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The Effect of Action Video Game Play on the Distribution and Resolution of Visuospatial Attention

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THE EFFECT OF ACTION VIDEO GAME PLAY ON THE DISTRIBUTION AND RESOLUTION OF
VISUOSPATIAL ATTENTION

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By

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY <u>Andrew Thomas Fent</u> ENTITLED <u>The Effect of Action Video Game Play on the Distribution and Resolution of Visuospatial Attention</u> BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF <u>Master of Science</u>.

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ABSTRACT

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Previous research has found that Video Game Players, or VGPs, perform better on a variety of attention tasks (i.e. attentional blink, useful field of view, flanker compatibility, etc.) as compared to Non-Video Game Players, or NVGPs. We examined the extent of this previously observed VGP attentional advantage on a target identification task. Most VGP studies have examined the VGP advantage on tasks that primarily require detection but not identification. Identification is an important process beyond detection for encoding and later retrieving information. VGPs and NVGPs were tested on briefly flashed strings of digits subtending less than 10 degrees of visual angle. They were tasked with identifying a target among distractors. Some of the strings were visually crowded and others were spaced such that crowding was not present. Our results indicated that the previously observed VGP attentional advantages do not extend to an identification task. VGPs and NVGPs performed similarly on all conditions of number of digits and spacing. One previous study indicated that VGPs had a lower crowding threshold than NVGPs even at 0 degrees of visual angle. We did not find that this reduction in crowding threshold allowed for better performance on an identification task. Future research is needed to fully investigate whether VGPs are able to perform with better accuracy than NVGPs on identification or a similar task.

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I.   INTRODUCTION

In modern society, video game play is a ubiquitous activity among people under the age of forty. The pervasiveness of video games as a source of entertainment closely parallels the pervasiveness of technology use throughout the past forty years. Similar to technology, early video games had simple mechanics and basic graphical capabilities. Over the last twenty years, the fidelity of video game experiences has become richer leading to more engagement by gamers. At current, the psychological effects of extended video game play are the subject of much debate and academic research.

Gopher, Weil and Bareket (1994) documented one of the earliest studies examining the cognitive effects of video game play. The study examined *Space Fortress*, a game with a complex task presented with visually simple graphics. After 10 hours of training with the game, players showed significantly better performance on an indirectly related task than non-players. The results indicated a transfer of learning effect first posited by Thorndike and Woodworth (1901). If the effects of long-term action video game play result in better performance on real-world tasks, then long-term action video game play could be used as a training tool for tasks that have been identified as benefiting from transfer.

More recently, Green and Bevalier (2003) examined the effects of playing action video games on selective visual attention. The games included were *Grand Theft Auto 3 and Spider-Man*, third-person games involving combat, *Half-Life*, *Halo*, *Goldeneye 007*, and *Rogue Spear*, narrative driven first-person shooters, *Counter-Strike*, a competitive

team-based first-person shooter, *Team Fortress Classic*, a competitive team-based third-person shooter, *Marvel vs. Capcom*, a fighting game, *Crazy Taxi* and *Super Mario Kart*, racing games. The study included the first operational definitions of video game players, VGPs, and non-video game players, NVGPs. VGPs played action video games at least 4 days per week for a minimum of 1 hour per day over the last 6 months. NVGPs played little or no video games over the last 6 months.

Green and Bevalier (2003) found that VGPs performed significantly better on a variety of selective visual attention tasks including enumeration, useful field of view, and attentional blink. Each task tested a different aspect of selective visual attention. Enumeration examined the video-game playing zone (0° to 5° from fixation); useful-field-of-view examined the peripheral zone (10° to 30° from fixation); and attentional blink examined the temporal characteristics of selective visual attention. The enumeration task involved a briefly flashed display of squares. Participants were asked to report the number of squares present. Subitizing provides a brief glimpse of the numerosity of a small number of targets, 6 or less, that is rapid, accurate and independent of number (Kaufman, Lord, Reese & Volkman, 1949). VGPs were able to subitize significantly more items than NVGPs on the enumeration task. The useful-field-of-view task involved target recognition at three visual eccentricities (10°, 20°, and 30°). The stimulus had a central fixation box. Extending from the central box were 3 boxes, one at each eccentricity, along 8 equally spaced directions away from central box. Each location was a possible target location. VGPs performed significantly better than NVGPs at each

eccentricity. The attentional blink task involved rapidly presented black letters at a

fixation point followed by a target white letter. Then, a second series of rapidly

presented black letters with an 'X' presented 50% of the time. Participants had to

indicate whether an 'X' was present after target presentation. Participant accuracy of

detecting the 'X' was measured as a function of the number of intervening letters

presented before the 'X'. VGPs performed significantly better than NVGPs if the 'X'

was presented in the first 5 letters after the target and as early as the first letter. The

results indicate that VGPs were able to switch tasks more effectively, indicated by their

better performance at the first post-target letter, and reduce attentional blink.

In addition to the results discussed above, Green and Bevalier (2003) compared

VGPs and NVGPs on a flanker compatibility task with increasing difficulty. The flanker

compatibility task presents 6 potential target locations around a fixation point. Difficulty

increases as more distractors are placed in the possible target locations. In addition,

outside of the 6 potential target locations, there is another distractor. This distractor is

classified as either compatible, sharing characteristics of the target or exactly the same as

the target, or incompatible, sharing little or no characteristics with the target, such as a

diamond shape and a square shape. Results showed that VGPs RTs were larger in a trial

with a compatible peripheral distractor, compared to incompatible trials, even in the

hardest condition, when all potential target locations contained distractors. Lavie and

Cox (1997) identified this phenomenon as the compatibility effect. The explanation for

this effect is that VGPs do not exhaust their attentional resources, even in the hardest

condition, compared to NVGPs. VGPs are able to stretch their attention over more possible target locations than NVGPs. This result indicates potentially a capacitive increase or a strategic difference in VGPs.

After uncovering these results, Green and Bevalier (2003) examined the possibility that VGPs better performance on various attention tasks was due to self-selection. That is, VGPs choose to play games because they are inherently better at playing games than NVGPs. In order to rule out a self-selection bias, a group of NVGPs trained on an action video game, *Medal of Honor*, for one hour per day for 10 consecutive days. The training resulted in significantly better performance, measured before and after training, for the NVGP group on the useful-field-of-view, enumeration, and attentional blink tasks. The training was sufficient to improve performance on the selective visual attention tasks and eliminated the potential confound of self-selection bias. The training paradigm has been used repeatedly in VGP studies to further support the exclusion of self-selection bias as a confounding factor. However, Boot, Kramer, Simons, Fabiani and Gratton (2008) found that training of non-gamers did not show improved performance on object tracking, detection of changes to objects stored in short-term memory, or task-switching. This finding implies that training to improve performance may be limited to stimulus-driven attention tasks and not top-down, cognitive tasks.

Following the findings of Green and Bevalier (2003), a body of research arose examining both stimulus-driven and top-down, cognitive attentional advantages of VGPs

compared to NVGPs. Each area of study contributes to the documented advantages of VGPs and provides insight when predicting how VGPs compare to NVGPs on a novel or unexplored task.

Task-switching is the ability to disengage from the current task and engage a subsequent task. In traditional task-switching experiments, participants engage in interleaving sets of tasks that must be performed alternatively or in repetition. A switch cost, a reduction in completion time and reduced accuracy, occurs when tasks are performed alternatively, that is switching to task B after performing task A, as opposed to repeatedly, that is performing task A after task A. Task-switching is typically used as a measure of cognitive flexibility and executive control. Cain, Landau and Shimamura (2012) found that VGPs had smaller and more symmetric switch costs than NVGPs while alternately performing a familiar task, responding in the same direction as a presented arrow, and a novel task, responding in the opposite direction of a presented arrow. In addition, Strobach, Frensch and Schubert (2012) found that VGPs performed better than NVGPs on task-switching and dual-task paradigms, but only when two different tasks were performed simultaneously or sequentially. The advantage was not present in a single-task condition. However, this observed advantage of VGPs does not generalize across all task-switching paradigms. Karle, Watter and Shedden (2010) tested the effect of trial-to-trial interference on the VGP task-switching advantage. The advantage normally observed disappeared as the interference between trials increased. This suggests that the task-switching advantage of VGPs may be due to control of selective

attention. Rapid trial-to-trial times require quick disengagement of the current task followed by quick engagement of the proceeding task. As the trial times increase, the need to rapidly disengage and subsequently engage becomes unnecessary and the advantage displayed by VGPs is lost.

In addition to potential cognitive attentional advantages expressed by VGPs, there is evidence that VGPs have exogenous (or stimulus-driven) attentional advantages as a result of improved control. Cain, Prinzmetal, Shimamura and Landau (2014) used an anti-cueing task, in which an onset cue indicated that a target would likely appear on the opposite side of the presented cue. When the onset asynchrony between cue and target was short, NVGPs were faster at recognizing targets at the less likely cued location compared to the more likely anti-cued location. Apparently, VGPs were less likely to draw their attention to the cue meaning their attention was free to monitor the less likely cued location and the more likely anti-cued location. However, when the onset asynchrony was long, both VGPs and NVGPs were able to successfully attend to the more likely anti-cued location. VGPs were able to more flexibly control their exogenous attention in the more attention demanding condition than NVGPs, but once that control was unnecessary the advantage was lost. This suggests that processing speed cannot account for the difference in performance in the quick onset asynchrony condition.

Visual short-term memory, or VSTM, is the ability to maintain relevant visual information in the absence of visual input, and is important for solving problems, learning new skills, and acquiring new knowledge (Baddeley, 1986). VSTM has

naturally limited capacity; therefore, people develop strategies to overcome this natural limitation as evidenced by the 'subitizing' behavior used in the enumeration task discussed earlier (Green & Bevalier, 2003). The change detection paradigm is another useful method for testing the capacity of VSTM. Blacker and Curby (2013) used a change detection task that involved presentation of a screen with 2, 4, or 6 colored squares for either a short (168 ms) or long (1018 ms) presentation time, followed by a 900 ms blank fixation screen, then a 3000 ms test screen that had no changes 50% of the time or the color of one square changed 50% of the time. Half of the trials presented a test screen with one different colored square. VGPs were significantly more accurate than NVGPs in the most challenging condition, 6 squares, regardless of encoding time duration, 168 ms or 1018 ms. The VGP advantage was present even at the long encode time (1018 ms) when NVGPs had ample time to encode the array which indicates that the advantage is not due to speed of processing but instead due to an advantage of VSTM processing. As a follow up, the authors used the same experimental procedure with complex shapes instead of colored squares. Complex shapes were used to test whether the prior experiment was not perceptually challenging enough to reveal encoding effects. In the second experiment, overall performance was worse than the first experiment; however, VGPs were significantly more accurate than NVGPs in the most challenging condition, 4 complex shapes, regardless of encoding duration, 168 ms or 1018 ms. This result confirmed the previous finding that the VGP advantage was not due to a speed of

processing advantage. Further, the VSTM processing advantage was not lost when the perceptual complexity was increased.

Visual crowding occurs when the distance between two objects decreases to the point that identifying the target object is impaired by an adjacent non-target object, or distractor. Identification is impaired due to the jumbling of target characteristics at the target location caused by the proximal distractor (Whitney & Levi, 2011; Balas, Nakano & Rosenholtz, 2009), but only to a point. If enough distractors are present, then the distractors become a texture and the target's identification is not impaired (Whitney & Levi, 2011; Balas et al. 2009). However, before this "texture" threshold is reached, performance for identifying a target decreases as the number of distractors increases and as the distance from distractors to the target object decreases. (Leat, Li & Epp, 1999; Miller, 1991). Bouma (1970) stated that the critical spacing for visual crowding was proportional to the target eccentricity. For a target, in his case a letter, located at an eccentricity of 0°, another target, or letter, should not be placed within approximately 0.5^o in order to achieve visual isolation for the target. This generalized to other eccentricities such that crowding occurs if distractors are closer to the target than one half the eccentricity of the target. This critical crowding region established a crowding threshold; that is the distance that a distractor can be placed from a target without impairing the spatial resolution of an observer. Green and Bevalier (2007) tested the crowding threshold of VGPs compared to NVGPs. Participants fixated a cued spot and were

presented three 'T' shapes aligned vertically to the right of fixation. The 'T' shapes were oriented either right side up or upside down (See Figure 1).
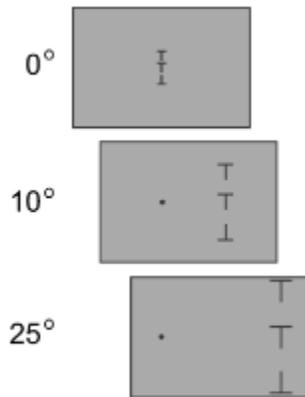
Figure 1. Green and Bevalier (2007). Three 'T' objects were presented either right side up or upside down. The task was to identify the orientation of the middle 'T'.

The task was to determine the orientation of the center 'T'. Stimuli were presented at three eccentricities (0°, 10°, and 25°) with each eccentricity viewed at three different distances (300 cm, 90 cm, and 50 cm, respectively). The 'T' stimuli were scaled with eccentricity to account for reduction in acuity. The center-to-center spacing of the 'T' shapes varied by participant based on T-alone discriminations obtained for each participant. The T-alone discriminations were used in order to set the size of the stimulus 'T's to 1.5 times each participant's T-alone threshold. Thresholds were obtained by averaging two blocks of performance of the T-alone condition. VGPs demonstrated smaller crowding thresholds than NVGPs across all three eccentricities. Further, VGP status did not interact with eccentricity suggesting that VGP status was consistent across eccentricities. In addition, VGPs were able to discriminate smaller 'T' shapes in the T-

alone condition, which was used to measure individual participant detection thresholds, at each eccentricity. These results suggest that VGPs have lower crowding thresholds and better visual acuity. This is further evidenced by the improved VGP performance at 0° eccentricity, or foveal vision, which is generally considered to be optimal.

Throughout the previously discussed findings, VGPs are defined as playing action video games between 1-5 hours a week for the previous 6-month period. The defining visual tasks of an action video game are: 1) detect new enemies; 2) track existing enemies; 3) avoid getting damaged; and 4) update those visual tasks while navigating a three-dimensional environment. Action video games require players to update visual tasks and simultaneously engage the sensory-motor system to effectively navigate. First-Person Shooter, or FPS, is a subgenre of action games in which the player experiences the environment through the eyes of the protagonist and predominantly uses guns or other weapons to interact with enemy avatars and the environment. Recent evidence suggests that FPS games provide a visually rich environment requiring precise navigation in an effective and efficient manner which separates them as a special genre compared to the more generic classification of action game (Colzato, van Leeuwen, van den Wildenberg & Hommel, 2010; Wu & Spence, 2013; Dobrowolski, Hanusz, Sobczyk, Skorko & Wiatrow, 2015).

Gamer studies to date have focused on tasks which require various types of detection in order to test the limits and characteristics of gamer attention. However, detection is a lower level process that does not facilitate memory storage or learning. To

those ends, identification is a critical process. Based on previous findings, gamers have an advantage in attention allocation and are able to reduce the impairing effects of visual crowding. Therefore, gamers are a prime population for investigating a potential advantage in target identification within a challenging visual stimulus. In a recent study, Watamaniuk and Heinen (2015) used a set of stimuli adapted from Lovejoy, Fowler and Krauzlis (2009) in which an alphanumeric target must be identified within a visually crowded array (subtending less than 10° of visual angle) with a quick presentation time (200 ms). Many studies require gamers to recognize targets outside of the 10° range despite the fact that 0°-5° is the training window, especially for FPS games, as that is the region with the most focus. This is due to the presence of the crosshair which is the region of interaction for FPS games. The stimulus and testing procedure used by Watamaniuk and Heinen (2015) presents a good test for a gamer identification advantage. We predict that gamers, who play predominantly FPS games, will perform better than non-gamers on the character identification task with the visually crowded stimulus.

II. METHOD

PARTICIPANTS

Twenty men with normal or corrected to normal vision, classified as either a VGP or NVGP, participated in the study. VGPs were recruited with a flyer placed at various locations on the campus of Wright State University. The flyer exclusively recruited participants who currently played first-person shooter games for 5-10 hours a week and had done so for the last 6 months. First-person shooter games were selected as the criterion due to their inclusion of fast action, vigilant screen monitoring, and multiple object tracking as activities necessary for playing these games well. VGPs contacted the PI via email. The PI asked follow up questions regarding specific games played and amount of time spent playing weekly. NVGPs were recruited based on self-reporting of not playing first-person shooter games. Only men responded to the VGP flyer recruitment, therefore only men were tested in the NVGP condition in order to match groups on this characteristic. Previous studies also used all male groups due to lack of availability of female VGPs.

Ten VGPs, with a mean age of 22.2 years (range of 18-34 years), self-reported playing Call of Duty, Halo, and Counterstrike for the required 5-10 hours a week for the last 6 months with most reporting more play time over that period. They also reported first-person shooters as their primary gaming over that period. Ten NVGPs, with a mean age of 26.9 years (range of 22-52 years), self-reported playing no first-person shooter games for the last 6 months.

Participants were compensated $15/hour and provided informed consent prior to testing. All testing occurred on campus at Wright State University.

STIMULI

All stimuli were adapted from Watamaniuk and Heinen (2015). Stimuli were presented on a 23-in. Samsung SA750 LED monitor with a 100Hz refresh rate. Participants viewed the display from a distance of 57 cm with their head stabilized with a chin/forehead rest with the overhead lighting on. Stimuli were a set of white alpha numeric characters (luminance = 17.5 cd/m^2) arranged either in a '+' configuration (5 & 9 characters) or in a horizontal array (15 characters) on a dark background (luminance = 50 cd/m^2). The characters were 0.28^o x 0.5^o in size, with a stroke width of 0.05^o. The character's center-to-center spacing was 0.6^o in the 15-character array and varied between 0.6^o, 2.0^o and 4.0^o for the 5 and 9 character stimuli (See Figure 2). Table 1 shows the extent of the stimuli for each spacing.
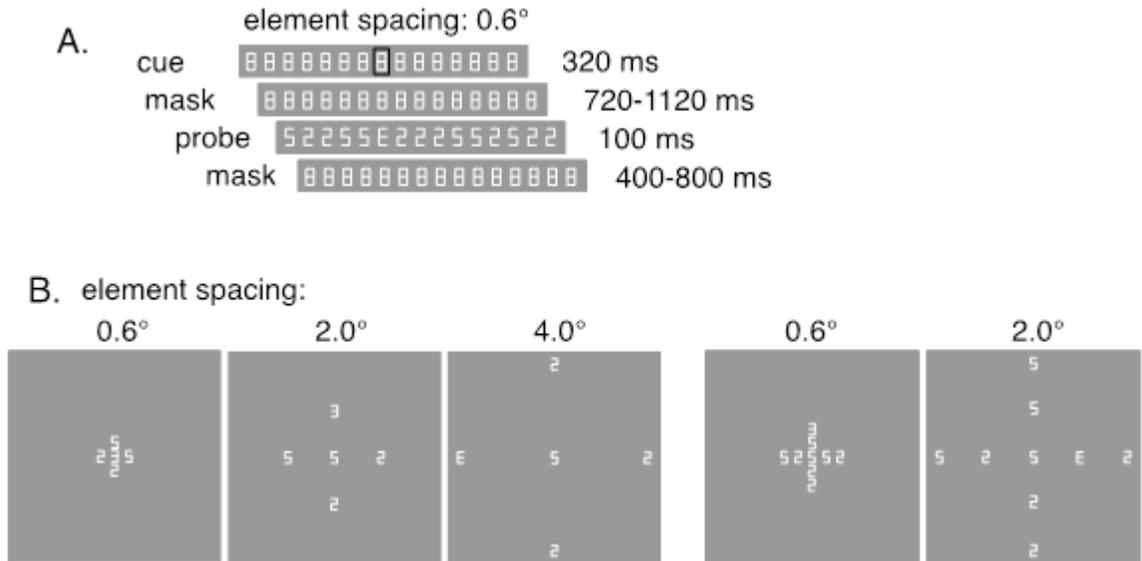
Figure 2. Watamaniuk and Heinen (2015). A, Stimuli timeline without fixation time. B, Item spacing for the characters in the 5 and 9 character stimuli. Item size and spacing are shown to scale. Adapted from Watamaniuk and Heinen (2015).

Table 1. Character spacing for each set # of characters

	Character Spacing		
# of Characters	0.6°	2.0°	4.0°
5	1.48	4.28	8.28
9	2.68	8.28	-
15	8.68	-	-

PROCEDURE

Participants entered the lab and gave their informed consent prior to the first experimental session. Then, participants adjusted the seat and headrest to accommodate comfort. Participants were then calibrated on the Eyelink 1000 eye tracking system. No eye movement data was collected. The eye tracker was used to monitor participant's eye movement behavior during training and testing trials to ensure that they were maintaining gaze on the central spot during fixation and target presentation. If participants failed to

maintain fixation, then they were instructed to maintain fixation and to not perform eye movements during trials. All participants were able to maintain stable fixation.

Participants were then given instructions for an acuity check. The acuity check was done with the 15-character condition with only the central digit and the target present. For each acuity trial, only the center digit was present during cueing. The center digit was cued by a black box around the perimeter of the digit for 320 ms. Then, the target mask appeared at one of the 14 other possible locations. If a second target digit did not appear, then the center digit was the target. Participants were instructed to fixate on the cued central digit but their attention was free to observe the other digit. The first block was 96 trials and the target was presented for 200 ms to match Watamaniuk and Heinen (2015) and to provide practice viewing and judging briefly presented stimuli that do not allow for reactive eye movements. Performance for the 200 ms acuity test is summarized below (See Figure 3). Anyone performing at less than 85% overall performance or less than 50% performance at any individual location on the acuity test would have been excused from the experiment. None of our participants were excused. The second block was 96 trials and the target was presented for 100 ms to match the current experimental conditions. Performance did decline in the second block indicating that the task was more challenging (See Figure 4).
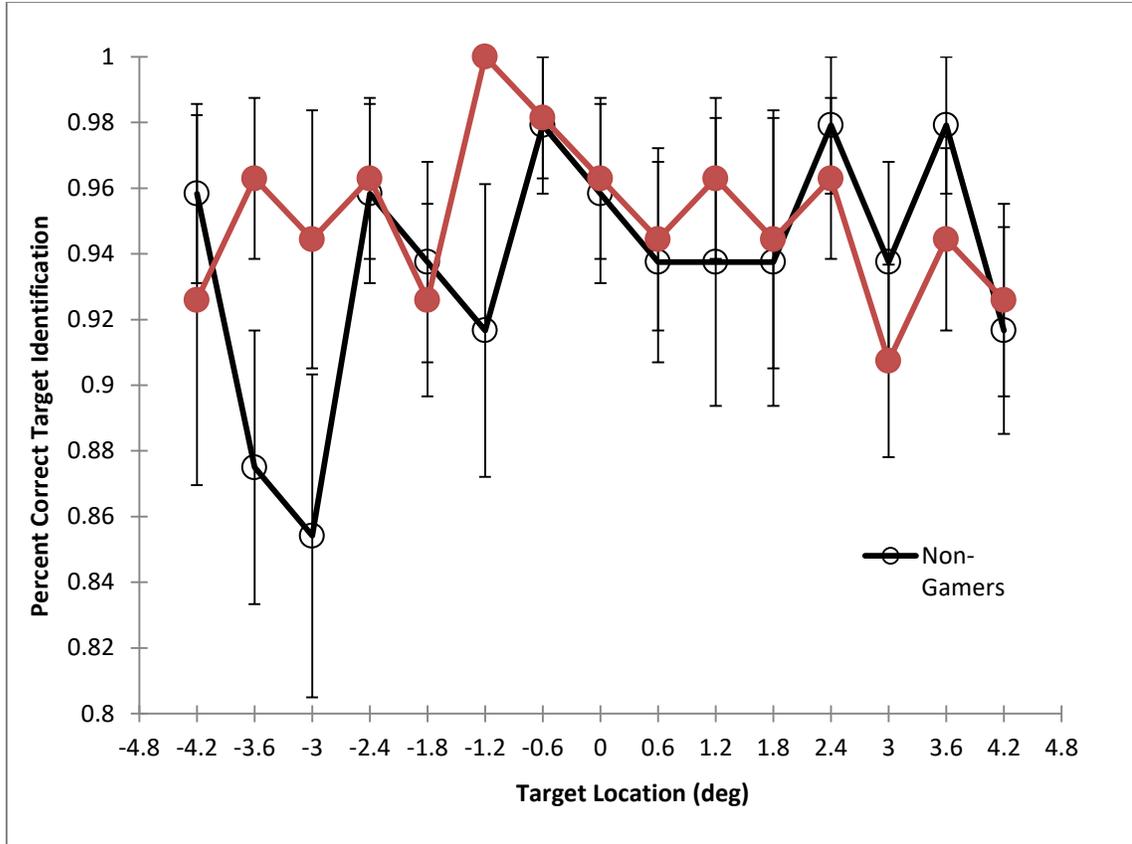
Figure 3. 200 ms acuity test results. Targets were presented in isolation 6 times at each location of the 15-charcter stimulus.
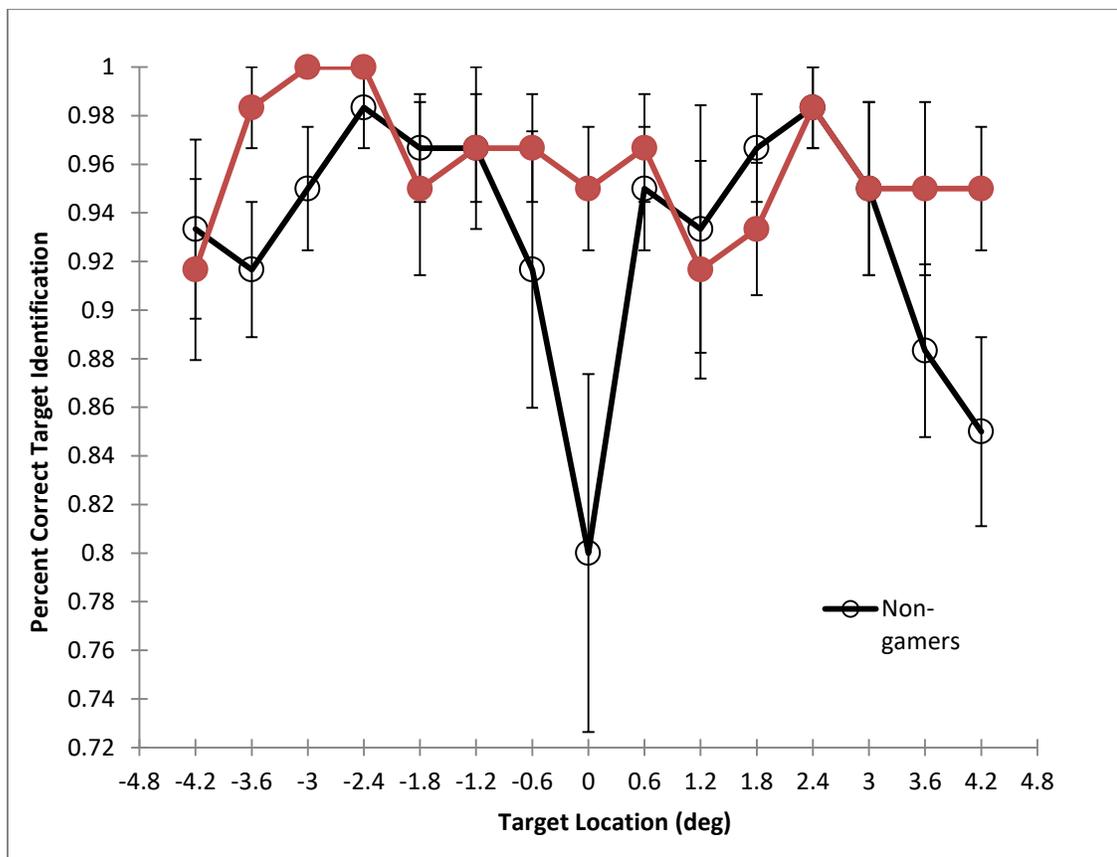
Figure 4. 100 ms acuity test results. Targets were presented in isolation 6 times at each location of the 15-charcter stimulus.

Following the acuity blocks, participants completed a practice block of trials for the 9-characters with a 2.0^o spacing condition, because that configuration provided the largest extent of the screen covered by the '+' configuration which extended both horizontally and vertically. The procedure for the practice block matched the testing blocks which is explained below.

In all testing and practice blocks, participants were cued to fixate at the center of the array containing all '8' characters. The cue was a black box surrounding the central digit for 320 ms. Then, after the cue was removed and after a random fixation time

interval, ranging from 720-1120 ms, the array changed for 100 ms to all '5' and '2'

characters except for one target character, which was a '3' or 'E', and then all returned to

'8's, as a mask, for 400-800 ms (See Figure 1). The task was to identify the target as

either a '3' or an 'E'. After each trial, a blank screen remained until the participant

responded with '3' or 'E' on the keyboard. The target appeared equally at all possible

locations. Accuracy was measured at each of the possible target locations. Participants

were told to fixate on the central digit, but their attention was free to observe the other

digits. Participants were told that an eye movement would impair their ability to do the

task. Further, participant's eye movements were monitored to ensure compliance.

Testing was done over 10 blocks. Each block of the 5 character stimulus had 150

trials with the target appearing 30 times at each possible location (1 block/observer for 30

trials/location). Each block of the 9 character stimulus had 144 trials with the target

appearing 16 times at each possible location (2 blocks/observer for 32 trials/location).

Each block of the 15 character stimulus had 150 trials with the target appearing 10 times

at each possible location (3 blocks/observer for 30 trials/location). Participants were

tested on the 10 blocks listed below (See Table 2).

Table 2. Number of testing blocks for each character spacing and set # of characters

# of Characters	Character Spacing		
	0.6°	2.0°	4.0°
5	1	1	1
9	2	2	-
15	3	-	-

The testing order for the 10 blocks was randomly generated by giving each block a number 1-10. Then, a 10 digit string containing each number once was generated by using 'Sequence Generator' on www.random.org. Twenty of these 10 digit strings were generated and listed as the testing order for each participant.

Testing took place over 2 sessions each lasting approximately an hour and a half. In the first session, participants completed the two acuity blocks, the practice block, and four test blocks. In the second session, participants completed the remaining six test blocks. After successfully completing all test blocks, participants were paid for their participation.

III.   RESULTS

For each condition, we used a 2-way mixed ANOVA; with VGP status (either VGP or NVGP) as a between subjects factor and the number of possible target locations along the array (5, 9, or 15) as a within subjects factor. For the 9-character and 5-character conditions, a separate ANOVA was used to analyze the vertical and horizontal dimensions separately for each spacing distance. This was done to investigate the possibility of different performance along each dimension.

The 15-character condition had a center-to-center spacing of 0.6^{o} and presented a visually crowded array subtending 8.68^{o}. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 15 (target location) mixed ANOVA (See Figure 5). A main effect for VGP status was not observed, $F(1, 18) = 0.017$, $p = 0.899$. A main effect for target location was observed, $F(14, 252) = 8.951$, $p < 0.001$. An interaction between VGP status and target location was not observed, $F(14, 252) = 0.561$, $p = 0.893$.
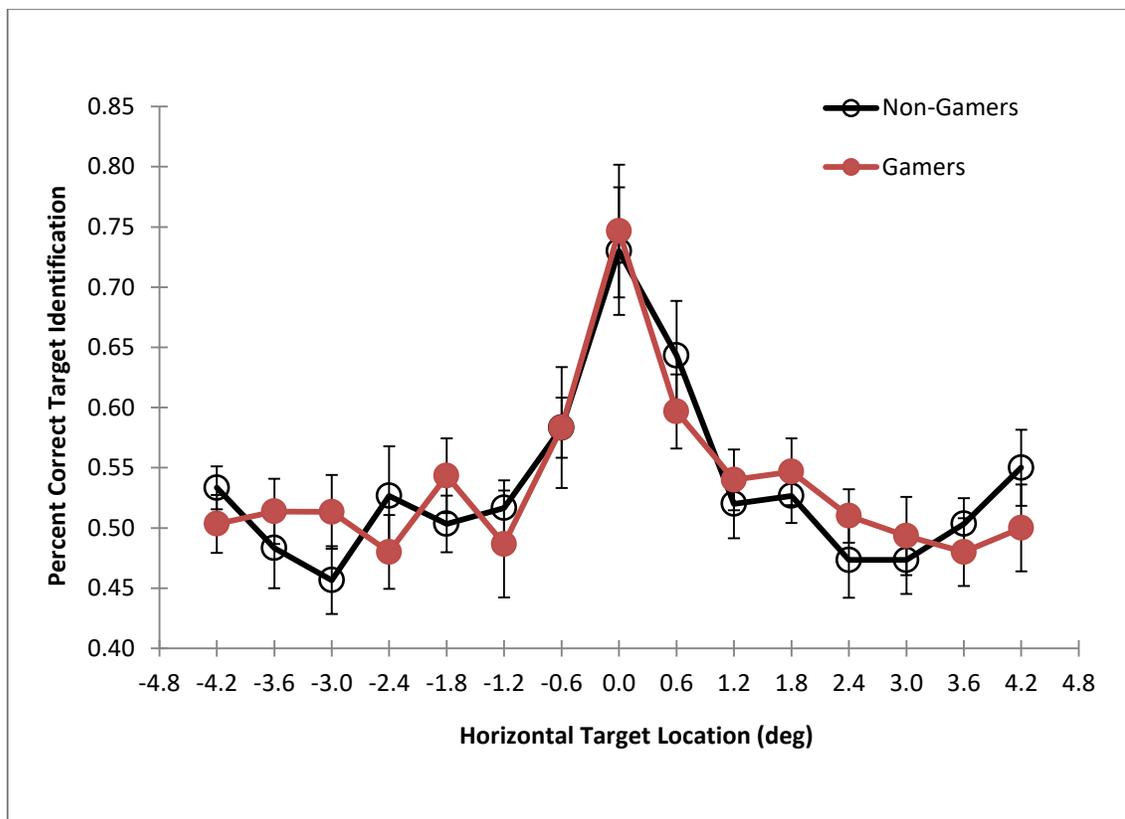
Figure 5. Percent correct target identification for 15-character 0.6^o spacing are presented as a function of target location; negative numbers indicate targets left of center.

The horizontal array of the 9-character condition with a center-to-center spacing of 0.6^o presented a visually crowded stimulus subtending 2.68^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 5 (target position) mixed ANOVA (See Figure 6). A main effect for VGP status was not observed, $F(1, 18) = 0.774$, $p = 0.391$. A main effect for target location was observed, $F(4, 72) = 10.661$, $p < 0.001$. An interaction between VGP status and target location was not observed, $F(4, 72) = 0.484$, $p = 0.747$.
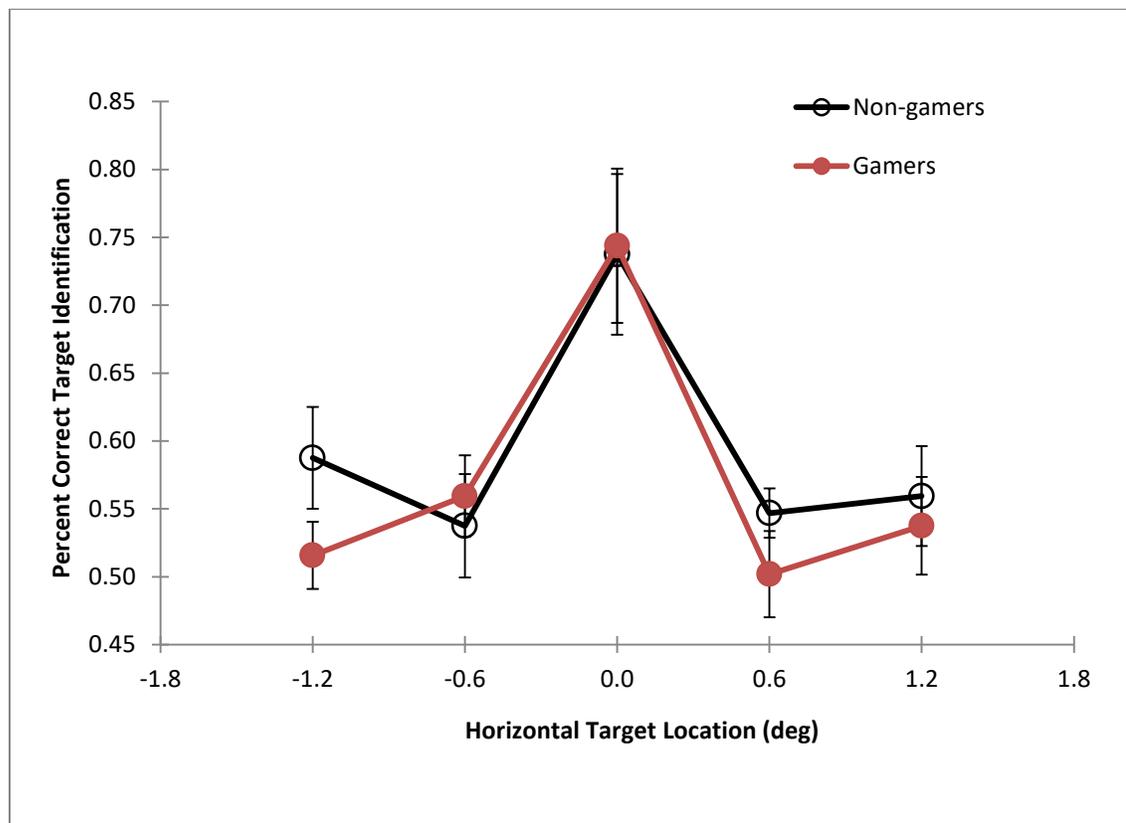

Figure 6. Percent correct target identification for 9-character horizontal 0.6^o spacing are presented as a function of target location; negative numbers indicate targets left of center.

The vertical array of the 9-character condition with a center-to-center spacing of 0.6^o presented a visually crowded stimulus subtending 2.68^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 5 (target location) mixed ANOVA (See Figure 7). A main effect for VGP status was not observed, $F(1, 18)$ = 0.425, p = 0.523. A main effect for target location was observed, $F(4, 72)$ = 13.227, p < 0.001. An interaction between VGP status and target location was not observed, $F(4, 72)$ = 0.306, p = 0.873.
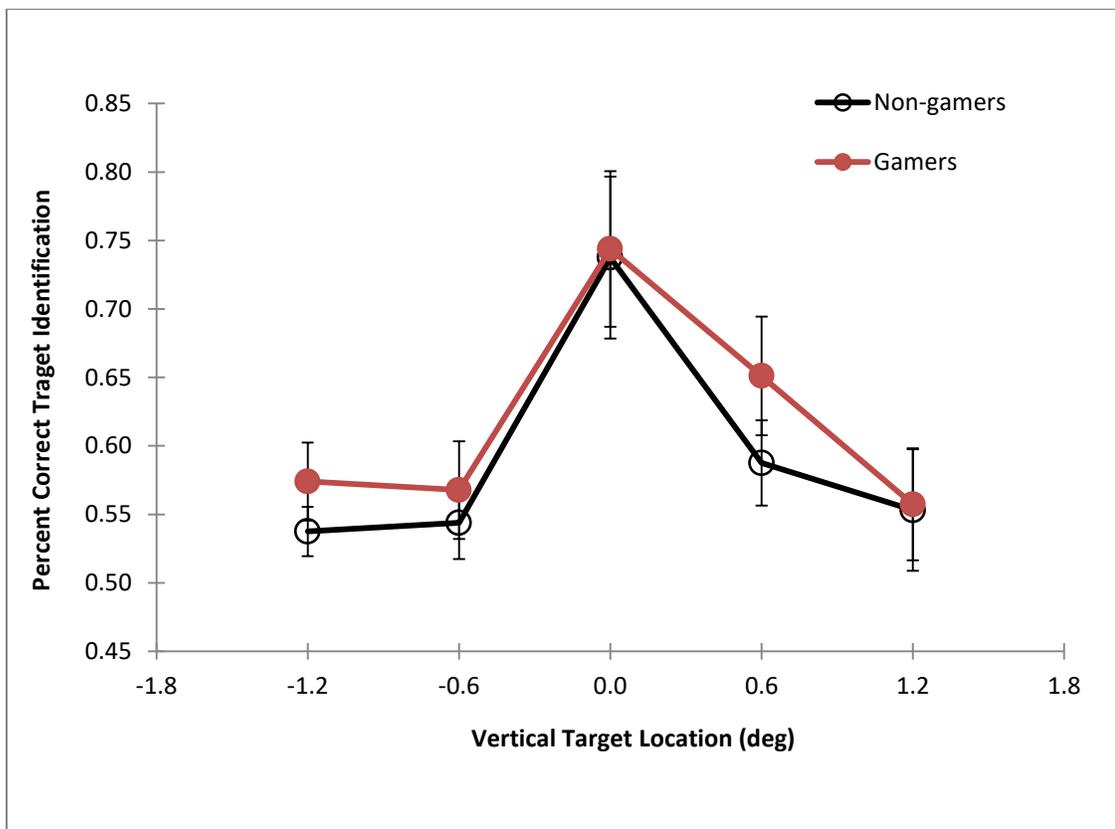

Figure 7. Percent correct target identification for 9-character vertical 0.6^o spacing are presented as a function of target location; negative numbers indicate targets below center.

The horizontal array of the 9-character condition with a center-to-center spacing of 2.0^{o} presented a stimulus subtending 8.28^{o}. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 5 (target location) mixed ANOVA (See Figure 8). A main effect for VGP status was not observed, $F(1, 18) = 0.072$, $p = 0.791$. A main effect for target location was observed, $F(4, 36) = 28.481$, $p < 0.001$. An interaction between VGP status and target location was not observed, $F(4, 36) = 1.264$, $p = 0.292$.
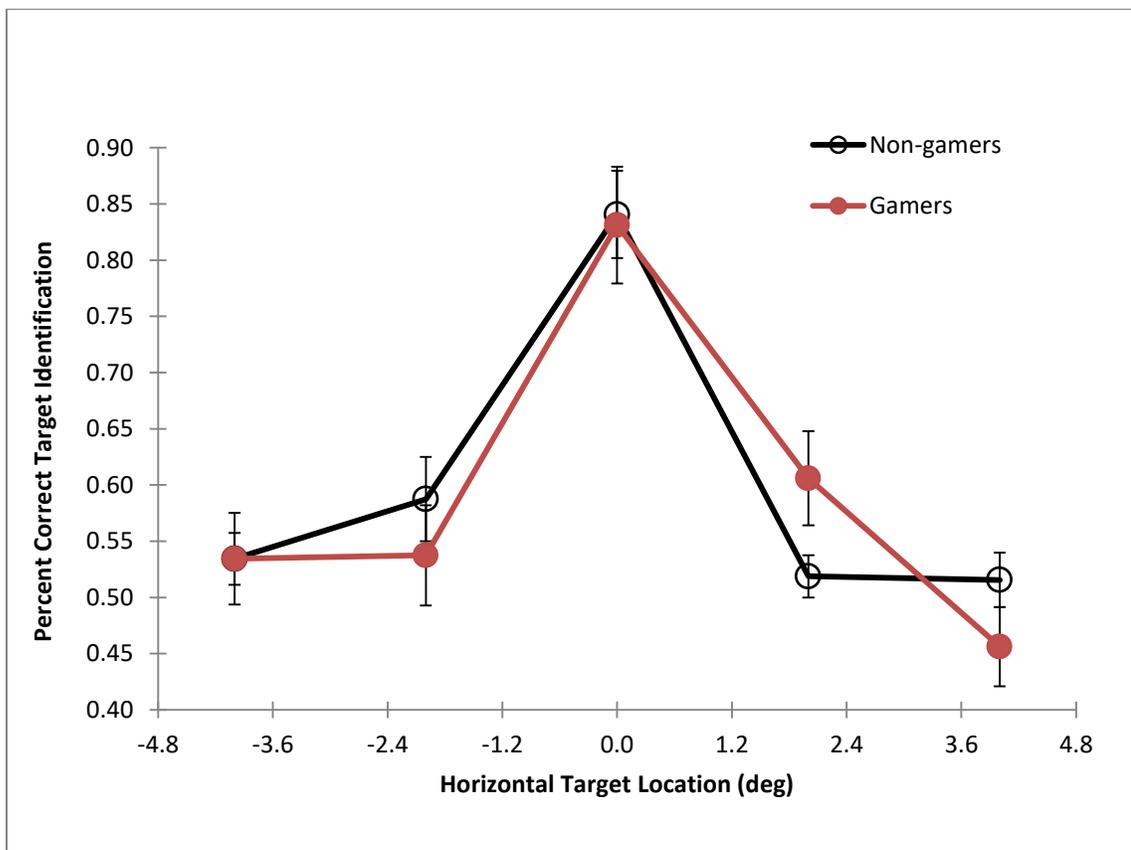

Figure 8. Percent correct target identification for 9-character horizontal 2.0^{o} spacing are presented as a function of target location; negative numbers indicate targets left of center.

The vertical array of the 9-character condition with a center-to-center spacing of 2.0^o presented a stimulus subtending 8.28^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 5 (target location) mixed ANOVA (See Figure 9). A main effect for VGP status was not observed, $F(1, 18) = 0.842$, $p = 0.371$. A main effect for target location was observed, $F(4, 72) = 32.251$, $p < 0.001$. An interaction between VGP status and target location was not observed, $F(4, 72) = 0.191$, $p = 0.942$.
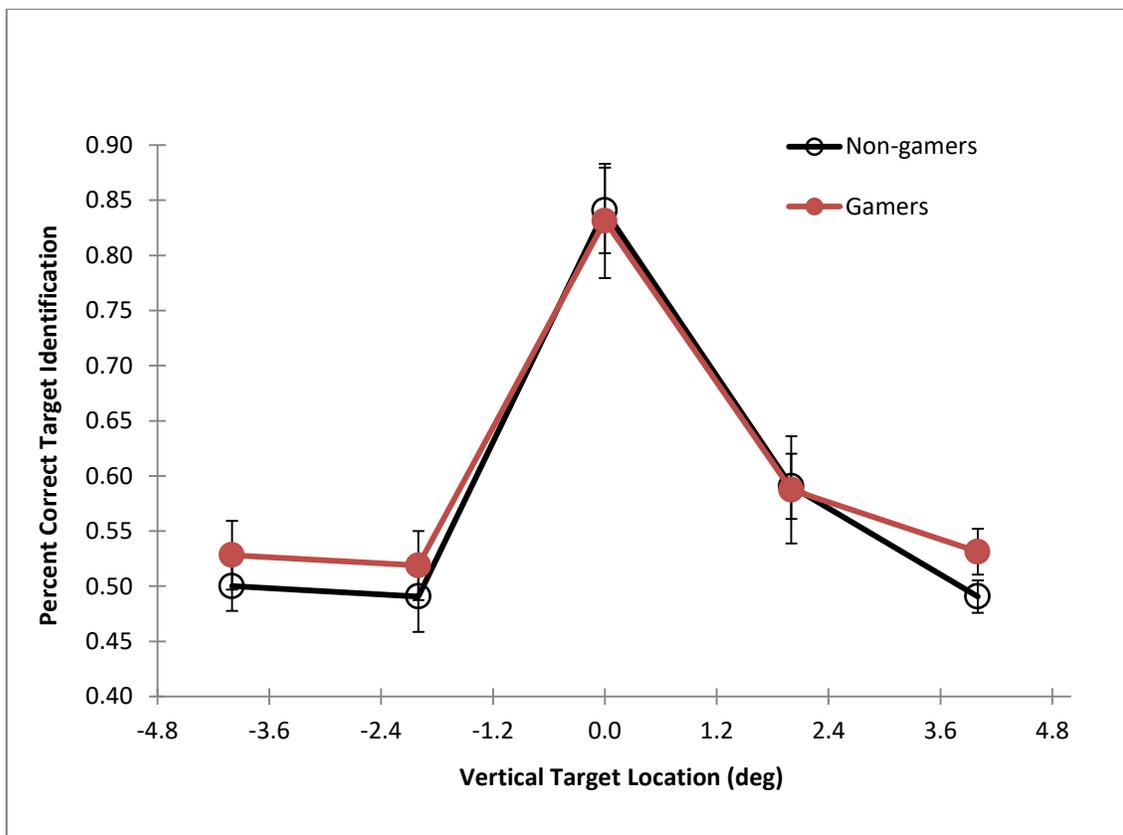

Figure 9. Percent correct target identification for 9-character vertical 2.0^o spacing are presented as a function of target location; negative numbers indicate targets below center.

The horizontal array of the 5-character condition with a center-to-center spacing of 0.6^o presented a visually crowded stimulus subtending 1.48^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 3 (target location) mixed ANOVA (See Figure 10). A main effect for VGP status was not observed, $F(1, 18) = 0.232$, $p = 0.636$. A main effect for target location was not observed, $F(2, 36) = 4.207$, $p = 0.228$. An interaction between VGP status and target location was not observed, $F(2, 36) = 1.206$, $p = 0.311$.
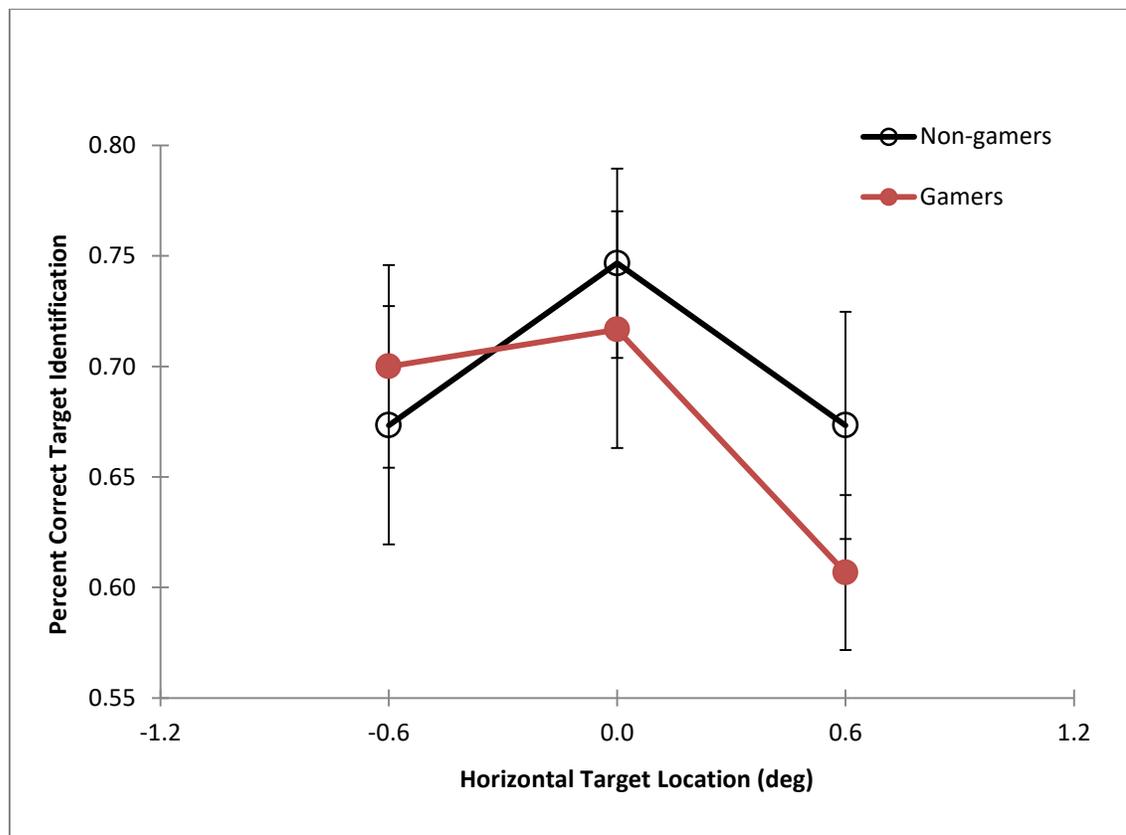

Figure 10. Percent correct target identification for 5-character horizontal 0.6^o spacing are presented as a function of target location; negative numbers indicate targets left of center.

The vertical array of the 5-character condition with a center-to-center spacing of 0.6^o presented a visually crowded stimulus subtending 1.48^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 3 (target location) mixed ANOVA (See Figure 11). A main effect for VGP status was not observed, $F(1, 18) = 0.087$, $p = 0.771$. A main effect for target location was not observed, $F(2, 36) = 0.974$, $p = 0.387$. An interaction between VGP status and target location was not observed, $F(2, 36) = 1.177$, $p = 0.320$.
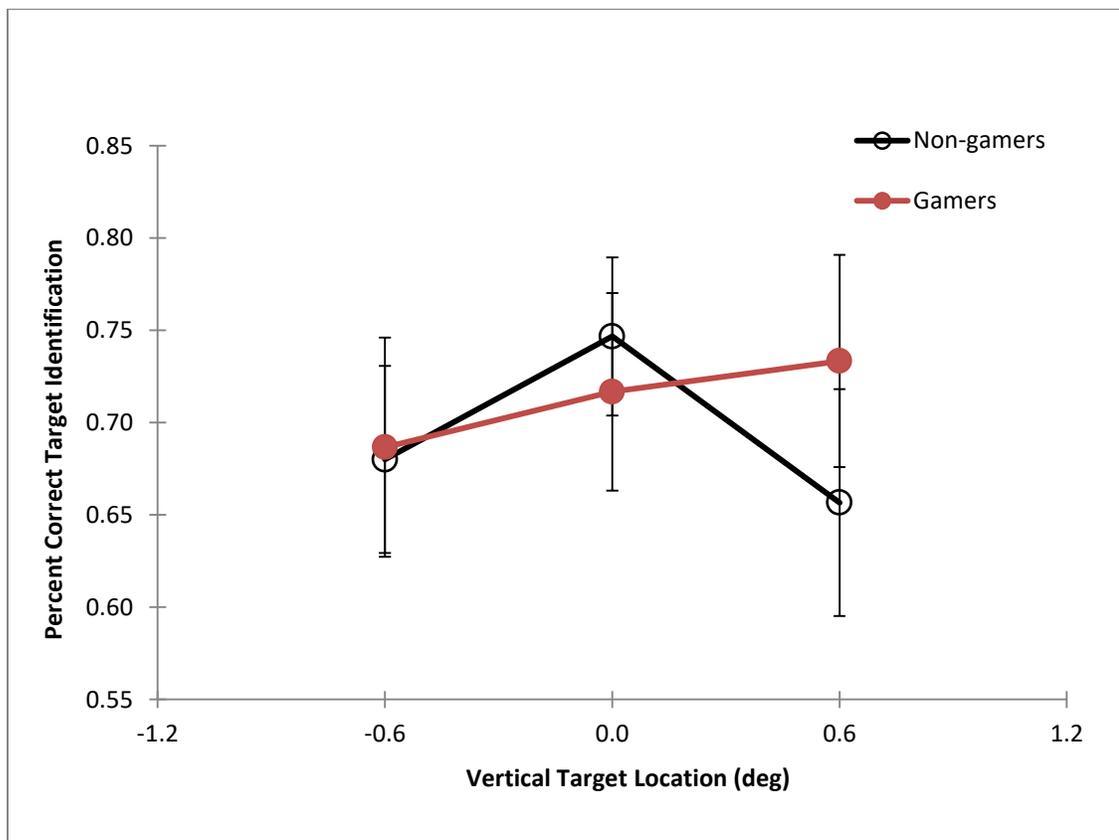

Figure 11. Percent correct target identification for 5-character vertical 0.6^o spacing are presented as a function of target location; negative numbers indicate targets below center.

The horizontal array of the 5-character condition with a center-to-center spacing of 2.0^o presented a stimulus subtending 4.28^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 3 (target location) mixed ANOVA (See Figure 12). A main effect for VGP status was not observed, $F(1, 18) = 3.273$, $p = 0.087$. A main effect for target location was observed, $F(2, 36) = 15.033$, $p < 0.001$. An interaction between VGP status and target location was not observed, $F(2, 36) = 0.237$, $p = 0.790$.

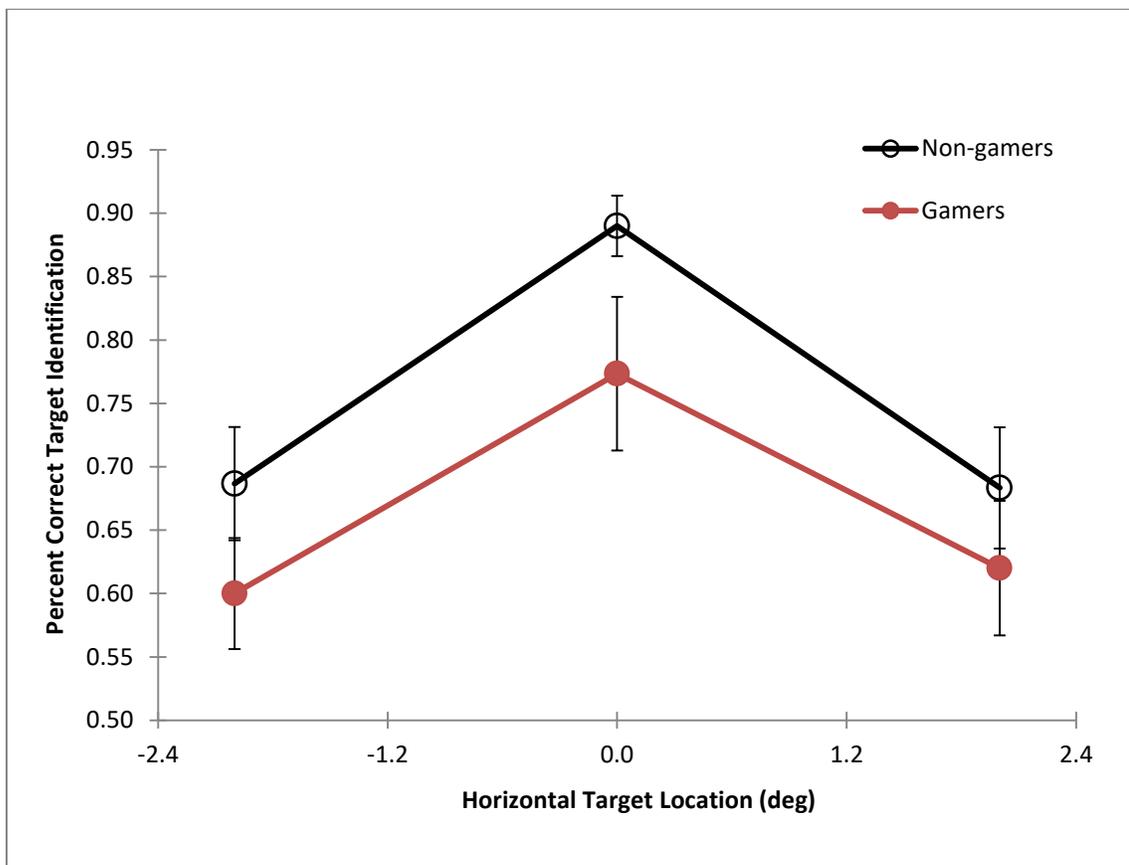*Figure 12*. Percent correct target identification for 5-character horizontal 2.0^o spacing are presented as a function of target location; negative numbers indicate targets left of center.

The vertical array of the 5-character condition with a center-to-center spacing of 2.0^o presented a stimulus subtending 4.28^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 3 (target location) mixed ANOVA (See Figure 13). A main effect for VGP status was not observed, $F(1, 18) = 0.038$, $p = 0.847$. A main effect for target location was observed, $F(2, 36) = 20.404$, $p < 0.001$. An interaction between VGP status and target location was not observed, $F(2, 36) = 3.352$, $p = 0.046$.
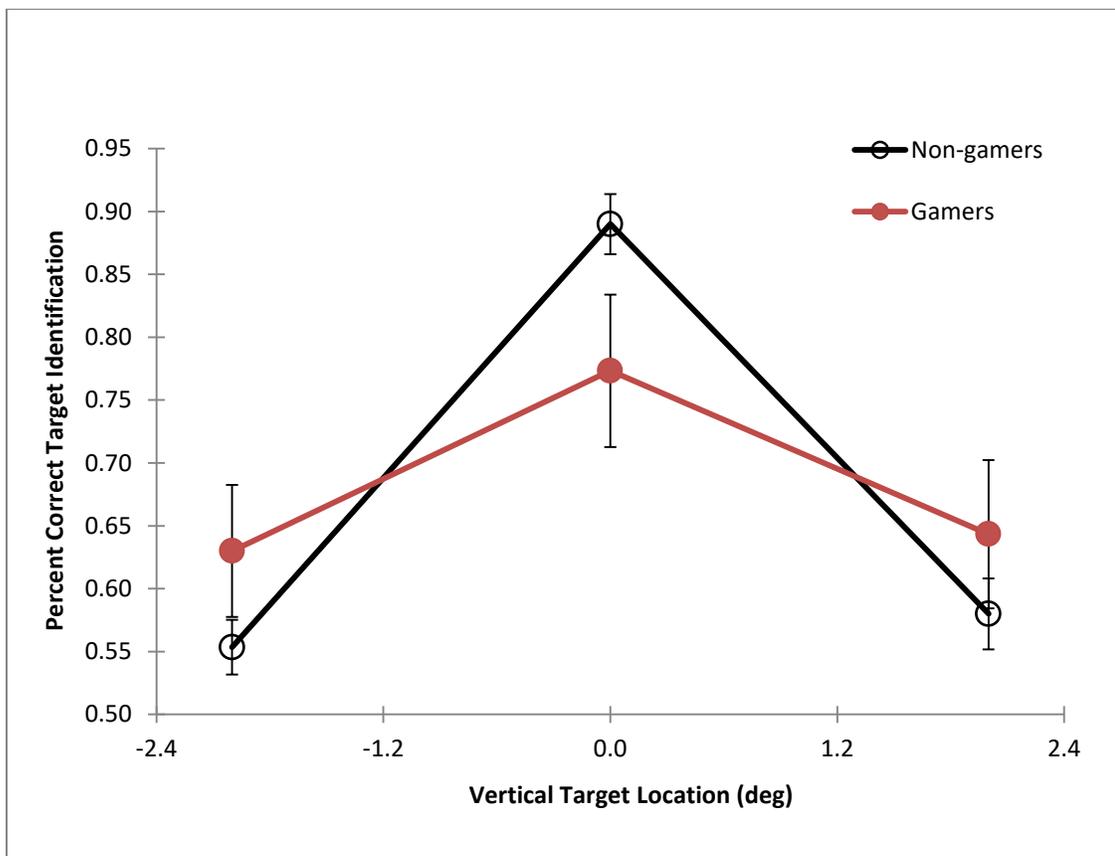

Figure 13. Percent correct target identification for 5-character vertical 2.0^o spacing are presented as a function of target location; negative numbers indicate targets below center.

The horizontal array of the 5-character condition with a center-to-center spacing of 4.0^o presented a stimulus subtending 8.28^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 3 (target location) mixed ANOVA (See Figure 14). A main effect for VGP status was not observed, $F(1, 18) = 0.560$, $p = 0.464$. A main effect for target location was observed, $F(2, 36) = 40.526$, $p < 0.001$. An interaction between VGP status and target location was not observed, $F(2, 36) = 1.368$, $p = 0.268$.
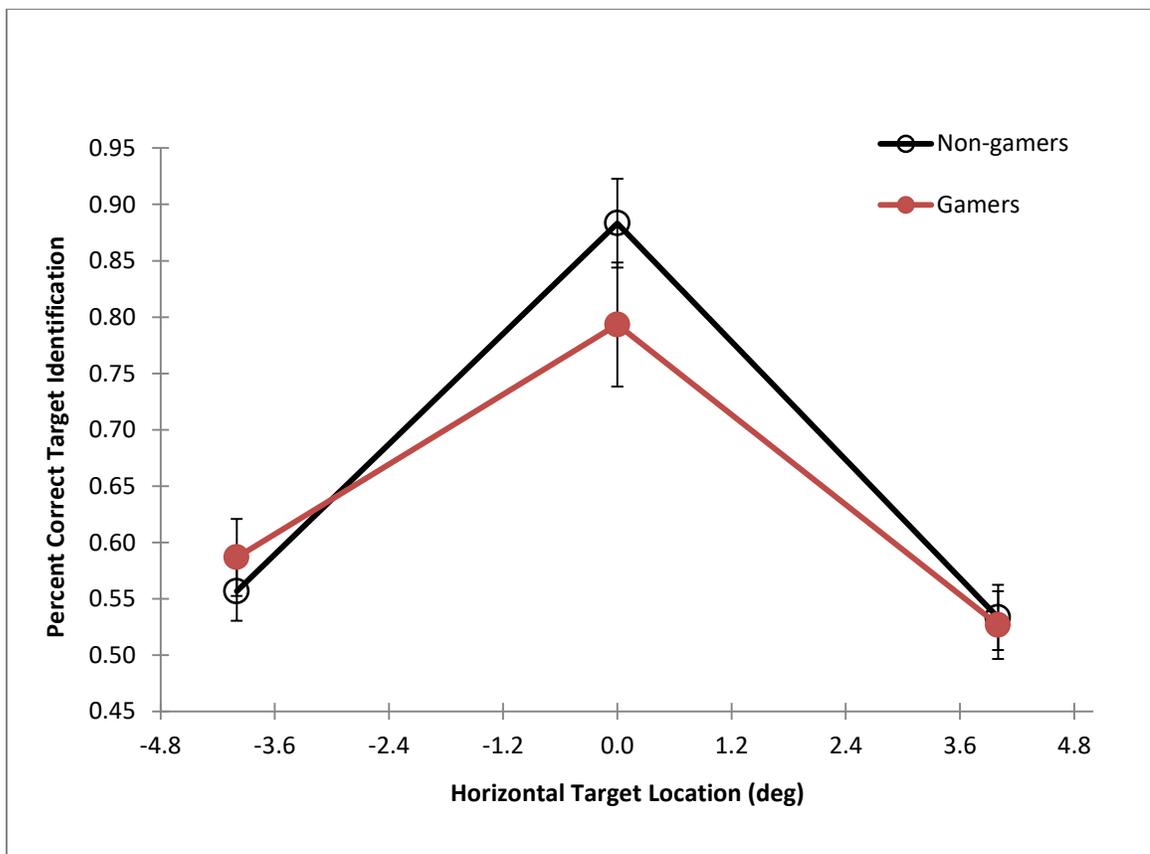

Figure 14. Percent correct target identification for 5-character horizontal 4.0^o spacing are presented as a function of target location; negative numbers indicate targets left of center.

The vertical array of the 5-character condition with a center-to-center spacing of 4.0° presented a stimulus subtending 8.28°. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 3 (target location) mixed ANOVA (See Figure 15). A main effect for VGP status was not observed, $F(1, 18) = 0.634, p = 0.436$. A main effect for target location was observed, $F(2, 36) = 47.183, p < 0.001$. An interaction between VGP status and target location was not observed, $F(2, 36) = 1.425, p = 0.254$.
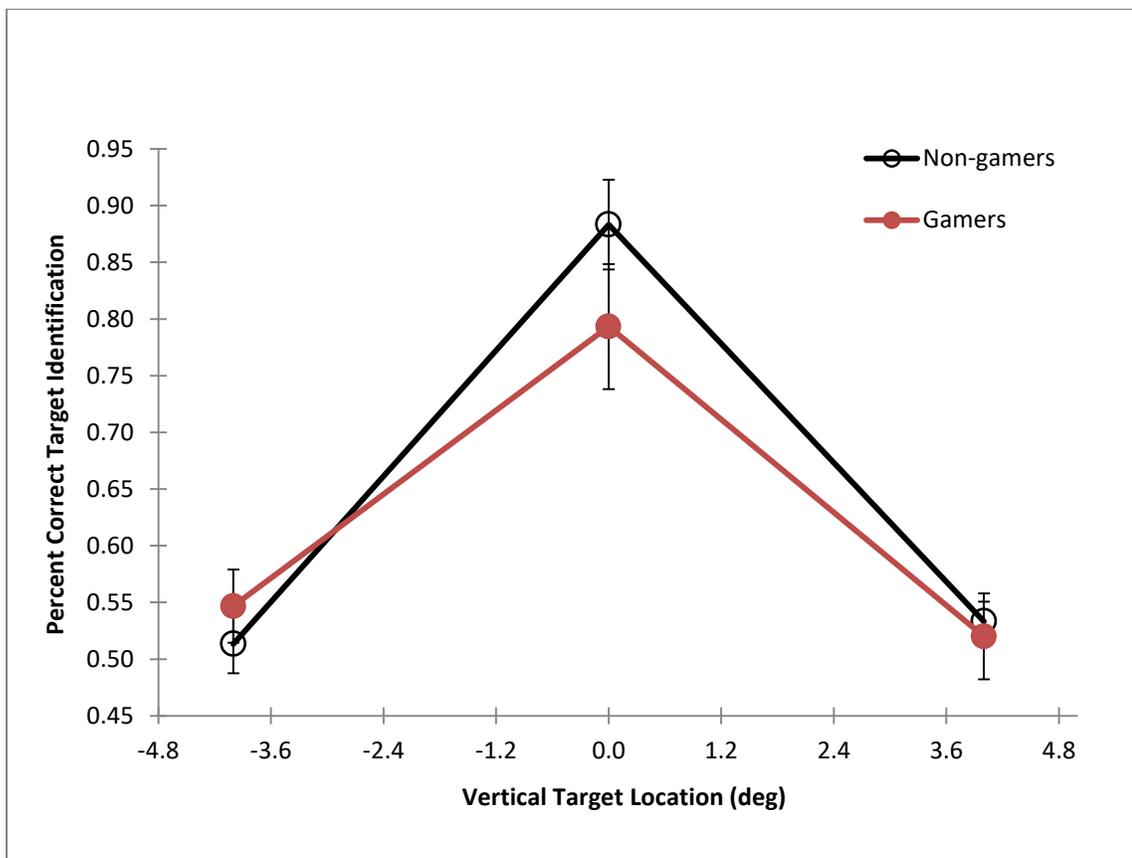

Figure 15. Percent correct target identification for 5-character vertical 4.0° spacing are presented as a function of target location; negative numbers indicate targets below center.

After conducting the analysis for VGPs and NVGPs, we were concerned that the VGP group may have had variance that caused the group to lose its definition as a separate group from NVGPs. This concern was raised because we relied on the self-report of gaming behavior and several individual VGPs seemed to show performance similar to NVGPs while others showed a more distinct performance difference. In order to check for this possibility, we conducted the same ANOVAs as above for the top 5 participants from the VGPs and NVGPs. Top 5 qualification was based on overall performance on the 15-character condition. The 15-character condition was chosen as it presented the most visually crowded condition.

The 15-character condition had a center-to-center spacing of 0.6^o and presented a visually crowded array subtending 8.68^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 15 (target location) mixed ANOVA (See Figure 16). A main effect for VGP status was not observed, $F(1, 8) < 0.001$, $p = 0.983$. A main effect for target location was observed, $F(14, 112) = 7.361$, $p < 0.001$. An interaction between VGP status and target location was not observed, $F(14, 112) = 0.574$, $p = 0.880$.
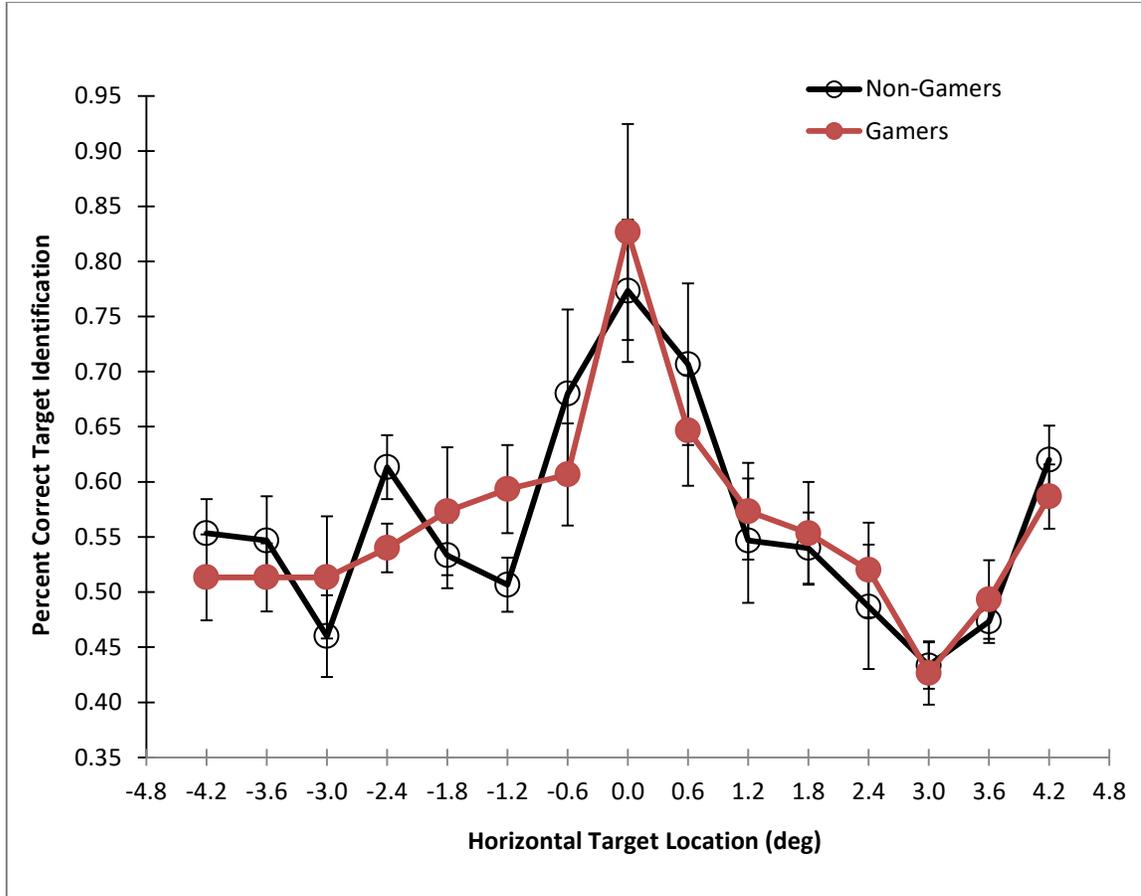
Figure 16. Percent correct target identification for 15-character 0.6^o spacing are presented as a function of target location; negative numbers indicate targets left of center.

The horizontal array of the 9-character condition with a center-to-center spacing of 0.6^o presented a visually crowded stimulus subtending 2.68^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 5 (target position) mixed ANOVA (See Figure 17). A main effect for VGP status was not observed, $F(1, 8) = 2.048$, $p = 0.190$. A main effect for target location was observed, $F(4, 32) = 9.216$, $p < 0.001$. An interaction between VGP status and target location was not observed, $F(4, 32) = 0.402$, $p = 0.806$.
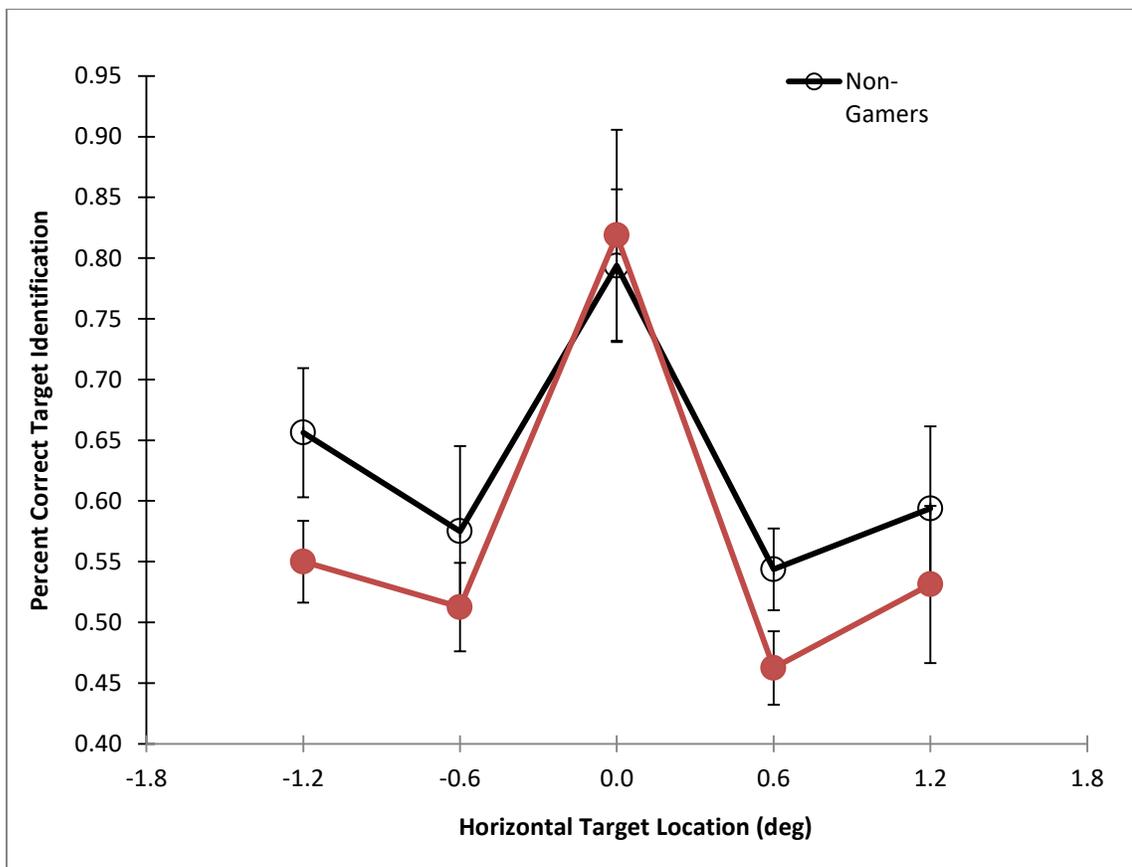

Figure 17. Percent correct target identification for 9-character horizontal 0.6^o spacing are presented as a function of target location; negative numbers indicate targets left of center.

The vertical array of the 9-character condition with a center-to-center spacing of 0.6^o presented a visually crowded stimulus subtending 2.68^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 5 (target location) mixed ANOVA (See Figure 18). A main effect for VGP status was not observed, $F(1, 8) = 0.586$, p = 0.466. A main effect for target location was observed, $F(4, 32) = 7.464$, p < 0.001. An interaction between VGP status and target location was not observed, $F(4, 32) = 0.476$, p = 0.753.
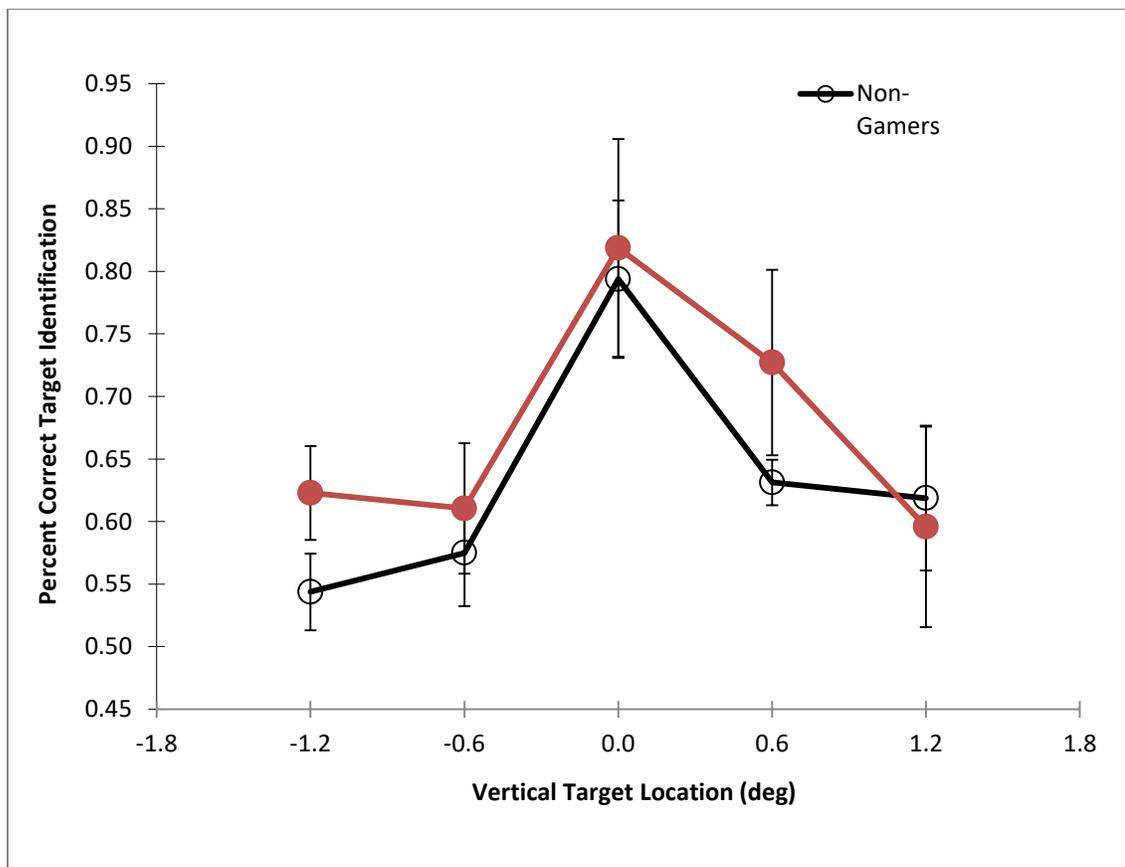

Figure 18. Percent correct target identification for 9-character vertical 0.6^o spacing are presented as a function of target location; negative numbers indicate targets below center.

The horizontal array of the 9-character condition with a center-to-center spacing of 2.0^o presented a stimulus subtending 8.28^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 5 (target location) mixed ANOVA (See Figure 19). A main effect for VGP status was not observed, $F(1, 8) = 1.412$, $p = 0.269$. A main effect for target location was observed, $F(4, 32) = 11.939$, $p < 0.001$. An interaction between VGP status and target location was not observed, $F(4, 32) = 0.746$, $p = 0.568$.

Figure 19. Percent correct target identification for 9-character horizontal 2.0^o spacing are presented as a function of target location; negative numbers indicate targets left of center.

The vertical array of the 9-character condition with a center-to-center spacing of 2.0^o presented a stimulus subtending 8.28^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 5 (target location) mixed ANOVA (See Figure 20). A main effect for VGP status was not observed, $F(1, 8) = 0.060$, $p = 0.813$. A main effect for target location was observed, $F(4, 32) = 12.073$, $p < 0.001$. An interaction between VGP status and target location was not observed, $F(4, 32) = 0.654$, $p = 0.629$.

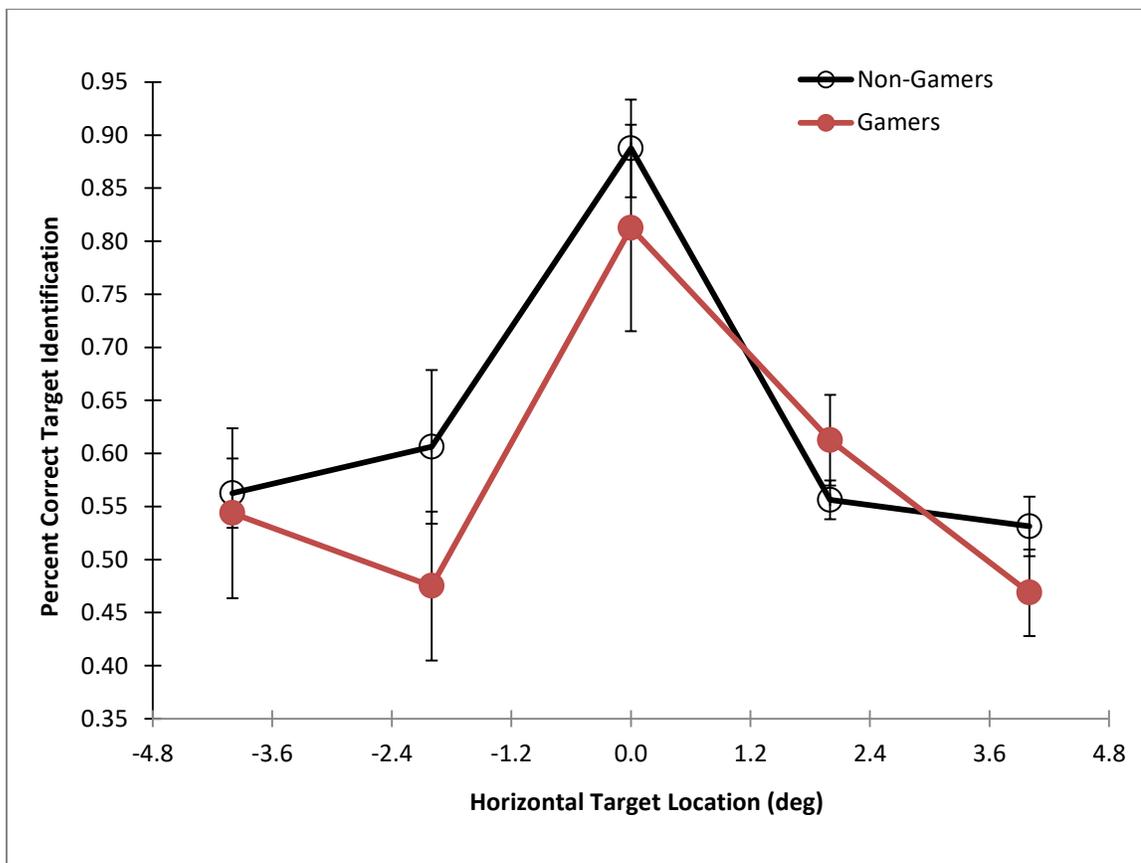*Figure 20.* Percent correct target identification for 9-character vertical 2.0^o spacing are presented as a function of target location; negative numbers indicate targets below center.

The horizontal array of the 5-character condition with a center-to-center spacing of 0.6^o presented a visually crowded stimulus subtending 1.48^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 3 (target location) mixed ANOVA (See Figure 21). A main effect for VGP status was not observed, $F(1, 8) = 0.222$, $p = 0.650$. A main effect for target location was not observed, $F(2, 16) = 0.860$, $p = 0.442$. An interaction between VGP status and target location was not observed, $F(2, 16) = 1.045$, $p = 0.374$.
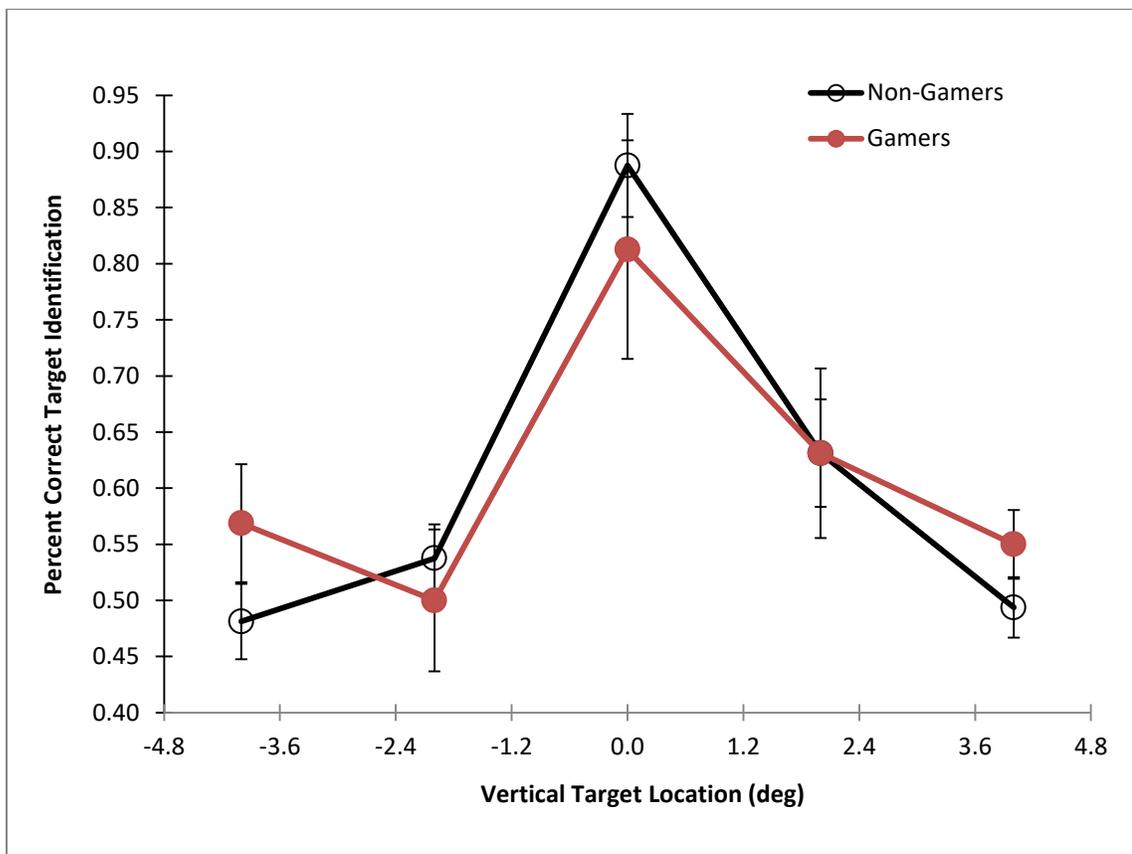

Figure 21. Percent correct target identification for 5-character horizontal 0.6^o spacing are presented as a function of target location; negative numbers indicate targets left of center.

The vertical array of the 5-character condition with a center-to-center spacing of 0.6^o presented a visually crowded stimulus subtending 1.48^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 3 (target location) mixed ANOVA (See Figure 22). A main effect for VGP status was not observed, $F(1, 8) = 0.456$, $p = 0.519$. A main effect for target location was not observed, $F(2, 16) = 0.340$, $p = 0.717$. An interaction between VGP status and target location was not observed, $F(2, 16) = 1.686$, $p = 0.217$.

Figure 22. Percent correct target identification for 5-character vertical 0.6^o spacing are presented as a function of target location; negative numbers indicate targets below center.

The horizontal array of the 5-character condition with a center-to-center spacing of 2.0^o presented a stimulus subtending 4.28^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 3 (target location) mixed ANOVA (See Figure 23). A main effect for VGP status was not observed, $F(1, 8) = 0.980$, $p = 0.351$. A main effect for target location was observed, $F(2, 16) = 7.938$, $p < 0.01$. An interaction between VGP status and target location was not observed, $F(2, 16) = 0.109$, $p = 0.897$.
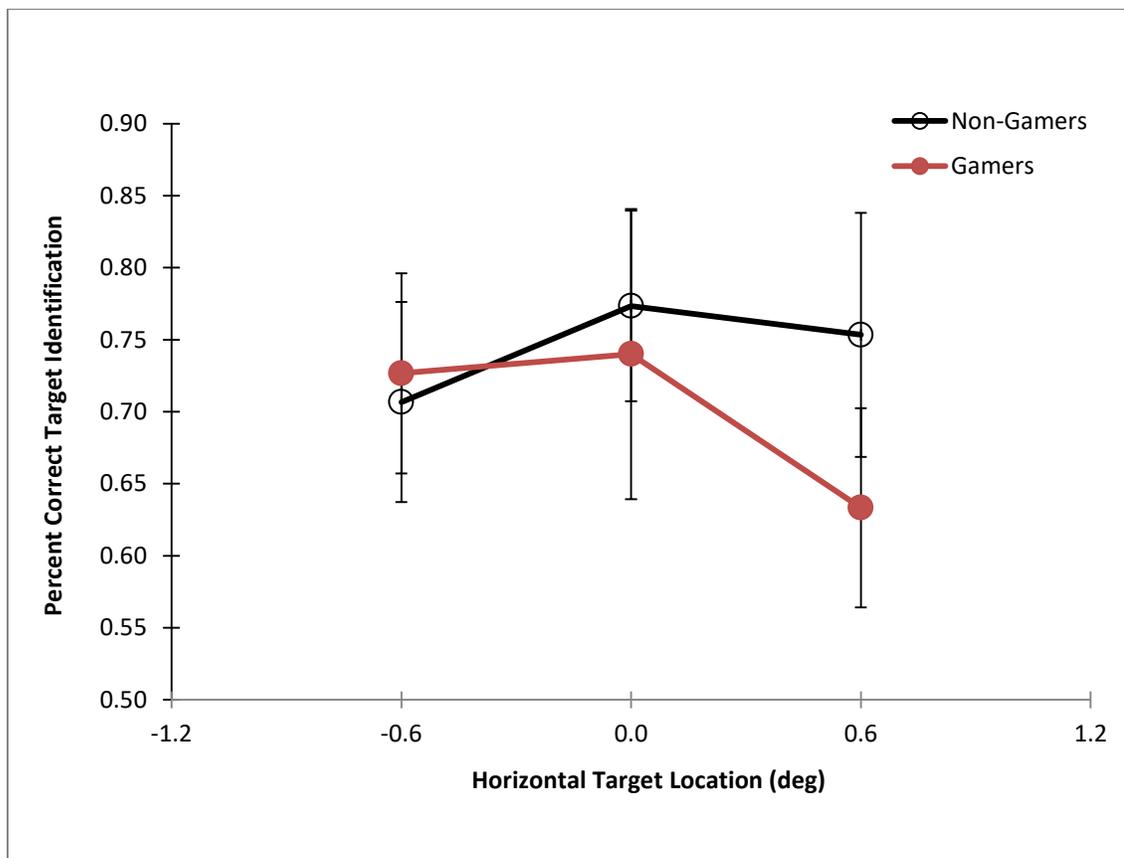

Figure 23. Percent correct target identification for 5-character horizontal 2.0^o spacing are presented as a function of target location; negative numbers indicate targets left of center.

The vertical array of the 5-character condition with a center-to-center spacing of 2.0^o presented a stimulus subtending 4.28^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 3 (target location) mixed ANOVA (See Figure 24). A main effect for VGP status was not observed, $F(1, 8) = 0.356$, $p = 0.567$. A main effect for target location was observed, $F(2, 16) = 14.252$, $p < 0.001$. An interaction between VGP status and target location was not observed, $F(2, 16) = 2.606$, $p = 0.105$.
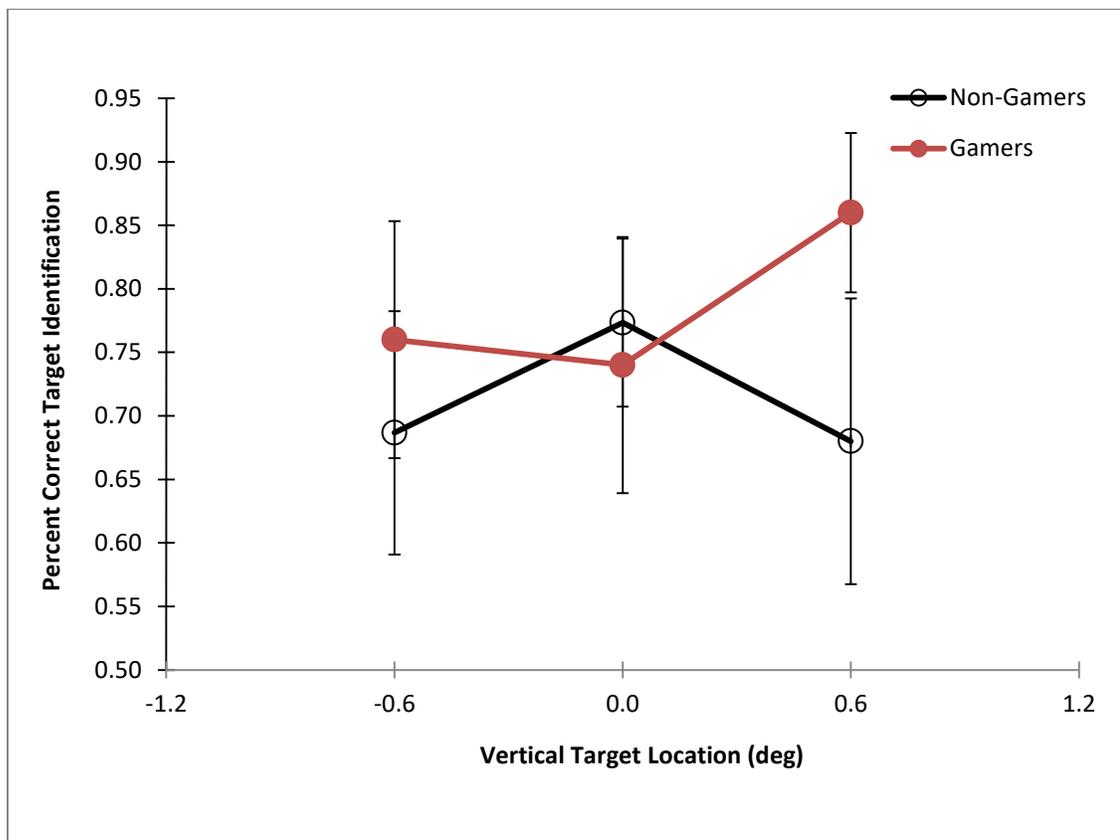

Figure 24. Percent correct target identification for 5-character vertical 2.0^o spacing are presented as a function of target location; negative numbers indicate targets below center.

The horizontal array of the 5-character condition with a center-to-center spacing of 4.0^o presented a stimulus subtending 8.28^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 3 (target location) mixed ANOVA (See Figure 25). A main effect for VGP status was not observed, $F(1, 8) = 1.589$, $p = 0.243$. A main effect for target location was observed, $F(2, 16) = 23.562$, $p < 0.001$. An interaction between VGP status and target location was not observed, $F(2, 16) = 1.211$, $p = 0.324$.
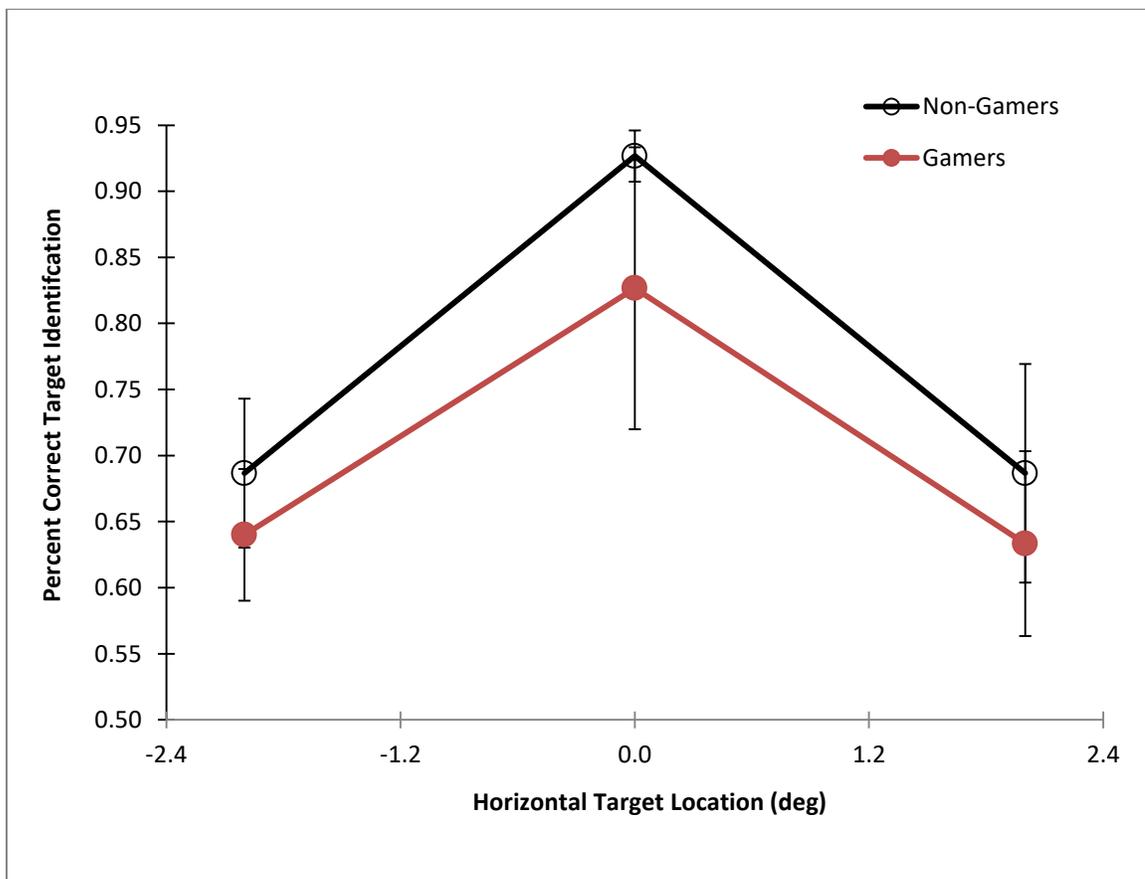

Figure 25. Percent correct target identification for 5-character horizontal 4.0^o spacing are presented as a function of target location; negative numbers indicate targets left of center.

The vertical array of the 5-character condition with a center-to-center spacing of 4.0^o presented a stimulus subtending 8.28^o. The effects of VGP status and possible target locations were analyzed in a 2 (VGP status) x 3 (target location) mixed ANOVA (See Figure 26). A main effect for VGP status was not observed, $F(1, 8) = 1.364$, $p = 0.276$. A main effect for target location was observed, $F(2, 16) = 19.434$, $p < 0.001$. An interaction between VGP status and target location was not observed, $F(2, 16) = 1.062$, $p = 0.369$.
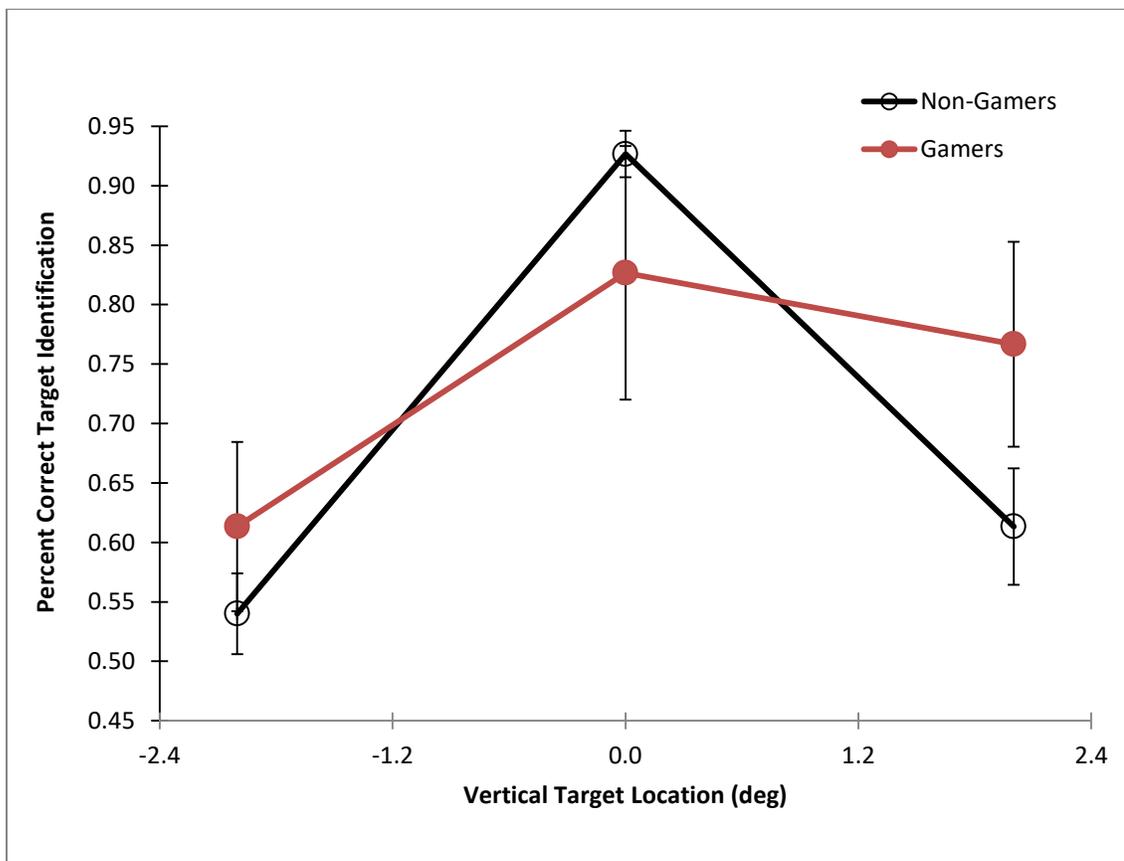

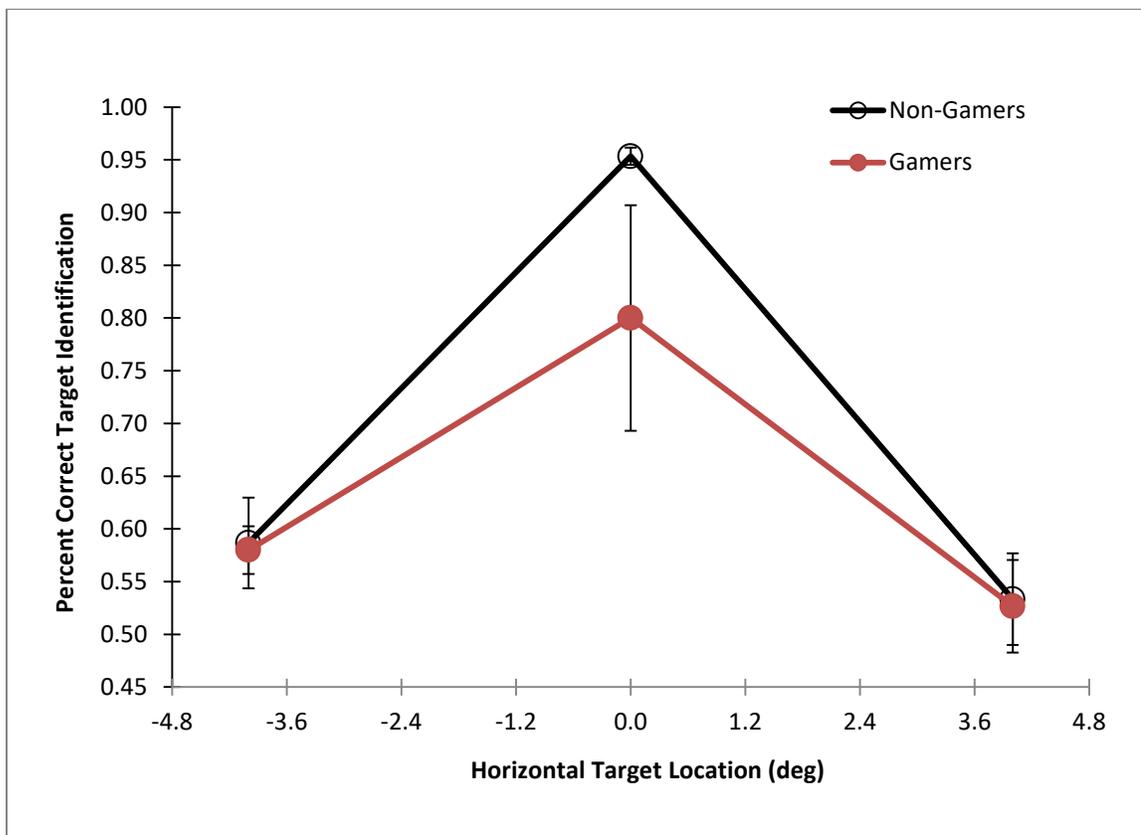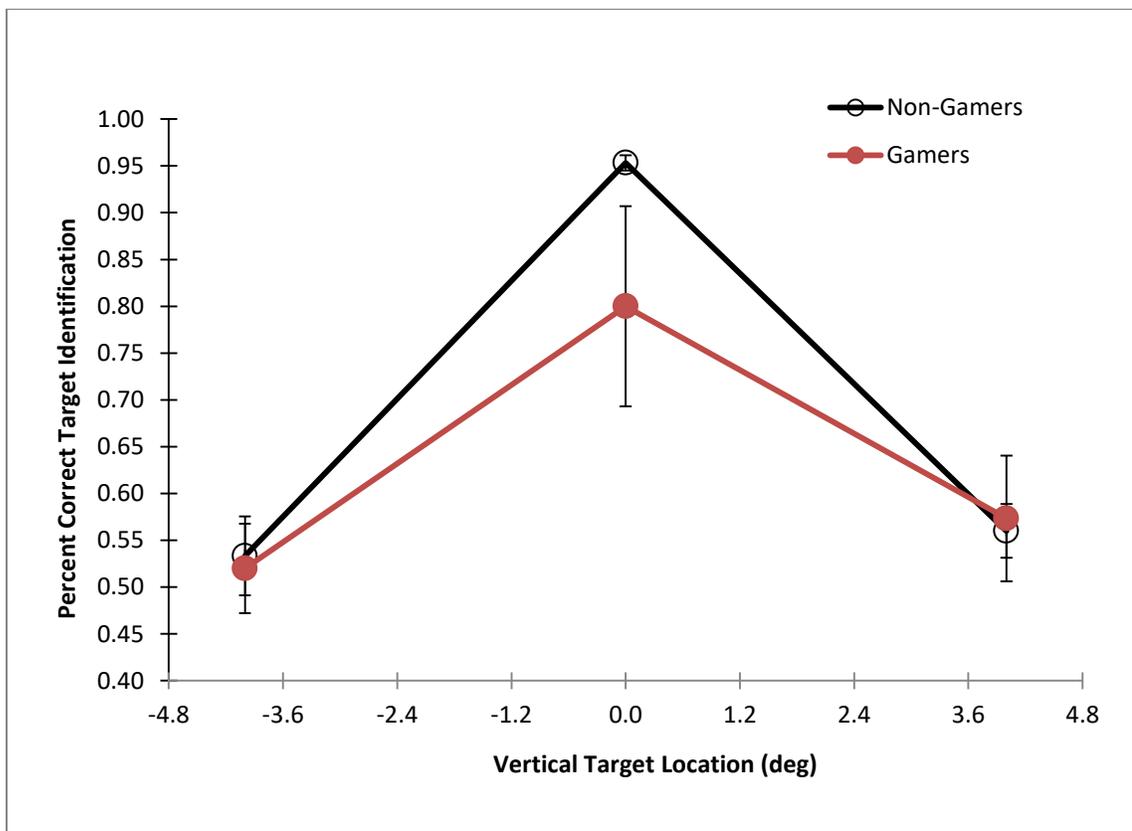*Figure 26.* Percent correct target identification for 5-character vertical 4.0^o spacing are presented as a function of target location; negative numbers indicate targets below center.

IV.   DISCUSSION

Currently, a large body of research evidence suggests that action video game players have advantages in various attention behaviors such as allocation, visual short term memory, and task-switching. These data suggest that VGPs have clear advantages for detecting new stimuli in all regions of a visual display. However, identification of a detected target is a critical step for memory storage and learning. Additionally, findings by Green and Bevalier (2007) suggest that VGPs have an advantage of better spatial resolution which may reduce the impairment caused by visual crowding, which is an important quality for improving target identification. However, current models suggest that crowding does not impair spatial resolution. Instead, these models suggest that crowding causes the attended targets and distractors to become jumbled such that elements of those targets and distractors cannot be clearly differentiated to allow for identification (Whitney & Levi, 2011; Balas et al. 2009).

Despite these previously observed advantages, we did not find any significant global differences between the performances of VGPs and NVGPs for any condition in the overall analysis. The lack of significance indicates that the attentional advantages of VGPs, observed in other studies, may not extend to an identification task like this. Specifically, Green and Bevalier (2007) observed a VGP advantage on a visual crowding task. However, we did not observe the same performance advantage on a visual crowding task requiring identification of the target. Further, previous research has found that VGPs perform better on recognition tasks, but there is little data for VGP

performance on target identification. Our results indicate that observed VGP advantages may not improve performance on an identification task.

We had some concern that our VGPs performed inconsistently. Some performed similarly to NVGPs. This could be due to variance within our VGP group or inaccurate reporting of play time from our VGPs. In order to investigate this possibility, we ran the previously discussed analysis for the Top 5 VGPs and NVGPs. Top 5 classification was determined by overall performance on the 15-character condition. The analysis of the Top 5 VGPs and NVGPs did not reveal any significant differences between the groups for any condition. The lack of significant results after conducting the Top 5 analysis indicates that self-reporting inaccuracy cannot account for the lack of difference between groups.

For the 2-dimensional arrays, we separately analyzed the horizontal and vertical target locations. We did this to investigate the possibility of performance differences between the groups based on where targets were presented, which could potentially indicate a location-based performance bias within either of the groups. Specifically, first-person video games may be a task that biases players to react to or search for targets differently along dimensions. However, there were no significant differences between the groups based on horizontally or vertically presented targets. Pairwise comparisons of each individual location did not reveal any significant difference between the groups at individual locations either.

The previous definition of VGPs originally used by Green and Bevalier (2003) required having played action video games for at least 1 hour a day for at least 4 days a week for the last 6 months. We used a more strict definition of VGPs in order to create a bigger defined difference between VGPs and NVGPs. For our study, VGPs were required to have played first-person shooter games for at least 6-10 hours a week for the last 6 months. We used only first-person shooter players as opposed to action video game players because action video games are divided into various sub genres that are potentially unequal video game experiences. Further, some sub genres may not present the same stimulus environment or task difficulty as other sub genres. However, the tasks and behaviors necessary to play first-person shooter games are relatively equivalent across games. Therefore, tightening the genre definition of our VGPs should have reduced potential variance in our group by seeking equivalent play experiences in our VGPs. In addition, we increased the required number of weekly hours played. We did this in order to have a VGP group of experienced players that would further increase the game play experience gap between our VGPs and NVGPs. Despite these deliberate definitional differences between the groups, we did not observe any significant differences.

Watamaniuk and Heinen (2015) used a 200 ms stimulus presentation time for their study. In the 15-character condition, accuracy performance for the central digit was near 100%. We used a 100 ms stimulus presentation time in order to increase the difficulty and consequently reduce accuracy performance for the central digit. We

wanted to be able to observe differences for the central digit, because Green and Bevalier (2007) observed a reduced crowding threshold for VGPs at 0° of visual angle. We did observe accuracy performance for the centrally located targets that was well below 100%. Therefore, our reduced presentation time did result in reduced accuracy performance. However, we were not able to confirm Green and Bevalier's (2007) finding of a lower crowding threshold for VGPs, because we did not observe any differences between VGPs and NVGPs for centrally located targets across all conditions.

Currently, action video games, including first-person shooters, are being used as training devices to potentially improve visual performance in a variety of populations for a variety of tasks. However, before a full deployment of this training technique, we must have a comprehensive understanding of the benefits and limitations of such training. To that end, VGPs have shown improved performance for a variety of tasks requiring detection of a variety of stimuli (Boot et al., 2008; Green & Bevalier, 2003; Strobach et al., 2012). However, our results indicate that such advantages may be limited to detection and may not benefit an identification task. This is a critical distinction as most everyday tasks require not only quick detection but accurate identification. For example, driving requires constantly updating a visually crowded field of view, a task that is well served by improved detection, as well as identifying the entities within that field. Identification is important for making quick, correct decisions about braking, steering, or not reacting at all to detected entities. If game playing were used to train and improve the attentional scope of older adults for driving or other tasks requiring such an improvement,

then the limitations of that training must be well understood as well as the advantages (Anguera et al., 2013; Belchior et al., 2013). Otherwise, training may be used that does not transfer or benefit the to-be-improved tasks. Substantially more research must be done in order to fully understand these aspects of using game playing as a training procedure.

The current study presented some limitations. For this study, we used VGPs who spent the majority of their game playing with first-person shooters. Recent research has shown that other video game genres, including real-time strategy (or RTS) and multiplayer online battle arena (or MOBA), provide a stimulus rich environment requiring different behaviors in order to be successful (Dobrowolski et al. 2015). For example, real-time strategy games require players to constantly update their information pool in order to make quick, effective decisions about resource allocation and combat opportunities. The information is placed at the edges of the screen which requires constant saccades to those regions. By contrast, first-person shooter players mostly attend to the centrally located crosshairs and the region surrounding the crosshairs while making large movements of the crosshair when enemies appear in the environment. Future studies could benefit from including expert players from a variety of genres in order to examine the effects of genre and to gain a complete view of the advantages and limitations of those specific players.

In the results section, we discussed some concern that our VGPs were not completely transparent in self-reporting their accurate game playing behavior. This

presented limitations to the definition of our groups in the overall analysis. For future studies, we may need to develop more rigorous techniques for assessing a participant's gaming experience. One way to do this would be to develop a discreet questionnaire for potential participants. This would allow us to get a clear view of their gaming experience without directly asking.

Future studies need to further investigate the limitations and potential benefits of the previously observed VGP attentional advantages. A task analysis of gaming behavior is a critical component for future research. Each game genre needs to be defined by the tasks that players must do while playing those specific genres. The task analysis would provide gaming research with a set of core behaviors for each genre by which comparisons could be made within and across genres. Further, the observed behaviors and data could be compared to previous, non-gaming research in order to understand how gaming research fits into the whole of attention research. From there, gaming research could start to develop a cohesive, theoretical foundation around which a theoretical understanding of the underlying attentional theories and mechanisms could develop. This would give gaming research more credence and allow researchers to codify the currently sporadic findings.

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