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Yamada, Yuki
Hiroshima University

Kawahara, Jun-ichiro
Hiroshima University

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ORIGINAL ARTICLE

# Lag-1 sparing in the attentional blink with multiple RSVP streams

*Yuki Yamada, Jun-ichiro Kawahara*

## Abstract

**When two targets are presented in a rapid stream of distractors, the accuracy of identifying the second target is impaired when the temporal lag between the targets is brief (attentional blink; AB). When the second target is presented immediately after the first target, the AB deficit is considerably reduced, a phenomenon called Lag 1 sparing. A recent study (Kristjánsson & Nakayama, 2002) however, reported that Lag 1 sparing did not occur when multiple distractor streams were presented, al-though it had occurred in other studies (e.g., Peterson & Juola, 2000). The present study found that specific target attributes were the key for this inconsistency. When two targets in the same stream appear to be similar and are distinctive from the distractors, the first target is masked by the second. This masking of the first target increases the AB deficit, and Lag-1 sparing does not occur.**

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Correspondence to:
Yuki Yamada, Faculty of Human-Environment Studies, Kyushu University,
6-19-1 Hakozaki Higashi-ku, Fukuoka 812-8581, Japan
yamadayuk@gmail.com

## Introduction

We often encounter difficulties in processing two consecutive events in a brief interval. For example, when catching a cab, if we notice that the first approaching cab is occupied, it is highly likely that we will miss a second cab that appears immediately afterwards. Similarly, in the laboratory, when first and second targets (T1 and T2, respectively) are embedded in a rapid stream of distractors, T2 is frequently missed when the temporal lag between the two targets is short, although T1 is identified correctly. Successful T2 identification improves progressively as the temporal lag increases up to 700 ms. Poor identification of T2 in a rapid serial visual presentation (RSVP) is known as the attentional blink (AB; Raymond, Shapiro, & Arnell, 1992). The general consensus from studies of the AB is that this deficit derives from insufficient processing resources available for T2, because most of the available resources are used to process T1 when the temporal lag is brief (e.g., Shapiro, Arnell, & Raymond, 1997). As T1 processing releases more resources with increased lag time, T2 performance recovers.

It is, however, not possible to explain the AB solely in terms of such resource depletion. Under the resource depletion scenario, T2 performance should be most impaired when T2 is presented directly after T1 (i.e., at Lag 1), but this was found to be the case in only approximately half of the experiments in the extant AB literature. In the remaining half, T2 performance at Lag 1 was not impaired. Potter, Chun, Banks, & Muckenhoupt (1998) termed this "Lag-1 sparing." To understand this phenomenon, Visser, Bischof, & Di Lollo (1999) conducted a meta-analysis of previous AB studies. They defined Lag-1 sparing as the case in which identification of T2 at Lag 1 exceeded the lowest level of performance at the other lags by more than 5%. Visser, Bischof et al. (1999) found that changing spatial locations between T1 and T2 plays a critical role in determining whether Lag-1 sparing occurs. Their analysis indicated that T2 performance at Lag 1 is unimpaired when two targets appear in the same location. In contrast, when the two targets appear in different locations, Lag-1 sparing does not occur; the AB deficit is most severe at Lag 1.

Based on this analysis, Visser, Zuvic, Bischof, & Di Lollo (1999) used a single RSVP stream and showed that Lag-1 sparing occurred when there was no spatial switching between the targets, but that it did not occur when there was spatial switching. However, when there are two or more RSVP streams, the situation is more complex. For example, Peterson & Juola (2000) used three concurrent RSVP streams and showed that Lag-1 sparing occurred when the two targets appeared in the same stream, but not when the targets appeared in different streams. On the other hand, Kristjánsson & Nakayama (2002) used seven RSVP streams and reported that there was no Lag-1 sparing even when the two targets were presented in the same stream. This apparent inconsistency cannot be explained solely by the effect on Lag-1 sparing of spatial switching between the targets when using multiple RSVP streams, and the purpose of the present study is to determine the source of the inconsistency. We believe that it is important to understand the mechanisms for Lag-1 sparing, because it is one of the outstanding questions in AB studies (Shapiro et al., 1997) and because information about Lag-1 sparing will provide cues to characterize the temporal aspects of attention (Kawahara, 2003).

The two studies that reported inconsistent results in Lag-1 sparing differ in three important ways. First, temporal parameters, especially stimulus-onset asynchrony (SOA) between the targets, were different; Peterson & Juola (2000) used 110 ms, but Kristjánsson & Nakayama (2002) used 140 ms. This parameter seems critical, because Visser, Bischof et al. (1999) suggested that, in order to obtain Lag-1 sparing, T2 must appear within 150 - 200 ms after T1. Second, spatial manipulations, the number of RSVP streams, differed among studies; Peterson & Juola used three streams, and Kristjánsson & Nakayama used seven. This is an important difference, because there is a widely accepted notion that the number of items in the display affects the focus of attention (e.g., Lavie & Tsal, 1994; Treisman & Gelade, 1980). Finally, the target definitions differed; Peterson & Juola defined the two targets by two different colors presented against black distractors, whereas Kristjánsson & Nakayama distinguished the targets (digits) from distractors (letters) by category and brightness. In Peterson & Juola, a target was highly distinguishable from the other target and from distractors; however, in Kristjánsson & Nakayama, the two targets were highly salient from the distractors but indistinguishable from each other when they appeared in the same stream. Because the effect of masking increases when the target and the mask are similar (Hellige, Walsh, Lawrence, & Prasse, 1979; Kawahara, Enns, & Di Lollo, in press) and when the mask is salient (Shelley-Tremblay & Mack, 1999), T1 masking of salient and similar items might be especially effective and consume many visual system resources. Since T1 processing effort increases the AB (McLaughlin, Shore, & Klein, 2001), it is highly likely that Lag-1 sparing was eliminated only when two targets appeared in the same stream in Kristjánsson & Nakayama.

The present study, therefore, contrasted the procedural differences between Peterson & Juola (2000) and Kristjánsson & Nakayama (2002). Experiment 1 replicated the results of these two studies. Experiment 2 examined the hypothesis that the target definition increased T1 masking, eliminating Lag-1 sparing. In Experiment 2, two targets were defined by their categories, rather than by brightness and categories as in Kristjánsson & Nakayama, which should reduce the relative salience of T2 and the T1-T2 similarity. If the target definition was the critical factor to eliminate Lag-1 sparing when two targets appeared in the same stream in Kristjánsson & Nakayama, then Lag-1 sparing should be obtained in the same-stream condition of Experiment 2. Experiments 3 and 4 examined whether temporal and spatial manipulations (i.e., SOA, inter-stimulus interval (ISI), the number of RSVP streams and eccentricity) determine the presence or absence of Lag-1 sparing.

## Experiment 1

We replicated Peterson & Juola (2000) and Kristjánsson & Nakayama (2002) in Experiments 1A and 1B, respectively. We made a minor deviation in Experiment 1A; the spatial cues that Peterson & Juola used were eliminated, because they seemed to be essentially orthogonal to Lag-1 sparing. In Experiment 1B, we initially ran a pilot study with naive observers to replicate Kristjánsson & Nakayama, but we found that their performance was too low and that extensive practice was necessary. Therefore, we report the results from the performance of two well-trained observers. In summary, when two targets appeared in the same location, we predicted that Lag-1 sparing would be obtained in Experiment 1A but not in Experiment 1B.

### Method

**Experiment 1A**

*Observers* Ten experimentally naive Hiroshima University students (mean age: 22.8 yrs) participated in Experiments 1A for course credit. All of the observers in all four experiments had normal or corrected-to-normal visual acuity.

*Apparatus and stimuli* The stimuli were displayed on a computer monitor. Targets and distractors were chosen randomly from 20 capital letters (subtended 1.0º in height with viewing distance of 72.5 cm) comprising the English alphabet omitting the letters H, I, O, Q, V, and W. T1 (red) and T2 (white) and the distractors (black) were displayed on a grey background. Three RSVP streams were presented simultaneously at the vertices of an equilateral triangle inscribed in an imaginary circle with a radius equivalent to 1.4º of visual angle (Figure 1). In the fixation display, black parallel bars, which were used in Peterson & Juola's (2000) study as the placeholder of uncued location(s), were presented where each stream would appear.

The experiment was conducted in a dark room. At the beginning of each trial, a fixation cross and the placeholders were displayed. The observers initiated each trial by pressing the spacebar. After a delay of 800 ms, three RSVP streams were presented, which contained two targets and a variable number of distractors. Items were displayed for 40 ms with an ISI of 70 ms. The frame that contained T1 was preceded by 7-11 frames of distractors. T2 appeared 1 to 5 frames after T1 (Lag 1 to 5). The T2 frame

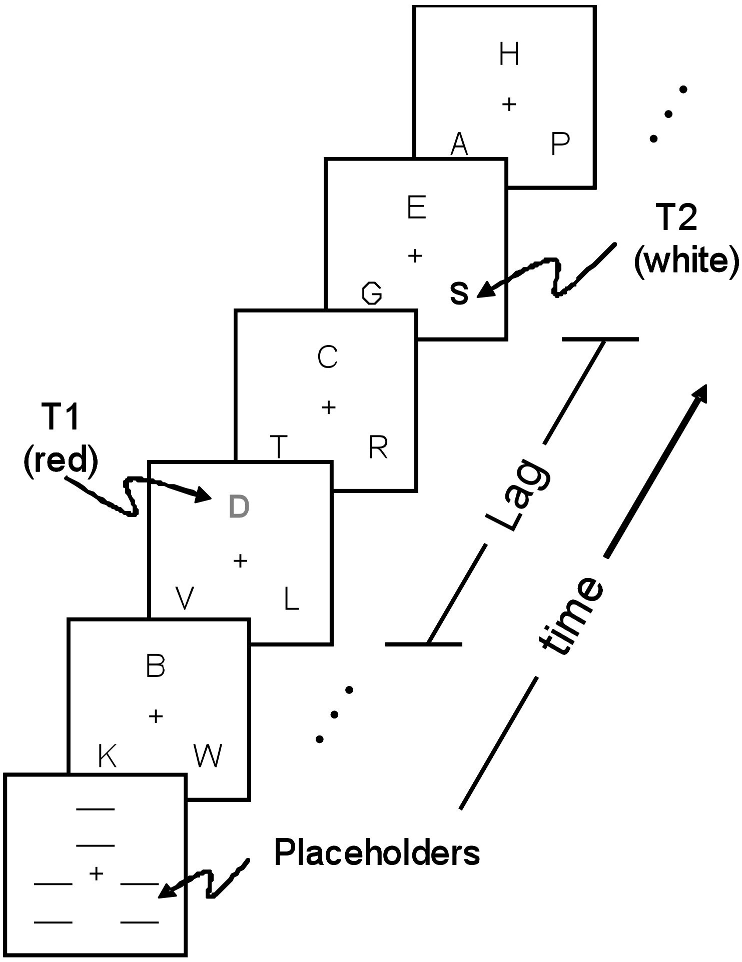


Figure 1
Schematic representation of the sequence of events in Experiment 1. T1 was red, T2 was white.

was followed by a distractor frame. Observers identified the target letters by typing the corresponding keys on the computer keyboard, regardless of the order in which the targets were presented.

Prior to the 320 experimental trials, 30 practice trials were conducted. Two variables were combined in a 2 × 5 factorial design (target locations: both targets were presented either in the same or different locations; and lag: 1, 2, 3, 4, or 5).

**Experiment 1B**

The methods were identical to those of Kristjánsson & Nakayama (2002). Two well-trained observers (authors, YY and JK), who had participated in more than 800 practice trials, served as subjects.

The stimuli were white characters displayed on the dark background of a computer monitor and subtended 1.1° in visual angle. The targets were digits (2-9), and distractors were capital letters. The target digits were slightly brighter than the distractors. Seven RSVP streams were presented simultaneously at the vertices of an equilateral heptagon inscribed in an imaginary circle with a radius equivalent to 6.1° of visual angle.

*Procedures and Design* The observers initiated a trial by pressing the spacebar when they fixated on the fixation point. T1 appeared in one of the streams, preceded by 12-18 frames of distractors. T2 appeared after 1, 2, 3, 4, 5, or 6 frames of lag. The observers identified the target digits by typing the corresponding keys on the keyboard, regardless of the order in which the targets were presented. Two variables were combined in a 4 × 6 factorial design (target distance: 0°, 4.5°, 8.75°, and 11.8°; and lag: 1, 2, 3, 4, 5 and 6). YY and JK participated in 840 and 1050 experimental trials, respectively.

## Results and Discussion

*Experiment 1A* In these and all subsequent experiments, estimates of the identification of T2 were based only on those trials in which T1 had been identified correctly. T1 was correctly identified in 89.4 % of the trials averaged across all lags. Figure 2 presents mean percentages of correct T2 identification as a function of lag. A two (target locations: same or different) × five (lag: 1-5) repeated measures two-way analysis of variance (ANOVA) of the T2 reports revealed significant effects of target location [$F(1, 9) = 13.39$, $p < .01$] and lag [$F(4, 36) = 27.90$, $p < .001$]. The interaction between the target location and the lag was also significant [$F(4, 36) = 12.53$, $p < .001$]. Post hoc comparisons by Ryan's method (hereafter, we used the same methods) indicated that when the target locations were the same, performance was significantly better at Lag 1 than at Lag 2 [$t(72) = 3.86$, $p < .001$]. The results were consistent with those of Peterson & Juola (2000); Lag-1 sparing occurred only when the two targets appeared in the same stream. Moreover, these results were quite similar to those of previous studies that used a single RSVP stream (e.g., Visser, Zuvic et al., 1999), in that Lag-1 sparing was observed only when the two targets appeared in the same location.

*Experiment 1B* Percentages of correct T2 identification as a function of lag are displayed for each observer in Figure 3. The averaged T1 correct identification rates for YY and JK were 80.7 % and 88.5 %, respectively. Both observers exhibited typical AB functions in their performance; when two targets appeared in different locations, T2 performance improved progressively as the lag increased. More importantly, when two targets appeared in the same location, Lag-1 sparing was not obtained for either observer; performance at Lag 1 was lowest among the six lags. These results are consistent with Kristjánsson & Nakayama (2002). Their finding that the AB deficit was smaller when the T1-T2 spatial distance was shorter was not clearly apparent in the present study, but for both observers, T2 performance in the 0º condition was lower than that in the other conditions. At present, there is no explanation for this difference.

## Experiment 2

As mentioned in the introduction, several procedural differences between Peterson & Juola (2000) and Kristjánsson & Nakayama (2002) might have led to inconsistent Lag-1 sparing when two targets appeared in the same location. One notable difference was the target definition; Kristjánsson & Nakayama defined target by category (digits among letters) and brightness (bright items among dark items), whereas Peterson & Juola (and the present Experiment 1A) defined T1 by color. We propose that this difference in target definition is responsible for the critical effect on Lag-1 sparing. When the targets were defined by category and brightness, two targets became highly salient from the distractors but were indistinguishable when they appeared in the same stream. Because the masking effect increases when the target and the mask are similar (Hellige et al., 1979; Kawahara et al., in press) and when the mask is salient (Shelley-Tremblay & Mack, 1999), the effect of masking to T1 from such a salient and similar T2 should be especially strong and require heavy visual system resources. As increasing T1 processing effort increases the AB (McLaughlin, et al., 2001), Lag-1 sparing should disappear when two targets appear in the same stream.

To test this hypothesis, we defined the targets only by category. If the target definition was critical for the absence of the Lag-1 sparing effect when two targets appeared in the same stream in Kristjánsson & Nakayama (2002), then Lag-1 sparing should have been obtained in the same location condition in our Experiment 2 because such a target definition will increase target discrimination. We assume this improved ability to differentiate between targets will reduce processing requirements for T1 and lead to unimpaired performance at Lag 1.

### Method

The procedures were identical to those used in Experiment 1A, except that all the items in the RSVP were black and the participants identified two target digits among letter distractors. Twelve experimentally naive adults (mean age: 21.4 yrs) participated in this experiment.

### Results

T1 was correctly identified in 89.7% of the trials averaged across all the lags. Figure 4 presents the percentages of correct T2 identification as a function of lag. A two (target location: same or different) × five (lag: 1-5) ANOVA of the T2 reports revealed significant effects of target

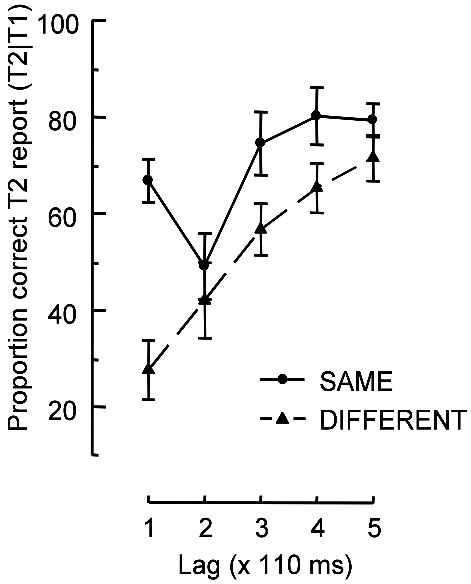


Figure 2
Mean percentages of the correct identification of T2, given correct identification of T1 in Experiment 1A, with the targets in the same or different locations. Error bars indicate standard errors.

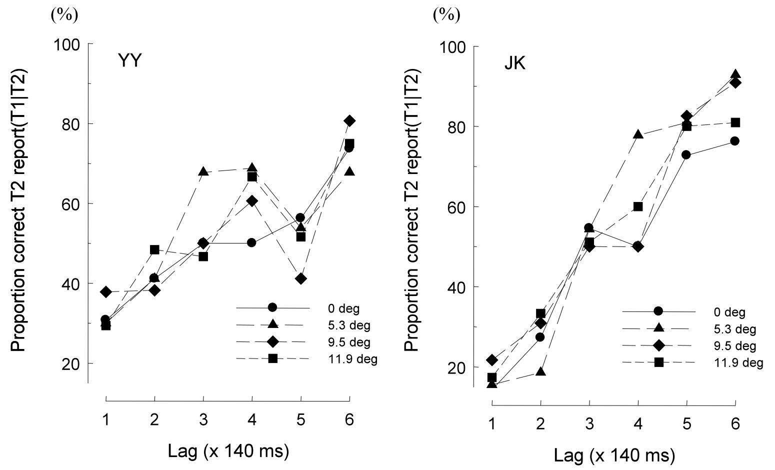


Figure 3
Mean percentages of correct identification of T2, given correct identification of T1 in Experiment 1B, with the targets appearing at various visual angles from each other at the vertices of an equilateral heptagon. Data from two observers (YY and JK) are shown.

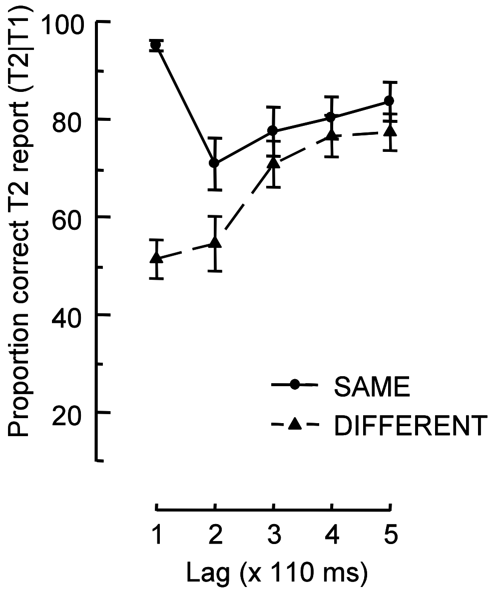


Figure 4
Mean percentages of correct identification of T2, given correct identification of T1 in Experiment 2, with the targets in the same or different locations. Error bars indicate standard errors.

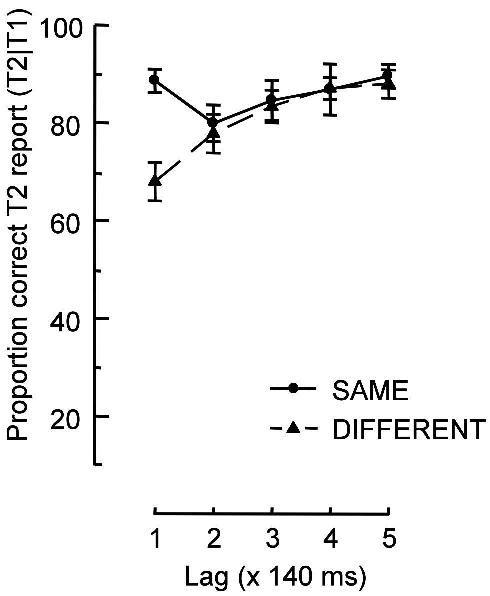


Figure 5
Mean percentages of correct identification of T2, given correct identification of T1 in Experiment 3, with the targets appearing at various visual angles from each other at the vertices of an equilateral heptagon. Error bars indicate standard errors.

location [$F(1, 11) = 30.97$, $p < .001$] and lag [$F(4, 44) = 10.71$, $p < .001$]. The interaction between target location and lag was also significant [$F(4, 44) = 21.55$, $p < .001$]. Post hoc comparisons revealed that, when the target locations were the same, T2 performance was significantly better at Lag 1 than at Lag 2 [$t(88) = 6.21$, $p < .001$].

### Discussion

Lag-1 sparing was obtained when two targets defined by a category appeared in the same location. Although Lag-1 sparing can be obtained with categorically defined targets within a single stream, the present results are the first report of Lag-1 sparing with categorically defined targets in multiple streams. The results suggest that target definition was responsible for the differences in the occurrence of Lag-1 sparing. This supports our target-definition hypothesis that salient and similar T2s mask T1s, severely constraining Lag-1 sparing, because the visual system requires fewer resources at Lag 1. We must also evaluate, however, the temporal and spatial factors that differed from Kristjánsson & Nakayama's (2002) study. Experiment 3 examined the temporal factor.

## Experiment 3

Comparing the results of Experiments 1B and 2, it is tempting to argue that there is no Lag-1 sparing when two targets appear in the same location if the targets are defined by category and brightness as in Kristjánsson & Nakayama (2002). This conclusion, however, is premature, because the temporal parameters in Experiment 2 (i.e., SOA and ISI) differed from those in Experiment 1B. The temporal issue is important because it has been suggested that to obtain Lag-1 sparing, T2 must appear within 150 - 200 ms after T1 (Visser, Bischof, et al., 1999). Experiment 3 used the same temporal parameters as in Experiment 1B but maintained the target definition of Experiment 2. If the temporal parameters are critical to the presence or absence of Lag-1 sparing, then Lag-1 sparing will be eliminated. On the contrary, if target definition is critical, Lag-1 sparing should be present.

### Method

The SOA was 140 ms, and the ISI was 0 ms. All other parameters and procedures were identical to those used in Experiment 2. Twelve experimentally naive adults (mean age: 21.4 yrs) participated in this experiment.

### Results

T1 was correctly identified in 92.6% of the trials averaged across all lags. Figure 5 presents the percentages of correct T2 identification as a function of lag. A two (target location: same or different) × five (lag: 1-5) ANOVA of the T2 reports revealed significant effects of the target location [$F(1, 11) = 5.19$, $p < .05$] and lag [$F(4, 44) = 4.18$, $p < .01$]. The interaction between the target location and the lag was also significant [$F(4, 44) = 5.98$, $p < .001$]. When the target locations were the same, performance was significantly better at Lag 1 than at Lag 2 [$t(88) = 2.39$, $p < .05$].

### Discussion

Experiment 3 used the same temporal properties as Kristjánsson & Nakayama (2002), but the pattern of the results was the same as for Experiments 1 and 2; Lag-1 sparing occurred when the two targets appeared in the same stream. This is in sharp contrast to the results in Kristjánsson & Nakayama, where Lag-1 sparing did not occur in the equivalent condition. We conclude that different temporal properties cannot solely determine the presence or absence of Lag-1 sparing.

## Experiment 4

Experiment 4 examined whether the spatial parameters that differed between Experiments 1B and 2 were critical for the presence or absence of Lag-1 sparing. Experiment 1B (and Kristjánsson & Nakayama, 2002) and Experiment 2 (and Peterson & Juola, 2000) differed in two respects: the number of RSVP streams and eccentricity. Specifically, in Experiment 1B, there were seven RSVP streams, each of which was evenly positioned on an imaginary circle of 6.1° radius; whereas in Experiment 2, three streams were presented with 1.4 ° of eccentricity. Experiment 4 tested the effects of these spatial factors separately. In Experiment 4A, the number of RSVP streams was increased to seven. In Experiment 4B, the three streams were presented at the same eccentricity as in Kristjánsson & Nakayama's study, but the height of the letters was increased to 4.8° to more closely match the visibility of the stimuli in our Experiment 2, by considering a cortical magnification factor (Anstis, 1974). If the number of distractor streams or eccentricity were responsible for the absence of Lag-1 sparing in Kristjánsson & Nakayama, no Lag-1 sparing will be present in Experiment 4.

### Method

The apparatus, stimuli, and procedure were identical to those in Experiment 3 except for the following changes. In Experiment 4A, seven RSVP streams were presented. The streams were presented simultaneously at the vertices of an equilateral heptagon inscribed in an imaginary circle with a radius equivalent to 1.4° of visual angle. This stimulus configuration yielded four possible inter-target distances; depending on the vertices at which the targets appeared, the distance between T1 and T2 was 0°, 1.2°, 2.2°, or 2.8°, respectively. In Experiment 4B, three streams were presented as in Experiment 2, stimulus eccentricity was increased to 6.1°, and the height of the letters was 4.8°. Twenty-two naive adults (mean age: 21.6 yrs) were assigned randomly to Experiments 4A and 4B.

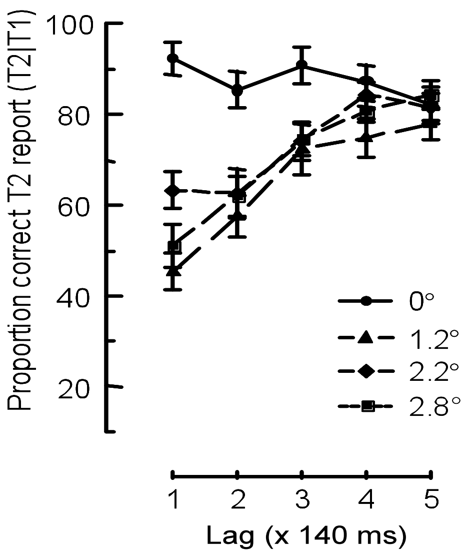


Figure 6
Mean percentages of correct identification of T2, given correct identification of T1 in Experiment 4A, with the targets in the same or different locations. Error bars indicate standard errors.

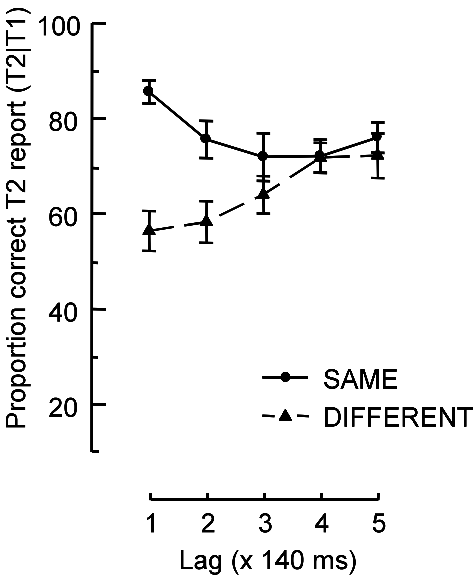


Figure 7
Mean percentages of correct identification of T2, given correct identification of T1 in Experiment 4B, with the targets in the same or different locations. Error bars indicate standard errors.

### Results and Discussion

*Experiment 4A* Averaged T1 performance was 85.5 %. Figure 6 displays the mean percentages of the correct T2 identification as a function of lag. A four (target distance: 0º, 1.2º, 2.2º, and 2.8º) × five (lag: 1–5) ANOVA of the T2 reports revealed significant effects of target distance [$F(3, 27) = 16.10$, $p < .001$] and lag [$F(4, 36) = 20.85$, $p < .001$]. The interaction between target distance and lag was also significant [$F(12, 108) = 6.36$, $p < .001$]. The simple main effect at distance 0º was not significant, but performance at Lag 1 was higher than that at Lag 2 by more than 5 %.

*Experiment 4B* T1 was correctly identified in 80.5% of the trials. Figure 7 presents the percentages of correct T2 identification as a function of lag. A two (target location: same or different) × five (lag: 1–5) ANOVA of the T2 reports revealed significant effects of target location [$F(1, 11) = 17.70$, $p < .005$] and lag [$F(4, 44) = 4.09$, $p < .01$]. The interaction between target location and lag was also significant [$F(4, 44) = 8.79$, $p < .001$]. Post hoc comparisons revealed that, when the target locations were the same, performance was significantly better at Lag 1 than at Lag 2 [$t(88) = 3.01$, $p < .005$].

In Experiments 4A and 4B, T2 performance at Lag 1 was better than at Lag 2. More importantly, T2 performance was unimpaired at Lag 1 in both Experiments 4A and 4B when the two targets appeared in the same location. These results are inconsistent with Kristjánsson & Nakayama's (2002) finding that T2 performance was lowest at Lag 1. We conclude that spatial parameters, such as the number of streams and eccentricity, are not critical for the absence of Lag-1 sparing.

An interesting incidental finding in Experiment 4A was that performance decreased as the lag increased. This unusual tendency has been reported in several recent studies (Dell'Acqua, Pascali, Jolicoeur, & Sessa, 2003; Shih, 2000), and we assume that it is specific to multiple-RSVP procedures, because the pattern is obtained only when multiple RSVP streams are used. Dell'Acqua et al. provided a tentative explanation for this effect in terms of controlled attentional shift. They proposed that when T1 identification required effort because observers had to search for T1 within multiple streams, it took time to disengage the attentional focus from T1 to T2. The constrained AB function is assumed to reflect this shift in attentional focus, but the full explanation awaits further investigation.

## General Discussion

The present study explored the source of inconsistencies in the reported occurrence of Lag-1 sparing. Peterson & Juola (2000) found Lag-1 sparing when two targets were presented at the same location, but Kristjánsson & Nakayama (2002) did not. In four experiments, we examined the major differences between previous studies in terms of temporal and spatial aspects and target definition.

Experiment 1 replicated previous findings that Lag-1 sparing occurs when two targets are presented at the same location using Peterson & Juola's procedure, but not with Kristjánsson & Nakayama's. The results of Experiment 2 suggested that this inconsistency was owing to target definition. When the targets were defined only by category, Lag-1 sparing occurred if they appeared in the same stream. We argued that target definition plays a role in the presence or absence of Lag-1 sparing for the following reasons. In Peterson & Juola's procedure, as in Experiment 1A, the two targets were defined by two different colours against black distractors; whereas in Kristjánsson & Nakayama's procedure, as in Experiment 1B, the two targets were distinguished from distractors by their category and brightness. In the latter procedure, the two targets were highly salient among the distractors and, at the same time, the two targets were indistinguishable when they appeared in the same stream. Because the masking effect increases when target and mask are similar (Hellige et al., 1979; Kawahara et al., in press) and when the mask is salient (Shelley-Tremblay & Mack, 1999), T1 will be masked more from an item that is both salient and similar than when it is masked by an ordinary distractor. Such intensive masking on T1 requires more processing resources. Together with the fact that T1 processing effort increases the AB (McLaughlin, Shore, & Klein, 2001), it is highly likely that Lag-1 sparing was eliminated when two targets appeared in the same stream only if the two targets were both similar to each other and salient against distractors. This idea is supported by Experiment 2, which demonstrated that when the targets were defined only by category, Lag-1 sparing occurred if they appeared in the same stream.

Subsequent investigations (Experiments 3 and 4) implied that different temporal and spatial parameters in Peterson & Juola (2000) and Kristjánsson & Nakayama (2002) were not critical for the presence or absence of Lag-1 sparing. Experiments 3 and 4 repeatedly indicated that Lag-1 sparing of the same-stream targets occurred when two targets were defined only by category.

It is important to note that there is another unexplored possibility that the inconsistency between the two previous studies might be due to the difference in the observers' populations; Peterson & Juola (2000) used unpracticed observers, and Kristjánsson & Nakayama (2002) used practiced observers. Extensively practiced observers showed a substantially reduced dual-task cost compared to unpracticed observers in Braun (1998), so the present results do not exclude the possibility that skill may contribute to the absence of Lag-1 sparing for same-stream targets. As there is no obvious reason why skill reduces the AB only when the two targets appear in the same stream, this question remains to be addressed in future research.

Lag-1 sparing has been explained in terms of an attentional gate (Chun & Potter, 1995). Their model proposes that the visual system controls the flow of incoming information by means of an attentional gate that opens instantly when T1 is presented and that closes sluggishly (150-200 ms). An item that has passed the gate (T1) is processed at the semantic level. If T2 is presented directly after T1 (i.e., at Lag 1), both targets are processed together, and the recognition deficit at Lag 1 is abolished. It is assumed that two or more gates cannot co-exist and that each gate can open only after another has closed completely (Visser, Zuvic, et al., 1999). Therefore, if T2 appears at a different location from T1 at Lag 1, the ability to identify T2 is greatly diminished because the attentional gate is not open at the T2 location. The results of the present study are consistent with this account and suggest that the attentional gate opens in a location-specific manner.

In conclusion, the present study examined possible reasons for an apparent inconsistency in Lag-1 sparing observed in previous studies (Kristjánsson & Nakayama, 2002; Peterson & Juola, 2000). We suggested that target definition was the source of this inconsistency. When two targets are similar to each other and salient among the distractors, T1 will be masked by T2 if the targets appear in the same stream. This intensive masking imposes extra processing requirements on the visual system, leading to impaired T2 performance at Lag 1 and non-occurrence of Lag-1 sparing when the two targets appear in the same stream.

## References

Anstis, S. (1974). A chart demonstrating variations in acuity with retinal position. *Vision Research*, **14**, 589-592.

Braun, J. (1998). Vision and attention: the role of training. *Nature*, **393**, 424-425.

Chun, M. M., & Potter, M. C. (1995). A two-stage model for multiple target detection in rapid serial visual presentation. *Journal of Experimental Psychology: Human Perception & Performance*, **21**, 109-127.

Dell'Acqua, R., Pascali, A., Jolicoeur, P., & Sessa, P. (2003). Four-dot masking produces the attentional blink. *Vision Research*, **43**, 1907-1913.

Hellige, J. B., Walsh, D. A., Lawrence, V. W., & Prasse, M. (1979). Figural relationship effects and mechanisms of visual masking. *Journal of Experimental Psychology: Human Perception & Performance*, **5**, 88-100.

Kawahara, J. (2003). The attentional blink. *Japanese Psychological Review*, **46**, 501-526.

Kawahara, J. Enns, J. T., & Di Lollo, V. (in press). The attentional blink is not a unitary phenomenon. *Psychological Research*.

Kristjánsson, A., & Nakayama, K. (2002). The attentional blink in space and time. *Vision Research*, **42**, 2039-2050.

Lavie, N. & Tsal, Y. (1994). Perceptual load as a major determinant of the locus of selection in visual attention. *Perception & Psychophysics*, **56**, 183-197.

McLaughlin, E. N., Shore, D. I., & Klein, R. M. (2001). The attentional blink is immune to masking-induced data limits. *Quarterly Journal of Experimental Psychology*, **54A**, 169-196.

Peterson, M. S., & Juola, J. F. (2000). Evidence for distinct attentional bottlenecks in attentional switching and attentional blink tasks. *The Journal of General Psychology*, **127**, 6-26.

Potter, M. C., Chun, M. M., Banks, B. S., & Muckenhoupt, M. (1998). Two attentional deficits in serial target search: The visual attentional blink and an amodal task-switch deficit. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **24**, 979-992.

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception & Performance*, **18**, 849-860.

Shapiro, K. L., Arnell, K. M., & Raymond, J. E. (1997). The attentional blink. *Trends in Cognitive Sciences*, **1**, 291-296.

Shelley-Tremblay, J., & Mack, A. (1999). Metacontrast masking and attention.

*Psychological Science*, **10**, 508-515.

Shih, S. I. (2000). Recall of two visual targets embedded in RSVP streams of distractors depends on their temporal and spatial relationship. *Perception & Psychophysics*, **62**, 1348-1355.

Treisman, A., M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, **12**, 97-136.

Visser, T. A. W., Bischof, W. F., & Di Lollo, V. (1999). Attentional switching in spatial and non-spatial domains: evidence from the attentional blink. *Psychological Bulletin*, **125**, 458-469.

Visser, T. A. W., Zuvic, S. M., Bischof, W. F., & Di Lollo, V. (1999). The attentional blink with targets in different spatial locations. *Psychonomic Bulletin & Review*, **6**, 432-436.