2025 ■ Vol. 21 ■ no. 1

Effect of physical activity and interstimulus interval on an RSVP task: A replication of Raymond et al. (1992)

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Abstract ■ Raymond et al. (1992) introduced the term "attentional blink" to characterize the impairment in post-target processing that occurs during the presentation of a second stimulus closely after a first. This study aimed to replicate the original methodology of the second experiment by Raymond et al. (1992) while increasing the sample size and investigating the impact of physical activity on selective attention. A sample of participants (n = 132) aged 18-70 years old (M = 31.91, SD = 17.25) were recruited to complete the study. Participants underwent a rapid serial visual presentation task in which they were asked to complete an experimental and a control condition. In the experimental condition, they were asked to identify a white letter (target) presented in a succession of black letters and determine if the letter "X" (probe) was present at any point. In the control condition, they were asked to ignore the white letter (target) and determine whether the letter "X" (probe) was present. Each condition included 180 trials of which 90 included the probe located in the positions 0-8 following the target and never before the target. The International Physical Activity Questionnaire – Short Form was used to determine physical activity levels. Consistent with Raymond et al.'s (1992) findings, there was a significant attentional blink effect. However, no significance was found in the role of physical activity levels on the attentional blink. Future studies should explore the potential effect of demographic variables, such as age and gender, as well as mental health (e.g., ADHD and dyslexia) to provide understanding as to the impact of different cognitive abilities on the attentional blink.

Keywords ■ Attentional Blink, Attention, Selective Attention, Physical Activity, Rapid Serial Visual Presentation (RSVP), Replication.

Acting Editor ■ Denis Cousineau (Université d'Ottawa)

Reviewers ■ No authors from the original article reviewed this article.

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10.20982/tqmp.21.1.p013

Introduction

Visual processing is a complex cognitive task that requires focusing cognitive resources on pertinent information while excluding extraneous environmental stimuli, requiring the efficient allocation of cognitive resources. Selective attention, a fundamental cognitive mechanism, allows us to sort through all this information by focusing on the important information and filtering out the unnecessary information (Baghdadi et al., 2021; Martens & Wyble, 2010; Shapiro et al., 1997). Research suggests that this mechanism can be affected by two independent effects, delay or suppression (Vul et al., 2008). The processing of previous stimuli can delay future processing of new information, while attention allocated to earlier stimuli suppresses subsequent information. The allocation of this attention has been a subject of study in psychology. Rapid Serial Visual Presentation (RSVP) tasks (tasks in which multiple stimuli are shown in rapid succession) are commonly used to measure different phenomena.

One such phenomenon is the attentional blink, an expression coined by Raymond et al. (1992), where the processing of a first stimulus (T1) impairs the processing of a second stimulus (T2), particularly when these stimuli are presented closely in time (150 ms to 500 ms) to one another (Spence & Witkowski, 2013; Yildirim et al., 2024). This attentional deficit can last up to several hundred milliseconds and highlights the temporal dynamics of attentional allocations (Martens & Wyble, 2010). Globally, this process seems to be observable across diverse contexts that present two stimuli within that time frame, regardless of environmental changes, with the effect's severity depending on the area of focus (Chua, 2015; Eich & Beck, 2023; Karabay et al., 2022; Nieuwenstein et al., 2005). For example, the close positioning of two road signs in a fast highway can cause the driver to be blind to the second sign after passing the first, and can result in car accident.

One of the most prominent studies related to the attentional blink effect was conducted by Raymond et al. (1992), in which four distinct experiments explored the phenomenon to explain its mechanisms. Their second experiment aimed to explore two main questions. First, it investigated whether the post-target processing deficit occurs at the letter-recognition stage, rather than at the letter identification stages. Second, it examined whether this deficit is due to sensory or attentional factors.

The experiment involved an RSVP task where trials featured a rapid stream of 16 to 24 black letters at a speed of 11.11 letters per second. Positioned between the 8th and 16th letters was a white letter (the target), consistently followed by eight subsequent letters. In half of the trials, an X appeared either as a post-target black letter or as the white target letter, while it was absent in the remaining trials. Participants' task was to detect the presence of an X within the letter sequence for the control trials. In experimental trials, participants were also tasked with identifying the white letter, a requirement absent in control trials. The findings suggested that the deficit in processing post-target information was not due to the visual impact of a new white letter, as evidenced by the absence of this deficit in control trials. Instead, it indicated a suppression of attention when dealing with multiple critical stimuli in rapid succession. Furthermore, the study proposed that this mechanism operates early in processing, as participants only needed to identify the presence or absence of a black or white X without further probe details.

The results of Raymond et al.'s study have led to differing theories in cognitive psychology. A key area of debate is whether the attentional blink is due to a compromise in higher-level perceptual processes or a disruption in the encoding of information into working memory. Overall, there is no broad consensus on the underlying mechanism of the attentional blink (Zivony & Lamy, 2022).

Another factor rarely considered is physical activity. Encompassing a range of exercises and movements, this factor impacts multiple facets of human functioning, including cognitive abilities. Studies have shown that children who were more physically active demonstrated greater attentional resources and smaller attentional blinks, compared to children with lower levels of aerobic fitness (Sibley & Etnier, 2003; Tomporowski et al., 2008; Wu & Hillman, 2013). Similar impacts of exercise on cognitive function have also been found in older adults (Colcombe & Kramer, 2003). In more prevalent research questions related to cognitive functioning, significantly higher working memory performance was observed in individuals with higher physical activity (Yuan et al., 2023). Further expanding the definition of physical activity, faster reaction was observed with a sample of participants predominantly playing first-person shooter games (90%), thereby opening the door for more research in this area (Cagtay et al., 2022).

This study aims to replicate the findings of Raymond and colleagues (1992) in a more heterogeneous sample and to better understand how physical activity may impact the attentional blink in adults. With its prominence on the debate between attentional and sensory constraints in stimuli processing, a replication of the study would help increase the external validity of the results across different populations. With the original sample ($n = 10$) consisting entirely of students from the University of Calgary (Alberta, Canada), a larger sample size would reduce the chance of potentially homogeneous but unrepresentative effects in cluster sampling (Cousineau & Laurencelle, 2016). In line with Raymond et al.'s (1992) results, we hypothesize (1) a higher proportion of correct probe detection in control trials than in experimental trials, and (2) a lower proportion of correct probe detection in the 180-450 ms after presentation of the T1 target. Finally, in line with recent research on physical activity and attention, we hypothesize (3) a higher proportion of correct probe detection among participants with a high physical activity level.

Methods

Recruitment

University of Ottawa undergraduate students enrolled in a cognitive psychology course during the 2024 winter semester collaborated on this replication in exchange for course credit. Students recruited a convenience sample of Canadian community members known to them by sending a standard email with an invitation to the study, a link, and a unique participant identifier to access the experiment. Participants had two weeks to complete the study and were instructed to reserve a 45- to 60-minute period, free from distractions, to complete the online study. Ethics approval was not required for this study and no direct compensation was offered to participants.

Participants

Data was obtained from a convenience sample of 132 English-speaking and French-speaking participants. Individuals with epilepsy were asked not to participate in the study because of the nature of the rapidly presented visual stimuli, but no participants ($n = 0$) reported a history of photosensitive epilepsy. The sample is comprised largely of cisgender women (59.4%) and cisgender men (28.6%), but participants reported a range of gender identities (cisgender women: 59.4%, cisgender men: 28.6%, transwomen: 1.5%, transmen: 0.8%, non-binary or gender-fluid: 2.3% and other: 2.3%). Participant ranged from 18 to 70 (M = 31, SD = 20.59) years old. This sample included participants who had completed various levels of education (high school, college, bachelor, Masters, or Ph.D.). The majority of participants were students (54.9%) including undergraduate students (39.8%). Most participants in the sample self-identified as white (68.4%), and a range of other ethnic backgrounds were reported (White, Black, East Asian, Southeast Asian, East Indian, Arab, North African, Latin American, First Nations, Métis, and Inuit). Table 1 reports a detailed list of the demographic information.

IPAQ questionnaire

All participants ($n = 132$) also completed a modified version of the International Physical Activity Questionnaire (IPAQ) - Short Form (see Table 2). This questionnaire assesses the frequency and intensity of physical activity as well as time spent sitting within the past 7 days. Questions regarding video game usage as well as the type of physical activity were added to the original IPAQ questionnaire developed in 1998 by an international consensus group (Craig et al., 2003). The sample included participants who performed various vigorous and moderate physical activities over their past week (Aerobic/cardio exercise, Cycling, Dance, Hockey, Martial Arts, Running, Skiing, Swimming, Tennis, Volleyball, Strength Training, Brisk Walking, as well as multiple sports over that time), and played various types of video games (Shooter Games (1st or 3rd person), Strategy Games, Simulation Games, Horror Games, Sports Games, and multiple games over that time).

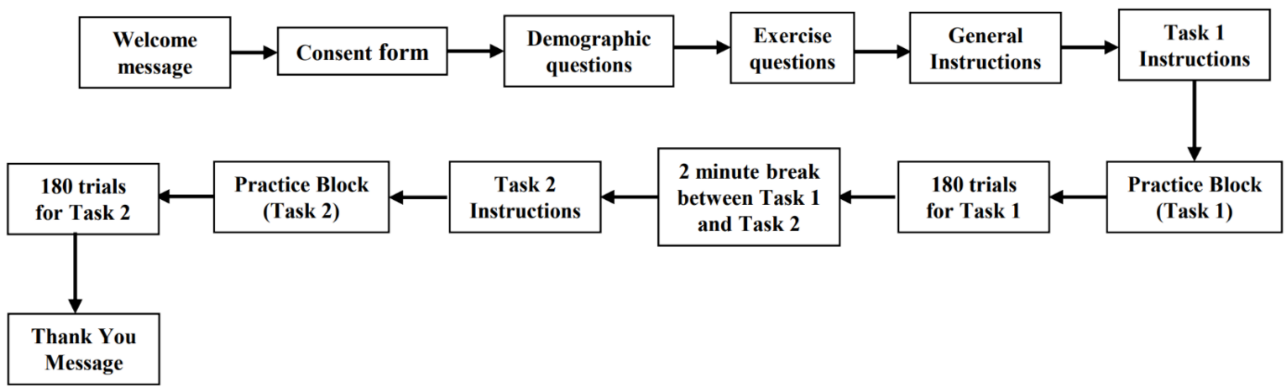
Materials

This study was programmed in JsPsych version 7.3 (De Leeuw et al., 2023), a library that help create experiments using JavaScript to be run in a web browser using an HTML file (see Bradley-Garcia & Bolton, 2023, for a detailed description). The program was set up to present the experiment in full-screen mode to minimize potential distractions. Participants were sent the link of the experiment to complete the study along with a unique participant ID. Participants were asked to use their personal electronic devices, such as desktops, laptops, or tablets and to sit approximately 35cm away from the screen. Participants were asked not to use their smartphones to complete the study as the stimulus may appear very small, making it more difficult to complete the task. Participants with visual impairments were asked to wear their visual aids to complete the study. All participant responses were saved on a dedicated web server using the library BornOpen4jsPsych (Cousineau, 2021), downloaded into an Excel sheet. Afterwards, each participant's results were restructured into one line and then exported to be analyzed in SPSS (Version 29.0).

Stimulus

The stimuli used in this replication study consisted of randomly generated letters presented in black, size 36 capitalized letters, apart from the target letter that was displayed in white Open sans font. All stimuli were displayed in the middle of the screen on a grey background. The trials started with a presentation of a small white fixation dot for 183.33 ms (180 ms in Raymond et al.'s study), presented in the middle of the screen. In each trial, the letters were presented for 16.6 ms which differed from the original study (15 ms). There was also an 83.3 ms inter-stimulus interval (75 ms in the original study). The sequence of letters was made up of the 26 letters of the alphabet, randomized to ensure no letter was presented twice in the same sequence. Each trial was randomly determined by the computer, but always contained between 7 and 15 letters before the target, and always had 8 letters following the target. Of the 180 trials per condition, 90 contained the probe (an "X") and 90 did not contain the probe (no "X"). During the 90 trials in which the probe was presented, it appeared 10 times in each of the possible positions (from 0 to + 8 positions following the presentation of the target). The "X" could be the

Figure 1 ■ Flowchart of Experimental Protocol – Replication of Raymond et al. (1992). During a trial, fixation points (•) were presented before and after each array of letters for 183.33 ms. Each letter was presented for 16.66 ms with an interstimulus time of 83.33 ms. The background of the experiment is grey, and each letter is presented in black font except for the target letter, which is presented in white. Additionally, a 1-minute break was provided every 60 trials in each task. Task #1 and Task #2 are counterbalanced in the experiment, having participants start randomly with either the control condition or experimental condition.



target and a probe, but not both within the same sequence. Additionally, the probe could not be presented before the target. Both conditions had 10 practice trials.

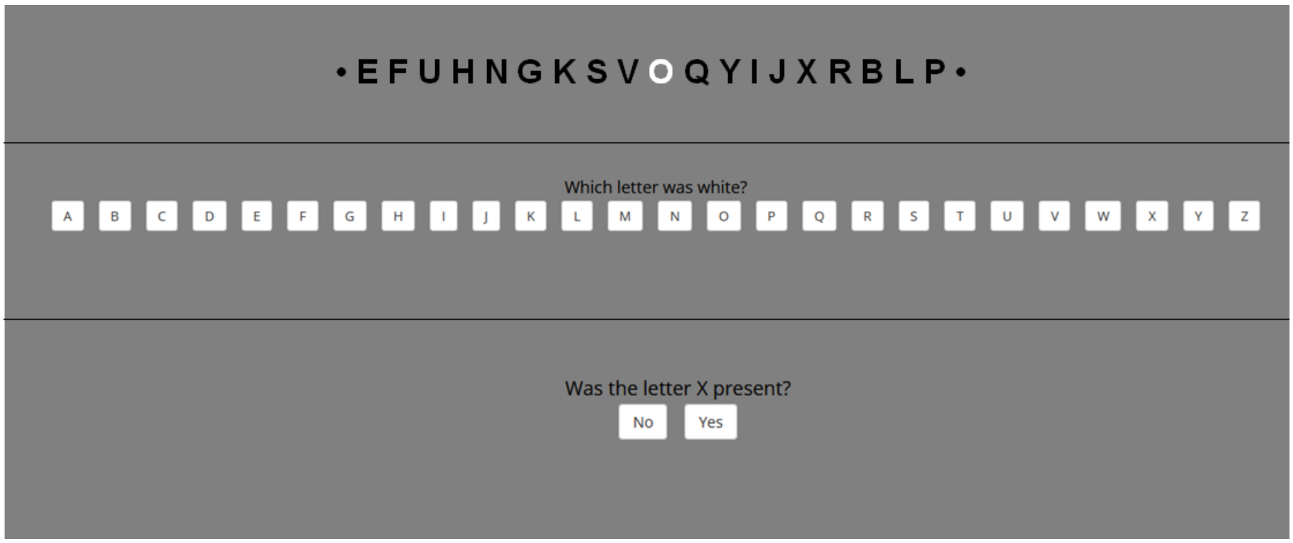
Procedure

The procedure was identical for all participants, apart from counterbalancing and randomization procedures (see Figure 1 for the study design). To counterbalance the study, half of the participants started with the experimental condition and the other half started with the control condition, thereby preventing order effects. The study began by asking participants if they wanted to complete the experiment in English or French. Next, participants were shown a welcome message and then asked to read the consent form and select whether they consented to participate in this online study. Afterward, they were asked to complete a demographic questionnaire (Table 1) and the modified IPAQ - Short Last 7 Days Self-Administered Format (Table 2). Participants were then presented with general instructions (e.g., not using their cell phones, minimizing potential distractions, wearing their glasses if applicable, and sitting approximately 35 cm from the screen) to minimize technical issues before beginning the RSVP task. In the experimental task, participants were asked to identify the white target letter as well as if a letter “X” was presented in the sequence of letters. An example of an experimental trial containing the letter “X” can be found in Figure 2. In the control task, participants were simply asked if the letter “X” was presented in the sequence of letters while ignoring the white letter. Participants were asked to complete 10 practice trials for each condition where the correct answers were then presented to participants, half of which contained the letter “X”. For the control and experimental condition, 180 test trials were presented to each participant, with the probe only present for 90 of them. Participants were allowed to take a 60-second break after each group of 60 trials and a break of two minutes between both conditions. The experiment ended with a thank you message, and participants were asked to provide feedback on their level of performance, whether they were distracted by their surroundings and/or had technical difficulties during the experiment. The experiment lasted an average of 45 minutes.

Coding

JavaScript was used to score the raw data files containing the responses to the trials of both conditions. Each response was marked as "true" if the right answer was given or "false" if the wrong answer was given. Afterward, each task was scored as follows: a score of 1 was given for every correctly reported target and probe, while a score of 0 was given for every incorrectly reported target or probe; as well as skipped questions. Out of the 47,520 trials for which data was collected (132 participants × 360 trials), 247 trials were excluded from data analysis (0.5% of the data) for having a response time higher than 10.00 seconds as this potentially indicated that participants may not have been paying attention to the task, which would therefore affect the accuracy of their responses. Trials were grouped based on (i) condition (control, experimental), (ii) probe presence

Figure 2 ■ Example of a Probe-Present Experimental Condition Trial. The fixation points (•) appear for 183.33 ms, while the letters appear one-by-one for 16.66 ms with an interstimulus time of 83.33 ms. Each stimulus appears at the centre of the screen, and once the sequence finishes, the questions appear. For probe-present trials such as the one presented above, the "X" (probe) is always present at or following the position of the target letter. For probe-absent trials, there is no "X" at any point in the sequence of stimuli. For experimental condition trials, such as the one presented above, participants are asked (1) which letter was presented in white, and (2) if there was an "X" present in the sequence of letters. For control condition trials, participants are only asked if there was an "X" present in the sequence of letters.



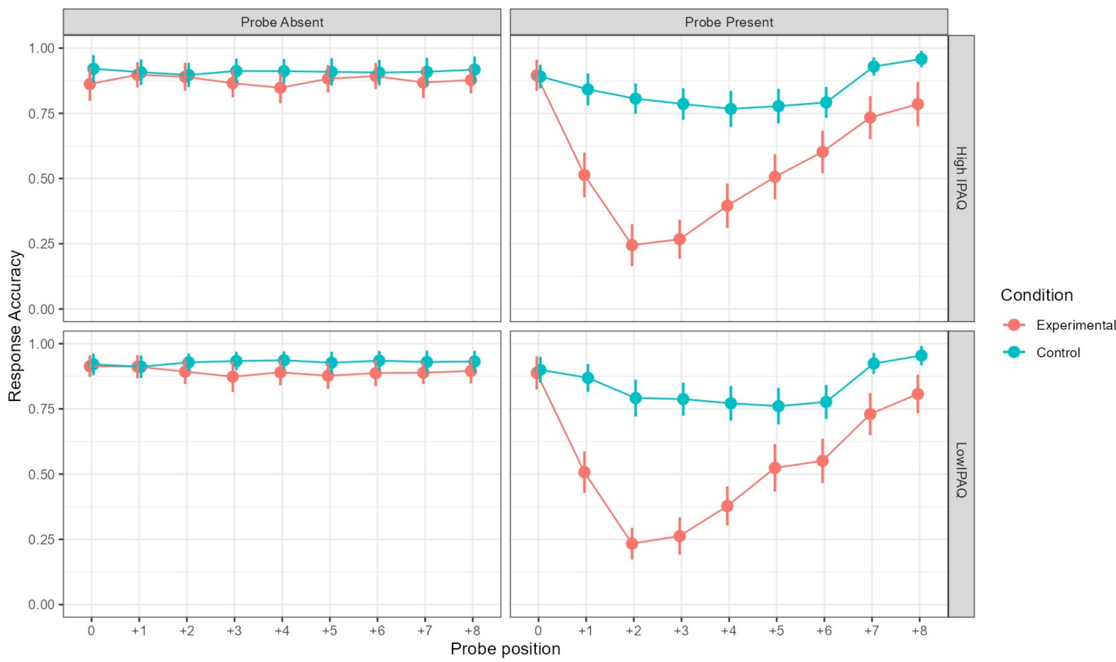
(present, absent), and (iii) probe position (0 - +8) to assess mean response accuracy in probe detection.

To determine the IPAQ scores, the participant's responses originally in time intervals, were converted to minutes by taking the mid-point of each interval. The responses were converted as follows: 15 min for "less than 30 minutes"; 45 minutes for "between 30 and 60 minutes"; 90 minutes for "1 to 2 hours"; 180 minutes for "2 to 4 hours"; and 240 minutes for "over 4 hours". These converted times were used to calculate scores for four different IPAQ categories: vigorous activity, moderate activity, walking, and sitting. Each category's score was presented as METs (Metabolic Equivalent of Task) per minute per day. The participant's IPAQ score was calculated by summing their score in the vigorous activity section (number of days completing vigorous physical activity × number of minutes per day completing vigorous physical activity × 8), moderate physical activity section (number of days completing moderate physical activity × number of minutes per day completing moderate physical activity × 4), and walking physical activity section (number of days walking × number of minutes per day walking × 3.3) (Wolin et al., 2008). Furthermore, the total IPAQ score was calculated by summing up the scores for vigorous, moderate, and walking (Kim et al., 2013). Two subgroups of physical activity were identified based on the median total IPAQ score of 1959.75 minutes. Participants having reported more than 1959.75 minutes of exercise were placed in the high physical activity group ($n = 66$), while those having reported less than 1959.75 minutes were placed in the low physical activity group ($n = 66$).

Statistical Analysis

The statistical analyses were conducted using SPSS (Version 29.0) with a 95% confidence interval and an alpha level set to $p = .05$. A repeated measures ANOVA (RMANOVA) was conducted to investigate four main effects on the participant response accuracy: the effects of the condition (within-subject factor; control, experimental), probe position (within-subjects factor; 0, +1, +2, +3, +4, +5, +6, +7, +8), probe presence (within-subjects factor; present, absent) and IPAQ (between-subjects factor; high, low) on probe-identification accuracy. Eleven interaction effects were investigated to explore the joint interaction of these main effects on participant response accuracy. In the case of a violation of the assumption of Mauchly's sphericity, a Greenhouse-Geisser correction was applied. Where applicable, pairwise comparisons were calculated using Fisher's

Figure 3 ■ Results of the Repeated-Measures Analysis of Variance (RMANOVA) on the RSVP Task Performance. RSVP task response accuracy (y-axis) indicated by the mean proportion of correctly identified probes. Probe position (x-axis) represents position of probe with respect to the target (i.e. 0 to +8). Condition is indicated by color, with experimental trials represented in red and control trials represented in green. Probe presence is differentiated by column with the two graphs on the left indicating probe-absent trials and the two graphs on the right indicating probe-present trials. IPAQ group is differentiated by row with the two upper graphs representing the high IPAQ group and the two lower graphs representing the low IPAQ group.



LSD ($p = .05$).

Results

A RMANOVA was conducted to examine the impact of three within-subjects variables ([1] condition: experimental, control; [2] probe presence: present, absent; and [3] probe position: 0, +1, +2, +3, +4, +5, +6, +7, +8) and one between-subjects variable (IPAQ: low, high) on participants' reporting accuracy during the study. Due to violations of the assumption of sphericity necessary to conduct a repeated-measures ANOVA, Greenhouse-Geisser corrections were applied for: probe position [$\chi^2(35) = 116.101$, $p < .001$], interaction between condition and probe position [$\chi^2(35) = 63.377$, $p = .002$], interaction between probe position and probe presence [$\chi^2(35) = 110.386$, $p < .001$], as well as interaction between condition, probe position and probe presence [$\chi^2(35) = 61,644$, $p = .004$].

The findings demonstrate a significant main effect of the condition on the participant's response accuracy [$F(1, 130) = 735.942$, $p < .001$, $\eta_p^2 = .850$] such that participants in the control condition performed significantly better than the participants in the experimental condition (see Figure 3). This is consistent with the findings of the original study (Raymond et al., 1992). These results suggest that there is a significant difference in performance (i.e. better accuracy) when asked to ignore the target and simply concentrate on the probe (i.e. control condition), as opposed to when asked to concentrate and remember both the target and the probe (i.e. experimental condition). Consistent with Cohen's (1988) benchmarks for partial eta square (η_p^2), the effect size is large, meaning that condition had a substantial effect on performance at the task.

A significant main effect of the nine possible probe positions (i.e. ranging from 0 to +8) on response accuracy [$F(6.395, 831.290) = 167.959$, $p < .001$, $\eta_p^2 = .564$] is observed, after applying the Greenhouse-Geisser correction. Pairwise comparisons revealed the following significant differences: 0 and +8 > +7 > +1 and +6 > +5 > +4 > +2 and +3. Notably, participants had the highest performance when the probe was at positions 0 and +8, and the lowest performance when the probe was at positions +2 and +3. This aligns with the results of the original study and indicates that the position at which the probe is presented within the sequence of letters influences the ability to accurately detect it. The estimated effect size is large (Cohen, 1988).

There is also a significant main effect of the presence or absence of the probe [$F(1, 130) = 215.505$, $p < .001$, $\eta_p^2 = .624$] on response accuracy. Participants performed significantly better when the probe was absent than when it was present. This demonstrates that the detection of the probe is not only related to its position in the sequence, but that its presence or absence also influences detection. Results for Partial eta square (η_p^2) indicate a large effect size on accuracy at the task (Cohen, 1988). In their study, Raymond et al. (1992) had also found a higher rate of correct probe identifications for probe-absent than probe-present trials. However, probe presence was not included as a within-subjects factor when conducting their analysis of variance (ANOVA).

After applying the Greenhouse-Geisser correction, a significant interaction between the condition and probe position [$F(7.079, 920.206) = 77.136$, $p < .001$, $\eta_p^2 = .372$] was observed, consistent with the original experiment of Raymond et al. (1992). The estimated effect size is large (Cohen, 1988). Pairwise comparisons revealed that participants in the control condition performed significantly better than participants in the experimental condition when the probe was at positions +1 +2, +3, +4, +5, +6, +7, and +8 ($p < .05$), but not at position 0 ($p > .05$). This means that the influence of the condition on response accuracy is different across the nine possible probe positions in the sequence, as shown in Figure 3.

There is a significant interaction between the condition and the presence or absence of the probe [$F(1, 130) = 240.284$, $p < .001$, $\eta_p^2 = .649$]. Pairwise comparisons revealed that, while participants generally performed better on trials where the probe was absent than present, this difference was more pronounced in experimental trials than control trials. The estimated effect size on response accuracy is large (Cohen, 1988). Figure 3 provides a visual of how condition affects the impact of probe presence on response accuracy.

After applying the Greenhouse-Geisser correction, a significant interaction between the probe position and its presence or absence is observed [$F(6.521, 847.790) = 166.181$, $p < .001$, $\eta_p^2 = .561$]. The probe's position only reveals significant differences for trials where the probe is present. According to pairwise comparisons, for trials where the probe is absent, there are no significant differences in performance ($p > .05$). This is because, for probe-present trials, the probe's position is randomly selected between 0 and +8. This indicates that the impact of the probe position on the participant's response accuracy differs on whether the probe is present or not. Results indicated a large effect size on task performance (Cohen, 1988).

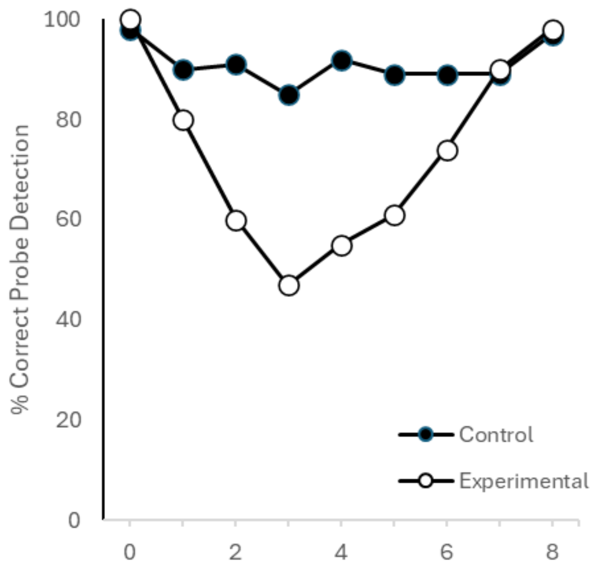
After applying the Greenhouse-Geisser correction, a significant interaction between the condition, the position of the probe, and the presence or absence of the probe is observed, [$F(6.974, 906.580) = 70.257, p < .001, \eta_p^2 = .351$]. Pairwise comparisons indicated that performance for control trials is significantly higher than for experimental trials when the probe is at position 0 for the probe-absent trials only. It is significantly higher at positions +1 and +2 for the probe-present trials only, and at positions +3, +4, +5, +6, +7, and +8 for both probe-absent and probe-present trials. Results indicated a large effect size on accuracy (Cohen, 1988).

Finally, contrary to expectations, there is no significant interaction between the two exercise groups, low and high IPAQ [$F(1, 130) = .419$, $p = .519$, $\eta_p^2 = .003$]. As shown in Figure 3, both exercise groups have very similar results in both conditions. Furthermore, all interactions involving the IPAQ variable were non-significant. This includes a condition by exercise group interaction [$F(1, 130) = .069$, $p = .793$, $\eta_p^2 = .001$], a probe position by exercise group interaction [$F(6.395, 831.290) = .418, p = .877, \eta_p^2 = 003$] (corrected using the Greenhouse-Geisser correction), a probe presence by exercise group interaction [$F(1, 130) = .371$, $p = .543$, $\eta_p^2 = .003$], a condition by probe position by exercise interaction [$F(7.079, 920.206) = .624$, $p = .739$, $\eta_p^2 = .005$] (corrected using the Greenhouse-Geisser correction), a condition by probe presence by exercise group interaction [$F(1, 130) = .019$, $p = .890$, $\eta_p^2 < .001$], a probe position by probe presence by exercise interaction [$F(6.521, 847.790) = .475, p = .841, \eta_p^2 = .004$] (corrected using the Greenhouse-Geisser correction), and a condition by probe position by probe presence by exercise group interaction [$F(6.974, 906.580) = .8$, $p = .525$, $\eta_p^2 = .007$] (corrected using the Greenhouse-Geisser correction). This supports the idea that the levels of physical activity performed by the participants did not have a significant influence on their performance in the study. The reported effect sizes are null, consistent with Cohen's (1988) benchmarks for partial eta squared (η_p^2).

Discussion

The attentional blink is a phenomenon that temporarily suppresses visual processing. Raymond et al. (1992) conducted a study on this process and our current work aimed to replicate and validate their findings. The present study replicated Raymond et al.'s procedure whereby participants identified a white letter and the presence of an "X" (experimental condition) or simply the presence of an "X"

Figure 4 ■ An estimation of Raymond and Colleagues' (1992) Repeated-Measures Analysis of Variance (RMANOVA) on the RSVP Task Performance. RSVP performance (y-axis) as indicated by the mean proportion of correctly identified probes. Lag (x-axis) represents position of probe with respect to the target (0 to +8). Condition is indicated by the color of the data points. Raymond and colleagues did not report estimates of variance.



(control condition) in an RSVP task. In contrast to the original study which included 10 university students between the ages of 19 and 37, participants from this study comprised of 132 community members spanning various ages, educational backgrounds, and ethnicities. This larger and more representative sample allows us to better validate and generalize the results. Moreover, the present study also aimed to investigate how physical activity may impact attentional blink.

Consistent with Raymond et al.'s findings, our study revealed a significant main effect of the condition and the probe's position on probe detection accuracy. These results support the theory that the differences in probe detection accuracy are due to attentional processes demonstrated by the two different conditions (Maki & Padmanabhan, 1994). In both conditions, participants were presented with a white target letter. As seen in the original data (reproduced in Figure 4), the control condition, where participants only needed to focus on the absence or presence of the probe, showed less impairment in probe detection accuracy compared to the experimental condition which required participants to identify the target letter and determine if the probe was present. This attentional process of target letter identification appears to reduce the attention available to detect the probe, which results in a decreased probe detection accuracy (Dux & Marois, 2009). The attentional blink phenomenon happens due to a delay in allocating and shifting attention to the second target, leading to impaired detection (Martens & Wyble, 2010).

Additionally, Figure 3 shows that when the probe is presented at positions 0 and +8 there is high accuracy in probe detection in both conditions. Unlike Raymond et al.'s study which didn't find any difference at the probe position +8, this study found significant differences in all probe positions. However, between positions +1 and +7, there is a drop in the percentage of accurate probe detection, illustrating the impact of the probe's position on accuracy. These findings align with previous research and support the hypothesis that the attentional blink is most significant when the target and probe are presented within approximately 200 to 500 ms of each other which would reflect the probe positions of 2 through 4 (Dux & Marois, 2009; Raymond et al., 1992). Furthermore, our results aligned with the hypothesis that the probe detection accuracy is higher when the probe is presented more than 500 ms after the target (Dux & Marois, 2009; Raymond et al., 1992).

The third significant main effect regards the probe presence; whether the probe was present or absent in the letter stream. As observed in Figure 4, correct probe detection is lower when the probe is present in the letter streams. In other words, when the probe is absent from the letter stream, probe detection accuracy improves. Importantly, there is a significant interaction among all three main effects: the condition, the probe position, and the probe presence. This interaction demonstrates that all three factors have an influence on probe detection accuracy. More specifically, the effect of any one variable on probe detection accuracy is mediated by the two other variables. The effect of condition, probe presence, and their positions affect response accuracy. This demonstrates the complexity of the phenomenon of the attentional blink and that it's a multi-factor process.

Raymond and colleagues' 1992 study has been a key reference in the understanding of visual working theory. In 2007, Bowman and Wyble proposed a theory on the identification, sustainability and encoding of salient stimulus in RSVP tasks. The theory is composed of a perceptual stage containing a salience filter, and an encoding stage where a temporary attentional enhancement (TAE) selects salient stimuli. In a RSVP task, the processing of the target suppresses the TAE when the probe appears, which causes the attentional blink (Bowman & Wyble, 2007; as cited in Popple & Levi, 2007). The effects of different variables on the attentional blink have been tested over the years, such as the colour of the target (Popple & Levi, 2007) or the effect of sleep on performance (Cellini et al., 2015).

In addition to the original goal, we tested the hypothesis that participants with a higher level of physical activity would have a smaller attentional blink and, therefore, higher response accuracy. A modified version of the IPAQ questionnaire was completed before the start of the trials. Contrary to our hypothesis, there were no significant differences found between these groups. This unexpected result could be attributed to the time framed limited to the past 7 days and binary categorization of the levels of physical activity. To enhance accuracy, future research could consider dividing the participants into three activity levels (low, moderate, and high), as seen in other studies (Bermúdez et al., 2013). When comparing the amount of time spent sitting daily between the high and low IPAQ groups, the difference was only 24.4 minutes. This small disparity may suggest that the physical activity levels between groups weren't different enough to detect any potential impact on their attentional blink.

Due to the widespread use of modern technology, participants did the experiment at home, using their own electronic devices. This facilitated the recruitment of a larger sample of participants because it was more convenient and did not require any transportation to complete the study. This decision enhanced the experiment's accessibility, which is one of this study's strengths, but it also introduced certain limitations. Firstly, it's possible that participants conducted the study in a distracting environment. Participants used their own electronic devices, which meant that we couldn't regulate the screen colour or the stimulus position in their field of view. Additionally, we adjusted the stimulus presentation timing to be compatible with LED screens which refresh at 16.66 ms intervals with an 83.3 ms interstimulus interval instead of the 15 ms and 75 ms intervals used by Raymond et al. (1992). Furthermore, since the experiment was unsupervised, some participants took longer breaks than intended or took breaks outside of the designated times. However, to mitigate this, when participants took longer than 10 seconds to respond, the score from that trial was not used and removed from the analysis of the results.

Future research efforts should consider testing the potential effect of demographic variables, such as age and gender, on the correct identification of rapidly presented stimuli. This could provide a more comprehensive understanding of how different individuals process and recall briefly presented stimuli, and whether age-related declines in cognitive and perceptual abilities affect their attentional blink. Moreover, limiting the number of trials and duration of the study could improve participant engagement and potentially reduce attrition rates, thereby increasing the potential generalizability of the results. Moreover, the effects of mental health and learning disabilities such as ADHD and dyslexia could be further investigated, because Laasonen and their team (2012) found longer recovery times in attentional blink among individuals with dyslexia. This demonstrates a potential gap in our understanding of attentional blink and calls for further investigation of dyslexia and the impacts of other mental health or learning disabilities on attentional blink. Additionally, further investigation into the influence of cognitively demanding activities such as video games and rapid chess on the attentional blink calls for exploration. Lastly, incorporating physical measurements such as maximal oxygen consumption, respiratory exchange ratio, and a computerized indirect calorimetry system could yield significantly more precise data regarding physical activity.

Authors' note

All authors contributed as part of an undergraduate course project while Anqi Zhang, Arda Erbayav, Artemis Arranz, Danica Leclair, Gabe Kotch, Matthieu Mallet, and Thomas Boivin contributed an equal amount towards the preparation of this manuscript. Meenakshie Bradley-Garcia conceptualized, programmed, supervised, and assisted with the preparation of this manuscript.

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Open practices

The *Open Data* badge was earned because the data of the experiment(s) are available on osf.io/p4xsv/

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Citation

Bradley-Garcia, M., Zhang, A., Erbayav, A., Arranz, A., Leclair, D., Kotch, G., Mallet, M., Boivin, T., Bensmaia, S., Brisebois, R., Carraro, F., Coulombe Grinham, M., Ekoly-Wambi, R., Estephan, R., Josiah, K., Lacroix, É., Mayotte, E., Meyerovich, E., Montminy-Bergeron, C., … T-Beauchamp, C. (2025). Effect of physical activity and interstimulus interval on an RSVP task: A replication of Raymond et al. (1992). *The Quantitative Methods for Psychology*, *21*(1), 13–23. doi: 10.20982/tqmp.21.1.p013.

Received: 09/03/2024 ~ Accepted: 10/12/2024