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The Limits of Attention for Visual Perception and Action in Aging

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ABSTRACT

This study aimed to investigate whether aging results in an increased attentional blink effect in older adults as compared to young adults. A rapid serial visual presentation (RSVP) paradigm was employed in which participants were asked to identify two targets (dual-task condition) presented in rapid succession. These targets were separated by various intervals in a stream of stimuli. The performance for identifying the second target was normally diminished as compared to identification of a single-task target. Various combinations of tasks, such as two perceptual tasks or one perceptual and one action task, as well as different types of pointing action, such as pointing to a displaced target, pointing to a stationary target or pointing to a disappeared target, were manipulated in this study to see if aging may further impact these variables. The results of this study showed that in young adults, successful identification of the first target interfered with identifying the second target, as well as the initiation time (action planning) of pointing to the second target. However, identification of the first target did not interfere with pointing movement time and pointing accuracy, even when the target was displaced, which required online control of action. Conversely, for older adults, successful central identification not only interfered with identifying the second target and with the pointing initiation time, but also interfered with pointing movement time for a displaced target. This suggests that older adults seem to be unable to concurrently identify the first target and correct their already-initiated pointing movement compared to young adults.

Keywords: Rapid serial visual presentation (RSVP); Attentional blink; Stimulus onset asynchrony (SOA); Action planning; Online control of action.

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INTRODUCTION

It has been well documented that although perception is vital for our lives, attentional constraints for visual perception exist. A classic debate focuses on the attentional bottleneck along the visual information-processing stream (e.g., Broadbent, 1958; Deutsch & Deutsch, 1963). One common paradigm used to identify in which stage of information-processing that bottleneck takes place is the dual-task paradigm (Pashler, 1994). In dual-task paradigms, participants are asked to report two targets presented concurrently or in rapid succession. Typically, interference occurs between the two tasks under dual-task conditions as compared to single-task conditions. One example of dual-task interference is the attentional blink (AB). In this subtype of dual-task paradigm, participants are asked to identify and report two visual targets presented in succession separated by various intervals (stimulus onset asynchrony or SOA). These targets are embedded in a rapid serial visual presentation (RSVP) sequence of visual distractors. The stimuli in such a sequence are presented at a rate of eight to 12 items per second. Participants can identify and report the fist target (T1) in the sequence, but show a dramatic decrease in identifying the second target (T2) when T2 appears in close temporal proximity to T1 (e.g., between 100 and 450 ms following T1). This deficit is known as 'attentional blink' (Chun & Potter, 1995; Jolicoeur, 1998; Raymond, Shapiro, & Arnell, 1992). A number of research reports have confirmed that when both target tasks are perceptual tasks, the attentional blink effect occurs.

In real life situations, humans not only perform perceptual judgments, but also perform actions, such as pointing and grasping. Milner and Goodale (1995) proposed that human vision consists of two separate visual systems, known as the dual systems theory: (1) 'what' (perception of objects) and (2) 'how' (online control of action towards objects) (see also Ganel & Goodale, 2003; Goodale & Milner, 2004; Milner & Goodale, 1995). According to the dual systems theory, one might predict that no interference would occur in a dual-task situation in which one task is perceptual and one task is action. However, Kunde, Landgraf, Paelecke, and Kiesel (2007), using psychological refractory period paradigm, showed that a dorsal task, such as grasping an object, is also subject to massive dual-task interference. Kunde et al. (2007) concluded that although vision for perception and vision for action are dissociated, they do not differ in terms of capacity limitations. Accordingly, performing a perceptual and an action task simultaneously in an RSVP paradigm should result in attentional blink, as is normally found when performing two perceptual tasks. To the best knowledge of the authors, there is only one study (Liu, Chua, & Enns, 2008) using the RSVP paradigm to systematically address this issue among young adults. Contrary to Kunde et al.'s findings (2007), Liu et al. (2008) found that identifying a target interfered with action planning, although it did not interfere with action execution.

Components of Visually-Guided Pointing Actions

In Liu et al.'s (2008) study, some components of visually guided pointing action were distinguished: action planning (i.e., pointing initiation time (IT): the time between target onset and movement onset), and pointing execution (i.e., movement completion time (MT): the time between movement onset and completion and pointing accuracy). The literature has shown that action planning and action execution may involve different visual systems, with planning involving a more ventral stream of the visual system and execution involving a more dorsal stream of the visual system (Glover, 2004; Goodale & Milner, 2004; Henry & Rogers, 1960; Liu et al., 2008). Liu et al. (2008) supported dual systems theory by showing that although perception of the first target did not interfere with action execution among young adults, it interfered with action planning.

Liu et al. (2008) further compared pointing MTs among different types of pointing actions, such as pointing to a stationary target as opposed to pointing to a displaced target upon movement initiation. The logic was based on literature suggesting that online control of a pointing action to a displaced target ('the peripheral target moved unpredictably to a nearby location upon movement onset') is separable from mere action execution toward a stationary target. Elliott, Helsen, and Chua (2001) suggested that movement execution can be decomposed into two component phases: an initial ballistic phase that reflects programming movement characteristics, and a later phase in response to visual feedback to correct online the movement error between the effector and the target. Elliott et al. (2001) hypothesized that pointing to a displaced target may demand more of the later phase, in which online refinement and error-correction of the movement are required. Accordingly, the pointing MT to a displaced target can serve as a better candidate for tapping dorsal stream visually-guided action.

By differentiating these components of pointing action, Liu et al. (2008) demonstrated that for young adults, successful identification of the first target interfered with the identification of the second target and with pointing IT to the second target, but did not interfere with the pointing MT and pointing accuracy for the second target, even when the second target was displaced upon movement initiation.

Aging and the Limits of Attention for Perception and Action

In contrast to available studies regarding limits of attention on young adults, relatively fewer research studies exist that investigate limits of attention in older adults using RSVP paradigms. To the best knowledge of the authors, there are only four studies available (three journal papers and one conference paper: Georgiou-Karistianis et al., 2007; Lahar, Isaak, & McArthur, 2001; Maciokas & Crognale, 2003; Zacks, Henderson, Mangum, &

Hasher, 1994). Furthermore, among these studies, two of them did not measure T2 performance on the condition of T1 accuracy, making it difficult to compare with other studies using the typical way of measuring attentional blink (see Georgiou-Karistianis et al., 2007 for a similar comment). Therefore, this study aimed to contribute additional empirical evidence examining whether aging impairs an individual's ability to perform two tasks in the RSVP paradigm. Moreover, this study differs from other available studies in that not only were two perceptual tasks were used, but action tasks were also included. The purpose of this study was to see if different combinations of the two tasks in the RSVP paradigm were equally prone to attention deterioration as a result of aging. The investigation of this issue is of theoretical importance. According to the contemporary unified visual attention model (e.g., Schneider, 1995), if aging impairs the attentional system, then attentional blink would increase regardless of which two tasks are performed simultaneously. One would likewise expect to observe enlarged attentional blink effects on both perceptual and action tasks for older adults as compared to young adults. On the other hand, according to the dual-systems theory (e.g., Milner & Goodale, 1995), perceptual and action tasks may tap different visual attentional systems. Thus, if aging impairs one attentional mechanism, it does not necessarily impair another attentional mechanism. Furthermore, this study compared different types of pointing actions to examine whether older adults exhibit the same patterns of attentional blink effect among different types of pointing actions as young adults reported by Liu et al. (2008), or whether older adults display generally larger attentional blink effects for all types of pointing actions.

Memory-Guided vs. Visually-Guided Pointing Actions

In addition to the two types of visually-guided pointing action conditions (pointing to a stationary or disappeared target condition) used in Liu et al.'s (2008) study, this study also incorporated a memory-guided action condition (e.g., pointing to a disappeared target upon movement initiation) in the RSVP paradigm to investigate whether the attentional blink effect was the same as or different from a visually-guided action task when in combination with a perceptual task, and to determine if the patterns of results differed among young and older adults. Although the evidence mentioned above has demonstrated that perception and action involve different visual systems, there is also further evidence showing that memory-guided action may differ from visually-guided action, which relies on stored representations that are derived from ventral stream perceptual processing rather than from dorsal stream processing that makes use of absolute metrics and body coordinates (e.g., Goodale & Milner, 2004; Pisella et al., 2000; Singhal, Culham, Chinellato, & Goodale, 2007; Westwood & Goodale, 2003). Milner and Goodale (2008) also suggested that grasping an object no longer visible relies on perceptual information stored in ventral systems. Therefore, it would be interesting to examine if a perceptual task would interfere with a memory-guided action but not a visually-guided action. To the best knowledge of the authors, such an interesting issue has yet to be researched using RSVP paradigms with young or older adults.

Specific vs. General Attentional Deficit in Aging

Using RSVP paradigms in this study also allowed us to investigate whether older adults' attentional deficits are due to general cognitive slowing. A number of studies have used various spatial attentional tasks, such as cued location (e.g., Hartley, Kieley, & Slabach, 1990), visual conjunction search (e.g., Madden, 1990) and divided attention tasks (e.g., Salthouse, Rogan, & Prill, 1984) to investigate age-related attentional deficits. Numerous behavior studies have reported significant decreases in cognitive performance, such as longer reaction time (RT) and decreased accuracy (Salthouse, 1996). Thus, researchers have put forward a 'general slowing' hypothesis to account for the aging effect. On the other hand, some studies investigating dynamic attention among older adults, such as task switching, have suggested a specific rather than general slowing deficit. These studies suggested that only those tasks that depend highly on frontal lobe activity would deteriorate with aging (e.g., Band, Ridderinkhof, & Segalowitz, 2002; Mayr & Liebscher, 2001; Raz, Gunning-Dixon, Head, Dupius, & Acker, 1998; Ridderinkhof, Span, & van der Molen, 2002; West, 1996). Therefore, it remains unclear if older adults are impaired, specifically or generally, in other types of dynamic attention, such as performing dual-tasks in RSVP paradigms.

If aging results mainly in general slowing, then one would expect to find a deficit in performance independent of time between the first and the second target in the RSVP stream. Such a general deficit should be revealed in a single-task condition with a downward shift in the data between young and older adults. On the other hand, if aging results in a specific attentional deficit, then one would expect to find an enlarged attentional blink effect in RSVP paradigms. Such a specific deficit should be revealed in performance differences in dual-task as compared to single-task conditions, and the difference would further interact with the time lag between the first and the second target in the RSVP stream.

Objectives of this Study

To summarize, this study aimed to investigate whether aging impairs, specifically or generally, an individual's ability to perform two tasks in the RSVP paradigm. Various combinations of tasks, such as two perceptual tasks or one perceptual and one action task, as well as different types of pointing action, such as pointing to a displaced target (online action control), pointing to a stationary target (mere action execution) or pointing to a disappeared target (memory-guided action), were manipulated in this study to see if aging may further impact these variables.

METHOD

Participants

A group of 12 young adults (19–30 years; $M = 21 \pm 3.3$; education years: $M = 14.1 \pm 2.1$) and 12 older adults[1] (55–62 years; $M = 59.3 \pm 2.5$; education years: $M = 11 \pm 3.3$) participated in this study. The young adults were recruited from the National Chung Cheng University located in Chia-Yi county and received credit toward an introductory psychology course. The older adults were recruited from local villages in Chia-Yi county and paid NT$ 200.00 (US$ 7.00). All participants were right-handed, free of neurological and psychological disorders, and had self-reported normal or corrected-to-normal vision. The experiment was conducted with the understanding and consent of each participant.

All participants were screened for depression using the Beck Depression Inventory (BDI-II) (Beck, Steer, & Brown, 1996; screening criteria: 0–13: normal; 14–19: mild depression; 20–28: moderate depression; 29–63: severe depression) and for dementia using Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975; screening criteria: 25–30: normal; 21–24: mild dementia; 14–20: moderate dementia; ≤13: severe dementia). The mean BDI-II score was 5.9 ± 3.7 for young adults and 5.5 ± 4.0 for older adults (young vs. older: $t(22) = 0.27$, $p = .79$). The mean MMSE score was 28.4 ± 1.1 for young adults and 27.5 ± 1.7 for older adults (young vs. older: $t(22) = 1.84$, $p = .08$).

Apparatus and Stimuli

Stimuli were generated using Delphi 7.0 operating on an Acer notebook computer (Acer TravelMate C110) with an Intel Pentium M Centrino 900MHz processor operated by Window-XP system. Participants sat a distance of approximately 57 cm from the computer screen. Participants used a stylus held in the right hand to touch the screen which was tilt-mounted so that participants' hands could rest on it at waist height. Digit responses were inputted with the left hand using a keyboard.

[1]Admittedly, the older adults we recruited in this study were considered middle-aged (i.e., age range between 50 and 65 years) who were younger than the age (>65 years) that is generally considered as the beginning of older adulthood. One practical reason for recruiting the age range between 55 and 62 years is availability. Another more theoretical reason is that since Georgiou-Karistianis et al. (2007) observed deterioration in attentional blink effect for participants at the age of 40 onwards and suggested that 40 years is a possibly critical psychological and physiological milestone, it is reasonable for this study to investigate the aging effect on attentional blink effect using middle-aged adults.

Stimuli were presented in white on a light-grey background. The stylus home position was a circle with a 0.6° visual angle near the screen's left edge, and the gaze home position was a square (fixation) with a 0.4° visual angle located 2.4° above the stylus home position. Each trial commenced when the stylus held by the subject's right hand was placed in the home position. A series of letters ('A'–'Z,' excluding 'B', 'I', 'O', 'S' and 'Z') was presented with a rate of 60 ms per item followed by a 40 ms blank interval. After 5 to 8 letters were presented, the first target (a digit, '2'–'9') was presented at the central location where the RSVP stream occurred, followed by 14 additional letters (see Figure 1 for an example). At a temporal lag of 100, 300, or 700 ms following the onset of the central target, the to-be-pointed target (a digit) was presented at a pheripheral location with a size of 0.8° × 0.9° of visual angle. It appeared only for 100 ms and was then followed by a mask (a white square with 0.9° × 0.9° of visual angle) that remained visible until the completion of pointing action.[2] The peripheral digit could be presented at one of three peripheral locations, 11°, 12°, or 13° of visual angle to the right of fixation. These peripheral to-be-pointed targets could be either stationary (both digit target and mask appeared at the same location), displaced (both target digit and mask originally appeared at the 12° of visual angle location, but upon the initiation of stylus movement, the mask was displaced to a neighboring location, e.g., 11° or 13° of visual angle to the right of fixation) or disappeared (both digit target and mask appeared at the same location, but as soon as the initiation of stylus movement, the mask disappeared). These three types of peripheral targets were arranged to appear with equal probability within each block.

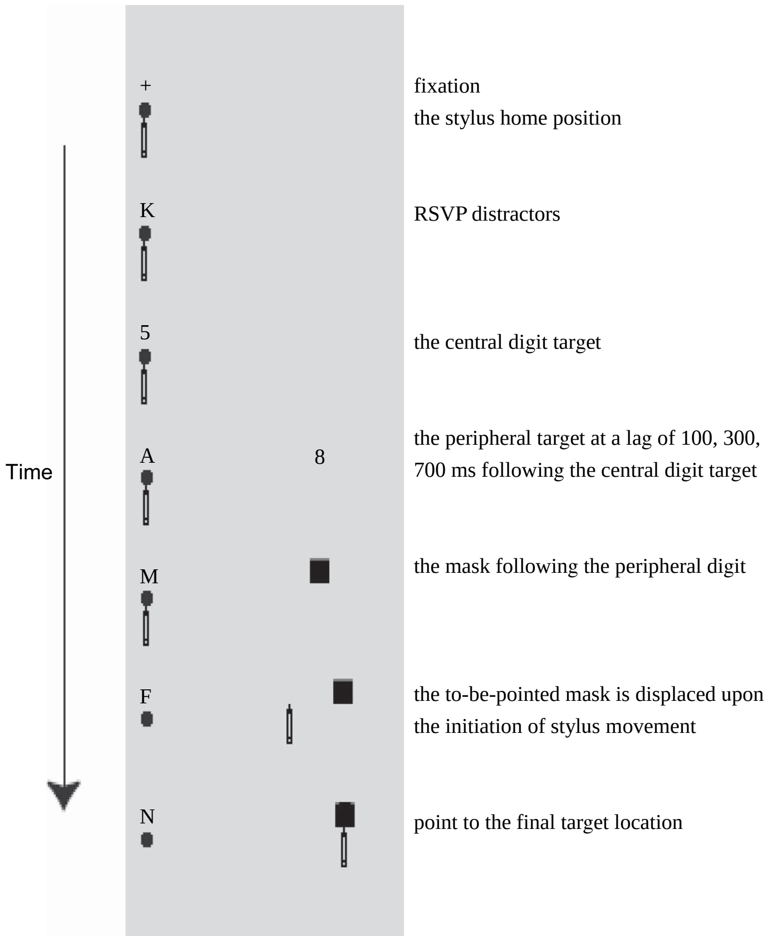
Design and Procedure

Participants initiated each trial by placing the stylus on the home position. Participants were instructed to remain on the home position until the peripheral digit onset, and then to identify and point to the final location of the peripheral digit (replaced by a mask after 100 ms of presentation). Participants were instructed to perform the tasks as accurately and as quickly as possible. A practice session of 20 trials was provided followed by the formal experiment of 432 trials.

There were one single-task block (216 trials) and one dual-task block (216 trials) and the order of these two blocks was counterbalanced across participants. The dependent variables, temporal lag (100, 300, or 700 ms) between central and peripheral digits, peripheral digit's location (11°, 12°, or

[2]The mask replaced the peripheral digit after 100 ms of the digit's presentation and was served as the to-be-pointed target for the following pointing action.

FIGURE 1. Schematic illustration of a typical trial sequence in which the to-be-pointed target (peripheral digit) was presented for 100 ms with a temporal Lag of 100, 300, or 700 ms following the onset of a central target, and was then followed by a mask. A displaced peripheral target trial is illustrated, in which both peripheral digit and mask originally appeared at the same location, but upon the initiation of stylus movement, the mask was displaced to a neighboring location.



13° of visual angle to the right of fixation) and peripheral digit's displacement, were randomized with equal probability within each block. In a single-task block, participants were instructed to ignore the first (central) digit and report by pointing to and identifying only the second (peripheral) digit. In a dual-task block, participants were instructed to respond to both targets by identifying the central digit and pointing to and identifying the peripheral digit. However, participants were instructed to report the central digit as accurately as possible. Digits were reported after the pointing action was completed.

Data Analysis

This study measured identification errors of central and peripheral digits, pointing initiation time (IT), pointing movement time (MT) and pointing accuracy. Pointing IT was measured from the onset of the to-be-pointed peripheral target until the stylus was moved. Pointing MT was measured from the onset of moving the stylus until completion. Pointing accuracy was assessed with the absolute value of average horizontal deviation from the final target location (each pixel on the screen equals 0.2 mm).

According to Liu et al. (2008), only trials meeting the following criteria were included for analyses: (1) the stylus was always placed on the home position until the onset of the to-be-pointed target, (2) in the dual-task condition, trials with correct identification of the central digit, (3) IT was between 100 and 2000 ms, and (4) MT was between 100 and 1000 ms. For young adults, an average of 2.1% of trials were excluded from analyses due to premature movement of stylus, 0.02% of trials were excluded due to IT over 2000 ms, and 1% of trials were excluded due to MT over 1000 ms. Among older adults, an average of 1.62% of trials were excluded from analysis due to premature stylus movement, 1.39% of trials were excluded due to IT over 2000 ms, and 2.35% of trials were excluded due to MT over 1000 ms.

A number of ANOVAs were conducted on the experimental results including one three-way ANOVA (one between-subject factor: age: young vs. older; two within-subject factors: Lag: SOA 100, 300 vs. 700 ms; Peripheral Target Type: stationary vs. displaced vs. disappeared) on central-digit target identification errors. Two three-way ANOVAs (Age, Task Condition: single- vs. dual-task, Lag) examined peripheral-digit target identification errors and pointing IT to the peripheral target, respectively, and two four-way ANOVAs (Age, Task Condition, Lag, Peripheral Target Type) examined pointing MT and pointing accuracy, respectively. The significant level was $p < .05$.

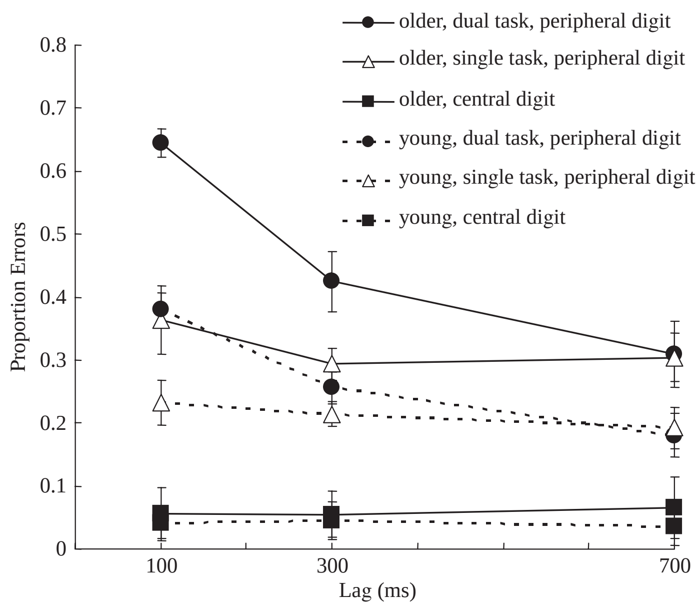
RESULTS

Digit Identification (Proportion Errors)

Central-Digit Target Identification

Mean central-digit identification errors (Figure 2) showed that participants were able to successfully identify the central-digit target, with 4.1% errors for young adults and 5.9% errors for older adults. The results of a

FIGURE 2. Central and peripheral digit identification (in proportion errors) for young and older adults in single and dual task conditions.



three-way ANOVA showed that neither Age nor Peripheral Target Type (all p values >.08) affected central-digit identification.

Peripheral-Digit Target Identification

On the other hand, a three-way ANOVA on peripheral-digit target identification errors (Figure 2) showed significant effects of Age, Task Condition, and Lag (all p values $< .0001$). There was a significant two-way interaction of Task Condition × Lag, $F(2, 44) = 114.01$, $p < .0001$, exhibiting a typical attentional blink effect. At short lags (SOA 100 and 300 ms), peripheral-digit accuracy was decreased in the dual-task condition compared to the single-task condition (Lag 1: $F(1, 66) = 42.11$, $p < .0001$; Lag 3: $F(1, 66) = 18.87$, $p < .0001$), whereas at the final lag (SOA 700 ms), accuracy in two conditions did not differ from one another (Lag 7: $F(1, 66) = 0.67$, $p = .42$) indicating that by Lag 7, the identification of central-digit target no longer affected peripheral-digit target identification.

More importantly, a significant three-way interaction of Age, Task Condition and Lag, $F(2, 44) = 8.31$, $p < .001$, further showed that both young and older adults exhibited a typical blink effect (young: $F(2, 110) =$

106.27, $p < .0001$; older: $F(2, 110) = 36.35$, $p < .0001$), but older adults showed a larger blink magnitude[3] (Mean = 0.21 proportion errors, $SD = 0.03$) than young adults ($M = 0.09$ proportion errors, $SD = 0.03$) ($t(22) = –8.29$, $p <.0001$).

Pointing Initiation Time (IT) to the Peripheral Target

Mean pointing IT to peripheral targets also exhibited a typical attentional blink phenomenon as did peripheral target identification errors, namely a significant interaction of Task Condition × Lag, $F(2, 44) = 46.68$, $p < .0001$). That is, at short lags (e.g., Lags 1 and 3), dual-task pointing IT was longer than single-task pointing IT (Lag 1: $F(1, 66) = 6.14$, $p <.05$; Lag 3: $F(1, 66) = 4.36$, $p <.05$), but by Lag 7, there was no longer a difference between the two conditions (Lag 7: $F(1, 66) = 1.95$, $p = .17$). Furthermore, a significant three-way interaction, Age × Task Condition × Lag, $F(2, 44) = 6.37$, $p < .005$, indicated that the pointing IT of both young and older adults exhibited an attentional blink effect[4] (young: $F(2, 110) = 31.05$, $p < .0001$; older: $F(2, 110) = 6.63$, $p < .005$), though older adults showed a larger attentional blink effect ($M = 122.69$ ms, $SD = 50.85$) than young adults ($M = 54.71$ ms, $SD = 51.35$) ($t(22) = –3.25$, $p < .005$) (Figure 3).

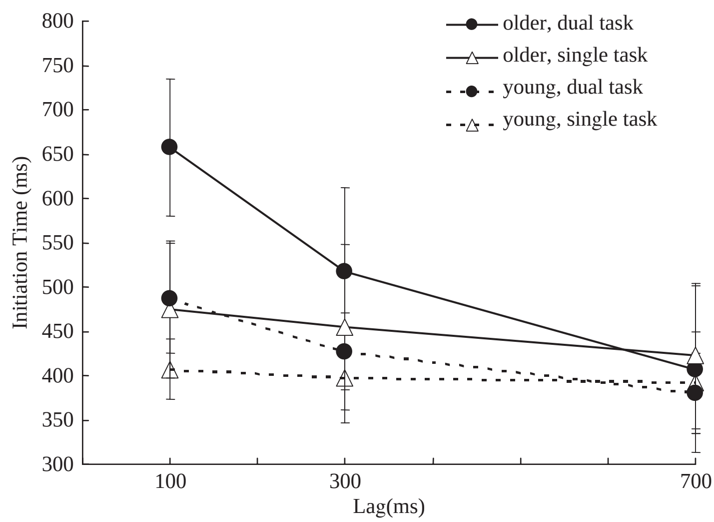
Pointing Movement Time (MT) to the Peripheral Target

Although mean pointing MT likewise showed a significant two-way interaction of Task Condition × Lag, $F(2, 44) = 19.44$, $p < .001$ indicating a typical attentional blink effect, there were significant three-way interactions of Task Condition × Lag × Peripheral Target Type, $F(4, 88) = 3.03$, $p < .05$, of Age × Task Condition × Lag, $F(2, 44) = 6.29$, $p < .005$, as well as a significant four-way significant interaction of Age × Task Condition × Lag × Peripheral Target Type, $F(4, 88) = 5.11$, $p <.001$, indicating not all young and older adults exhibited an attentional blink effect for all pointing MTs among all pointing action conditions. Simple effect tests following the four-way interaction showed that mean pointing MT was relatively constant across Task Condition, Lag and Peripheral Target Type for young adults as reported in Liu et al.'s (2008) study, suggesting no typical attentional blink on pointing MT for young adults, whereas there were some attentional blink effects in some conditions for older adults. Older adults exhibited longer pointing MT in dual-task as compared to single-task conditions at both Lags

[3]We calculated the magnitude of the attentional blink by averaging the differences in peripheral-digit target identification's proportion errors between single- and dual-task conditions across Lags 1 and 3 (typical attentional blink's temporal window) (see Lahar et al., 2001).

[4]We calculated the magnitude of the attentional blink by averaging the differences in pointing IT (in ms) to the peripheral target between single- and dual-task conditions across Lags 1 and 3 (typical attentional blink's temporal window) (see Lahar et al., 2001).

FIGURE 3. Peripheral-digit pointing initiation time (IT) for young and older adults in single and dual task conditions.



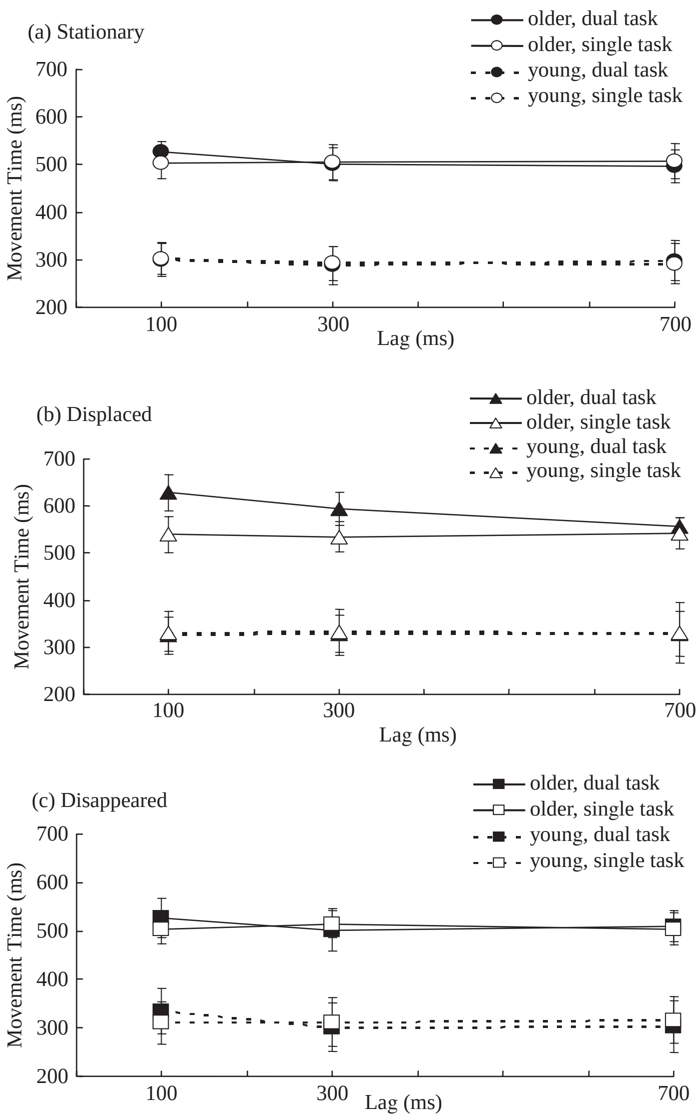
1 and 3 (Lag 1: $F(1, 33) = 57.38$, $p < .0001$; Lag 3: $F(1, 33) = 25.02$, $p < .0001$) for displaced peripheral targets, but no differences between single and dual-task conditions for either stationary (Lag 1: $F(1, 33) = 5.12$, $p = .03 >$ adjusted alpha value: .016) or disappeared (Lag 1: $F(1, 33) = 2.38$, $p = .13$) peripheral targets.

Moreover, among young adults, mean pointing MT across Task Conditions and Lags was longer, when pointing to displaced peripheral targets ($M = 329.56$ ms, $SD = 46.10$) than stationary ($M = 295.51$ ms, $SD = 36.83$) ($F(1, 142) = 35.15$, $p < .0001$) and disappeared peripheral targets ($M = 312.93$ ms, $SD = 48.73$) ($F(1, 142) = 8.38$, $p < .005$). Likewise for older adults, mean pointing MT was longer when pointing to displaced peripheral targets ($M = 565.92$ ms, $SD = 47.36$) than to stationary ($M = 506.70$ ms, $SD = 33.36$) ($F(1, 142) = 124.17$, $p < .0001$) and to disappeared peripheral targets ($M = 509.93$ ms, $SD = 34.75$) ($F(1, 142) = 110.97$, $p < .0001$) (Figure 4).

General Slowing vs. Specific Attentional Blink Effect

Given that mean pointing MT between single and dual-task conditions were significant at Lags 1 and 3 for older adults but not for young adults, it is worth clarifying if such differences were simply due to general slowing. Two sets of 2×2 ANOVAs with Age and Task Condition as variables for Lags 1 and 3 were conducted. The results showed a significant interaction of

FIGURE 4. Peripheral-digit pointing movement time (MT) for (a) stationary, (b) displaced, and (c) disappeared peripheral targets for young and older adults in single and dual task conditions.



Age and Task Condition at Lag 1 ($F(1, 22) = 29.44$, $p < .001$) and Lag 3 ($F(1, 22) = 20.99$, $p < .001$). All pointing MT data were further under logarithmic transformation and re-submitted to ANOVAs. The results were the same as raw MT data. That is, the interaction of Age and Task Condition was significant at Lag 1 ($F(1, 22) = 15.46$, $p < .001$) and Lag 3 ($F(1, 22) = 14.26$,

$p < .001$). The results thus suggest that the MT differences between young and older adults at Lags 1 and 3 were not simply due to general slowing (see also Bopp & Verhaeghen, 2007; Faust, Balota, Spieler, & Ferraro, 1999).

Pointing Accuracy to the Peripheral Target

The results of a four-way ANOVA on mean absolute horizontal deviations (in mm) (Figure 5) showed only one significant main effect of Peripheral Target Type, $F(2, 44) = 32.49$, $p < .0001$. There was a significant two-way interaction of Lag × Peripheral Target Type, $F(4, 88) = 5.08$, $p < .001$. No other main effects or interactions were significant. Thus, no typical attentional blink effects and no age differences occurred with this measure.

DISCUSSION

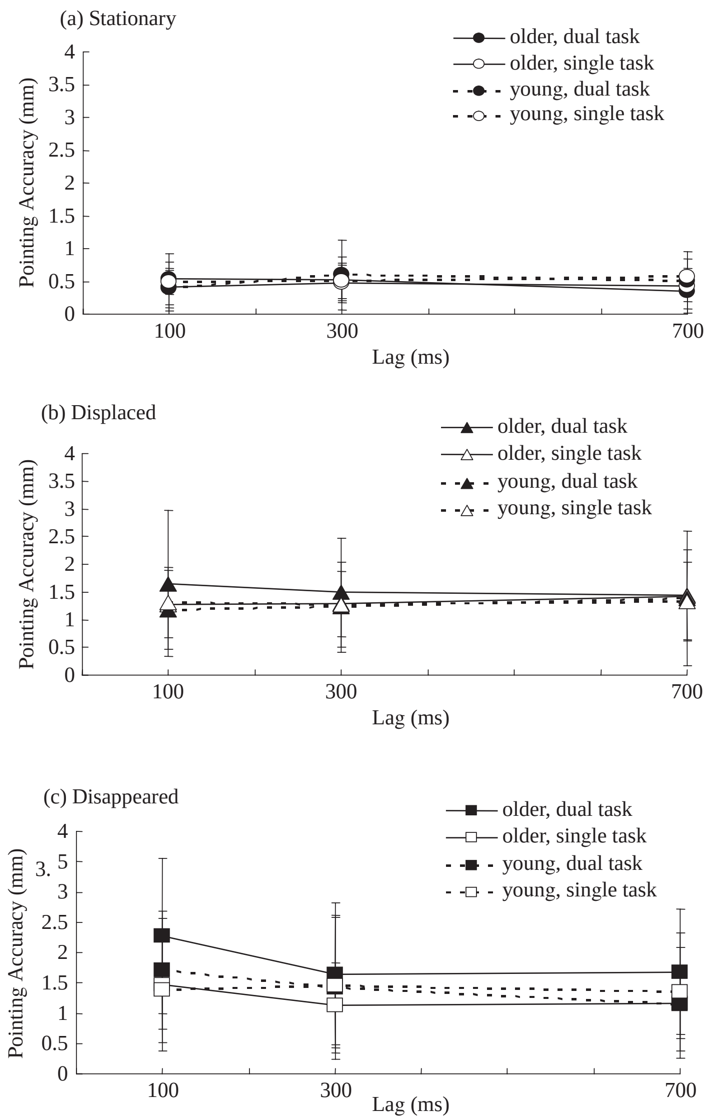
The main results of this study showed that successful central-digit identification interfered with identifying the second target and with the initiation time (action planning) of pointing to the second target (typical attentional blink effect) in young adults, but did not interfere with pointing movement time and pointing accuracy, even when the to-be-pointed peripheral target was displaced. Conversely, for older adults, successful central identification not only interfered with identifying the second target and with the initiation time of pointing to this peripheral target, but also interfered with pointing movement time to a displaced peripheral target, suggesting that older adults were unable to concurrently identify the first target and correct online their already-initiated pointing movement compared to young adults.

Aging and the Limits of Attention for Perception and Action

Previous studies using RSVP paradigms with two perceptual tasks have reported that older adults suffered from more severe attentional blink effect, such as a greater decrease in performance accuracy that lasted for more lags (e.g., Georgiou-Karistianis et al., 2007; Machiokas & Crognale, 2003; Lahar et al., 2001). Likewise, this study observed that older adults showed a larger attentional blink effect in dual-task conditions as compared to young adults.

A new contribution of this study is further investigation of whether older adults are able to perform one perceptual and one action task concurrently as young adults can, as reported by Liu et al. (2008). According to the dual systems theory, action task involves the parietal lobe, whereas identification involves the temporal lobe, thus resulting in little interference when performing the two tasks (Milner & Goodale, 1995). This study observed that although young adults are able to point to a peripheral target without interference while identifying the first target, older adults appeared to be less able to concurrently identify a target and point to a displaced peripheral target. The finding that online control of pointing action to a displaced target can be

FIGURE 5. Peripheral-digit pointing accuracy (absolute horizontal deviations; in mm) for (a) stationary, (b) displaced, and (c) disappeared peripheral targets for young and older adults in single and dual task conditions.



accomplished without interfering with the concurrent target identification among young adults suggested that the system guiding the hand registered the new target position and modified the action online without interference from the target identification (see also Liu et al., 2008). Conversely, among older adults, successful central identification of the first target interfered with pointing movement time when pointing to a displaced peripheral target, suggesting that older adults were unable to register the new target position and modify online their already-initiated movement.

One possible reason for this deficit is that the ability of older adults to identify a peripheral target had deteriorated, resulting in inefficiency of the online correction of their action. This can be evidenced by the finding that the ability of older adults to identify a peripheral target was decreased even in single-task conditions. One way of testing this hypothesis is to examine if trials in which the peripheral target was incorrectly identified resulted in faster pointing movement time. However, a *post-hoc* analysis showed no differences in pointing movement time between trials in which the peripheral target was misidentified vs. trials on which the peripheral target was correctly identified. Therefore, the result does not support such a hypothesis.

Another possibility is that aging directly affected the older adults' ability to re-estimate online a displaced new target location, resulting in less efficient modification of their already-initiated movement while identifying the first central target. Conversely, if the to-be-pointed target remains at the same location, such as a stationary target, older adults are just as able as young adults to concurrently perform a perceptual and an action task. This is evidenced by the result that pointing MT was slowest when pointing to a displaced peripheral target than either a stationary or a disappeared target. Further research is still needed to directly test this hypothesis. Nevertheless, although older adults are less efficient in adjusting online their action while identifying the first target, their pointing accuracy did not differ significantly from young adults. The finding appears to be consistent with previous research (e.g., Rossit & Harvey, 2007; Sarlegna, 2006) showing that although older adults' correction time is longer than that of young adults, their performance accuracy is similar to that of young adults.

In addition to examining how aging may affect people's ability to simultaneously perform object identification and online control of action tasks, this study also explored the issue of whether people's ability to perform object identification and online control tasks would cause more inference if the online control task is memory guided rather than visually guided. To address this issue, this study designed a condition in which the peripheral target would disappear upon the onset of the pointing movement. Some studies have indicated that memory-guided action, such as grasping, may involve ventral route processing rather than dorsal route processing (e.g., Milner & Goodale, 2008; Singhal et al., 2007; Westwood & Goodale, 2003). Accordingly, one may expect that in the disappeared peripheral-target type condition, the attentional blink effect would also be exhibited in pointing movement time and pointing accuracy for young adults. However, this study did not observe increasing pointing movement time for dual-task conditions at Lag 1 when pointing to disappeared targets for either young or older adults. This runs counter to what was expected. One critical difference between the previous study by Singhal et al. (2007) and this study is the timing of the disappearance of the target. In Singhal et al.'s (2007) study, the disappearance occurred earlier. Once the action planning has been completed, even when the target has disappeared upon action execution as is the case in this study, the involved system may be the dorsal route, like in other action conditions, rather than the ventral route. Furthermore, because the disappeared peripheral target remained at the same location as in the stationary target condition, no new target location needed to be registered and no movement needed to be corrected online. Thus, no attentional blink occurred for older adults under this circumstance.

Aging and General Slowing

A general slowing hypothesis for aging has been put forwarded by a number of studies that used various spatial attentional tasks. According to this theory, if aging results in general slowing, then one would expect to find a deficit in performance independent of task conditions and time lags between the first and the second targets in the RSVP stream. That is, for both single and dual-task conditions, there would be a downward shift in the data between young and older adults across all lags. Although the results of this study showed such a general decrease in performance across all three lags in the single-task condition, the performance decrease at Lags 1 and 3 were even greater in the dual-task condition for older adults. Moreover, the pointing movement time (with or without logarithmic transformation) for displaced peripheral targets produced a significant interaction with Age and Task Condition at Lags 1 and 3. The results suggest that MT differences in pointing to displaced peripheral targets between young and older adults at Lags 1 and 3 were not simply due to general slowing. Therefore, a general slowing hypothesis is not sufficient to explain the present finding of the increased attentional blink effect.

CONCLUSIONS

This study can be considered one of the pioneer studies examining older adults' ability to perform two tasks in rapid succession in RSVP paradigms. The results showed that older adults not only exhibited a larger attentional blink effect when performing two perceptual tasks (e.g., identifying a digit), but also when performing one identification task as well as one that required adjusting online their pointing action to a displaced target.

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REFERENCES

Band, G. P. H., Ridderinkhof, K. R., & Segalowitz, S. (2002). Explaining neurocognitive aging: Is one factor enough? *Brain and Cognition, 49,* 259–267.

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Manual for the Beck Depression Inventory* (2nd ed.). San Antonio, TX: The Psychological Corporation.

Bopp, K. L., & Verhaeghen, P. (2007). Age-related difference in control process in verbal and visuospatial working memory: Storage, transformation, supervision, and coordination. *Journal of Gerontology: Psychological Science*, *62*, 239–246.

Broadbent, D. (1958). *Perception and Communication*. London: Pergamon Press.

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.

Deutsch, J., & Deutsch, D. (1963). Attention: Some theoretical considerations. *Psychological Review*, *70*, 80–90.

Elliott, D., Helsen, W. F., & Chua, R. (2001). A century later: Woodworth's (1899) two-component model of goal-directed aiming. *Psychological Bulletin, 127*, 342–357.

Faust, M. E., Balota, D. A., Spieler, D. H., & Ferraro, F. R. (1999). Individual differences in information-processing rate and amount: Implication for group differences in response latency. *Psychological Bulletin*, *125*, 777–799.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). 'Mini-mental state'. A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, *12*, 189.

Ganel, T., & Goodale, M. A. (2003). Visual control of action but not perception requires analytical processing of object shape, *Nature*, *426*, 664–667.

Georgiou-Karistianis, N., Tang, J., Vardy, Y., Sheppard, D., Evans, N., Wilson, M., Gardner, B., Farrow, M., & Bradshaw, J. (2007). Progressive age-related changes in the attentional blink paradigm. *Aging, Neuropsychology, and Cognition*, *14*, 213–226.

Glover, S. (2004). Separate visual representations in the planning and control faction. *Behavioral Brain Science*, *27*, 3–78.

Goodale, M. A., & Milner, A. D. (2004). Plans for action. *Behavioral Brain Science*, *27*, 3–78.

Hartley, A. A., Kieley, J. M., & Slabach, E. H. (1990). Age differences and similarities in the effects of cues and prompts. *Journal of Experimental Psychology: Human Perception and Performance*, *16*, 523–537.

Henry, F. M., & Rogers, D. E. (1960). Increased response latency for complicated movements and a 'memory drum' theory of neuromotor action. *Research Quarterly*, *31*, 448–458.

Jolicoeur, P. (1998). Modulation of the attentional blink by on-line response selection: Evidence from speeded and unspeeded Task1 decisions. *Memory & Cognition, 26*, 1014–1032.

Kunde, W., Landgraf, F., Paelecke, M., & Kiesel, A. (2007). Dorsal and ventral processing under dual-task conditions. *Research Report*, *18*, 100–104.

Lahar, C. J., Isaak, M. I., & McArthur, A. D. (2001). Age differences in the magnitude of attentional blink. *Aging Neuropsychology and Cognition*, *8*, 149–159.

Liu, G., Chua, R., & Enns, J. T. (2008). Attention for perception and action: Task interference for action planning, but not for online control. *Experimental Brain Research*, *185*, 709–717.

Maciokas, J. B., & Crognale, M. A. (2003). Cognitive and attentional change with age: Evidence from attentional blink deficits. *Experimental Aging Research*, *29*, 137–153.

Madden, D. J. (1990). Adult age differences in the time course of visual attention. *Journal of Gerontology: Psychological Sciences*, *45*, 9–16.

Mayr, U., & Liebscher, T. (2001). Is there an age deficit in the selection of mental sets? *European Journal of Cognitive Psychology*, *13*, 47–69.

Milner, A. D., & Goodale, M. A. (1995). *The visual brain in action*. Oxford, UK: Oxford University Press.

Milner, A. D., & Goodale, M. A. (2008). Two visual system re-viewed. *Neuropsychologia, 46*(*3*), 774–785.

Pashler, H. (1994). Dual-task interference in simple tasks: Data and theory. *Psychological Bulletin*, *116*, 220–244.

Pisella, L., Grea, H., Tilikete, C., Vighetto, A., Desmurget, M., Rode, G., Boisson, D., & Rossetti, Y. (2000). An 'automatic pilot' for the hand in human posterior parietal cortex: Toward reinterpreting optic ataxia. *Nature Neuroscience, 3*, 729–756.

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 and Performance*, *18,* 849–860.

Raz, N., Gunning-Dixon, F. M., Head, D., Dupius, J. H., & Acker, J. D. (1998). Neuroanatomical correlations of cognitive aging: Evidence from structural magnetic resonance imaging. *Neuropsychology*, *12*, 95–114.

Ridderinkhof, K. R., Span, M. M., & van der Molen, M. W. (2002). Perseverative behavior and adaptive control in older adults: Performance monitoring, rule induction, and set shifting. *Brain and Cognition*, *49*, 382–401.

Rossit, S., & Harvey, M. (2007). Aged-related differences in corrected and inhibited pointing movements. *Experimental Brain Research*, *10*, 1126–1136.

Salthouse, T. A. (1996). Th processing-speed theory of adult age differences in cognition. *Psychological Review*, *103*, 403–428.

Salthouse, T. A., Rogan, J. D., & Prill, K. A. (1984). Division of attention: Age differences on a visually presented memory task. *Memory & Cognition*, *12*, 613–620.

Sarlegna, F. R. (2006). Impairment of online control of reaching movements with aging: A double-step study. *Neuroscience Letter*, *403*, 309–314.

Schneider, W. X. (1995). VAM: A neurocognitive model for visual attention control of segmentation, object recognition, and space-based motor action. *Visual Cognition*, *2,* 331–375.

Singhal, A., Culham, J. C., Chinellato, E., & Goodale, M. A. (2007). Dual-task interference is greater in delayed grasping than in visually guided grasping. *Journal of Vision*, *7*, 1–12.

West, R. J. (1996). An application of prefrontal cortex function theory to cognitive aging. *Psychological Bulletin*, *120*, 272–292.

Westwood, D. A., & Goodale, M. A. (2003). Perceptual illusion and the real-time control of action. *Spatial Vision*, *16*, 243–254.

Zacks, R. T., Henderson, J. M., Mangum, R. S., & Hasher, L. (1994). *The attentional blink: Comparison of older and younger adults.* Poster presented at the 35th Annual Meeting of the Psychonomics Society, St. Louis, MO, November.