Competitive Action Video Games' Effect on Cognitive Abilities: The Case of *Overwatch*

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Abstract

Research into the effects of video game play on performance in psychophysical tasks has seen a surge in the last decade. The type of players studied however might not have been the optimal population. This study focuses on the effects of playing one particular, competitive, multiplayer, action video game. The game examined is *Overwatch*, a highly popular action video game. Participants playing *Overwatch* are compared with a non-action video game playing control group. Additionally was the possibility of *Overwatch* player's in-game rank having an influence on their performance examined. Participants were measured using a spatial Stroop task, the attentional blink task, change detection task and a useful field of view task. Significance analysis revealed no effects of playing *Overwatch* or *Overwatch* rank on the performance on any of the psychophysical tests. A Bayesian information criterion analysis did reveal an effect of *Overwatch* rank on visual working memory capacity. Shortcomings of the study, reasons for the lack of finding the hypothesized results and implications for future research are discussed.

Keywords: Video games, Cognitive Abilities, Psychophysical abilities, Overwatch, Bayesian analysis, Spatial Stroop task, Attentional blink, Useful field of view, Change detection task

Competitive Action Video Games' Effect on Cognitive Abilities: The Case of *Overwatch*

The fascination of people for video games has grown immensely over the last two decades and so has the video game industry (Statistic Brain, 2016; Video game industry, n.d.). The increasing availability and quality of video games has led to more people spending an ever increasing amount of time and money playing them. Video games have entered pop culture and have become part of the mainstream.

The kind of games being played are also more diversified than two decades ago. One of today's most popular video game genres are action video games (AVGs) (List of video game genres, 2017). Modern AVGs require a level of cognitive performance from the player that is rare to find in other parts of everyday life. They push human cognitive capacities to the limit, by imposing harder and harder tasks (Hubert-Wallander, Green & Bavelier, 2011).

Action video games and cognitive ability

A typical situation one might encounter while playing an AVGs is attacking an enemy base as part of a team. This endeavor requires the player to quickly assess enemies' actions and act on them in the face of uncertain stimuli. Such a situation might arise when confronted with two enemies at once, requiring the player to decide in a split second which of the two should get priority. The player might need to react to being shot at, a grenade being thrown and an additional opponent appearing; all of which are happening in rapid succession. Additionally will the player need to keep enemy positions in mind, since they will not be in the player's field of view at all times. All of these tasks require the use of cognitive abilities which can be assessed using psychophysical tests.

One of the situations encountered in the hypothetical example was a player that had to decide which one out of multiple enemies should be prioritized, in the face of ambiguous stimuli. In terms of skills and processes distinguished in cognitive psychology, this process can be categorized as attentional control. Attentional control is to direct one's cognitive capacities to task-relevant information in the face of uncertainty, so that task-irrelevant information is suppressed and task-relevant information processed (Milham et al., 2002). In praxis this means that the player needs to decide which enemy to prioritize based on conflicting action tendencies. Enemy A might be shooting at the player, while enemy B is in the process of throwing a grenade at the player's teammates. The player's automatic reaction would be to take cover or to shoot back at enemy A. However the overall more beneficial action for the team would be to hinder enemy B from throwing a grenade at his teammates. The player needs to use his/her attentional control to overrule his automatic response of shooting back, in order for the task to have a higher likelihood of success. A high level of attentional control would thus enable a player to more often perform the correct, non-automatic response to a complicated situation. It could thus be hypothesized that AVG players show an increased level of attentional control.

Attentional control was measured in the past using the Stroop task (Kronenberger et al., 2005; MacLeod, 2005). The Stroop task highlights differences in processing speeds between congruent and incongruent trials. Congruent meaning that the stimulus' two aspects are representing the same concept. E.g., a word being written in the color it semantically represents. Incongruent meaning that the two aspects are different. Participants are asked to indicate the color of the word shown, while disregarding the word's semantic meaning. The theory being that participants need longer for the incongruent trials, as the automatically processed aspect (the semantic meaning) interferes with making a decision based on the color of the word. The Stroop task might have been a decent enough fit for assessing cognitive abilities of AVG players, since they constantly have to make decisions in which the automatic- is not the correct response. The spatial version of the Stroop task however seemed more appropriate, as it requires participants to act on conflicting stimuli which only differ in their position and direction. This mimics a typical scenario in an AVG more closely than stimuli which differ in color and semantic meaning. Unsworth et al. (2015) used a spatial Stroop task in which the incongruent condition had a lower chance of appearing than the congruent one. Having a low chance of appearance could introduce vigilance into the performance, as the participant has to keep a high level of attention, while not being cognitively challenged on most of the trials (as the congruent trials do not require the same level of attention as the incongruent trials). The present study opted for a 50% chance of appearance, to diminish any effect that vigilance may have on the performance.

Another element of cognition, important in the example situation is the player's temporal, attentional capacity. Since several, relevant different stimuli might present themselves to the player in a short period of time, is it important that the player can attend to all of these. Not being able to do so would lead to an important stimuli being missed, this could have fatal consequences for the player's virtual wellbeing. If the player misses a grenade being thrown, because his/her attentional capacity is occupied by being fired upon, would this probably lead to the player's defeat. It could thus be hypothesized that AVG players show an increased level of temporal, attentional capacity.

Temporal, attentional capacity has been measured in the past using the attentional blink paradigm (Boot, Kramer, Simons, Fabiani & Gratton, 2008). The attentional blink paradigm states that an attentional blink exists when processing two rapidly presented stimuli. This blink is caused by the attentional resources still being used to process the first stimuli (T1), causing a possible second stimuli (T2) to be missed (Martens & Wyble, 2010; Raymond, Shapiro & Arnell, 1992). The original version employs a rapid presentation of a string of characters, one of which being white, the others black. This white letter being the first stimuli (T1), the second (T2) being an *X* appearing with a 50% chance, 1 to 8 letters after the white letter. The present study employed an altered version. The first stimuli remained as in the original, the second stimuli however was a number instead of an *X*. The presentation time was shortened as well, to make the task more sensitive for differences at a high performance level, as AVG players were hypothesized to be at this level. Additionally has the attentional blink task been shown to be very demanding for participants (Lawson et al., 1998). The attentional blink task thus consisted of only 40 trials to diminish any effect that fatigue might have on the performance.

Another aspect of the described situation is the fact that the player might not have visual contact with the enemies at all times. This requires the player to remember their positions. Remembering the positions of enemies is part of the visual working memory. Further does the player not only need to remember where an enemy is located, but also information about this enemy. This might be information about their weapons or the amount of health they possess. Not being able to remember one or more aspects of the enemies' make-up, would lead to the player being unprepared for this aspect, which would likely end in failure of the mission. It could thus be hypothesized that AVG players show an increased visual working memory capacity.

The described actions of the visual working memory are mimicked by the change detection task. This task has been used to assess gaming related differences in visual working memory in the past (Anguera et al., 2013). It shortly presents an arrangement of colored squares. After a short time another single square is presented. The participant has to indicate whether the second square was part of the first arrangement, in the same position and color. A difference of this study's task however was that both presentations of stimuli were masked afterwards, diminishing any aftereffect that the images of the stimuli may have.

A further psychophysical aspect of AVGs, present in all mentioned situations, is the player's ability to detect relevant information in the periphery. This ability is an aspect of the player's useful field of view (UFOV). It indicates the distribution of attention over the visual field, especially in the periphery (Ball, Beard, Roenker, Miller & Griggs, 1988). AVGs constantly require the player to be able to attend to stimuli in their peripheral vision. An enemy entering the visual field of the player needs to be acknowledged immediately. This means recognizing the enemy while he/she is still in the peripheral vision. Failing to recognize the enemy in the peripheral, would give the enemy an advantage, since he/she would spot the player first. It could thus be hypothesized that AVG players possess a greater UFOV.

The UFOV task has been used to measure participant's ability to detect stimuli in their peripheral vision (Achtman, Green & Bavelier, 2008; Feng, Spence & Pratt, 2007; Hubert-Wallander et al., 2011). It employs a number of distracting stimuli and one target stimuli in the peripheral vision of the participant, which the participant has to identify. The present study employed heavy masking between stimulus presentations. To reconcile for possible effects that processing speed may have on the likelihood of stimulus detection due to masking, was a longer stimulus presentation time used than the usual 60 to 90 milliseconds (ms) (Ball et al., 1988; Sekuler, Bennett & Mamelak, 2000).

The constant requirement of AVGs to use these psychophysical skills leads to the hypothesis that AVG players perform better on these tasks than non-AVG players. It should thus be possible to detect differences in performance on these tasks, between AVG players and non-AVG players.

The influence of competition

An element of effects of video game exposure that has not yet received much attention by researchers is the possibility of players that play competitive, multiplayer, AVGs (CMAVGs); showing an even higher increase in performance on psychophysical measurements. CMAVGs might promote skill in the game even more than less competitive ones, as a lack of skill is punished harshly by losing to more skilled opponents. CMAVGs create an environment that allows skilled players to feel more accomplished than less skilled players, providing a stronger incentive to improve in the game. AVGs already reward skillful behavior very effectively. CMAVGs might do so even more, since studies have already found a positive connection between perceived competitiveness of a game and the player's level of involvement (Green & Bavelier, 2012; Liu, Li & Santhanam, 2013; Vorderer, Hartmann & Klimmt, 2003). A higher level of involvement in turn, could easily be speculated to increase a player's motivation to increase his/her level of skill.

The competitive environment of CMAVGs suggests that higher ranked, more skilled players perform better in the psychophysical tasks than lower ranked, less skilled players. It should thus be possible to detect a positive influence of rank on the performance on these tasks.

Choosing a context

Most studies into the cognitive effects of playing video games use players of different games as their experimental condition (Castel, Pratt & Drummond, 2005; Chisholm, Hickey, Theeuwes & Kingstone, 2010; Donohue, Woldorff & Mitroff, 2012; Green & Bavelier, 2006; Spence & Feng, 2010). This could be detrimental to the studies' findings, as video game genres differ enormously from each other. A puzzle game does not require the same cognitive skills as a first-person-shooter. Video game players thus show huge differences between genres, both demographically as in the amount of time spent playing and their level of immersion during play (The Average Gamer: How the Demographics Have Shifted, n.d.; Jennett et al., 2008). This introduces additional variability in the experimental group's performance. This is detrimental when trying to identify specific cognitive skills, engaged during play. Identifying which would be easier when only using a single game (Dye, Green & Bavelier, 2009; Green & Bavelier, 2012).

The current study focused on the effects of a single CMAVG, *Overwatch*. *Overwatch* was chosen as it has a large enough player-base to enable sampling without the need to oversample certain demographics and because *Overwatch* is an accurate representation of the average CMAVG (Games sales, n.d.; Netherlands - Country Stats, n.d.; Tassi, 2016; Barrett, 2017). It combines elements of the two most popular CMAVG genres, first-person shooters and multiplayer-online-battle-arena games (First-person shooter, 2017; Multiplayer online battle arena, 2017). It should thus provide an accurate representation of the average CMAVG experience. *Overwatch* is a very young game as well, which suggests a more active player-base (Overwatch (video game), 2017).

It should be noted that this study's goal cannot be to establish a causal relationship between playing CMAVGs and improved psychophysical skills. This is because self-selection bias would provide a valid alternative explanation for any positive relationship between gaming expertise and psychophysical skills, which this study could find. A participant highly skilled in a game and performing above average in the experiments measurements could be highly skilled in the game because of his unusually high psychophysical skills, rather than vice versa (Heckman, 2010).

The fact that there is not reasonable expectation to establish a causal link shifts this study's focus to a more methodological one. The versions of the tasks used for the psychophysical measurements have not been used in this context before. The relationship between gaming-expertise and cognitive abilities was still examined, however without the claim of causality. The focus thus lies on the reliability and validity of using these tasks to detect differences in performance between AVG players and non-AVG players.

Methods

Participants

Twenty-nine male participants were selected using convenience sampling. Only male participants were considered as using both female and male participants would have led to possible gender-differences between the experimental- and the control group. Participants were students at the University of Twente. Participants had an average age of 20 years (SD = 1.86). Twenty-one participants were right handed and eight participants left handed. Fourteen participants were German, 13 Dutch, one Brazilian and one Taiwanese. All participants had normal or corrected vision.

Seventeen participants fell into the experimental group, reporting to have played *Overwatch*. The median of time played in *Overwatch* for participants in the experimental group was 51-100 hours. The average highest rank achieved was 'Gold', the third lowest rank out of seven (Competitive Play, 2017). Twelve participants fell into the control group, reporting to have no experience with AVGs.

All participants received credit for participating in the study and provided informed consent. The study was approved by the ethical committee of the University of Twente.

Apparatus

Two different laptops were used to conduct the measurements. One ran on an Intel Core i5-4200m CPU with a 17-inch monitor, the other on an Intel Core i3-6100U with a 15.6-inch monitor. All participants were seated approximately 60 cm from the screen. All tasks were programmed in Python 3.5.2 (see Supplementary Materials for the source code). Spyder 3.5 was used to compile and run the scripts.

Stimuli and Tasks

All participants had to complete four psychophysical tests (spatial Stroop task, attentional blink task, change detection task and UFOV task) and a questionnaire. The psychophysical tests were organized in a test battery, immediately starting the subsequent test once the former was done.

Spatial Stroop task. The first test in the test battery was the spatial Stroop task. Participants were presented with an arrow either in the top or bottom half of the screen and either pointing downwards up upwards (Figure 1). The arrow was presented for two seconds or until the participant input his/her answer. The participant had to indicate whether the arrow was in the top or bottom half of the screen while disregarding its direction, using the up and down arrow keys on the keyboard. After every trial feedback was displayed until the participant pressed the spacebar, starting the next trial. The variables used for analysis are the overall mean reaction time for correct trials and reaction time difference between congruent (arrow position and direction equal) and incongruent (arrow position and direction not equal) trials. The reaction time difference was computed by subtracting participant's times for the congruent trials by the times for the incongruent ones. The test consisted of 60 trials.

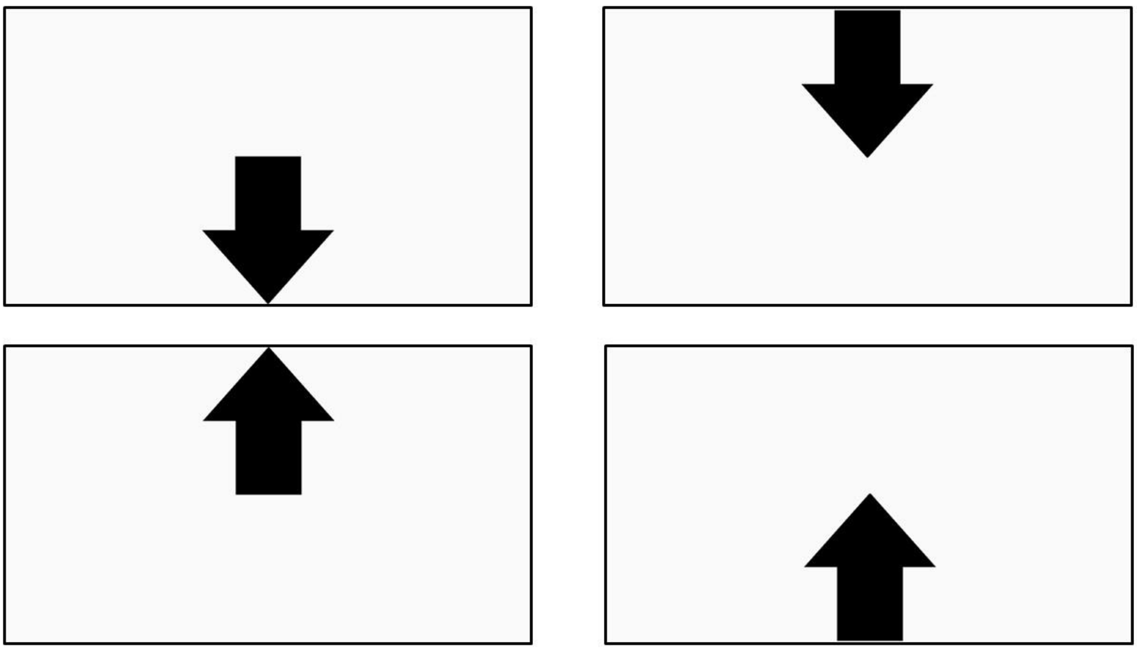


***Figure 1*. The four possible stimuli for the spatial Stroop task.**

Attentional blink task. The second test in the test battery was the attentional blink task. Participants were presented with a string of 31 characters presented rapidly, showing each letter for 33 ms with an interstimulus interval (ISI) of 50 ms. The letters were presented in the middle of the top half of the screen. One of the letters appeared white (T1) instead of black (on a grey background). A black number instead of a letter followed the white letter with a chance of 50% (T2). The black number appeared in place of a letter between 1 and 8 letters after the white letter (Figure 2). Participants had to indicate which letter was white using the letters on the keyboard and subsequently if a number appeared, using the ‘y’ (yes) and ‘n’ (no) keys. After every trial feedback was displayed until the participant pressed the spacebar, starting the next trial. The dependent variable was the amount of correct trials, at the position of the observed attentional blink. The position of the attentional blink is indicated by a drop in correct identification of the number (T2), when the white letter (T1) was correctly identified. The test consisted of 40 trials.

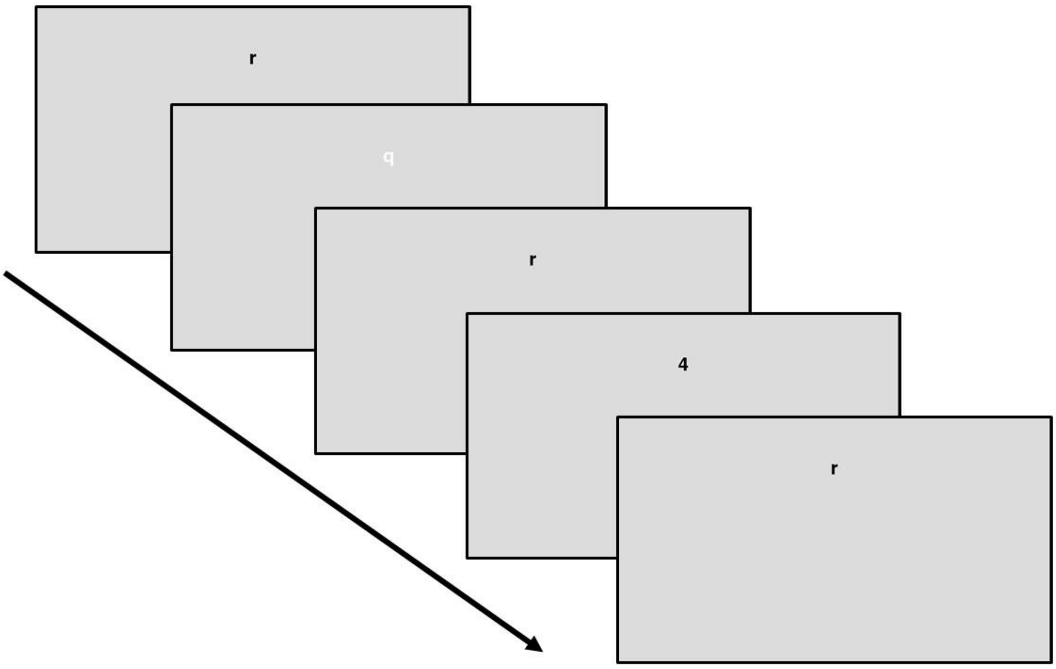


***Figure 2.* Sequence of stimuli in the attentional blink task.**

Change detection task. The third task in the test battery was the change detection task. Participants were presented with five rectangles in either black, grey, yellow, red, blue or green. The rectangles were organized in a virtual 5x5 matrix, although a grid was not visible. The five initial rectangles were presented for one second followed by a mask being displayed for another second. The mask consisting of randomly colored rectangles filling the entire screen. Following the first mask, was another singular rectangle displayed for one second, followed by another mask lasting one second (Figure 3). The participant had to indicate whether the second, singular rectangle was part of the first five rectangles, being equal in position and color, using the ‘y’ and ‘n’ keys. After every trial was feedback displayed until the participant pressed the spacebar, starting the next trial. The dependent variable was the amount of correct trials. The task consisted of 50 trials.

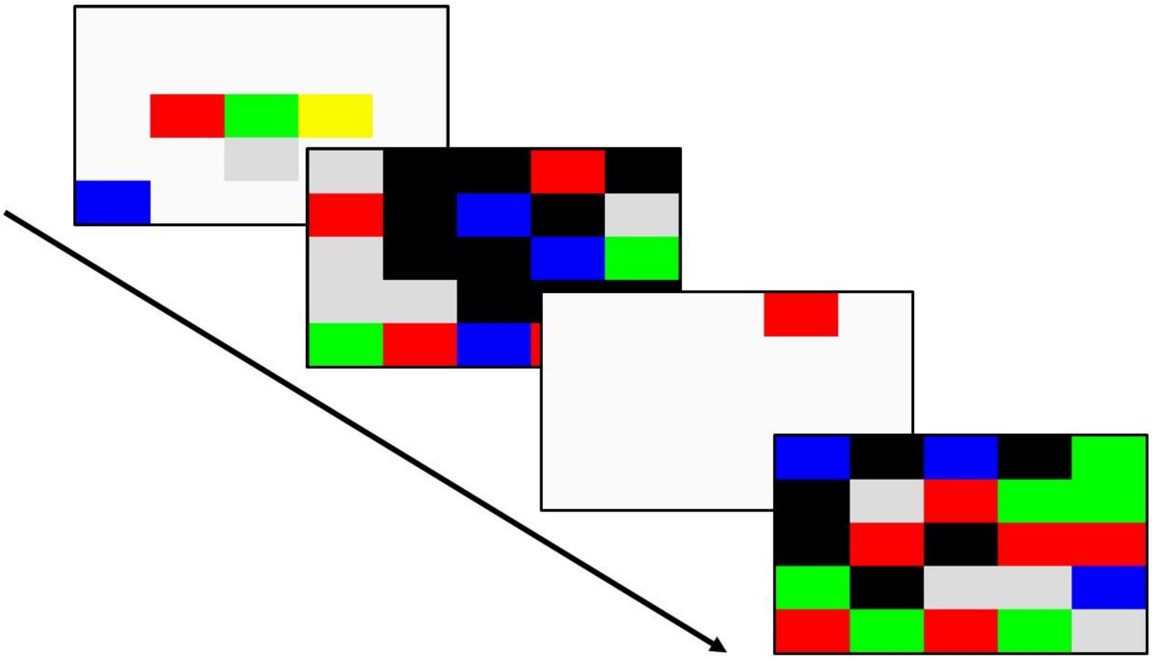


Figure 3. **Sequence of stimuli in the change detection task.**

UFOV task. The fourth test in the test battery was the UFOV task. Participants were presented with an array of 25 black dots equally distributed across the screen following a virtual 8x8 matrix, although a grid was not visible. After one second one of the dots lit up red for 200 ms. After one of the dots lit up, was a mask displayed consisting of 49 randomly positioned, black dots and one red dot (Figure 4). The participant had to click on the dot that lit up in the initial formation, using the touchpad. After every trial was feedback displayed until the participant pressed the spacebar, starting the next trial. The dependent variable was the amount of correct trials. The task consisted of 60 trials.

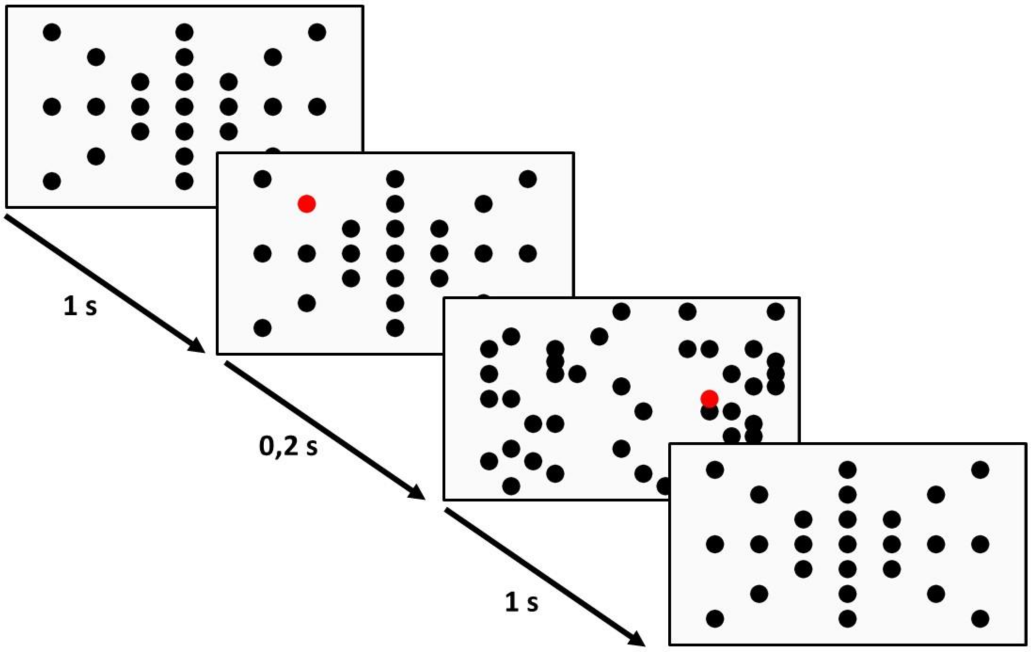


Figure 4. **Sequence of stimuli in the UFOV task.**

Questionnaire. Every participant had to complete a questionnaire as well. The questionnaire was made up of demographical questions, questions about time played and highest rank achieved in *Overwatch*, a test to determine whether the participant was right- or left handed and questions about whether the participant was color blind (Appendix I).

Visual acuity test. A short visual acuity test was used to examine whether or not any participants had severe impairment in their visual acuity, which would have harmed the validity of the psychophysical tests used in the test battery (Appendix II).

Procedure

The testing took place over a two and a half week period. The tests were conducted in a quiet, dimly lit room, without any disturbances. The participant first had to fill in an informed consent, informing him/her on the fundamental goals and circumstances of the study (Appendix III). After the consent was signed, was the participant handed a standardized set of instructions to read through (Appendix IV). If questions about the tasks still remained after reading through the instructions, were these answered by the instructor. If no questions remained was a practice run started. This consisted of the same tasks used in the actual test, but only lasted five trials per task. If the participant completed the trial run without any more questions, was the actual test battery started. The participant was alone in the test room for the duration of the test, being observed by a camera. The progress of the participant and eventual complications could be observed through the camera. The instructor resolved complications by personally fixing them on the testing computer. The test resumed as planned once a complication was fixed. After the test was done, was the participant handed a questionnaire and a visual acuity test was conducted. The test ended with the participant being debriefed by the researcher, offering the opportunity to voluntarily give out their email address, should they be interested in obtaining the results of the study. The whole procedure took approximately 45 minutes.

Design

This study used a between-group- as well as a within-group design. A between-group comparison was used to assess possible differences on performance on psychophysical measurements between regular players of *Overwatch* and non-players. A within-group, regression approach was employed to test for an influence of *Overwatch* rank on participant's performance on the psychophysical measurements.

Analysis

IBM's SPSS 22 was used to assess the gathered data. The data for the attentional blink-, change detection- and UFOV tasks were transformed using an arcsine transformation, before performing statistical, hypothesis-testing on it. The formula used follows Cohen, Cohen, West and Aiken's (2013) approach:

$$TD = 2\ ARCSINE\ (\sqrt{D}) \tag{1}$$

With TD being the transformed- and D being the untransformed data.

To test for differences in performance between the experimental- and control group, independent samples t-tests were conducted. To test for differences in performance based on *Overwatch* rank in the experimental group, regression analysis and a Bayesian model selection process were conducted.

The approach used for the Bayesian model selection process followed a framework provided by Masson (2011), which was based on Wagenmaker's (2007) work. First was an estimate of the difference of goodness of fit between the two competing models computed. The two competing models being the models used to represent the null- and alternative hypothesis. The measure used for goodness of fit was the Bayesian information criterion (BIC). The difference of the BIC between the two models was computed as follows in equation 2:

$$\Delta BIC = n \ln\left(\frac{SSE_1}{SSE_0}\right) + (k_1 - k_0) \ln(n) \tag{2}$$

With n being the number of observations, SSE_1 and SSE_0 being the sum of squares error for the alternative- and null hypothesis models and k_1 and k_0 being the numbers of free parameters in the respective models. The sum of squares errors were computed by regression analysis. The sum of squares error for the alternative hypothesis (SSE_1) was equal to the sum of squares for the error term in the regression analysis' model. The sum of squares error for the null hypothesis (SSE_0) was equal to adding up the sum of squares for the error term and the sum of squares for the effect term in the regression analysis' model.

Using the estimate for the goodness of fit difference between the models could the Bayesian factor (BF) be computed. The BF is a representation of the ratio between two models' goodness of fit to the data. The BF is computed as follows in equation 3:

$$BF = e^{(\Delta BIC)/2} \tag{3}$$

The BF can then be used to compute the respective probabilities of the two hypotheses being true in equation 4 and 5:

$$p_{BIC}(H_0|D) = \frac{BF}{BF+1} \tag{4}$$

$$p_{BIC}(H_1|D) = 1 - p_{BIC}(H_0|D) \tag{5}$$

With $p_{BIC}(H_0|D)$ and $p_{BIC}(H_1|D)$ being the chances for the null- and alternative hypothesis being true respectively, given the data and BF being the Bayesian factor.

A confirmatory factor analysis was conducted to control for internal validity. The proposed factor model was based on a single factor. The single factor being *Overwatch* experience, as this was hypothesized to impact performance on all four psychophysical measurements. A high validity of the tests used should thus hypothetically result in a single underlying factor being found.

Results

The statistical tests conducted on the performances measured and their results will be organized by task. Tests were conducted to test for construct validity of the used measurements, before analyzing possible differences between or within samples. Between group differences were analyzed using t-test for independent samples. Within group differences were analyzed using regression and the BIC model selection process. The spatial Stroop task's analysis was an exception to this, as the t-test and regression analysis were replaced by two-way ANOVAs.

Table 1

Descriptive statistics for the four test variables.

Task	Condition means			
	Experimental	Control	Skewness	Kurtosis
Spatial Stroop task	-0.03 (0.05)	-0.03 (0.05)	-0.84	0.42
Attentional Blink	1.35 (0.66)	1.19 (0.84)	-0.59	-0.54
UFOV task	2.72 (0.36)	2.6 (0.37)	0.17	-1.31
Change detection task	2.18 (0.37)	2.14 (0.29)	-0.15	-0.41

Note. Standard Deviations appear in parentheses below means.

The descriptive statistics for the performance data shows that parametric tests can be conducted to analyze them (Table 1). Skewness and kurtosis are in the range of values deemed as approximately normal.

Spatial Stroop task. To test for the occurrence of a Stroop effect, a one-sample t-test was conducted. It tested whether the difference in reaction times between incongruent- and congruent trials was different from normal, defined as difference of 0 (no difference in reaction times). Mean reaction time difference (M = -0.03, SD = 0.05, N = 29) was lower than the normal reaction time difference of 0, by a statistically significant mean difference of -0.03, $t(28) = -3.31$, $p < .01$. (Figure 5)

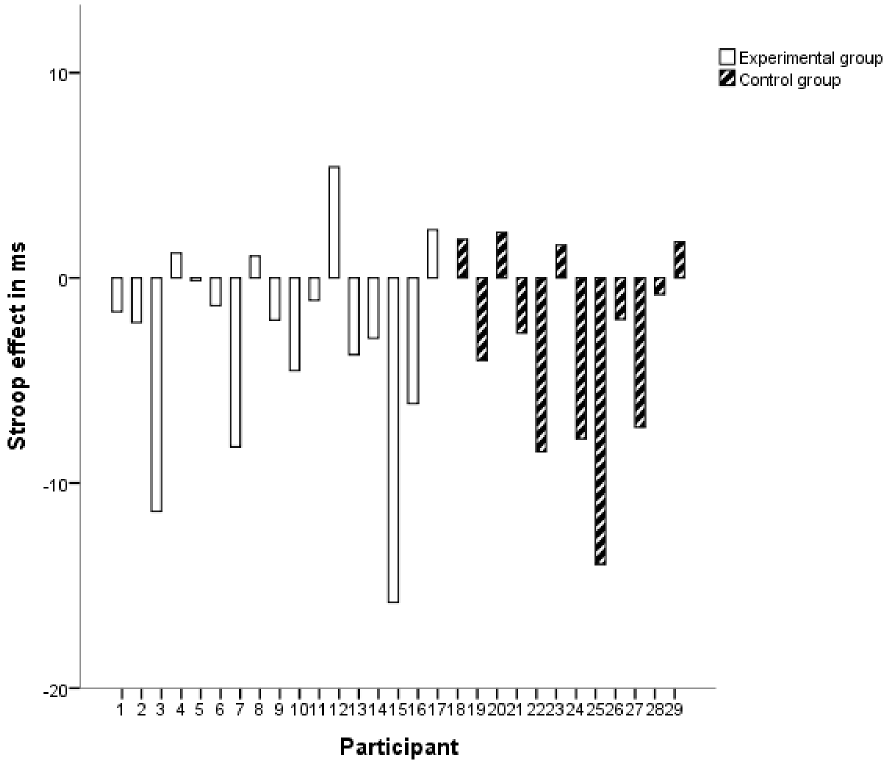


Figure 5. Stroop effect in ms by condition.

To test for differences between groups in performance on the spatial Stroop task, a two-way ANOVA was conducted. The ANOVA indicated no significant effect of participant's condition on their performance, $F(1, 21) = 0.23$, $p = .88$. The ANOVA indicated no significant interaction effect of the trial's condition (congruent vs incongruent) and the participant's condition (experimental vs control) on their performance, $F(3, 21) = 0.61$, $p = .62$ (Table 2).

Table 2

ANOVA results for performance on the spatial Stroop task for between group differences.

Source	*SS*	*df*	*MS*	*F*	*p*
Participant condition	<0.01	1	<0.01	0.02	.88
Trial condition	0.04	3	0.01	2.45	.09
Participant-*Trial condition	<0.01	3	<0.01	0.61	.62
Error	0.11	21	0.01		

To test for differences in performance on the spatial Stroop task because of *Overwatch* rank, a two-way ANOVA was conducted. The ANOVA indicated no significant effect of participant's *Overwatch* rank on their performance, $F(5, 5) = 0.85$, $p = .57$. The ANOVA indicated no significant interaction effect of the trial's condition (congruent vs incongruent) and the participant's *Overwatch* rank on their performance, $F(3, 5) = 0.68$, $p = .68$ (Table 3).

Table 3

ANOVA results for performance on the spatial Stroop task for within group differences.

Source	*SS*	*df*	*MS*	*F*	*p*
Overwatch rank	0.03	5	0.01	0.85	.57
Trial condition	0.02	3	0.01	1.11	.43
Overwatch rank*Trial condition	0.01	3	<0.01	0.53	0.68
Error	0.03	5	0.01		

A BIC comparison of the null- and alternative-hypothesis' models was conducted. The null hypothesis being that participant's *Overwatch* rank had no effect on the performance on the spatial Stroop task. The alternative hypothesis being that it had an effect. The comparison resulted in a 80% chance that the null hypothesis is true and a 20% chance that the alternative hypothesis is true, given the data, $P_{BIC}(H_0|D) = 0.8$, $P_{BIC}(H_1|D) = 0.2$, $n = 17$, $SSE_0 < 0.01$, $SSE_1 < 0.01$, $\Delta BIC = 2.83$, $BF = 4.12$ (Table 5).

Table 4.

Results of independent t-test analysis by task.

Task	Condition means: Experimental	Condition means: Control	*t*	*df*
Attentional blink task	1.35 (0.66)	1.19 (0.84)	0.58	27
Change detection task	2.18 (0.37)	2.14 (0.29)	0.27	27
UFOV task	2.72 (0.36)	2.6 (0.37)	0.89	27

Note. No significant results observed. Standard Deviations appear in parentheses below means.

Attentional blink task. To test whether or not an attentional blink in the attentional blink task could actually be observed, was a plot with the position of the number (T2) and the percentage of correct trials constructed (Figure 1). The plot shows a drop in performance for positions 3, 4, 5 and 6. To test whether this drop in accuracy of detecting T2, given that T1 was detected, was significant was a paired samples t-test conducted. The paired samples t-test found a significant difference in accuracy, between the position of the attentional blink (3, 4, 5 and 6) (M = 0.4, SD = 0.27, N = 29) compared to the rest of positions (1, 2, 7 and 8) (M = 0.67, SD = 0.31, N = 29), $t(28) = 5.83$, $p < .01$.

It can thus be assumed that an attentional blink occurred and the test measured the concept of interest correctly. The point of the attentional blink will be used as the dependent variable to assess differences between experimental- and control group, as well as differences in the experimental group based on rank.

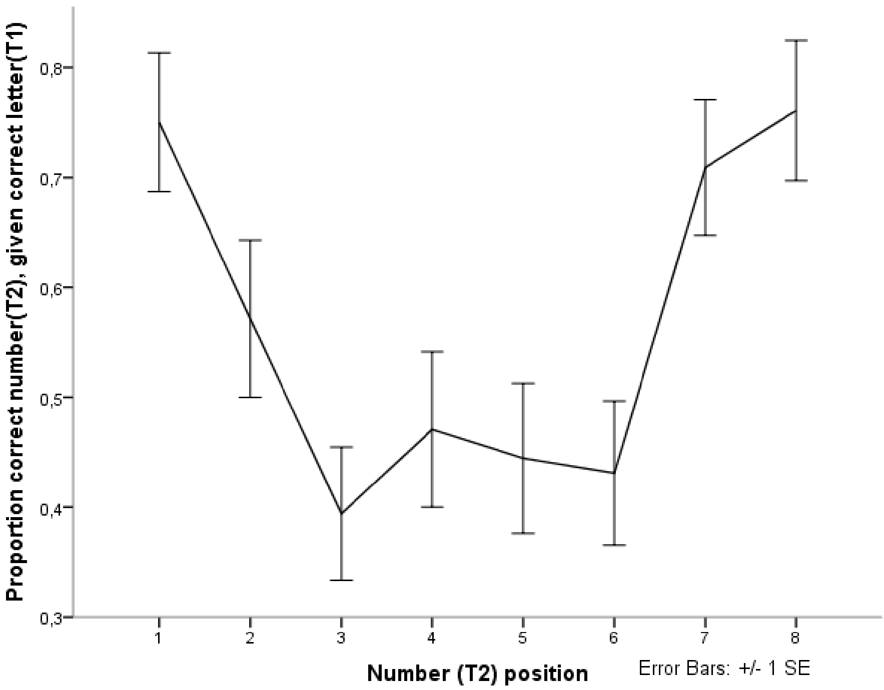


Figure 6. Observed position of the attentional blink.

To test for differences in performance on the attentional blink task between the experimental- (M = 1.35, SD = 0.66, N = 17) and control group (M = 1.19, SD = 0.84, N = 12), an independent samples t-test was conducted. The test found no significant differences in performance between the experimental- and control group, $t(27) = 0.58$, $p = .57$) (Figure 7).

To test for improved performance on the attentional blink task because of a higher *Overwatch* rank in comparison to lower ranked players, a regression analysis was conducted. Participant's *Overwatch* rank could explain 19.2% of variance in the performance on the attentional blink task, $R^2 = 0.192$. The test found no significant relation between higher rank and better performance, $F(1, 15) = 3.56$, $p = 0.08$ (Table 5).

A BIC comparison of the null- and alternative-hypothesis' models was conducted. The null hypothesis being that participant's *Overwatch* rank had no effect on the performance on the attentional blink task. The alternative hypothesis being that it had an effect. The comparison resulted in a 40% chance that the null hypothesis is true and a 60% chance that the alternative hypothesis is true, given the data, $P_{BIC}(H_0|D)$ = 0.4, $P_{BIC}(H_1|D)$ = 0.6, n = 17, SSE_0 = 6.96, SSE_1 = 5.62, ΔBIC = -0.79, BF = 0.67) (Table 5).

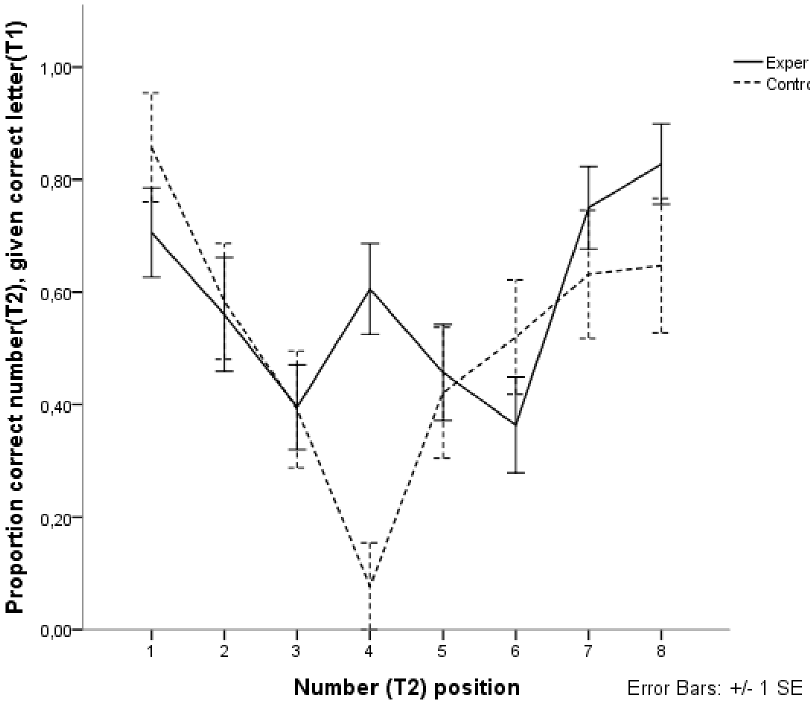


Figure. 7. Position of the attentional blink by condition.

Change detection task. To test for differences in performance on the change detection task between the experimental- (M = 2.18, SD = 0.37, N = 17) and control group (M = 2.14, SD = 0.29, N = 12), an independent samples t-test was conducted. The test found no significant differences in performance between the groups, $t(27)$ = 0.27, p = .79 (Table 4).

To test for improved performance on the change detection task because of a higher *Overwatch* rank in comparison to lower ranked players, a regression analysis was conducted. Participant's *Overwatch* rank could explain 5.9% of variance in the performance on the change detection task, R^2 = 0.059. The test found no significant relation between higher rank and better performance, $F(1,15)$ = 0.94, p = .35 (Figure 8).

A BIC comparison of the null- and alternative-hypothesis' models was conducted. The null hypothesis being that participant's *Overwatch* rank had no effect on the performance on the change detection task. The alternative hypothesis being that it had an effect. The comparison resulted in a 1% chance that the null hypothesis is true and a 99% chance that the alternative hypothesis is true, given the data, $P_{BIC}(H_0|D)$ = 0.01, $P_{BIC}(H_1|D)$ = 0.99, n = 17, SSE_0 = 0.27, SSE_1 = 0.14, ΔBIC = -8.4, BF = 0.02 (Figure 8).

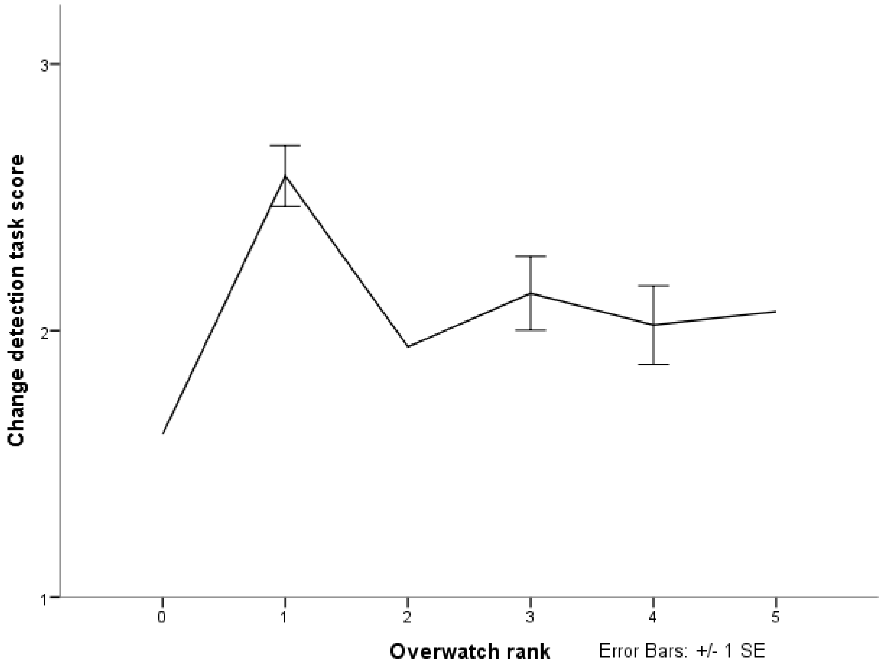


Figure 8. Participant's score on the change detection task by *Overwatch* rank.

UFOV task. To test whether the UFOV task measured differences in participant's performance based on the stimuli being in the left or right half of the screen (which would impair its validity), a paired samples t-test was conducted. The test found no significant difference in performance between stimuli appearing on the right (M = 0.92, SD = 0.09, N = 29) or left (M = 0.93, SD = 0.07, N = 29) side of the screen, $t(28)$ = 0.81; p = .42.

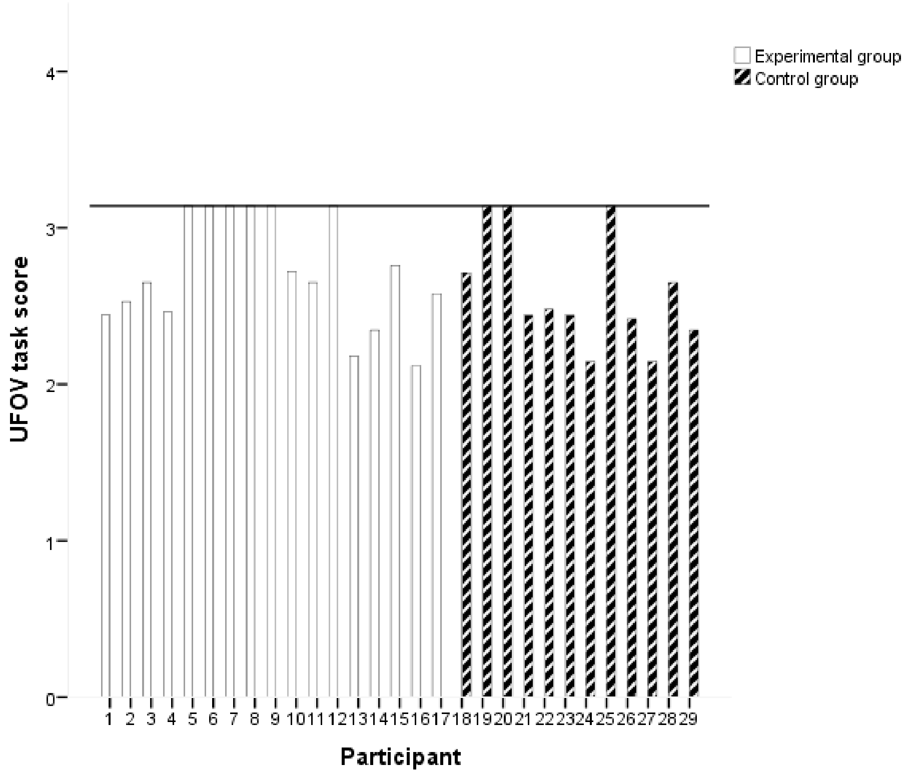


Figure 9. UFOV score for participants by condition (from 0 to π, due to arcsine transformation).

The descriptive statistics indicated a possible ceiling effect for the useful UFOV task (Table 1). The plot of participant's scores shows that this is the case (Figure 9). Most participants showed perfect or almost perfect scores on the task (on a scale of 0 to π, because of the arcsine transformation), undermining its validity.

To test for differences in performance on the UFOV task between the experimental- (M = 2.72, SD = 0.36, N = 17) and control group (M = 2.6, SD = 0.37, N = 12), an independent samples t-test was conducted. The test found no significant differences in performance between the groups, $t(27) = 0.89$, $p = .38$ (Table 4).

To test for improved performance on the UFOV task because of a higher *Overwatch* rank in comparison to lower ranked players, a regression analysis was conducted. Participant's *Overwatch* rank could explain 2.7% of variance in the performance on the

UFOV task, R^2 = 0.027. The test found no significant relation between higher rank and better performance, $F(1, 15) = 0.42$, $p = .53$ (Table 5).

A BIC comparison of the null- and alternative-hypothesis' models was conducted. The null hypothesis being that participant's *Overwatch* rank had no effect on the performance on the UFOV task. The alternative hypothesis being that it had an effect. The comparison resulted in a 17% chance that the null hypothesis is true and a 83% chance that the alternative hypothesis is true, given the data, $P_{BIC}(H_0|D) = 0.17$, $P_{BIC}(H_1|D) = 0.83$, $n = 17$, $SSE_0 = 0.19$, $SSE_1 = 0.13$, $\Delta BIC = -3.1$, $BF = 0.21$ (Table 5).

Table 5.

Results of regression- and BIC analysis by condition.

	Regression analysis					BIC analysis	
Task	*B*	*SE B*	β	*F*	R^2	$P_{BIC}(H_0\|D)$	$P_{BIC}(H_1\|D)$
Stroop task	-	-	-	-	-	0.8	0.2
Attentional blink task	-0.21	0.11	-0.44	3.56	0.19	0.6	0.4
Change detection task	-0.07	0.07	-0.24	0.94	0.06	0.01	0.99
UFOV task	-0.04	0.07	-0.17	0.42	0.03	0.17	0.83

Note. No significant results observed for the regression analysis.

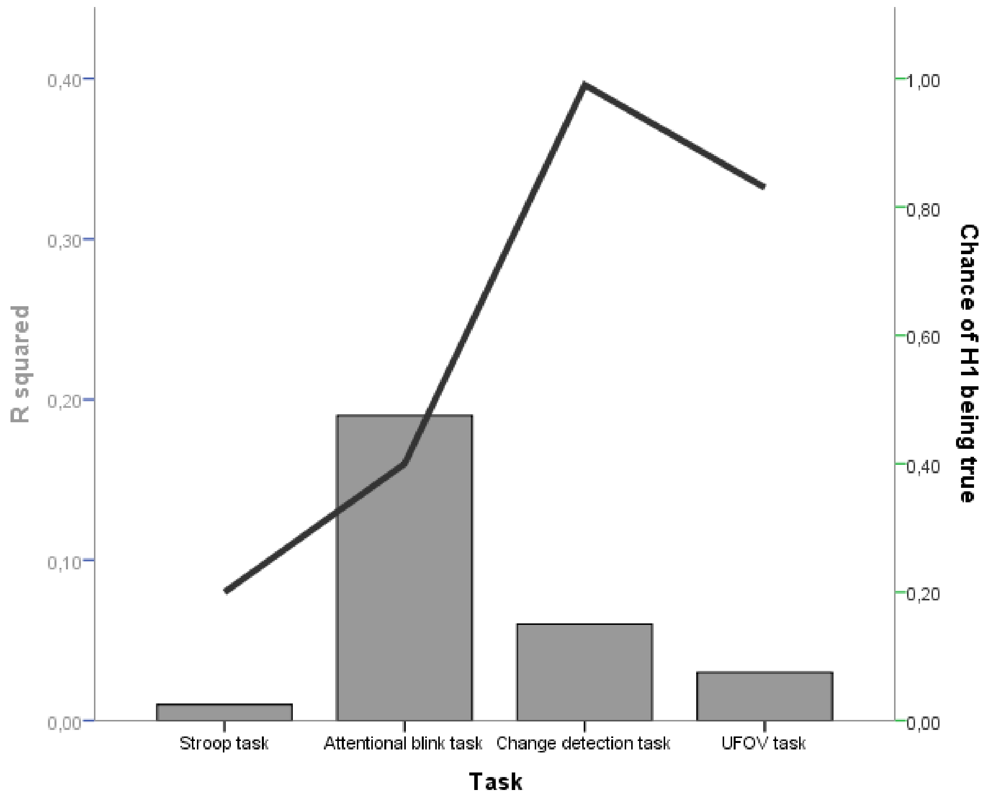


Figure 10. R^2 for regressions (grey bars) compared to chance of alternative hypothesis being correct given the data for BIC (black line), by task.

Factor analysis. To assess whether a common factor was underlying the psychophysical measurements, a confirmatory factor analysis was conducted. The factor analysis found two significant components underlying the variables’ scores with eigenvalues greater than 1, explaining 65.59% of variance in the data. Model fit was good, with Chi square indicating no significant differences between the modeled and actual variances, X^2 = 4.23; p = 0.65; X^2/df = 0.71; *RMSEA* = 0.

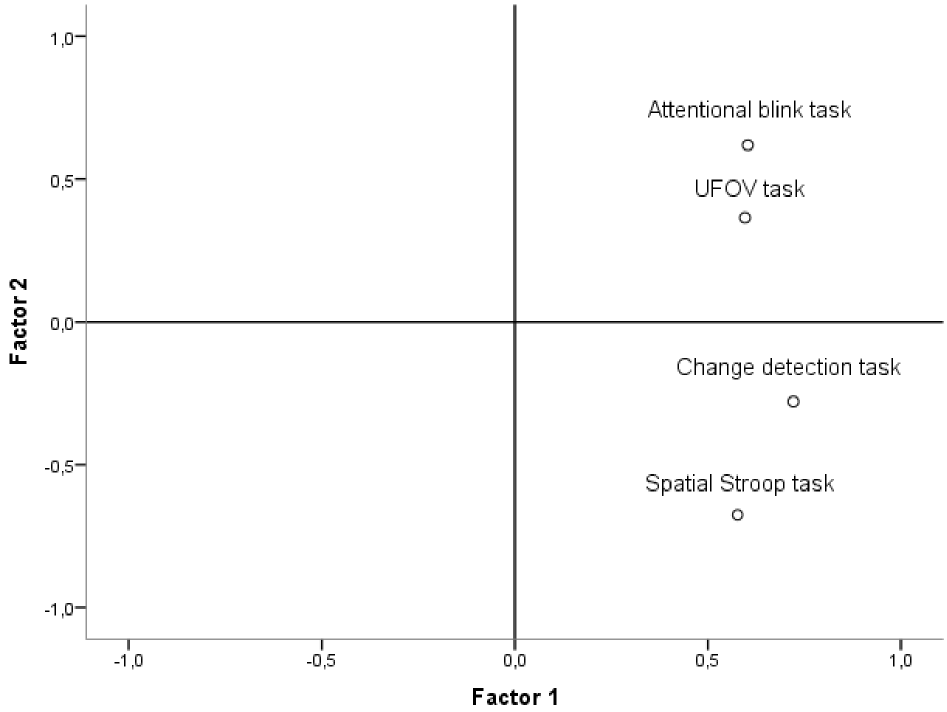


Figure 11. Factor loadings of the four tasks on the two discovered factors.

Discussion

The purpose of this study was to examine the link between playing AVGs and cognitive abilities. Different methods of measurement were employed, with the intend to broaden the methodological spectrum of measuring differences in psychophysical abilities, related to video game experience. Further was this study focused on the effects of playing one particular CMAVG (*Overwatch*). This was hypothesized to show even greater differences in psychophysical performance between players and non-players, than similar studies have found with less competitive games (Castel et al., 2005; Colzato, Van Leeuwen, Van Den Wildenberg & Hommel, 2010; Dye et al., 2009; Chisholm et al., 2010; Donohue et al., 2010; Green & Bavelier, 2012; Spence & Feng, 2010). Additionally was the competitive nature of *Overwatch* hypothesized to produce differences in performance on psychophysical measurements based on the player's positioning in the in-game ranking system.

The psychophysical tests measured no significant differences in attentional control, temporal attentional capacity, visual working memory capacity or spatial distribution of attention in the peripheral vision between *Overwatch* players and non-action-video-game players. The regression analysis did not reveal a significant effect of *Overwatch* players' rank on the performance in any of the psychophysical measurements. The BIC comparison did yield results suggesting a possible effect of *Overwatch* rank on visual working memory capacity and spatial distribution of attention in the peripheral vision. Reasons for the failure to detect any differences using significance testing as well as the validity of the tests, the value of this study in comparison to other similar studies and the differences in the statistical analysis, will be discussed in the following.

The analysis of the data obtained from the attentional blink task did not yield any significant differences. The task did however detect the attentional blink. It could be observed and was statistically significant for a placement of T2 3 to 6 letters (166 to 415 ms) after T1.

This is comparable to Raymond et al.’s (1992) findings, which detected the blink between 180 and 450 ms after T1. Interesting is that the present study, compared to other similar studies, employed a short presentation time of 83 ms (Achtman et al., 2008). This indicates that using a shorter presentation time will still produce an attentional blink, while possibly making the task more sensitive to high-end performance differences.

This study’s attentional blink task consisted of only 40 trials. This is lower than the 90 to 180 trials that were conducted by Raymond et al. (1992) and was done to reduce the effect that fatigue might have on the task performance, since the attentional blink task was the most demanding out of all four tests used. The trial number was not too low however, since the concept of interest, the attentional blink, could still be observed.

One interesting finding of the observed attentional blink, is that its exact distribution seemed different for the two conditions. Superimposing both distribution over one another shows this (see Figure 7). The control group falls below 10% accuracy at T2 position 4, while the experimental group shows higher accuracy for position 4 when compared with position 3 or 5. This suggests that a difference in performance might have been detectable for T2 position 4. The statistical tests however could not reveal this difference in performance, as both distributions taken together show a larger attentional blink. The failure to detect a difference in performance on the attentional blink task might thus have been a product of the two conditions’ accuracy distributions cancelling out each other’s extreme values in such a way, that the observed attentional blink appeared to be larger than it was for the individual conditions.

The BIC analysis delivered highly interesting results, suggesting a positive influence of higher *Overwatch* rank on performance for both the change detection- (chance of 99%) and UFOV task (chance of 80%). Since the UFOV task has had shortcomings in its design that will be discussed later, is especially the change detection task’s difference in performance of interest. The change detection task's performance difference within the experimental group, is the only effect that was detected as hypothesized. The observed difference is however not in the theorized direction (Figure 8). The figure shows that lower ranked players actually performed better than higher ranked players. Interestingely is this difference largely because of participants with rank 1 (*bronze)* performing better than other ranks. This seems counterintuitive, as rank 1 players performed better than both non-ranked players (rank 0) and higher ranked players. It is possible that this difference was observed because of some intrinsic value of players on rank 1. Lower ranks might promote advantages in cognitive abilities more than higher ranks, which require more knowledge specific to the game learned by practice (e.g., knowledge of the map layout or specific combinations of weapons). I.e., players learn highly specific tricks as they gain experience, giving them an advantage over less experienced players, which have to rely more on their raw cognitive abilities to reach their in-game goal. Differences in cognitive ability might have a stronger influence on performance on lower ranks because of this. This in turn would explain why rank 1 players performed better, namely that the higher ranked players rely more on abilities not measured in the psychophysical tests (knowledge specific to the game).

Another interesting aspect of finding a within group difference on the change detection task, is that the t-test could not detect a between group difference. The combination of finding a difference within the experimental group, based on an estimator of skill (the *Overwatch* rank), with the failure to find a difference compared to the control group that is supposed to be completely unskilled in the game, indicates that the control group might not have been less skilled at all. Rather was the experimental group already sectioned into skill categories (the *Overwatch* rank), while the control group was not. Both populations might possess similar distributions of visual working memory capacity, only that the experimental group was already categorized into levels of skill, of which visual working memory capacity is a determinant. The difference in performance on the change detection task based on *Overwatch* rank might thus have been found within the control group as well, only were they never categorized based on their psychophysical performance, prior to this study .

Limitations

A spatial Stroop task instead of a more common color based Stroop task was used (Kronenberger et al., 2005). The spatial version of the Stroop task was hypothesized to be more fitting to the situations commonly encountered in an AVG. Unsworth et al. (2015) used a similar version of the spatial Stroop task, one main difference being that the incongruent condition had a much lower chance of appearing. The present study's spatial Stroop task opted for a 50% chance of the incongruent condition appearing. This was done to reduce any effect that vigilance may have on the participant's performance. However the incongruent condition having a low chance of appearance may result in a higher Stroop effect. The participant is not as prepared for an incongruent trial when they have a low chance of appearing, resulting in longer reaction time on the incongruent trials. This results in a greater Stroop effect, which in turn makes the test more sensitive to performance differences. Unsworth et al. (2015) conversely found a much greater Stroop effect (137.12 ms) than the present study (30 ms). The low Stroop effect may partly be to blame for the ANOVA's failure to find a significant influence of the trial's condition (congruent vs incongruent) or the particiapant's condition (experimental vs control and *Overwatch* rank) on the participant's performance. A greater Stroop effect would have increased the chance for the analysis to find a significant effect. Opting for a low chance of the incongruent condition appearing might thus be the overall more sensitive approach, since it seems to increase the observed Stroop effect. This in turn makes finding differences more likely.

The scores on the UFOV task were near perfect for every participant, indicating a ceiling effect. This might have been due to the fact that participants were asked to mostly control their distance to the screen themselves. Participants may have been too far away from the screen, for the task to be difficult, due to this. Further was the stimulus presentation time of 200 ms too long. Other studies have used much shorter appearances of 60 to 90 ms (Ball et al., 1988; Sekuler et al., 2000). The reason for this study's long presentation time was to exclude any effect that processing speed may have on the performance. This however made the task too easy, suggesting a presentation time of 60 to 90 ms, or a slightly longer one combined with heavy masking might be more effective.

A confirmatory factor analysis was conducted, as a tool to assess internal validity. The intention being that one factor would be found on which all tasks load heavily, since all tasks' performance was hypothesized to be partly depending on one factor, playing *Overwatch*. The factor analysis revealed not one, but two components underlying the data, explaining 65.59% of variance. 65.59% of variance is low for two factors explaining four variables. By chance one would expect 50% of variance explained. The unexpected outcome of the factor analysis can partially be blamed on the shortcomings (as discussed) of some of the tests used. The attentional blink- and UFOV tasks loaded highly positively on both factors (see Figure 11). The change detection- and spatial Stroop tasks loaded positively on one- and negatively on the other factor. This leads to the four tests building pairs of two. This suggests that the ceiling effect in case of the UFOV task and the high difficulty of the attentional blink task, may have had a limiting effect on the variance produced by participant's performance. I.e., the distribution of scores could not display itself as it did for the other two tasks, which in turn produced highly positive factor loadings on a second factor, where the other two more valid tasks, show negative loadings. The first factor might thus represent the concept of interest, the influence of *Overwatch* play on the measured abilities. The second factor would then conversely represent 'anomalies' in the variance of results produced, due to floor- or ceiling effects. This explains why the second factor splits the tasks into a pair of 'robust' tests and a pair of tests that have been diagnosed with shortcomings. This underlines the problematic validity of the attentional blink- and UFOV task.

The reasons for the failure of the attentional blink- and change detection tasks to find significant performance differences partly lie in the chosen methods of sampling and analysis. One of the problems that comes with convenience sampling, is the fact that the size of the control and experimental conditions cannot easily be controlled. This lead to the experimental group having 17 participants, while the control group only had 12. While this does not undermine the validity of the study, is it detrimental to the power of the statistical analysis. The significance analysis' power to detect a significant difference is partly governed by the smallest group's sample size, meaning the small control group diminished the chance to detect a difference. This made finding significant differences less likely, which in turn is partly responsible for not finding most of the hypothesized results.

One central motivation for this study was to research the possibility of high level video game players showing an even higher performance on psychophysical measurements than lower level ones. The sampling method of convenience sampling however did not yield the kind of elite players needed to confirm such a hypothesis. The mean *Overwatch* rank in the experimental group was 'Gold', this is the third worst of the seven ranks in *Overwatch* (Overwatch (video game), 2017). This means that while the participants played semi-competitively, did they not do so at a high level. This is crucial as only playing at the top level can provide the kind of 'cut-throat', competitive environment, which promotes skill and severely punishes lack of it. Exactly this environment was what was hypothesized to yield higher performance on the psychophysical measurements. The fact that participants were not commonly playing in this environment is partly to blame for the lack of significant results.

Future research

This study's change detection tasks' main difference with one used in a similar study was that a mask was being shown after every stimulus (Anguera et al., 2013). The lack of ceiling or floor effects suggests that adding a mask might be beneficial to the task, as it diminishes any effect that an "afterimage" of the shown squares might have on the participant's performance. Future studies should thus consider masking the stimuli in their change detection task.

Contrary to having a low median rank in the experimental group being a limitation, do the change detection task's results suggest that the opposite might be true. It could actually be the group for which the difference in cognitive abilities is greatest, when compared to non-players. Future research might thus consider performing additional experiments with some representation of an in-game rank, to confirm such a hypothesis.

According to the BIC analysis had *Overwatch* rank a 99% chance of having an influence on the performance in the change detection task. This makes it highly surprising that the regression analysis was not able to find a significant influence. This failure to find an influence, highlights that significance testing is often not a useful tool, when trying to answer the question: "Which is more likely, the alternative- or null-hypothesis?". Significance testing does not answer this question, although researchers often act like it does. Rather does it answer the question: "How likely is the observed data, given that the null-hypothesis is correct?" What research using significant testing have been doing is to use $P(D|H_0)$ (the chance for the data to be observed given that the null-hypothesis is correct) as a substitute for $P(H_0|D)$ (the chance that the null-hypothesis is correct, given the data) (Masson, 2011). These two statements however are far from equivalent. The formula used for the transition of one to the other is Bayes theorem (equation 6):

$$P(A|B) = \frac{P(B|A)\,P(A)}{P(B)} \qquad (6)$$

It is obvious that this is very different from using $P(D|H_0) = P(H_0|D)$ as a basis for analysis. What the Bayesian model selection process does, is actually answer the question “Which is more likely, the alternative- or null-hypothesis?”.

The results of the Bayesian analysis for the change detection task indicate, that researchers should consider switching to Bayesian methods of analysis, or at least use both significance testing and Bayesian analysis. This is not a new notion, however was the impact limited until now (Wagenmakers, 2007). Part of the reason for this might be that Bayesian analysis is not as trivial to conduct as significance testing. Researchers in the social sciences might not always have the know-how to be able to conduct a Bayesian analysis. However frameworks do exist that render this almost as easy as significance testing (Masson, 2011).

Implications

Overall can this study’s failure to find significant results not be attributed to other studies finding relations were there weren’t any. Too many shortcomings in the sampling and measurements make it impossible to judge this study’s results as any indicator for the relation between gaming behavior and performance on psychophysical skills. This study is however not without merit. Modified measurement methods were used to (mostly) great effect, expanding the literature on methods to measure psychophysical skills with. Additionally does this study demonstrate the usefulness of including Bayesian analysis in the statistical testing procedure. Future research should focus on applying these methods in new environments to further solidify their performance in this study. Further is the study of competitive video game players psychophysical skills still an exciting prospect, needing of more research into the sort of skills these individuals possess.

References

Achtman, R. L., Green, C. S., & Bavelier, D. (2008). Video games as a tool to train visual skills. *Restorative Neurology and Neuroscience*, *26*(4-5), 435–446. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2884279/

Anguera, J. A., Boccanfuso, J., Rintoul, J. L., Al-Hashimi, O., Faraji, F., Janowich, J., Kong, E., Larraburo, Y., Rolle, C., Johnston, E. & Gazzaley, A. (2013). Video game training enhances cognitive control in older adults. *Nature*, *501*(7465), 97-101. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3983066/

Ball, K. K., Beard, B. L., Roenker, D. L., Miller, R. L., & Griggs, D. S. (1988). Age and visual search: Expanding the useful field of view. *JOSA A*, *5*(12), 2210-2219. doi: 10.1364/JOSAA.5.002210

Barrett, B. (2017, January 27). Overwatch passes 25 million player milestone, just getting silly now. Retrieved from https://www.pcgamesn.com/overwatch /overwatch-sales-numbers

Boot, W. R., Kramer, A. F., Simons, D. J., Fabiani, M., & Gratton, G. (2008). The effects of video game playing on attention, memory, and executive control. *Acta psychologica*, *129*(3), 387-398. doi: 10.1016/j.actpsy.2008.09.005

Castel, A. D., Pratt, J., & Drummond, E. (2005). The effects of action video game experience on the time course of inhibition of return and the efficiency of visual search. *Acta psychologica*, *119*(2), 217-230. doi: 10.1016/j.actpsy.2005.02.004

Chisholm, J. D., Hickey, C., Theeuwes, J., & Kingstone, A. (2010). Reduced attentional capture in action video game players. *Attention, Perception, & Psychophysics, 72*(3), 667-671. doi: 10.3758/APP.72.3.667

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2013). *Applied multiple regression/ correlation analysis for the behavioral sciences*. Retrieved from https://books.google.nl/books?hl=en&lr=&id=gkalyqTMXNEC&oi=fnd&pg=PP1&dq=Applied+multiple+regression/correlation+analysis+for+the+behavioral+sciences&ots=tQKXY7s5fc&sig=-5tL6uDHcoSPua3_e4AUx7G-0HE#v=onepage&q=Applied%20multiple%20regression%2Fcorrelation%20analysis%20for%20the%20behavioral%20sciences&f=false

Colzato, L. S., Van Leeuwen, P. J., Van Den Wildenberg, W., & Hommel, B. (2010). DOOM'd to switch: superior cognitive flexibility in players of first person shooter games. *Frontiers in psychology*, *1*, 8. doi: 10.3389/fpsyg.2010.00008

Competitive Play. (2017, April 07). Retrieved from http://overwatch.gamepedia.com/Competitive_Play

Donohue, S. E., Woldorff, M. G., & Mitroff, S. R. (2010). Video game players show more precise multisensory temporal processing abilities. *Attention, Perception, & Psychophysics, 72*(4), 1120-1129. doi: 10.3758/APP.72.4.1120

Dye, M. W., Green, C. S., & Bavelier, D. (2009). Increasing speed of processing with action video games. *Current directions in psychological science*, *18*(6), 321-326. doi: 10.1111/j.1467-8721.2009.01660.x

Feng, J., Spence, I., & Pratt, J. (2007). Playing an action video game reduces gender differences in spatial cognition. *Psychological science, 18*(10), 850-855. doi: 10.1111/j.1467-9280.2007.01990.x

First-person shooter. (2017, April 17). Retrieved from https://en.wikipedia.org/wiki /First-person_shooter

Games sales. (n.d.). Retrieved from http://steamspy.com/

Green, C. S., & Bavelier, D. (2006). Effect of action video games on the spatial distribution of visuospatial attention. *Journal of experimental psychology: Human perception and performance*, *32*(6), 1465-1478. doi: 10.1037/0096-1523.32.6.1465

Green, C. S., & Bavelier, D. (2012). Learning, attentional control, and action video games. *Current biology*, *22*(6), R197-R206. doi: 10.1016/j.cub.2012.02.012

Heckman, J. J. (2010). Selection bias and self-selection. In *Microeconometrics* (pp. 242-266). Palgrave Macmillan UK. doi: 10.1057/9780230280816_29

Hubert-Wallander, B., Green, C. S., & Bavelier, D. (2011). Stretching the limits of visual attention: the case of action video games. *Wiley interdisciplinary reviews: cognitive science*, *2*(2), 222-230. doi: 10.1002/wcs.116

Jennett, C., Cox, A. L., Cairns, P., Dhoparee, S., Epps, A., Tijs, T., & Walton, A. (2008). Measuring and defining the experience of immersion in games. *International journal of human-computer studies*, *66*(9), 641-661. doi: 10.1016/j.ijhcs.2008.04.004

Kronenberger, W. G., Mathews, V. P., Dunn, D. W., Wang, Y., Wood, E. A., Giauque, A. L., Larsen, J. J., Rembusch, M. E., Lowe, M. J., & Li, T. Q. (2005). Media violence exposure and executive functioning in aggressive and control adolescents. *Journal of clinical psychology*, *61*(6), 725-737. doi: 10.1002/jclp.20022

Lawson, M. L., Crewther, D. P., Duke, C. C., Henry, L., Kiely, P. M., West, S. J., & Crewther, S. G. (1998). Attentional blink in global versus local attentional modes. *Clinical & Experimental Ophthalmology*, *26*(S1). doi: 10.1111/j.1442-9071.1998.tb01384.x

List of video game genres. (2017, May 09). Retrieved from https://en.wikipedia.org/wiki /List_of_video_game_genres

Liu, D., Li, X., & Santhanam, R. (2013). Digital Games and Beyond: What Happens When Players Compete. *Mis Quarterly*, *37*(1), 111-124. Retrieved from http://aisel.aisnet.org /cgi/viewcontent.cgi?article=3086&context=misq

MacLeod, C. M. (2005). The Stroop task in cognitive research. *Cognitive methods and their application to clinical research*, *9*. Retrieved from http://arts.uwaterloo.ca/~cmacleod /Research/Articles/CMM04.pdf

Martens, S., & Wyble, B. (2010). The attentional blink: Past, present, and future of a blind spot in perceptual awareness. *Neuroscience & Biobehavioral Reviews*, *34*(6), 947-957. doi: 10.1016/j.neubiorev.2009.12.005

Masson, M. E. (2011). A tutorial on a practical Bayesian alternative to null-hypothesis significance testing. *Behavior research methods*, *43*(3), 679-690. doi: 10.3758/s13428-010-0049-5

Milham, M. P., Erickson, K. I., Banich, M. T., Kramer, A. F., Webb, A., Wszalek, T., & Cohen, N. J. (2002). Attentional control in the aging brain: insights from an fMRI study of the stroop task. *Brain and cognition*, *49*(3), 277-296. doi: 10.1006/brcg.2001.1501

Multiplayer online battle arena. (2017, April 12). Retrieved from https://en.wikipedia.org/wiki /Multiplayer_online_battle_arena

Netherlands - Country Stats -. (n.d.). Retrieved from http://steamspy.com/country/NL

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*(3), 849-860. doi: 10.1037/0096-1523.18.3.849

Sekuler, A. B., Bennett, P. J., & Mamelak, M. (2000). Effects of aging on the useful field of view. *Experimental aging research*, *26*(2), 103-120. doi: 10.1080/036107300243588

Spence, I., & Feng, J. (2010). Video games and spatial cognition. *Review of General Psychology*, *14*(2), 92-104. doi: 10.1037/a0019491

Statista. (2016). U.S. most popular video game genres 2016. Retrieved from https://www.statista.com/statistics/189592/breakdown-of-us-video-game-sales-2009-by-genre/

Statistic Brain (2016, September 08). STATS | Video Game Industry Sales. Retrieved from http://www.statisticbrain.com/video-game-yearly-sales/

Tassi, P. (2016, September 13). Riot Games Reveals 'League of Legends' Has 100 Million Monthly Players. Retrieved from http://www.forbes.com/sites/insertcoin/2016/09/13/riot-games-reveals-league-of-legends-has-100-million-monthly-players/?utm_source=yahoo&utm_medium=partner&utm_campaign=yahootix&partner=yahootix&yptr=yahoo#212c883610b1

The Average Gamer: How the Demographics Have Shifted. (n.d.). Retrieved from https://www.gamesparks.com/blog/the-average-gamer-how-the-demographics-have-shifted/

Video game industry. (n.d.). Retrieved from http://vgsales.wikia.com/wiki/Video_game_industry

Vorderer, P., Hartmann, T., & Klimmt, C. (2003, May). Explaining the enjoyment of playing video games: the role of competition. In *Proceedings of the second international conference on Entertainment computing* (pp. 1-9). Carnegie Mellon University. Retrieved from https://www.researchgate.net/profile/Tilo_Hartmann/publication/220851167_Explaining_the_enjoyment_of_playing_video_games_The_role_of_competition/links/0fcfd510037a364d8c000000.pdf

Wagenmakers, E. J. (2007). A practical solution to the pervasive problems of p values. *Psychonomic bulletin & review*, *14*(5), 779-804. doi: 10.3758/BF03194105

Overwatch (video game). (2017, April 17). Retrieved from https://en.wikipedia.org/wiki/Overwatch_(video_game)

Unsworth, N., Redick, T. S., McMillan, B. D., Hambrick, D. Z., Kane, M. J., & Engle, R. W. (2015). Is playing video games related to cognitive abilities?. *Psychological science*, *26*(6), 759-774. doi: 10.1177/0956797615570367

Appendix

Appendix I

Gender: ☐ Male ☐ Female

Age: ______

Nationality: ☐ Dutch ☐ German ☐ Other:____________________

I am experienced in (choose one):

☐ Counter Strike

Playtime(hrs):

☐ 0-150 ☐ 151-300 ☐ 301-450 ☐ 451-600 ☐ 601-750 ☐751-1000 ☐ >1000

Highest rank ever achieved:

€ Unranked

€ Silver I

€ Silver II

€ Silver III

€ Silver IV

€ Silver Elite

€ Silver Elite Master

€ Gold Nova I

€ Gold Nova II

€ Gold Nova III

€ Gold Nova Master

- € Master Guardian I
- € Master Guardian II
- € Master Guardian Elite
- € Distinguished Master Guardian
- € Legendary Eagle
- € Legendary Eagle Master
- € Supreme Master First Class
- € Global Elite

☐ Overwatch

Playtime (hrs):

☐ 0-50 ☐ 51-100 ☐ 101-200 ☐ 201-500 ☐ 501-1000 ☐ 1000+

Highest rank ever achieved:

- € Bronze
- € Silver
- € Gold
- € Platinum
- € Diamond
- € Master
- € Grandmaster
- € Top 500

☐ I have no experience in action video games

☐ Colour-blind

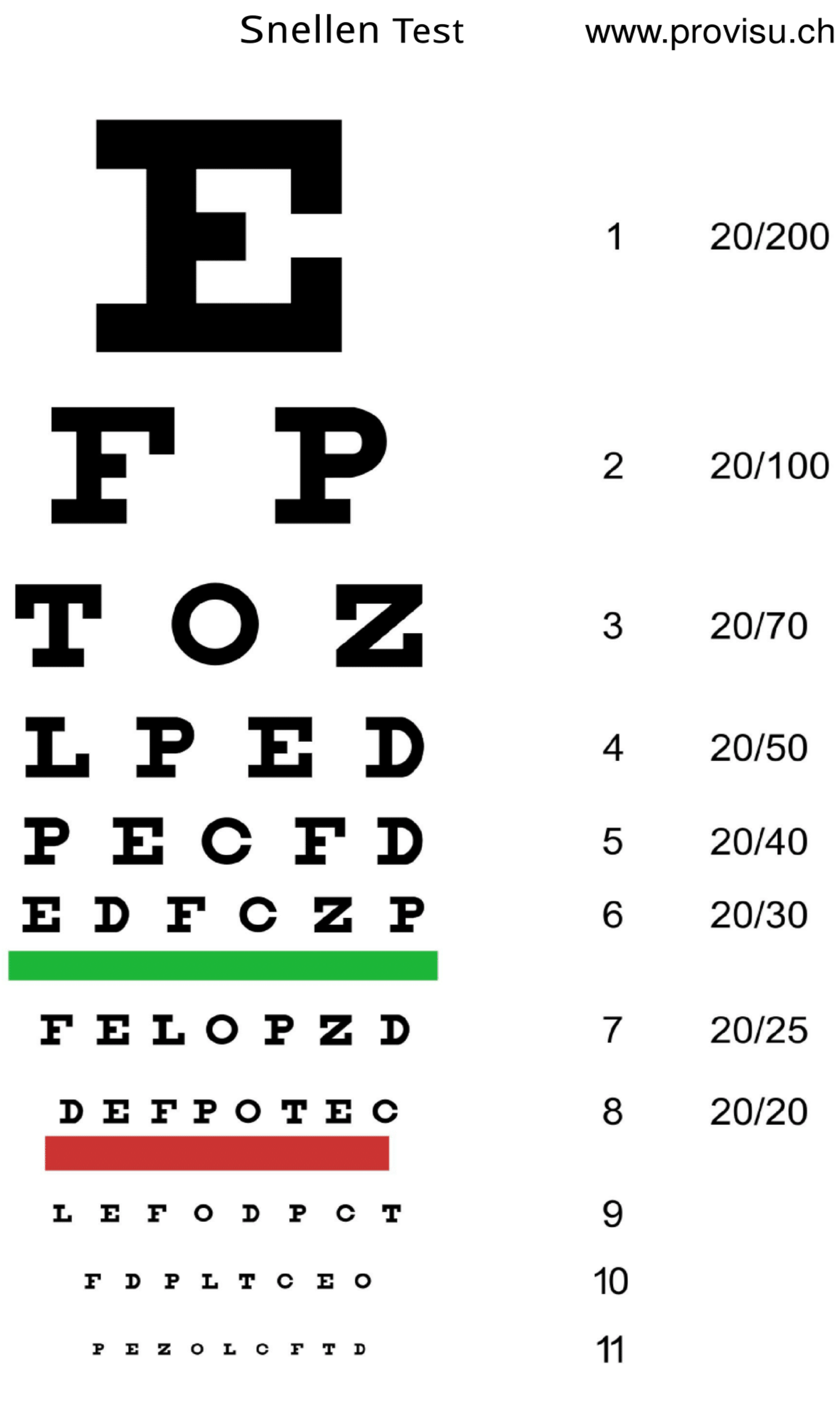
- € Deuteranopia (Green-blind)
- € Tritanopia (Blue-blind)
- € Protanopia (Red-blind)

Indicate the preferred hand

	Always left	Mostly left	No preference	Mostly right	Always right
Writing	☐	☐	☐	☐	☐
Throwing a ball on a target	☐	☐	☐	☐	☐
Playing with a racket	☐	☐	☐	☐	☐
What hand is up to handle a broom	☐	☐	☐	☐	☐
What hand is up to handle a shovel	☐	☐	☐	☐	☐
Lighting matches	☐	☐	☐	☐	☐
Scissors when cutting paper	☐	☐	☐	☐	☐
To hold a wire to move it through the eye of a needle	☐	☐	☐	☐	☐
To deal playing cards	☐	☐	☐	☐	☐
To hammer in a nail	☐	☐	☐	☐	☐
To brush your teeth	☐	☐	☐	☐	☐
To remove a jar lid	☐	☐	☐	☐	☐

-2 -1 0 1 2

Appendix II



In order to perform this test, please follow the instructions:

Appendix III

Informed Consent

On a voluntarily basis, I decided to participate in an experiment in which response times and the accuracy of my choices will be measured.

The experiment consists of subtasks, including a Stroop task, the attention blink paradigm, a useful field-of-view task, a delayed recognition task and a visual acuity test.

I have been informed about the specific purpose of the research will have the opportunity to ask further questions after the experiment. If I have additional questions later on, I can always contact the researcher Julian Steinke (j.steinke-1@student.utwente.nl).

I have the right to stop with the experiment at any time.

I understand that the data gathered in this experiment will be used for a thesis and might be published. My anonymity and the anonymity of my data is assured.

Name participant — Name researcher

Signature participant — Signature researcher

Place

Date

Appendix IV

Spatial Stroop task

Please indicate the position of the arrow as fast as possible. It can appear on the top or the bottom. Press the UP key, if the arrow is at the top and the DOWN key if the arrow is at the bottom of the screen. Disregard the direction it points to.

Attentional blink

You will see multiple characters very briefly on the screen, one after another. One of those characters will be white, the others black. Please indicate which character was white and if you saw a number at the end of each trial. Press Y if you saw a number, N if you did not.

Delayed Recognition

You will see multiple coloured rectangles on the screen. You will have to remember those rectangles. After a masking stimulus is shown, you will see one of those rectangles again. Ignore this mask. Please indicate, if the shown rectangle was among the others. Press Y, if it was, N if it was not.

Useful FOV

Please maintain the distance to the screen indicated by the researcher. Focus only on the middle of the screen. One of the circles will change colour. After a masking stimulus is shown, please click on the circle, that changed colour.