Attention, Perception, & Psychophysics (2019) 81:1880–1889
https://doi.org/10.3758/s13414-019-01761-0

Association between cue lead time and template-for-rejection effect

Tomoyuki Tanda[1] · Jun I. Kawahara[1]

Published online: 21 May 2019

Abstract
The human visual system can actively prioritize task-relevant features to search for a target. Recent studies have reported cases in which the system may suppress irrelevant features by using a template for rejection. However, in those studies, the templates used for rejection were limited to the color domain, and they have yielded mixed results. Our literature review identified three differences among studies that may be responsible for such mixed results: differences in the spatial segmentation of items (i.e., segregated or intermixed across the display), differences in how features are defined and reported (i.e., combined or separate), and differences in cue lead times (short or long). Participants searched for a target-line segment in a shape and identified its orientation from among non-target line-shaped compound shapes that were preceded by one of three cue displays. Positive cues indicated that the target segment would appear in a shape, and negative cues that it would not appear in a shape. Neutral cues indicated that a particular shape would not appear in the current search display. The results demonstrated that reaction times were faster under the negative-cue condition than the neutral-cue condition, reflecting the effect of a shape-based template for rejection (Experiment 1). Experiment 2 replicated the absence of the effect in the shape domain. Experiment 3 indicated that the template-for-rejection effect occurred only when the cue lead time was relatively long, suggesting that time is required (approximately 2,400 ms or longer) for the visual system to form rejection templates. Experiment 4 excluded the possibility that a confound in the target-defining/reporting feature was involved. These results indicated that apparent inconsistencies in research on the template-for-rejection effect can be explained in terms of the time required for templates to be configured.

Keywords Visual attention · Attentional control · Visual search · Template for rejection · Distractor inhibition

Introduction

We are subjected to a deluge of information in daily life. Due to limitations in our capacity for cognitive processing, visual attention plays a critical role in selecting a few target objects and prioritizing them over irrelevant nontargets (Lleras, Levinthal, & Kawahara, 2009; Watson & Humphreys, 1997; Wolfe, 2014). For example, consider searching for a room key of a particular color (e.g., blue) among many other keys of different colors. In this context, it would be advantageous to know the color of the target key, or of keys that would never be targets. The former situation involves top-down, feature-based visual searches in which attention is biased toward the positive features that are consistent with the current behavioral goal (Most & Astur, 2007; Olivers, Meijer, & Theeuwes, 2006; Vickery, King, & Jiang, 2005). The latter situation involves a subtype of feature-based attentional bias, known as a visual search template-for-rejection, which is based on the suppression of a specific feature. The advantage of the template-for-rejection attentional bias, as exemplified by the shorter reaction times of participants who were aware of the target feature that did not match the feature maintained in working memory, was identified by Woodman and Luck (2007) and Arita, Carlisle, and Woodman (2012). Since their initial research, several lines of evidence, reviewed below, have indicated that a cued nontarget feature can support the template-for-rejection effect. At the same time, however, there have been inconsistencies among studies, where some did not observe template-for-rejection effects. Therefore, we focused on identifying the boundary conditions for a template-for-rejection effect in the present study.

Extant studies have demonstrated a template-for-rejection effect based on a color cue presented prior to a search array, when the cue predicted the color of a target or of nontargets (Arita et al., 2012; Reeder, Olivers, & Pollmann, 2017). For example, participants in the study by Arita et al. (2012) viewed items presented on an imaginary clock-face array to search for a Landort-C-like target containing a gap on the top

✉ Jun I. Kawahara
jkawa@let.hokudai.ac.jp

[1] Department of Psychology, Hokkaido University, N10W7, Kita, Sapporo 060-0810, Japan

or bottom, and were asked to identify the gap location among distractors containing a gap on the left or right. A positive cue indicated that a cued color matched the target color. A negative cue indicated that a cued color matched the distractor color. A neutral cue indicated that a cued color would never appear in the current search array. Reaction times under the positive-cue condition were the fastest among the three cueing conditions, and those under the neutral-cue condition were the slowest. The effect of the template for rejection was exemplified by the faster reaction times under the negative-cue condition relative to under the neutral-cue condition.

Although the procedural definition of a template for rejection is clear, the results of research performed after Arita et al. (2012) have been less conclusive; one study replicated the template-for-rejection effect (Reeder et al., 2017), whereas others failed to find any such effect (Beck & Hollingworth, 2015; Becker, Hemsteger, & Peltier, 2016). There are at least two major potential reasons for this inconsistency. First, the use of color and spatial grouping as cues may have had a confounding effect. Specifically, the search arrays in Arita et al. (2012) were configured so that a group of the same-color items was located in the same hemifield (e.g., red items on the left and blue items on the right side of the display). Therefore, participants might have converted a color cue into a spatial cue. This possibility was tested by Beck and Hollingworth (2015), who intermixed two colored items across both hemifields and found no template-for-rejection effects. Becker et al. (2016) reported similar results. However, Reeder et al. (2017) found a template-for-rejection effect even under a condition wherein two colored items were intermixed across both hemifields. Therefore, extant findings are inconclusive with regard to whether spatial grouping is critical. Thus, it is reasonable to assume that other factors may determine the effect of a template for rejection.

Finally, cue lead times and/or cue durations varied substantially among previous studies reporting differences in the template-for-rejection effect. For example, one group of studies used relatively long durations and found an effect, whereas another group used a brief cue, 100 ms, and therefore a shorter cue lead time (e.g., 1,000 or 600 ms); their results showed no template-for-rejection effect (Beck & Hollingworth, 2015; Becker et al., 2016). Therefore, these results imply that a relatively longer cue lead time may be a prerequisite for the template-for-rejection effect. This view seems reasonable in that a large number of studies have shown that top-down attentional modulation requires time (e.g., Monsell, 2003; Spence & Driver, 1994; Theeuwes & Van der Burg, 2011). The benefits of negative cues by top-down attentional modulation have been observed later in time (Kawashima & Matsumoto, 2018; Moher & Egeth, 2012). Thus, a longer cue lead time may be a critical factor in the template-for-rejection effect.

Additionally, we question the generalizability of the findings of a template-for-rejection effect, because the preceding studies on templates for rejection used only color cues (Arita et al., 2012; Beck & Hollingworth, 2015; Becker et al., 2016; Reeder et al., 2017). Therefore, it is unclear whether the template-for-rejection effect would occur when other features were used as a cue. Given that shapes as well as colors have been used as features for restricting visual searches to improve performance (Becker, Harris, Venini, & Retell, 2014; Soto, Heinke, Humphreys, & Blanco, 2005; Treisman & Gormican, 1988), we assumed that these features could be used to prioritize access to working memory (Griffin & Nobre, 2003; Gilchrist, Duarte, & Verhaeghen, 2016; Li & Saiki, 2015), it is reasonable to assume that a shape cue should be able to elicit the template-for-rejection effect. We argue that it is premature to conclude that a feature-based template for rejection elicits a general effect only when the specific feature of color is used as the cue. Indeed, we tested whether the template-for-rejection effect could be elicited in shape-based searches.

Thus, we designed a set of experiments to address these issues. First, we examined whether participants could create a template for rejection based on the dimension of shape, and thereby sought to replicate a basic finding in this domain (Experiment 1). We also replicated the finding by Beck and Hollingworth (2015), who reported the absence of a template-for-rejection effect (Experiment 2). Second, we examined whether cue lead time is a prerequisite for a successful template for rejection (Experiments 3 and 4). It was hypothesized that cue lead time is a critical factor in determining the presence or absence of the template-for-rejection effect.

In summary, our initial goal was to determine whether the template-for-rejection effect reported in relation to color-based cues may be generalizable to shape-based cues. To this end, we performed two experiments that were replications of the original study (Arita et al., 2012) reporting the existence of a template for rejection (Experiment 1) and a study that failed to find such an effect (Beck & Hollingworth, 2015) when stimuli were spatially interleaved (Experiment 2). We replicated both outcomes with shape stimuli and then attempted to determine the factor responsible for the opposite effects between these two experiments. Where the obvious difference was whether the cued stimuli were spatially distinct from un-cued stimuli, we noted that others (Reeder et al., 2017) have found evidence of a template for rejection even when stimuli are spatially interleaved. After examining the methodological differences across studies, we posited that the critical factor determining whether one finds, or fails to find, evidence for a template for rejection may be the cue lead time (i.e., the temporal lag between the cue and search display). To investigate this, we conducted a third study that increased the cue-to-search display duration but used spatially interleaved stimuli similar to those in our Experiment 2. This experiment produced evidence of a template for rejection, supporting our theory that the cue-to-search display durations may be critical.

Experiment 1

The purpose of Experiment 1 was to examine whether participants could create a template for rejection based on the shape dimension, and to replicate a basic finding of template-for-rejection research. If templates for rejection improve the efficiency of visual searches, the identification of targets would be facilitated under positive and negative cue conditions relative to the control condition, under which no shape-related cues are provided.

Method

Participants Thirty-five undergraduate and graduate students participated in this experiment (16 males and 19 females; mean age = 20.9 years, *SD* = 5.1). All participants in this and the subsequent experiments had normal or corrected-to-normal visual acuity and normal color vision. The experiments were all approved by the Human Research Ethics Committee of Hokkaido University. All participants provided written informed consent prior to the experiment and were awarded a monetary honorarium or course credit.

Apparatus and stimuli Stimuli were displayed on an LCD monitor (100 Hz refresh rate, 1,920 × 1,080 pixels, XL2411T; BenQ) controlled by custom Matlab software using Psychophysics Toolbox extensions (Brainard, 1997; Kleiner, Brainard, & Pelli, 2007; Pelli, 1997). The viewing distance was approximately 57 cm.

The search array consisted of three types of outline shapes (circle, square, and diamond, each subtended 0.8° × 0.8°) arranged on an imaginary circle with a 5° radius and displayed on a gray background accompanied by a black central fixation cross (0.2° × 0.2°). The six items in the search array consisted of two of the three types of shape. These were randomly selected on every trial so that all items within a hemifield were of the same shape. Each search item contained a short line segment (1.5°), the orientation of which was randomly determined with the constraint that the target segment was either vertical or horizontal; the nontargets were tilted clockwise or anti-clockwise at 22.5° from the vertical or horizontal direction. One of the 12 items contained the target segment, and the other contained the nontarget segments. The type of shape containing the target segment was selected randomly on each trial.

Procedure As shown in Fig. 1, each trial began with the presentation of a fixation cross for 500 ms, followed by the presentation of a shape cue for 100 ms. After the shape cue

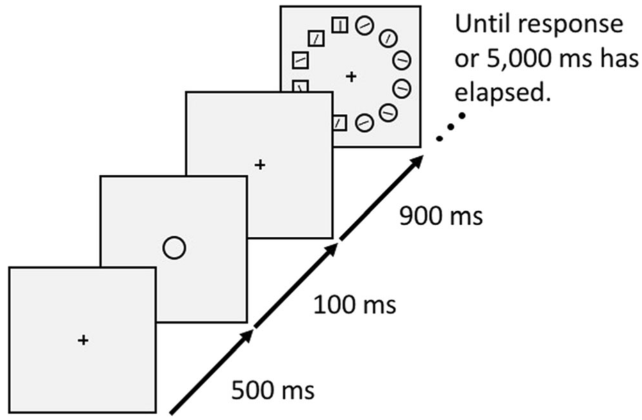

Fig. 1 Schematic diagram of the stimulus sequence in Experiment 1. At the beginning of a block, participants were informed of the type of a cue (e.g., negative cue). They viewed a cue display for 100 ms and were required to identify a target line segment (vertical in this example)

disappeared, a fixation cross was presented for 900 ms followed by a search array that remained until participants responded, or until 5,000 ms from the onset of the array had elapsed. One of three types of cue was randomly selected on each trial and presented at the center of the screen. Participants searched for, and indicated the orientation of, the target segment by pressing a designated key on the keyboard (the down and left arrow keys for vertical and horizontal targets, respectively) as quickly and accurately as possible.

We treated cue type as a within-subject factor with three potential values: positive, negative, or neutral. A positive cue indicated that a target segment would appear within the cued shape. The negative cue indicated that a target segment would never appear within the cued shape. The neutral cue indicated that the cued shape would never appear in the current search array. Under the positive and negative cue conditions, the cued shape and one of the uncued shapes appeared as search items. Under the neutral cue condition, the cued shape did not appear in the search array. The cues were presented according to a block design. Each condition consisted of 144 trials, and the order of conditions was counterbalanced across participants. Each block began with the instructions for the relevant condition and 12 practice trials.

Results

Data from one participant were excluded from the analysis due to an accuracy rate of less than 75% under one condition. Trials with reaction times 3 *SD* above or below the mean (1.6% of all data), and those with errors (4.8% of all data), were excluded from analyses. Figure 2 shows the mean reaction times across the three cue types in Experiment 1. Analysis of variance (ANOVA) of mean reaction times, treating cue type as a within-subject variable, indicated a significant main effect of cue type ($F(2, 66) = 46.43$, $p < .001$, $\eta_P^2 = .58$). In this and the following analyses, we used the Holm method for

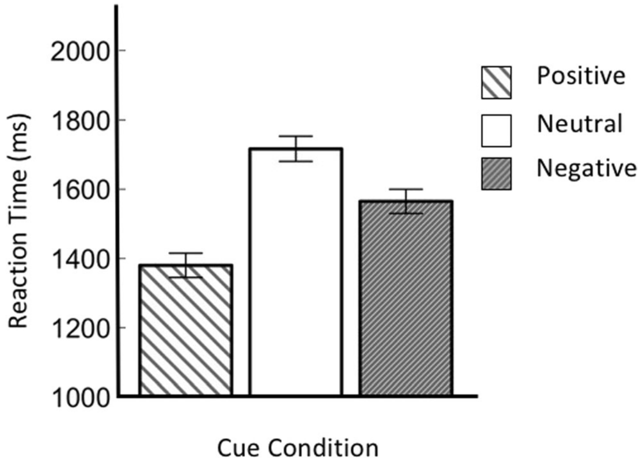

Fig. 2 Mean reaction times as a function of cue type from Experiment 1. Error bars represent within-subject 95% confidence intervals

multiple comparisons. Reaction times were shortest under the positive cue condition (positive vs. neutral, $t(33) = 9.50$, $p < .001$, $r = .86$; positive vs. negative, $t(33) = 5.40$, $p < .001$, $r = .69$). Reaction times under the negative cue condition were shorter than those under the neutral cue condition (negative vs. neutral, $t(33) = 4.30$, $p < .001$, $r = .60$). An ANOVA of accuracy rates, treating cue type as a within-subject variable, found no significant main effect of cue type ($F(2, 66) = 0.19$, $p = .83$, $\eta_P{}^2 = .005$).

Discussion

In Experiment 1, both the positive and the negative cues had beneficial effects on reaction times relative to the neutral cue. This pattern of mean reaction times replicated the findings of Arita et al. (2012), in that participants could exclude negatively cued features from searches and the template-for-rejection effect could be extended to the shape domain. Experiment 1 successfully replicated the findings of Arita et al. (2012). However, the presence of a template-for-rejection effect is not unequivocal. Specifically, Beck and Hollingworth (2015) failed to find the effect when the items were spatially intermixed in a search array. Thus, we replicated their findings using a similar paradigm in Experiment 2.

Experiment 2

The present experiment replicated Experiment 1 under a condition in which two groups of shapes were intermixed and distributed on both sides of the display. This stimulus configuration avoided location-based grouping of items, which could interfere with the effect of negative cues. We predicted no template-for-rejection effect, consistent with Beck and Hollingworth's (2015) finding.

Method

Participants Forty-two undergraduate and graduate students participated in this experiment (27 males and 15 females; mean age = 20.0 years, $SD = 1.4$).

Apparatus and stimuli Except for the search arrays, which were spatially intermixed and consisted of three versions of each of two types of shape, which were randomly selected on each trial so that two types of items appeared within each hemifield, the apparatus and stimuli were identical to those used in Experiment 1. The items were placed in two imaginary rectangular regions. The distance between the edge of the rectangular region nearest to the other region and the fixation cross was 5.5°, and that between items was 2.5°. Each item had a randomly determined (0–1°) spatial jitter.

Procedure As shown in Fig. 3, the procedure was identical to that used in Experiment 1. Cue lead time was 1,000 ms (cue duration: 100 ms; blank time after cue offset: 900 ms). The order of presentation of the conditions was counterbalanced across participants. Each block began with instructions about the conditions and 12 practice trials.

Results

Data from two participants were excluded from the analysis due to an accuracy rate of less than 75% under one condition. Trials with reaction times 3 *SD* above or below the mean (1.1% of all data), and those with errors (4.5% of all data), were excluded from the analyses. These exclusions did not alter the pattern of results. Figure 4 shows the mean reaction times for Experiment 2 as a

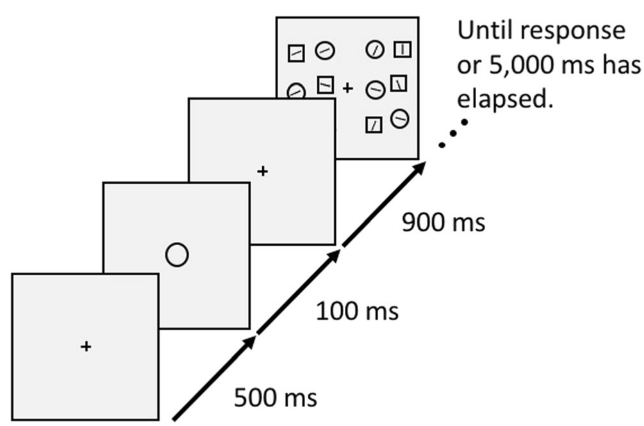

Fig. 3 Schematic diagram of the stimulus sequence in Experiment 2. At the beginning of a block, participants were informed of the type of a cue (e.g., negative cue). They viewed a cue display for 100 ms and were required to identify a target line segment (vertical in this example)

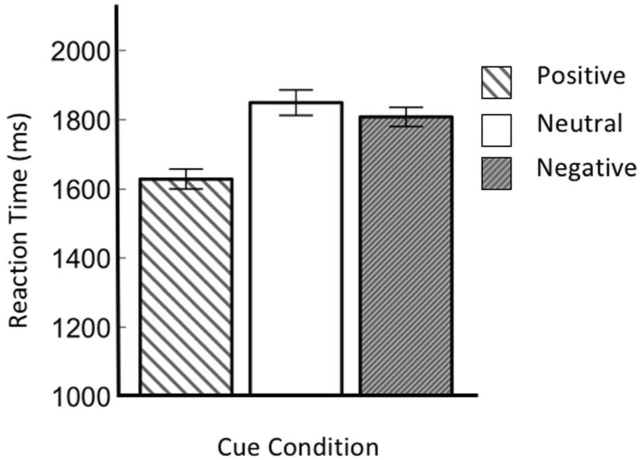

Fig. 4 Mean reaction times as a function of cue type from Experiment 2. Error bars represent within-subject 95% confidence intervals

function of cue type. An ANOVA on mean reaction time, treating cue type as a within-subject factor, indicated a significant main effect of cue type ($F(2, 78) = 28.69$, $p < .001$, $\eta_P^2 = .42$). The reaction times under the positive cue condition were the shortest (positive vs. neutral, $t(39) = 6.45$, $p < .001$, $r = .72$; positive vs. negative, $t(39) = 7.42$, $p < .001$, $r = .77$). The difference between the negative and neutral cue conditions was not significant ($t(39) = 1.23$, $p = .225$, $r = .19$). An ANOVA on accuracy, treating cue type as a within-subject variable, identified no significant main effect of cue type ($F(2, 78) = 2.09$, $p = .131$, $\eta_P^2 = .05$).

Discussion

In Experiment 2, only the positive shape cues produced beneficial effects on reaction times relative to the neutral cue. This pattern of mean reaction times replicated and extended the results reported by Beck and Hollingworth (2015). These findings are identical to those of previous studies showing that the template-for-rejection effect occurred only when the search items were spatially grouped (Beck & Hollingworth, 2015; Becker et al., 2016), even in the shape domain. Experiments 1 and 2 indicated that the template-for-rejection effect generalizes to the shape domain.

Experiment 3

As reviewed in the *Introduction*, studies on templates for rejection have yielded mixed results. To recapitulate, one set of studies found evidence of template-for-rejection effects (Arita et al., 2012; Reeder et al., 2017), whereas others reported negative findings (Beck & Hollingworth, 2015; Becker et al., 2016; see also Table 1 for summary). We argue that a critical factor underlies this inconsistency among studies. Specifically, cue lead time might play a critical role in the presence or absence of the template-for-rejection effect; i.e., one set of studies with shorter cue lead times reported no template-for-rejection effect. Beck and Hollingworth (2015) used a 100-ms cue followed by a 900-ms blank period, and Becker et al. (2016) used a 100-ms cue followed by a 500-ms blank period. In contrast, the other set of studies used much longer cue lead times (1,000–2,000-ms cue followed by a 2,000–6,000-ms blank period; Reeder et al., 2017) and reported the presence of the template-for-rejection effect. Given that top-down cues require time to be effective (e.g., Monsell, 2003; Spence & Driver, 1994; Theeuwes & Van der Burg, 2011), the participants in the study by Reeder et al. (2017) had sufficient time to receive the benefit of the cues, as the cue lead time in their experiment was long.

Experiment 3 examined whether a template-for-rejection effect would be obtained under a condition in which the cue lead time was long (2,400 ms) relative to a procedure that, as in Experiment 2, had a short cue lead time (1,000 ms). If the negative cue was found to be advantageous, then a long cue lead time would be a prerequisite for the template-for-rejection effect.

In contrast to Experiments 1 and 2, in which the cue conditions were blocked and which were conducted to replicate the findings of Arita et al. (2012) and Beck and Hollingworth (2015) with respect to the shape dimension, in the following two experiments, the cue conditions were not blocked, and the condition was randomly

Table 1 Studies on templates for rejection

	Arita et al. (2012) Expt. 1A	Beck and Hollingworth (2015) Expt. 2	Becker et al. (2016) Expt. 3	Reeder et al. (2017)	Present study		
					Expt. 2	Expt. 3	Expt. 4
Cue duration (ms)	100	100	100	1,000–2,000	100	1,500	1,500
Cue lead time (ms)	1,100	1,000	600	3,000–8,000	1,000	2,400	2,400
Defining and reporting feature	Combined	Combined	Combined	Separated	Separated	Separated	Combined
Presence/absence of template-for-rejection effect	Present	Absent	Absent	Present	Absent	Present	Present

selected in each trial to replicate the finding of Reeder et al. (2017).

Method

Participants Forty undergraduate and graduate students participated in this experiment (21 males and 19 females; mean age = 20.2 years, *SD* = 1.6).

Apparatus and stimuli Except for the presentation of cues, the apparatus and stimuli were identical to those of Experiment 2. Cues contained one of three types of Japanese Kanji characters (“同”, “否”, and “他”) to inform participants of the present condition.

Procedure The procedure was identical to that of Experiment 2, except for the way in which the cues were presented. In Experiment 3, the cue condition was not blocked, and the order of presentation of the cue conditions was random for each trial. A shape cue was presented for 1,500 ms. We used three Japanese Kanji characters (“同”, “否”, and “他”) to indicate positive, negative, and neutral cue conditions, respectively. One of these letters was presented within a shape frame as a cue on every trial. As shown in Fig. 5, for example, the character “否” surrounded by a circle represented a negative cue, indicating that the target segment would never appear in the circles in the search array of the following trial. A given shape appeared with the same frequency across trials under the positive, neutral, and negative cue conditions. We performed 720 trials, and each cueing condition was used in 240 trials. The experiment began with an instruction display, followed by 12 practice trials. Participants were prompted to take a break after every 72 trials.

Results

Trails with reaction times 3 *SD* above or below the mean (1.1% of all data), and those with errors (4.3% of all data), were excluded from the analyses. Figure 6 shows the mean reaction times for Experiment 3 as a function of cue type. An ANOVA of mean reaction times, treating cue type as a within-subject variable, indicated a significant main effect of cue type ($F(2, 78) = 76.07$, $p < .001$, $\eta_P^2 = .66$). Multiple comparisons revealed that the differences between all combinations of the three conditions were significant. The reaction times were shortest under the positive cue condition (positive vs. neutral, $t(39) = 10.34$, $p < .001$, $r = .86$; positive vs. negative, $t(39) = 9.05$, $p < .001$, $r = .82$). The reaction times under the negative cue condition were shorter than those under the neutral cue condition ($t(39) = 3.44$, $p = .001$, $r = .48$). An ANOVA of accuracy, treating cue type as a within-subject variable, showed that the main effect of cue type approached significance ($F(2, 78) = 2.9$, $p = .061$, $\eta_P^2 = .07$). Multiple comparisons showed that accuracy was significantly higher under the negative cue condition than under the neutral cue condition ($t(39) = 2.7$, $p = .031$, $r = .40$), and that the effects for other combinations were not significant (positive vs. neutral, $t(39) = 1.80$, $p = .16$, $r = .28$; positive vs. negative, $t(39) = 0.21$, $p = .832$, $r = .04$).

Discussion

Experiment 3 examined whether a template-for-rejection effect would be obtained when a relatively long cue lead time was used. The presence of the effect in this experiment, in conjunction with the null results using a relatively short cue lead time (Experiment 2), revealed that the template-for-rejection effect depended on the cue lead time. The results also clearly showed that the effect was obtained when the

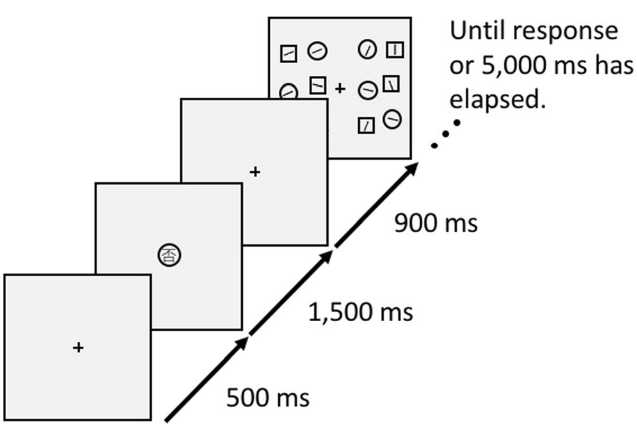

Fig. 5 Schematic diagram of the stimulus sequence in Experiment 3. Participants viewed a cue display for 1,500 ms and they were informed of the type of a cue (e.g., negative cue). They were required to identify a target line segment (vertical in this example)

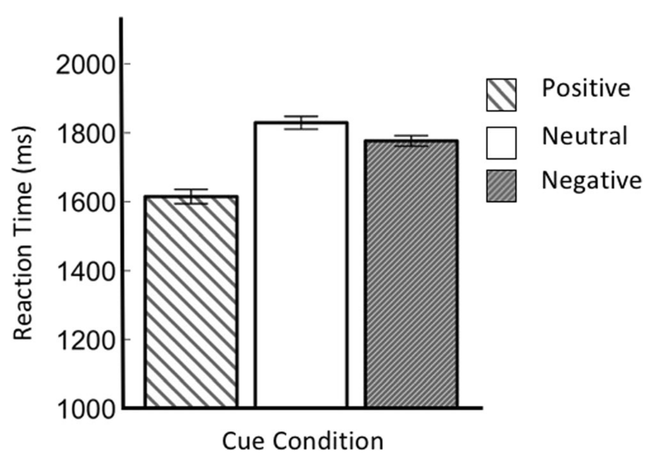

Fig. 6 Mean reaction times as a function of cue type from Experiment 3. Error bars represent within-subject 95% confidence intervals

items of search arrays were spatially intermixed, as examined by Beck and Hollingworth (2015), indicating that the spatial grouping of items was not a prerequisite for the effect.

However, it might be premature to conclude that long cue lead time is a prerequisite for the template-for-rejection effect. Indeed, cue lead time and separating the defining from the reporting feature may have confounded our results. In previous studies that have found no template-for-rejection effect (Beck & Hollingworth, 2015; Becker et al., 2017), the cue lead time was relatively short and the defining and reporting features were combined. However, in the study that found the rejection effect (Reeder et al., 2017; Experiment 3), the cue lead time was relatively long and the defining and reporting features were separated. Therefore, we designed Experiment 4 to overcome this potential confounding. Although we assume that the impact of the defining feature factor on the presence or absence of the template-for-rejection effect would be negligible, we conducted Experiment 4 to examine this factor and achieve a definitive conclusion as to whether the cue lead time, rather than the defining/reporting feature, is critical for the emergence of the template-for-rejection effect. In Experiment 4, we attempted to replicate the template-for-rejection effect by using a long cue lead time and combining the defining and reporting features.

Experiment 4

In Experiment 4, we tested whether combining/separating the defining and reporting features determined the occurrence of a template-for-rejection effect. Template-for-rejection effects were observed in studies using procedures ensuring that the defining and reporting features were separated (Reeder et al., 2017). In the present experiment, we manipulated the items in a search array so that participants identified the target in terms of the cued shape and reported the location of a gap (top or bottom) in the shape. If the template-for-rejection effect occurred only when the defining and reporting features were separated, no effect would be obtained in the present experiment. If the issue of defining and reporting features was irrelevant, the template-for-rejection effect would be obtained because we maintained a longer cue lead time (2,400 ms), as in Experiment 3.

Method

Participants Forty undergraduate and graduate students participated in this experiment (25 males and 15 females; mean age = 21.1 years, *SD* = 1.7).

Apparatus, stimuli, and procedure Except for the following changes, the apparatus, stimuli, and procedure were identical to those used in Experiment 3. As shown in Fig. 7, the items

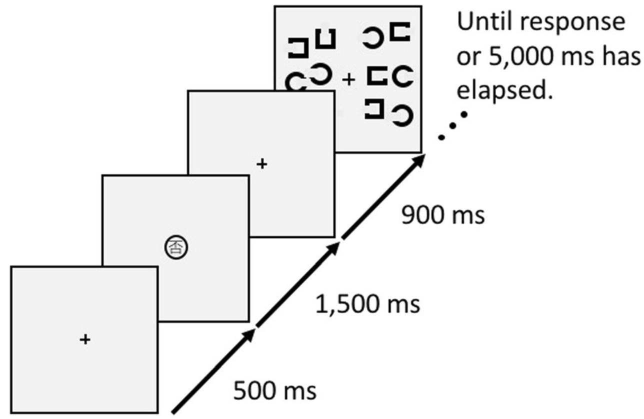

Fig. 7 Schematic diagram of the stimulus sequence in Experiment 4. Participants viewed a cue display for 1,500 ms and they were informed of the type of a cue (e.g., negative cue). They were required to identify a target gap location (top in this example)

did not contain a segment; however, similar to the Landort-C, they had a gap (0.5° long) on one side. The target had a gap at the top or bottom, and the distractors had a gap to the left or right. The line thickness was 0.2°. Participants searched for a target gap and indicated the location of the gap by pressing a designated key on the keyboard (the "B" and "N" key for top and bottom gaps, respectively) as quickly and accurately as possible.

Results

Trails with reaction times 3 *SD* above or below the mean (1.8% of all data), and those with errors (2.9% of all data), were excluded from the analyses. Figure 8 shows the mean reaction times for Experiment 4 as a function of cue type. An ANOVA on the mean reaction time, treating cue type as a within-subject variable, indicated a significant main effect of cue type ($F(2, 78) = 91.57$, $p < .001$, $\eta_P^2 = .70$). Multiple comparisons revealed that the differences between all

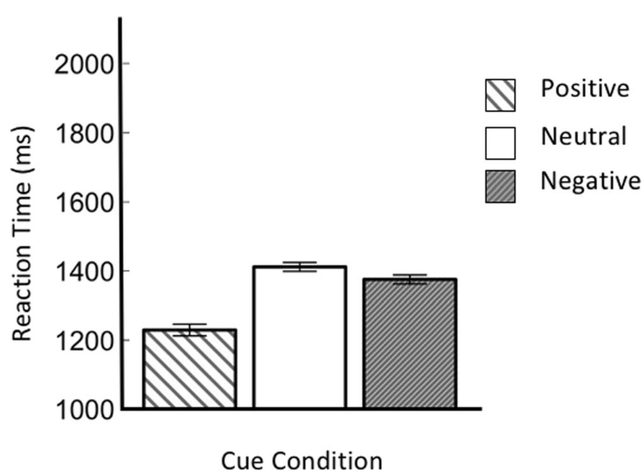

Fig. 8 Mean reaction times as a function of cue type from Experiment 4. Error bars represent within-subject 95% confidence intervals

combinations of the three cue conditions were significant. The reaction times were shortest under the positive cue condition (positive vs. neutral, $t(39) = 11.79$, $p < .001$, $r = .88$; positive vs. negative, $t(39) = 9.30$, $p < .001$, $r = .83$). The reaction times were shorter under the negative cue condition than the neutral-cue condition ($t(39) = 3.26$, $p = .002$, $r = .46$). An ANOVA of accuracy, treating cue type as a within-subject variable, identified no significant main effect of cue type ($F(2, 78) = 0.56$, $p = .574$, $\eta_P^2 = .01$).

Discussion

In Experiment 4, a template-for-rejection effect occurred when the defining and reporting features were combined. This indicated that the template-for-rejection effect did not depend on whether the definition and reporting features were combined or separated. Experiment 4 overcame the confounding of the defining and reporting features and the cue lead time and clearly showed that a long cue lead time is critical for the rejection effect.

General discussion

The purpose of the present study was to determine the conditions under which the template-for-rejection effect can be obtained. Three main findings emerged from four experiments. First, we found a shape-based template-for-rejection effect. Experiment 1 replicated the basic finding of a shape-based template-for-rejection effect. Second, the template-for-rejection effect occurred even when the items were not spatially grouped. Experiment 3 clarified the confounding effects of shape and space that remained unclear in Experiment 1. Third, and most importantly, we found that one of the prerequisites for the template-for-rejection effect was a long cue lead time (Experiment 2 vs. Experiments 3 and 4). In Experiment 4, we also showed that the minor differences in the previous studies regarding the defining and reporting features were irrelevant to the presence or absence of the template-for-rejection effect, because we obtained the effect with a combined procedure. The results of Experiment 4 were consistent with our primary finding that a relatively longer cue lead time is required for successful rejection of cued features.

Previous knowledge about the presence or absence of the template-for-rejection effect was mixed. Based on our literature review, we identified two factors, i.e., the dissociation between the target-defining and target-reporting features and the cue lead time, as potential contributors to such mixed results. We examined whether the cue lead time was critical by shortening its duration and found that the template-for-rejection effect disappeared. This finding indicated that a relatively long cue lead time, i.e., more than 2,400 ms, is required for the template-for-rejection effect. This is unsurprising given that the operation of top-down feature-based attention requires time (e.g., Theeuwes & Van der Burg, 2011; van Zoest & Donk, 2008), especially when irrelevant features have to be ignored (Moher & Egeth, 2012). If the dissociation between the defining and reporting features were critical, no template-for-rejection effect should have been obtained. However, the results of Experiment 4 indicated the presence of the effect even when the defining and reporting features were combined. Therefore, the apparent inconsistency regarding the presence or absence of a template-for-rejection effect in the literature can be explained by differences in the cue lead times used by different studies. The finding that positive cueing effects occurred in every experiment suggests that a template for acceptance can be built much faster than a template for rejection.

It is intriguing to explore the correlation in cue benefits between positive and negative cues, as Beck and Hollingworth (2015) and Becker et al. (2016) have reported. The present results also showed, as demonstrated in these previous studies, a strong correlation in cue benefits between positive and negative cues, with participants who showed a large positive cue benefit also showing a negative cue benefit ($r = .75$, $p < .001$). Specifically, a participant whose positive cue benefit was 826 ms showed a negative cue benefit of 396 ms. On the other hand, a participant whose positive cue benefit was only 217 ms showed a negative cue cost (-134 ms). These results indicated that the template-for-rejection effect depends on individual cueing effects. These results were consistent with the findings of Beck and Hollingworth (2015) and Becker et al. (2016).

Note that the reaction times under the negative cue condition were longer than those under the positive cue condition whenever the template-for-rejection effect was obtained (Experiments 1, 3, and 4). This pattern of results is consistent with the literature (Arita et al., 2012; Reeder et al., 2017). The delayed reactions cannot be attributed to an indirect cueing effect produced by the creation of a positive template for an uncued shape. Because the present search arrays consisted of two types of shape on every frame, it was theoretically possible that participants created a positive template for the uncued shapes. A recent study by Reeder, Olivers, Hanke, and Pollmann (2018) suggests a skeptical view of the idea of a template for rejection by arguing that there is no neural evidence for the rejection effect in functional magnetic resonance imaging (fMRI) BOLD signals, even though behavioral reaction times under the negative cue condition were shorter than those under the neutral cue condition. Nonetheless, the cause of the delay remains unclear. Future studies should examine whether the effect of the template for rejection was weaker than that of the template for selection or whether participants created a template for selection for uncued shapes.

In summary, the main contribution of the present study is its explanation of the apparent inconsistencies in the previous studies of the template-for-rejection effect in terms of differences in cue lead time. Its secondary contribution is its demonstration that the template-for-rejection effect reported in the literature generalizes to shape stimuli. Finally, Experiment 4 ruled out the potential confounding of cue lead time and the separation of the defining and reporting features. The ability to find evidence for a template-for-rejection effect depends critically on the amount of time between the cue and the display (i.e., less than approximately 2,400 ms). When the use of a negative cue is made easy, due to a spatial separation of features in the search array, even a short cue period may be sufficient to yield results consistent with a template for rejection. When, however, the ability to use such a cue is rendered more difficult by spatially interleaving stimuli, a template for rejection may or may not appear, and the critical determinant of whether this effect emerges may be the amount of preparation time. Sufficient preparation time will yield evidence of an effect, whereas insufficient preparation time will not. We excluded the possibility that spatial grouping and combining/separating the defining and reporting features contribute to the inconsistency. However, we acknowledge that whether the cue lead time or inter-stimulus interval (i.e., interval between the offset of the cue and the onset of the search display) is most critical for the presence or absence of the template-for-rejection effect remains unclear. To clarify this issue, as well as to explore the precise timing required for the successful creation of templates for rejection, we will systematically manipulate both the cue duration and cue lead time in future studies.

References

Arita, J. T., Carlisle, N. B., & Woodman, G. F. (2012). Templates for rejection: Configuring attention to ignore task-irrelevant features. *Journal of Experimental Psychology: Human Perception and Performance*, *38*, 580-584. https://doi.org/10.1037/a0027885

Beck, V. M., & Hollingworth, A. (2015). Evidence for negative feature guidance in visual search is explained by spatial recoding. *Journal of Experimental Psychology: Human Perception and Performance, 41*, 1190-1196. https://doi.org/10.1037/xhp0000109

Becker, M. W., Hemsteger, S., & Peltier, C. (2016). No templates for rejection: A failure to configure attention to ignore task-irrelevant features. *Visual Cognition, 23*, 1150-1167. https://doi.org/10.1080/13506285.2016.1149532

Becker, S. I., Harris, A. M., Venini, D., & Retell, J. D. (2014). Visual search for color and shape: When is the gaze guided by feature relationships, when by feature values? *Journal of Experimental Psychology: Human Perception and Performance, 40*, 264-291. https://doi.org/10.1037/a0033489

Brainard, D. H. (1997) The Psychophysics Toolbox. *Spatial Vision, 10*: 433-436. https://doi.org/10.1163/156856897X00357

Gilchrist, A. L., Duarte, A., & Verhaeghen, P. (2016). Retrospective cues based on object features improve visual working memory performance in older adults. *Neuropsychology, Development, and Cognition, Section B, 23*, 184-195. https://doi.org/10.1080/13825585.2015.1069253

Griffin, I. C., & Nobre, A. C. (2003). Orienting attention to locations in internal representations. *Journal of Cognitive Neuroscience, 15*, 1176-1194. https://doi.org/10.1162/089892903322598139

Kawashima, T., & Matsumoto, E. (2018). Negative cues lead to more inefficient search than positive cues even at later stages of visual search. *Acta Psychologica*, *190*, 85–94. https://doi.org/10.1016/j.actpsy.2018.07.003

Kleiner, M., Brainard, D., & Pelli, D. (2007). What's new in Psychtoolbox-3? *Perception, 36*, ECVP Abstract Supplement. https://doi.org/10.1068/v070821

Li, Q., & Saiki, J. (2015). Different effects of color-based and location-basedselection on visual working memory. *Attention, Perception, & Psychophysics, 77*, 450-463. https://doi.org/10.3758/s13414-014-0775-3

Lleras, A., Levinthal, B. R., & Kawahara, J. (2009). The remains of the trial: Goal-determined inter-trial suppression of selective attention. *Progress in Brain Research*, *176*, 195-213. https://doi.org/10.1016/S0079-6123(09)17611-2

Moher, J., & Egeth, H. E. (2012). The ignoring paradox: Cueing distractor features leads first to selection, then to inhibition of to-be-ignored items. *Attention, Perception, & Psychophysics, 74*, 1590-1605. https://doi.org/10.3758/s13414-012-0358-0

Monsell, S. (2003). Task switching. Trends in Cognitive Sciences, 7, 134-140. https://doi.org/10.1016/S1364-6613(03)00028-7

Most, S. B., & Astur, R. S. (2007). Feature-based attentional set as a cause of traffic accidents. *Visual Cognition, 15*, 125-132. https://doi.org/10.1080/13506280600959316

Olivers, C. N., Meijer, F., & Theeuwes, J. (2006). Feature-based memory-driven attentional capture: Visual working memory content affects visual attention. *Journal of Experimental Psychology: Human Perception and Performance, 32*, 1243-1265. https://doi.org/10.1037/0096-1523.32.5.1243

Pelli, D.G. (1997) The VideoToolbox software for visual psychophysics: Transforming numbers into movies. *Spatial Vision, 10*, 437-442. https://doi.org/10.1163/156856897X00366

Reeder, R., Olivers, C. N. L., Hanke, M., & Pollmann, S. (2018). No evidence for enhanced distractor template representation in early visual cortex. *Cortex*, *108*, 279-282. https://doi.org/10.1016/j.cortex.2018.08.005

Reeder, R., Olivers, C. N. L. & Pollmann, S. (2017). Cortical evidence for negative search templates. *Visual Cognition, 25*, 278-290. https://doi.org/10.1080/13506285.2017.1339755

Soto, D., Heinke, D., Humphreys, G. W., & Blanco, M. J. (2005). Early, involuntary top-down guidance of attention from working memory. *Journal of Experimental Psychology: Human Perception and Performance, 31*, 248-261. https://doi.org/10.1037/0096-1523.31.2.248

Spence, C. J., & Driver, J. (1994). Covert spatial orienting in audition: Exogenous and endogenous mechanisms. *Journal of Experimental Psychology: Human Perception and Performance*, *20*, 555 –574. https://doi.org/10.1037/0096-1523.20.3.555

Theeuwes, J., & Van der Burg, E. (2011). On the limits of top-down control of visual selection. *Attention, Perception, & Psychophysics, 73*, 2092-2103. https://doi.org/10.3758/s13414-011-0176-9

Treisman, A., & Gormican, S. (1988). Feature analysis in early vision: Evidence from search asymmetries. *Psychological Review, 95*, 15–48. https://doi.org/10.1037/0033-295X.95.1.15

van Zoest, W., & Donk, M. (2008). Goal-driven modulation as a function of time in saccadic target selection. *The Quarterly Journal of Experimental Psychology*, *61*, 1553-1572. https://doi.org/10.1080/17470210701595555

Vickery, T. J., King, L. W., & Jiang, Y. (2005). Setting up the target template in visual search. *Journal of Vision, 5*, 81-92. https://doi.org/10.1167/5.1.8

Watson, D. G., & Humphreys, G. W. (1997). Visual marking: Prioritizing selection for new objects by top-down attentional inhibition of old objects. *Psychological Review*, *104*, 90-122. https://doi.org/10.1037/0033-295X.104.1.90

Wolfe, J. M. (2014). Approaches to visual search: Feature integration theory and guided search. In A. C. Nobre and S. Kastner (ed.), *The Oxford handbook of Attention* (pp. 11-55). Oxford University Press: New York

Woodman, G. F. & Luck, S. J. (2007). Do the contents of visual working memory automatically influence attentional selection during visual search? *Journal of Experimental Psychology: Human Perception and Performance, 33*, 363-373. https://doi.org/10.1037/0096-1523.33.2.363

Open practices statement The data or materials for the experiments reported here are available upon request. None of the experiments was preregistered.