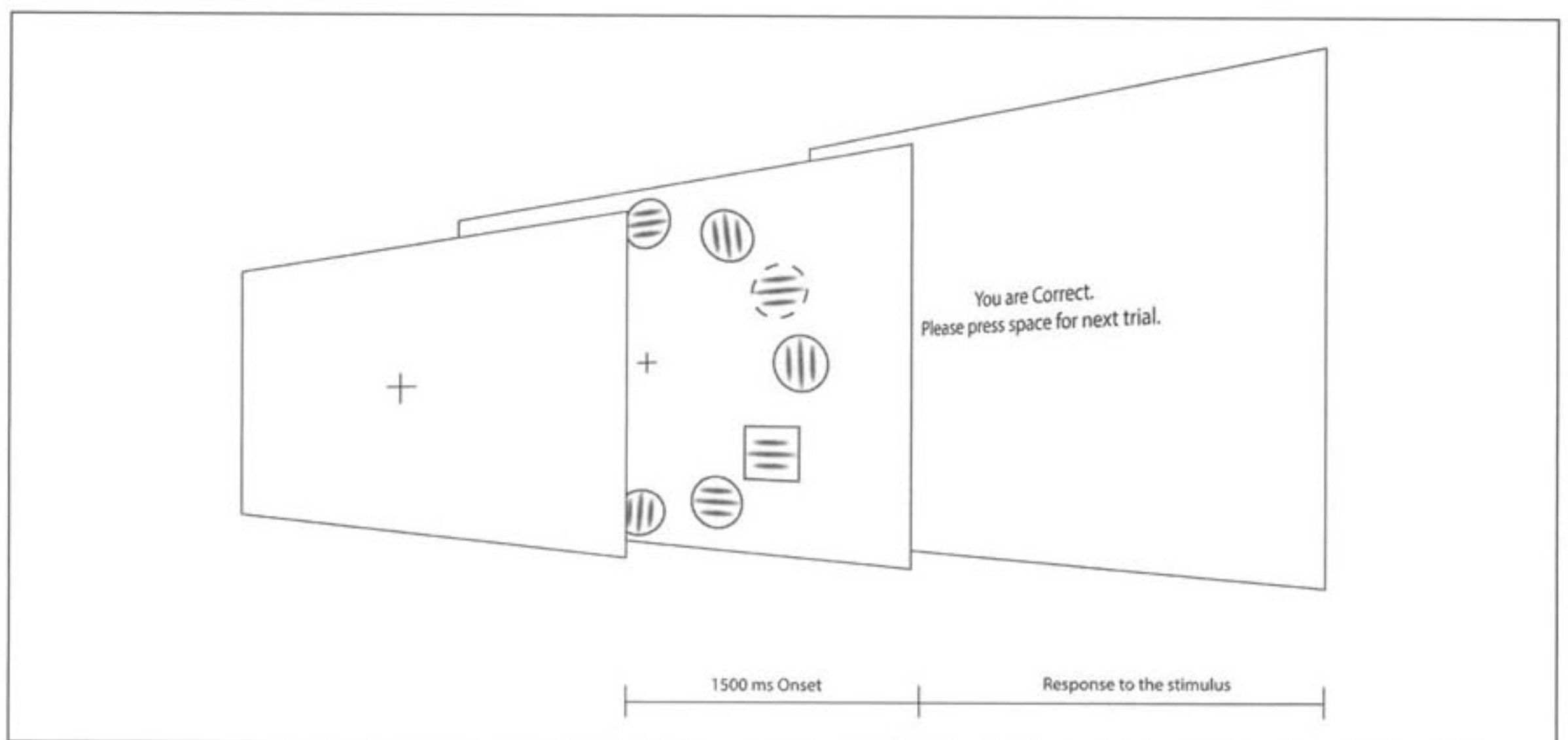


FIGURE 2. Design, Experiments 1 and 2. Observers responded as soon as possible after target display onset, then received feedback, and then self-initiated the next trial

TABLE 1. Accuracy Averaged Across Sessions and Observers, Experiment 1

Condition	No foils	1 foil	2 foils	Total
Gabor	0.9735	0.9676	0.9678	0.9686

similar patterns, which are not shown here. Large-circle target sessions are indicated by the fine dotted line (fastest responses), red target sessions by the solid line (next fastest), and square target sessions by the coarse dotted line (slowest). Two foils tended to cause more interference than one, although there were clear dimensional interactions. Red targets suffered little interference, and square and size stimuli showed mutual interference, although size interfered with square much more than the reverse.

The medians do not tell the entire story, however. Figure 4 shows the decile plots. The decile plots show medians of each next 10% of the response times, each decile calculated for a given observer and session and then averaged. It is clear from these plots that the largest interference effects occur for the slowest responses.

Response times did not differ by clock position of the target and did not differ as a function of the distance of foil from the target, however measured. This is consistent with findings of Sperling and Weichselgartner (1995) showing that attention does not traverse space but rather turns off at one position and on at another (a finding consistent with visual attention governed by or consistent with eye movements). However, response times were shorter when the target was in the same clock position of the target from the prior trial and slightly longer when a foil was in the clock position of the target from the prior trial (Figure 5). Figure 5 shows median response time

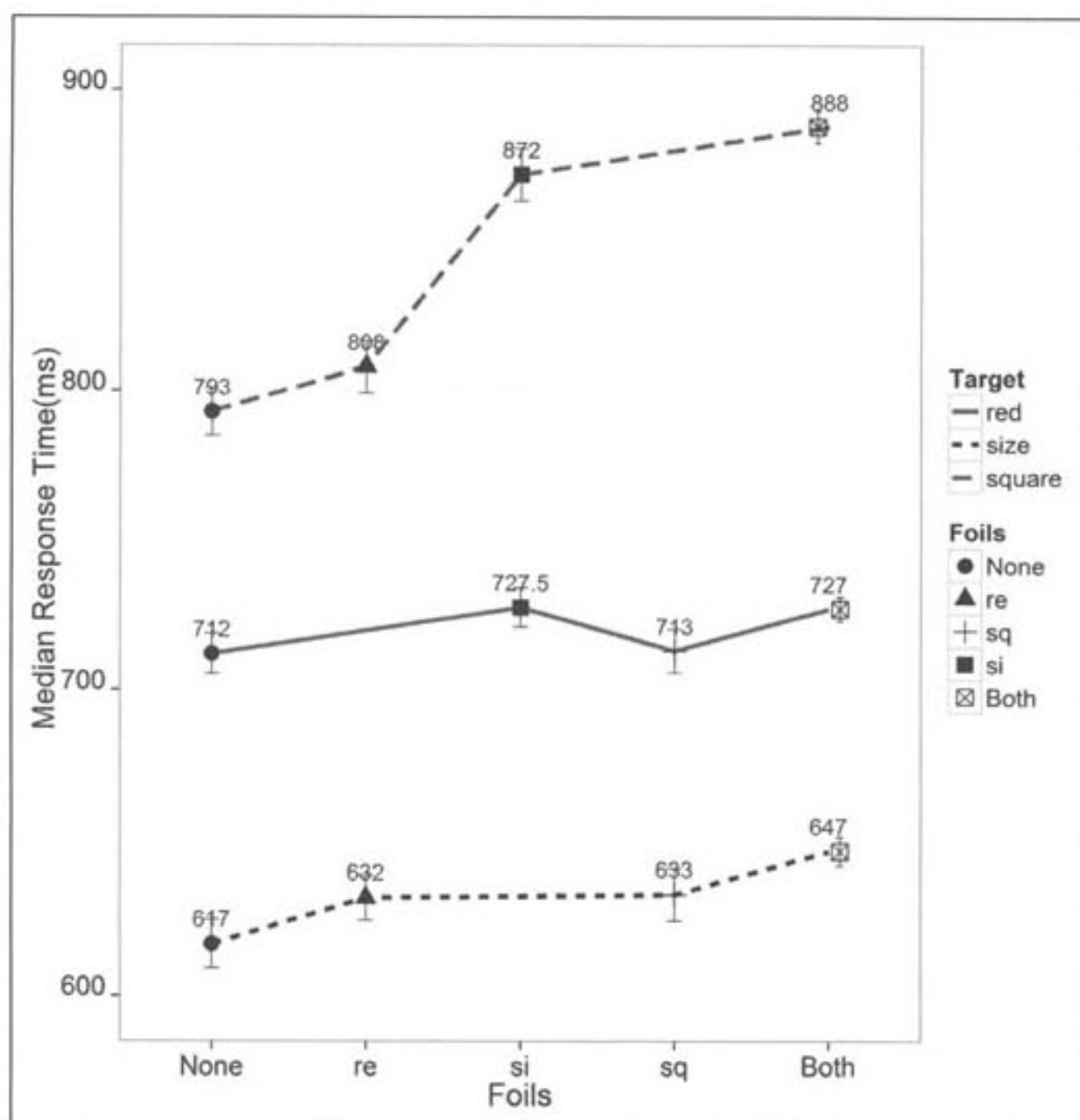


FIGURE 3. Median response times averaged across observers and sessions, Experiment 1. The horizontal axis indicates the foil or foils used on a trial. re = red; si = size; sq = square foil

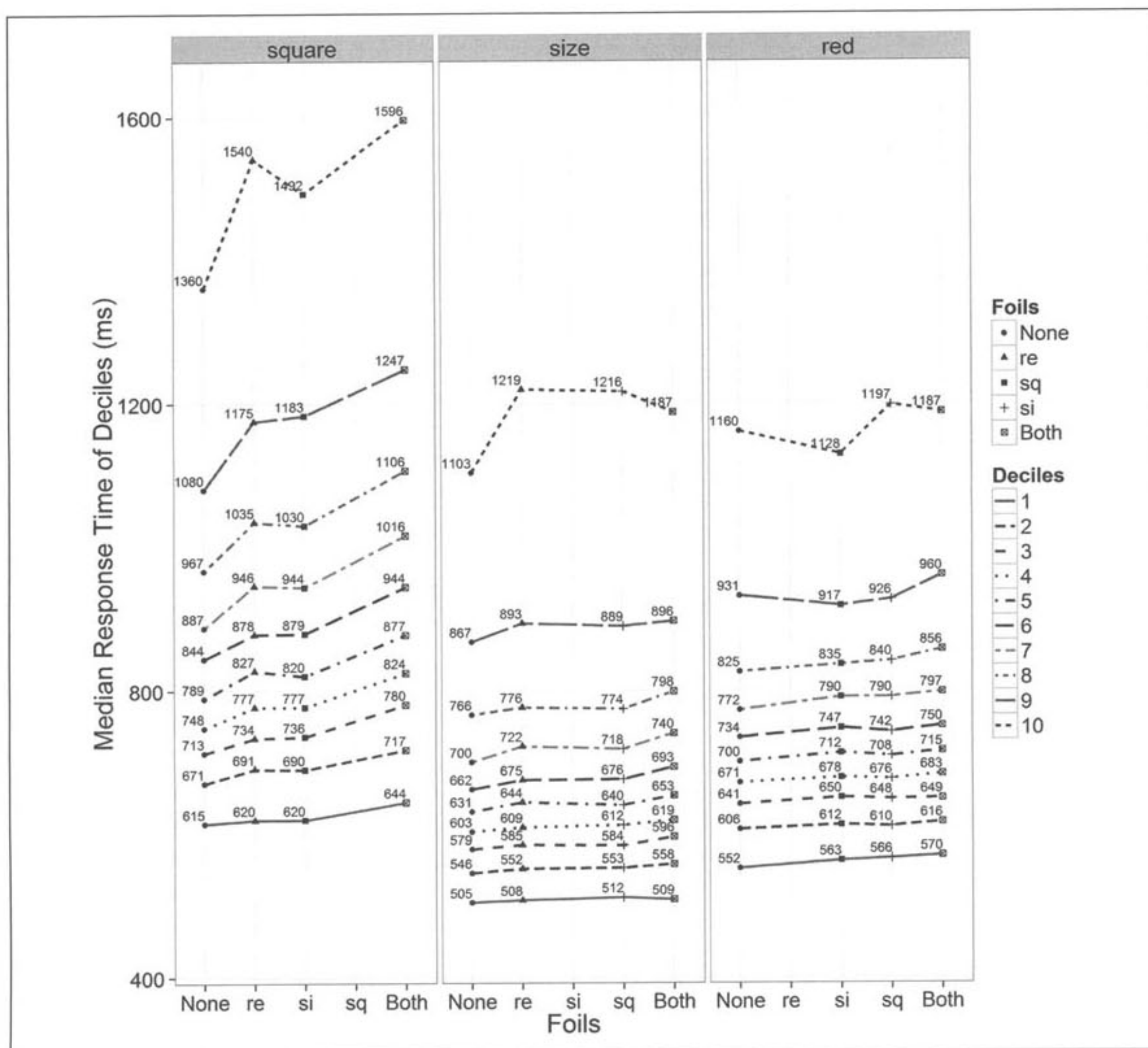


FIGURE 4. Deciles of median response times (RTs), Experiment 1. The target is indicated at the top of each panel. The horizontal axis indicates the foil or foils on a trial. re = red; si = size; sq = square foil

differences for each condition and observer for position matches of targets and foils from targets on prior trials. The largest such effects occurred for the case of square targets, and the difference goes from positive to negative in this condition. These prior trial contingencies occurred even though target and foil positions were randomized for each trial. The fact that the large sequential effects for square search did not vary with the type of target on the prior trial, in contrast to the dimensional interactions seen in Figures 3 and 4, suggests a different role for spatial attention across trials than dimensional attention within trial: Attention might have remained on the prior trial target position, or the repeated position could have a greater ability to attract attention.

Response times dropped both within session (about 90 ms) and across sessions (about 90 ms from first to last). Such results are unsurprising because practice generally speeds many aspects of responding (e.g., motor movements). Because targets for one session became foils for the next, and vice versa, one might think that interference would increase across sessions (see Dumais, 1981; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). They showed that consistently trained targets come to attract attention and consistently trained foils come to repel attention, and that both effects are difficult to undo once established. However, the mixing of target type by session by observer makes it difficult to assess whether this occurred in the present studies.

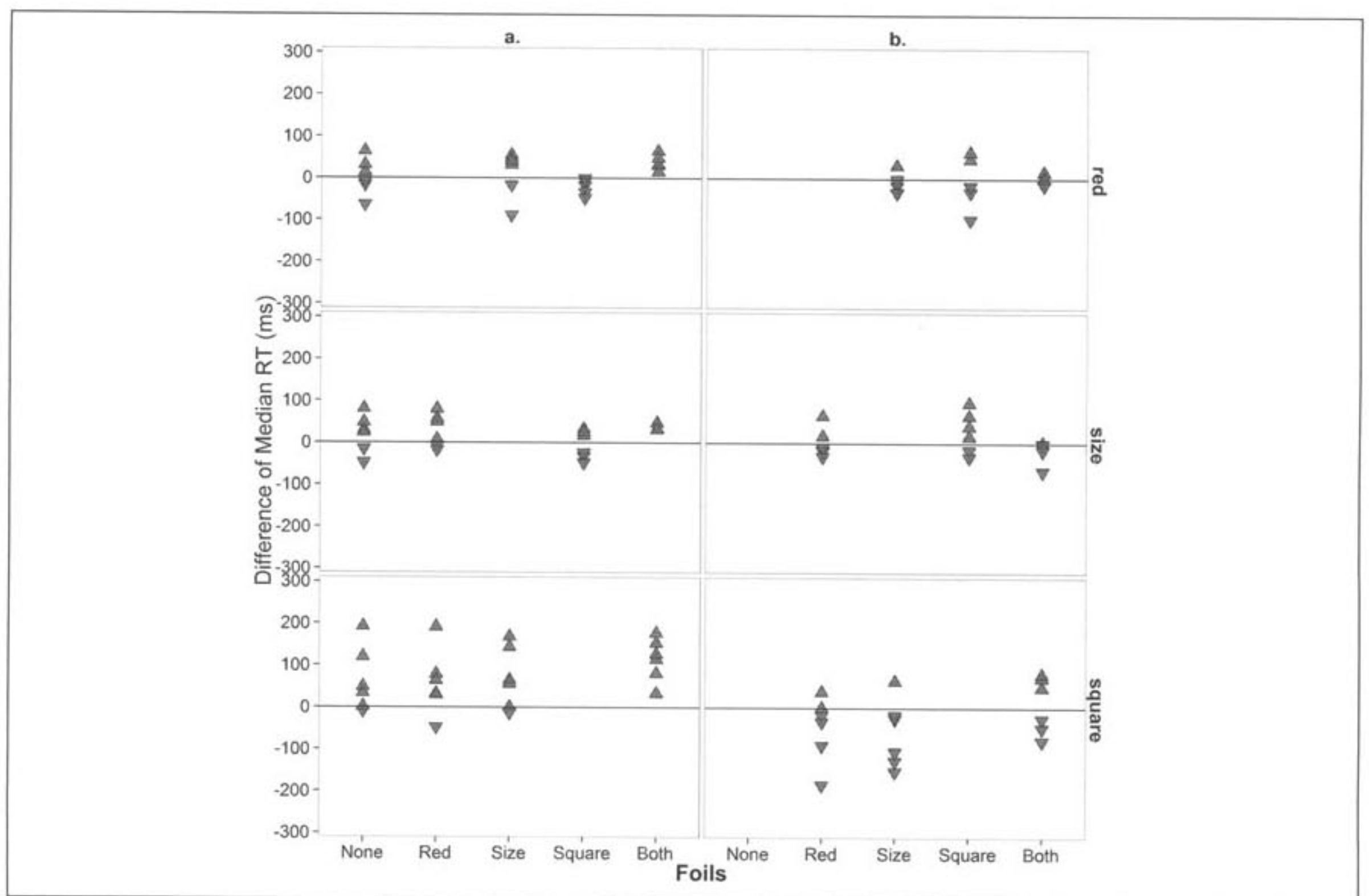


FIGURE 5. Median response time (RT) when (a) the present-trial target or (b) present-trial foil is not in the same display position as the target on the prior trial minus the same measure when the present target or foil is in the same display position as the target on the prior trial (positive numbers indicate faster responding for positions matching on successive trials), Experiment 1. The present-trial foils are indicated on the horizontal axis

EXPERIMENT 2

METHOD

Figure 1 illustrates trial types when a target was present, and Figure 6 illustrates trial types when no target was present. Seven observers who did not participate in Experiment 1 averaged close to 1,350 trials in each

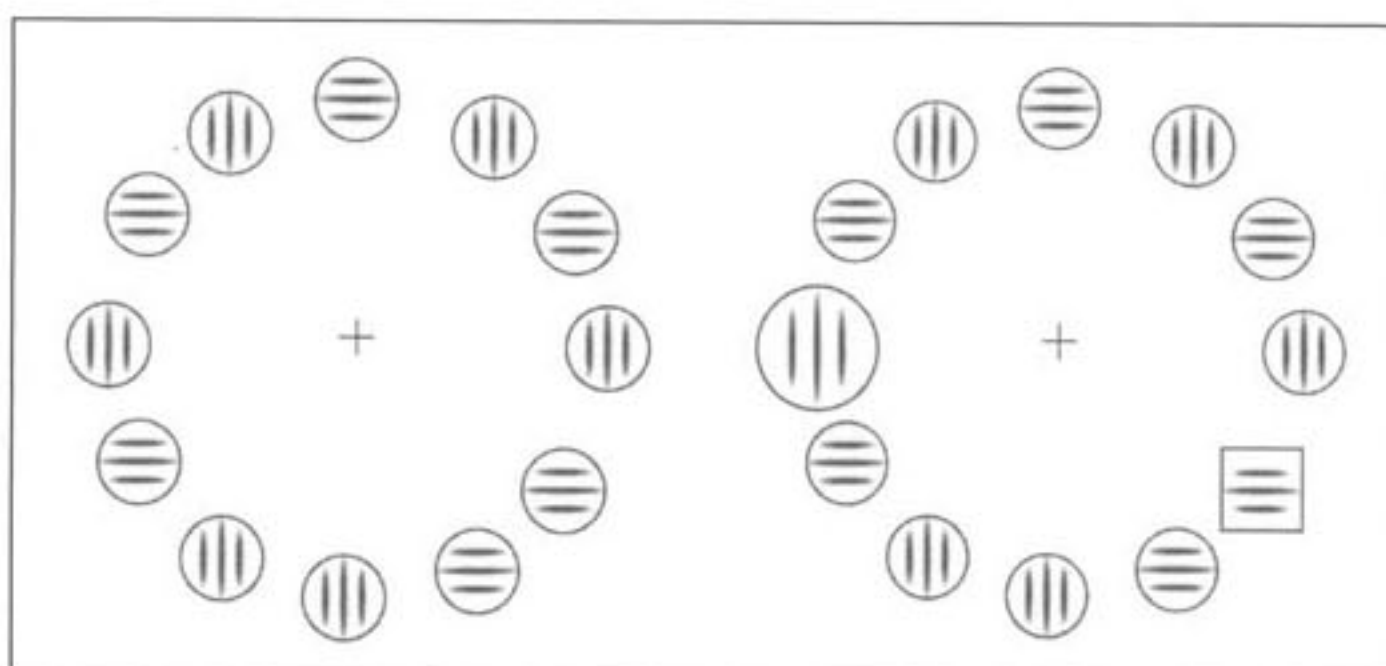


FIGURE 6. Examples of displays when search is for a red target but no target is present, Experiment 2. *Left*, No foil is present. *Right*, 2 foils are present. Other displays contained just 1 foil. Target-present displays were identical to those in Experiment 1 (see Figure 1)

of their three sessions. In Experiment 2 observers looked for the presence or absence of the salient target; they did not report the orientation for the embedded Gabor. The rest of the details are as in Experiment 1, except that 50% of trials had no target.

RESULTS

As in Experiment 1, accuracy was uniformly high, about 96% to 97%, as shown in Table 2; thus response times were the measure of interest. Median response times are shown in Figure 7, averaged across observers and sessions; target present results are in Figure 7a (the left panel), and target absent results are in Figure 7b (the right panel).

Response times were shorter in Experiment 2 than in Experiment 1. One would expect this for target-present trials given that Experiment 1 required not only that the target be found but also that the orientation of the embedded Gabor be reported. The fact that both present and absent responses were faster in Experiment 2 suggests that the detection of

absence is also a fast process. The fastest responses in Experiment 2 occurred for red targets, in strong contrast with the results from Experiment 1. For red targets without any foils, absent responses were faster than present responses, but when foils were present the present and absent responses were equal. However, for square and size targets the pattern was different, with present responses much faster than absent responses for all conditions. This is one indication that color is processed differently from square or size.

The pattern of interference in this study shows many similarities with that in Experiment 1 but also a few differences. For target-present responses, red targets exhibited no interference from other foils; size targets showed some interference but equal for red foils, square foils, and both foils. Square targets showed interference from either red or size foils but additional interference for both. For target-absent responses, red targets showed some but equal interference by size foils, square foils, and both; size targets showed interference from red foils but much more and equal interference by square foils and both foils; square targets showed interference from red foils, much larger interference by size foils, and even more interference by both foils.

TABLE 2. Accuracy for Observers Across Conditions, Experiment 2

Condition	No foils	1 foil	2 foils	Total
Target present	0.9691	0.9651	0.9666	0.9665
Target absent	0.9813	0.9763	0.9720	0.9749

Figure 8 shows the medians of response time deciles for each target and foil condition, averaged over sessions and observers. As in Experiment 1, the main effects, especially those of interference, are reserved for the slowest responses. The same interference pattern can be seen for red target through the deciles for target present responses, whereas size and square targets showed increasing effects with longer response times. For target-absent conditions, these effects were more pronounced for size and square targets, whereas a red target started to show effects in longer response times.

Other effects were generally similar to those in Experiment 1: There was no effect of target position, or distance from foil to target. Although the data are noisy and differ between observers, Figure 9 shows that a target in the same position as a target on the

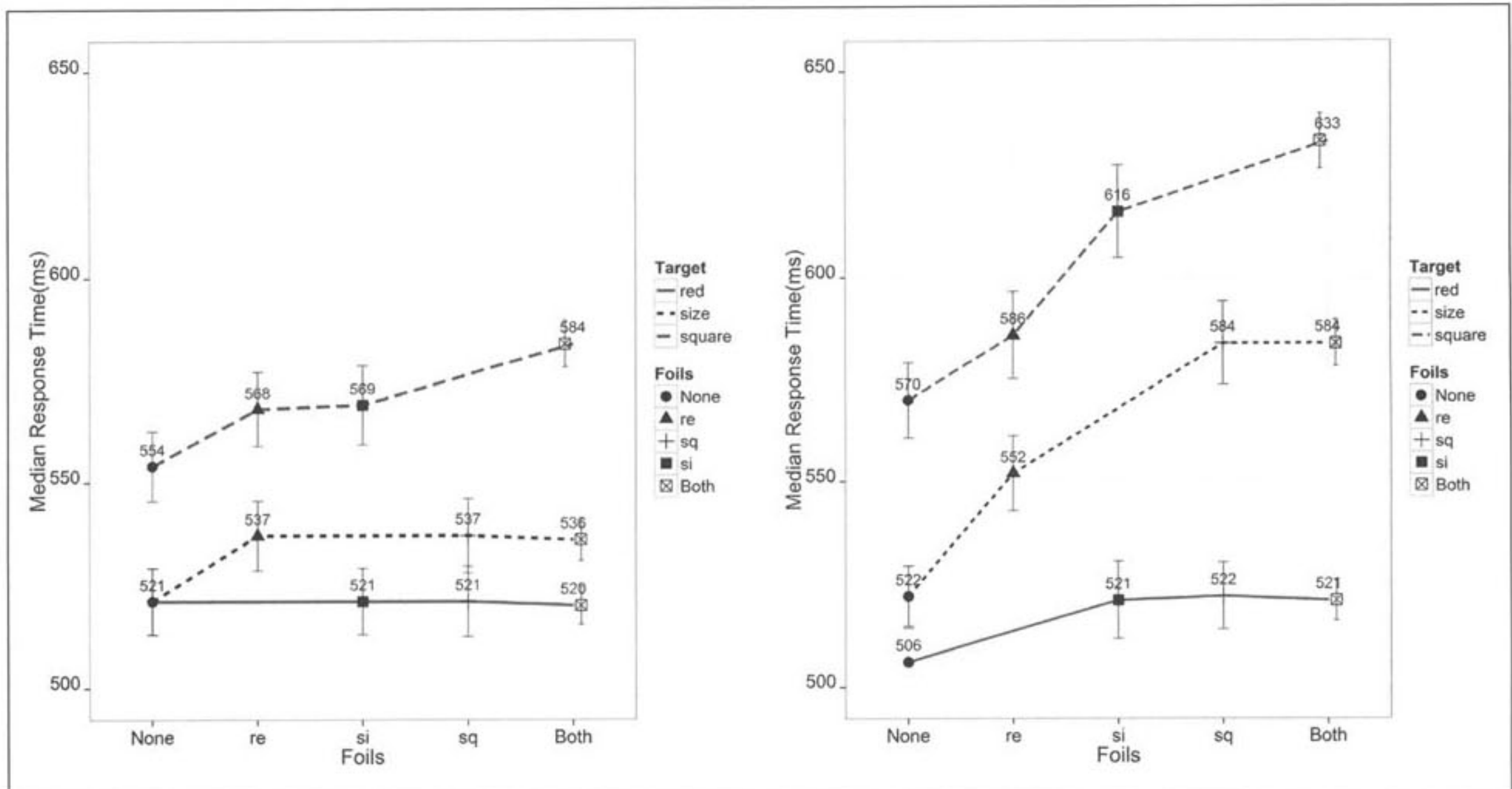


FIGURE 7. Median response times averaged across observers and sessions, Experiment 2. The horizontal axis indicates the foil or foils used on a trial. (a) Target present; (b) target absent. re = red; si = size; sq = square foil

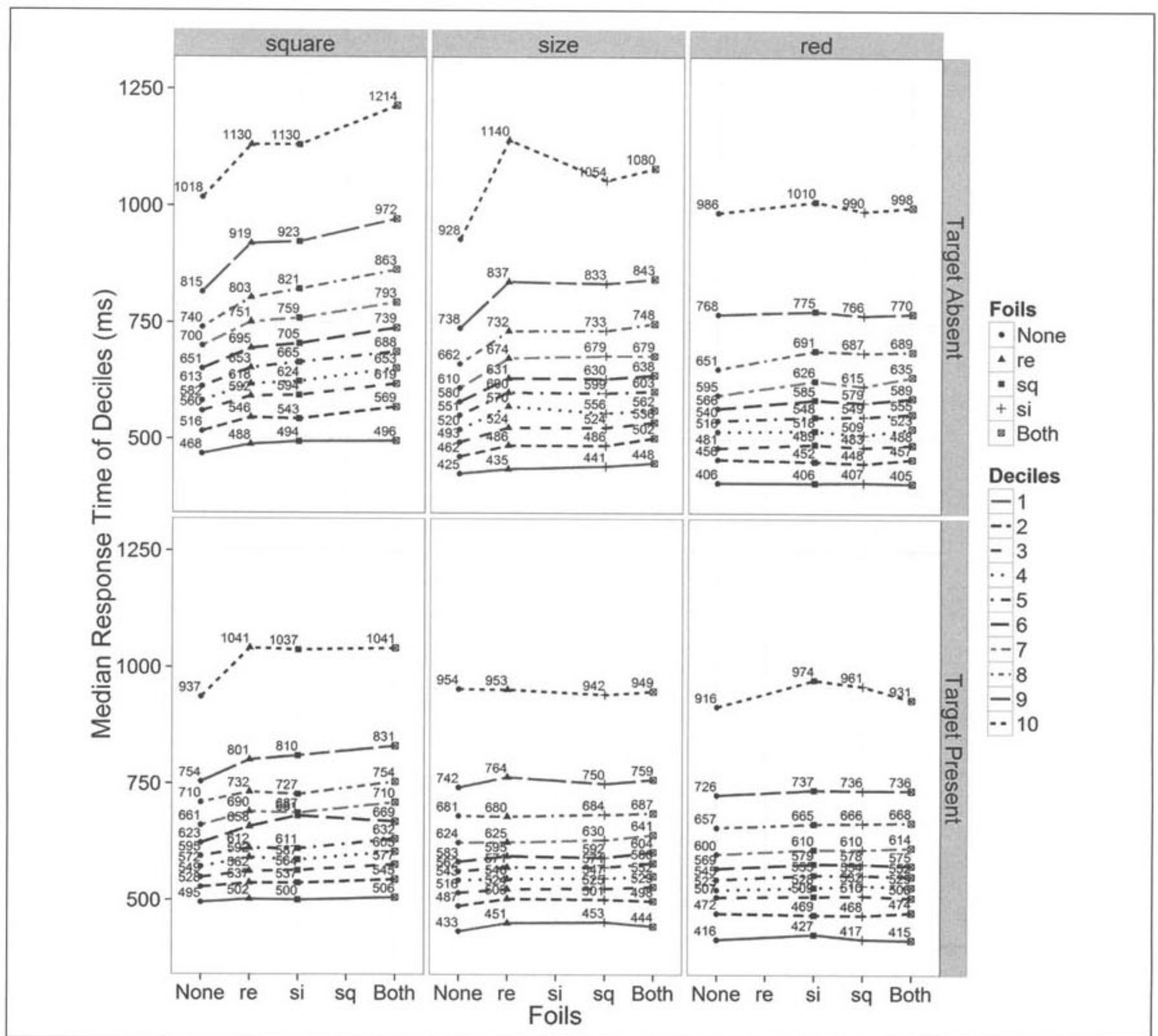


FIGURE 8. Deciles of median response times, Experiment 2. The target is indicated at the top of each panel. The horizontal axis indicates the foil or foils on a trial. *Top*, Target absent. *Bottom*, Target present. re = red; si = size; sq = square foil

prior trial generally speeded responding, and a foil in the position of a target from the previous trial slowed responding, at least for size and square targets. Response times generally decreased over training, both within and between sessions. The difference between target-absent and target-present trials consistently decreased across sessions.

DISCUSSION

This research aligns with many studies showing that well-learned or automatic processing can be interrupted by calls for attention, as expected. The best-known example is the Stroop effect (Stroop, 1935)

in which naming the ink color of a word is made more difficult when the word spells another color, although the interference in that case occurs arguably within dimension. Another well-known example is the flanker effect (Eriksen & Eriksen, 1974): Flankers assigned to a response inconsistent with a central target produce interference. In both our studies and in many prior ones the interference from task-irrelevant stimuli that call for attention occurs even when the primary task involves perceptual popout; the effects thus tend to be smaller than when the primary task requires attention, but nevertheless they are found reliably. A variety of theories have been put forth to explain the existence and sometimes failure of

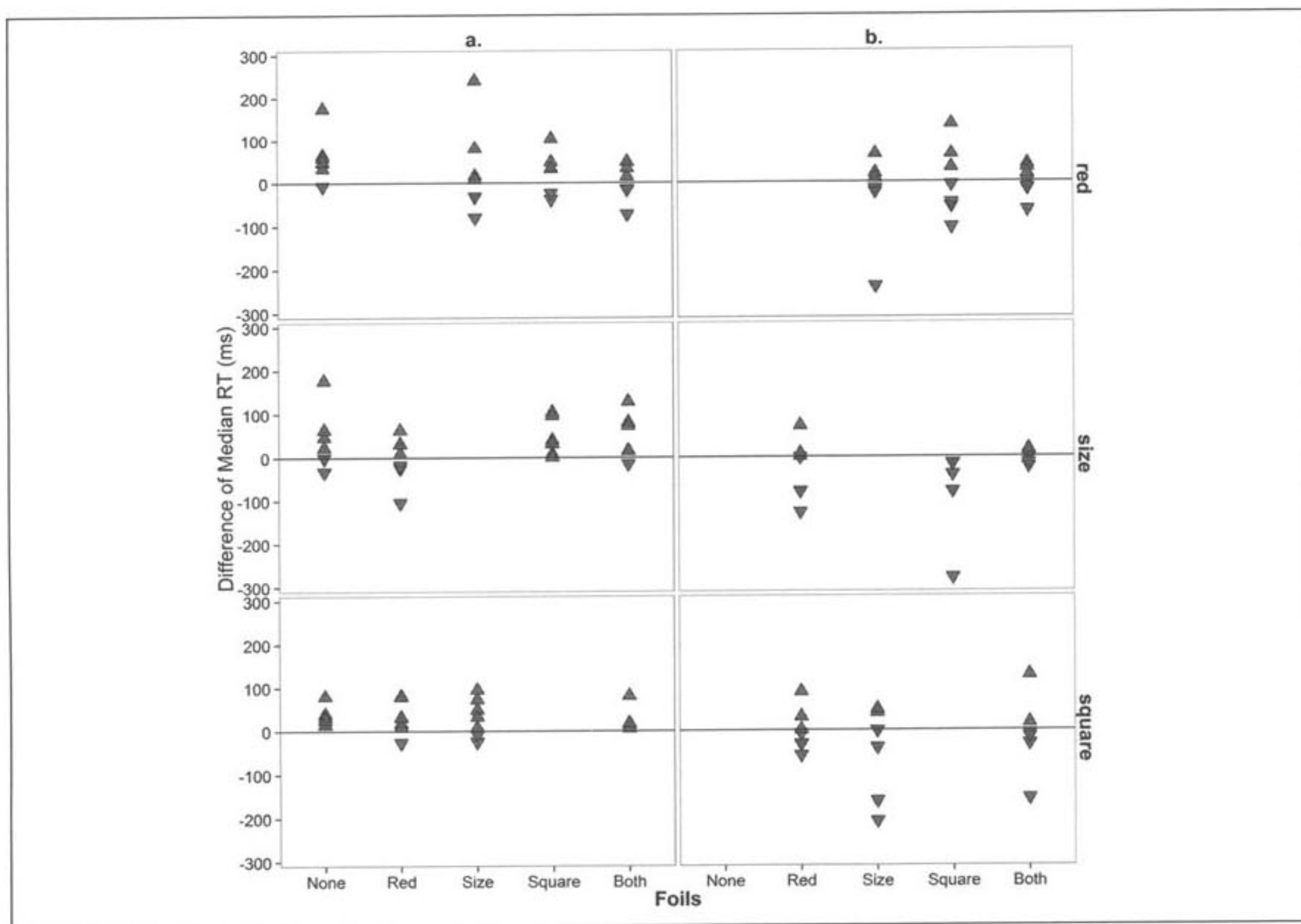


FIGURE 9. Median response time (RT) when (a) the present-trial target or (b) present-trial foil was not in the same display position as the target on the prior trial minus the same measure when the present target or foil was in the same display position as the target on the prior trial (positive numbers indicate faster responding for positions matching on successive trials), Experiment 2. The present-trial foil or foils are indicated on the horizontal axis

perceptual popout and the interference with popout, including the automatic and controlled search models of Schneider and Shiffrin (1977) and Shiffrin and Schneider (1977), feature integration theory (Treisman, 1982), guided search models (Cousineau & Shiffrin, 2004; Wolfe, 1994), and theory of visual attention (Bundesen, 1990). A number of these theories make use of the concept of salience to explain the speed with which perceptual popout takes place. Hermann Müller, Thomas Töllner, and colleagues (Müller, Heller, & Ziegler, 1995; Töllner, Müller, & Zehetleitner, 2012; Töllner, Rangelov, & Müller, 2012) argued that top-down control assigns weights to a dimension that eventually determines salience, and that salience then determines the speed of automatic popout and the degree of interference with popout. Certainly instructions and training to search for a given target in a given session will increase the salience of that object relative to the foils, but the pres-

ent findings reveal more to the story, because there are clear dimensional interactions.

The dimensional interactions are seen both within and between experiments and are most clearly evidenced by the results for the red stimuli as targets and foils. If one considers only square and size dimensions, the story seems consistent with an account that says size is more salient than square: In both experiments square produced less interference as a foil and when a target was harmed more by singleton foils on the other dimensions. However, this simple account does not hold up for red targets and foils. Red targets are clearly the fastest to find in the presence/absence experiment, suggesting they are the most salient of our three targets. (Red targets were second fastest in Experiment 1, but we believe that result is also caused by dimensional interactions, as discussed shortly). If red targets are the most salient, then one might expect they would be least harmed by the other stimuli as

foils, which indeed was the case. But one would also expect they would call for attention most strongly and produce the greatest harm when they appear as foils. Contrary to this expectation, red targets do not interfere much with the other target stimuli.

Although only suggestive at this point, the simplest account for these findings would hold that color and shape are superordinate dimensions that do not much interact: When participants focus on color, distraction by shape stimuli does not happen much, and when participants focus on shape, distraction by color does not happen much. This account might explain the slow responses to color targets in Experiment 1: The red target might be very fast to locate, but then a switch to the shape dimension would be needed to report the Gabor orientation. If this shift was time consuming, that could explain the somewhat slower responses to red in this experiment.

There are of course a variety of psychophysical results showing differences between color and shape perception and performance. There are also many differences in the ways color and shape are encoded and processed neurally: Orientation sensitivity forms a structured pinwheel pattern in primary visual cortex (Bonhoeffer & Grinvald, 1991), with color-sensitive cortical regions mostly at the pinwheel center, where orientation sensitivity is broad (see also research showing differences in orientation and color sensitivity with respect to ocular dominance; Landisman & Ts'o, 2002). It has been argued that the coding of form and color is mostly segregated in human visual cortex (Seymour, Clifford, Logothetis, & Bartels, 2010). Aside from neural differences in the coding of color and form, there are environmental and evolutionary reasons to think color and form would be treated differently: Object identification is more uniformly and regularly based on shape than on color, which changes with luminance and lighting conditions. However, the existence of dimensional differences is not by itself sufficient to explain the present dimensional interactions because auditory stimuli are processed in ways quite distinct from visual stimuli, behaviorally and neurally, but a sudden loud noise will interrupt ongoing processing of almost any sort. More research will be needed to sort out the mechanisms of dimensional interaction with attention and its distraction.

The concept of dimensional interaction is related to that of similarity (Duncan & Humphreys, 1989): One could argue that color is a dimension dissimilar to various shape dimensions and that the shape dimensions are more similar to each other. This could be the case, but the more common use of the similarity concept refers to similarity governing entry into an attention filter. The idea of an attention filter is that “set,” or “top-down control,” establishes the type of stimuli that the attention system is tuned to accept (see Chubb & Sperling, 1989; Itti, Koch, & Niebur, 1998; Weichselgartner & Sperling, 1987). In the context of the present task, let us assume for a session using size as a target that a filter is set to accept “large green circle,” with the emphasis on “large.” Suppose in this condition that an occasional foil is made to be a slightly smaller green circle than the target but sufficiently larger than the rest of the circles that it would pop out if used as a target. In this case it would be likely that both the target and the foil would be accepted by the filter on many trials and that if only one is accepted, it might be the foil almost as often as the target. In either event, processing would be severely affected. Error rates would probably rise and response times increase. Even when the target is the only object making it through the filter, response time would be increased by the need to decide whether the object’s size is larger than the foil.

Thus similarity of foil to target is one way to reduce task performance. However, the present tasks used dimensional singletons designed to ensure that this factor would not play a role. Furthermore, dimensional singletons involve another way that similarity affects performance, and it does so with a mechanism that is almost the reverse of that operating when targets and foils are similar: Attention is attracted by a display object (whether a target or foil) that is highly dissimilar from all others on some dimension. In the case of foils it is therefore *dissimilarity* that lowers performance. To say this another way, the fact that a large green circle target pops out from a set of smaller green circles shows that the dissimilarity is large enough to ensure that only the large circle passes the filter. Similarity as a unitary concept cannot be used to explain both that a small green circle does not enter the filter and that a small green square (which is surely more dissimilar) does. This is another way of

saying that the distraction in our tasks is caused by automatic calls for attention from a salient, dissimilar singleton on some different dimension.

These ideas may be compelling but still fall short of explaining the present results. If red is highly salient and dissimilar, it would be expected to call for attention very strongly when used as a foil, but the results show the opposite. Because similarity has two differing effects (as just described), we think it better not to use the term *similarity* to explain the present findings but instead to reduce confusion by describing them as a process of salience interacting with perceptual dimensions to produce demands for attention. Such an interaction could come about in various ways. For example, a fast and primitive process could operate globally on a display registering discontinuities and guiding attention to them, before a later stage that analyzes the content of the objects. Perhaps such an early stage would also respond to set or top-down control. Obviously the nature of these interactions warrants much more study.

Consider next the mechanisms that determine distraction by singletons (when such distraction does take place). One approach might suppose that the tendency to attract attention would be strongest for the defined target and that this tendency would compete with the weaker attention demands from the foil singletons. In many variants of this model the degree of slowing caused by foils would be spread more or less evenly throughout the range of target response times. The fact that the slowing seemed to occur rarely and then to a large degree (the slowest deciles of the response time distribution) might suggest a different mechanism: The competition for attention in most cases would be resolved quickly in favor of the target, in which case little slowing would be seen. However, on rare occasions competition would be won by a foil, causing attention to be sent to the foil display position. A correction would then be needed, causing slowing on those rare occasions. We did not monitor eye movements in our study, but such an account might be evidenced in future studies by an association between cases with large degrees of slowing and the occurrence of eye movements toward foil positions followed by a corrective eye movement (Kowler, Anderson, Doshier, & Blaser, 1995; McPeck, Maljkovic, & Nakayama, 1999). We note that a num-

ber of extant models could be used to implement these ideas. In race models to thresholds, trials on which a foil wins tend to be trials on which evidence for the target tends to accumulate more slowly than usual, producing long response times. Another possibility is models in which targets and foils mutually interact and inhibit each other as the evidence is accumulating, thereby slowing responses (Usher & McClelland, 2001).

That presence/absence decisions would be much faster than orientation decisions is easily predicted by any theory in which the target is located and then the orientation assessed. In principle it would be possible to carry out a parallel search for a conjunction of target features and Gabor orientation, but much research has shown that conjunction search is much harder than single feature search (Bundesen, 1990; Treisman, 1982; Wolfe, 1994), and popout would be unlikely to occur if used. Thus observers would almost certainly find it easier to let their attention be guided to a singleton location and then assess the orientation at that location.

Although Experiments 1 and 2 exhibited generally similar patterns of findings, one difference seems puzzling. In Experiment 2, search for size and square produced absent responses that were generally slower than present responses and much slower for the interference conditions. Search for red targets generally showed similar response times and little interference, a result we described as showing an interaction of salience and dimensions during attention allocation. However, in red search absent responses are faster when there are no foils. Why might this be the case? We suggest that again dimensional interaction plays a role. Absent responses without foils consist of all green circles; if the embedded Gabors play little role in color search, then a holistic all-same perception might speed responses. However, in shape search (size or square) the differing shapes of the Gabors might interfere with such an all-same perception.

The very large absent response times in Experiment 2 when there were foils is perhaps easy to explain: In both experiments a displayed target tended to dominate the attraction of attention, and only occasionally did a foil attract attention and slow responding. However, when no target was present, the foils that were present had no competition from the target

and hence may have attracted attention much more often. In such cases an additional check might be needed to determine that the object in question is not a target.

Conclusion

The two studies explored a number of factors that produced interruption of what is generally thought to be automatic, parallel popout search for perceptual singletons. Probably most interesting are the several findings suggesting that salience and similarity are concepts that require elaboration to explain the adjudication of calls for attention. We suggested that the calls for attention result from an interaction of salience and stimulus dimension. In particular, red targets were highly salient and found quickly but were neither much interfered by shape singletons as foils nor much interfered with when shape singletons were targets. Yet size and square targets and foils mutually interfered. In addition, search for red targets in Experiment 1 seemed to show that time was needed to switch from color to the shape dimension to respond with the orientation of an embedded Gabor. Finally, search for red targets in Experiment 2 when no foils or targets were present produced faster responses than almost all other conditions, consistent with the idea that the shape of the embedded Gabors did not interfere with an all-same perceptual response based on color that speeded search.

NOTE

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