4-25-2019

The Effects of High and Low Intensity Video Games on Cognitve Abilities

Juan J. Perez
College of Saint Benedict/Saint John's University, jjperez@csbsju.edu

The Effects of High and Low Intensity Video Games on Cognitive Abilities

Juan J. Perez

College of Saint Benedict and Saint John's University

Author Note

Juan Perez, Psychology Department, College of Saint Benedict and Saint John's University.

I thank Dr. Robert Kachelski for his support, feedback, and review of this paper, as well as Dr. Michael Livingston, and Dr. Benjamin Faber for their suggestions.

Correspondence concerning this article should be addressed to Juan Perez, 2540 W Ball RD Apt 46, Anaheim, CA 92804, JuanJPerez272@gmail.com

Abstract

The purpose of this experiment was to see whether or not video games have any effect on an individual's cognitive abilities. Specifically, I focused on working memory, information processing, context processing, and goal maintenance. In order to measure this, I had participants complete three tasks: the AX-CPT task, Eriksen's Flanker Task, and the N-Back Task. Participants were assigned to one of three groups: music group (Control), low intensity video game group, and high intensity video game group. Each group had exposure to the experimental variable for 15 minutes and then completed the three tasks. Scores on each task were compared for the different groups to see if there were any significant differences in performance.

Keywords: Video games, problem solving, speed of processing

The effects of high and low intensity video games on cognitive abilities

Cognitive abilities are the skills we apply to everyday tasks ranging from simple to even the most complex. Our cognition has less to do with knowledge already known, but rather our own ability to process, problem solve, remember, and pay attention to incoming information (Michelon, 2006). The task can be anything: deciding what you will be making for lunch, listening to a professor give a lecture, or paying attention to the road while driving. All these tasks use our individual cognition.

What is interesting about our cognitive abilities is that it is not just limited to affecting how we think. Having a lower level cognitive ability has been associated with many health-related problems and behaviors. These include but are not limited to; smoking, alcohol consumption, heart disease, diabetes etc. (Batty, Deary, & Macintyre, 2006; Batty, Deary, & Macintyre, 2007a; Batty, Deary, Schoon & Gale, 2007b; Batty, Deary, Schoon & Gale, 2007c). In addition to this, having a lower cognitive ability also seems to be a risk factor in the development of major depression disorder. Low cognitive ability could be a risk factor for especially early onset major depression in men, whereas the influence of cognitive ability on re-occurrence seems less strong. Lower cognitive ability increases the risk of major depression and should therefore be part of the depression risk assessment in clinical practice (Christensen, Rozing, Mortensen, & Osler, 2018). Lower cognitive ability is shown to have negative on a person and how they behave. This does beg the question; would external effects influence a person's cognitive ability?

Different research shows that cognitive abilities in adulthood are largely influenced by individual genetic background, but they have also been shown to be importantly influenced by environmental factors (Palomera, Vilas, Kebir, Gastó, Krebs, & Fañanás, 2015). Of the few studies that examined social stressors, results consistently showed cognitive development to be influenced by both positive and negative social interactions at home, in school or the community. Among behavioral factors related to diet and lifestyle choices of the mother, breastfeeding was the most studied, showing consistent positive associations with cognitive ability (Ruiz, Quackenboss, & Tulve, 2016). Cognitive abilities can clearly be affected by a variety of environmental factors. If external factors such as social interactions can affect cognitive ability; what can video games do for our own cognitive abilities?

Video games have become a byproduct of the surge in technology. In the last forty years the video game industry has greatly developed since the release of the first arcade machine and household gaming console (Wang, Liu, Zhu, Meng, Li, & Zuo, 2016). Games have now become engrained into many different cultures and is constantly evolving alongside the ever-growing capacity of modern technology. Video games, as of late, have come under fire for creating negative effects in its users. Video games as learning tools might come as a surprise to those who recall a congressional hearing in the early 1990s that considered negative effects on children who played games such as Mortal Kombat. Recent studies have not borne out these fears as far as effects on cognitive function, although concerns persist about whether games foster aggression or addictive play (Bavelier & Green, 2016). This back and forth between video games and media has portrayed video games as a negative factor that existed. Yet, even with the portrayal of video games in the media; researchers still have an understanding that there is a potential to benefit from video games. Now that researchers have begun to figure out how some video games improve cognition in players—by bettering attention and reaction times—

they have started to design nonviolent games geared toward people with brain injuries or cognitive deficits (Bavelier & Green, 2016).

Recently, video games have generated a lot of research interest. Games are now being used by psychologist and neuroscientist to help us understand our own neurocognition (Bavelier, Achtman, Mani, & Focker, 2012). Initial studies for video games; tended to focus on the possible negative behavior consequences of violent video games. Originally, video games were usually associated with aggressive behaviors, poor school performance, video game addiction, motion sickness, seizures, and instability of mood (Wang, Liu, Zhu, Meng, Li, & Zuo, 2016). There were a few early exceptions to this. An early study conducted by Green and Bavelier (2003), showed that participants of action video games enhanced the players visual attentional system when compared to non-video game players. However, a notable shift has occurred prompting increased interest in the benefits of video game play and the practical ramifications of gaming on our everyday lives. In particular, the potential for video game play to augment perceptual, motor and neurocognitive abilities has been the focus of recent research attention (Kowal, Toth, Exton, & Campbell, 2018). Interestingly enough, studies suggest that there is a link to having improved mental capabilities when they are exposed to video games.

Recent research suggests that frequently playing fast paced shooter games changes certain aspects of cognition including: attention, faster processing of information, flexibility of switching from one task to another and visualizing the rotation of an object. Rigorous testing has provided evidence for these gains (Bavelier & Green, 2016). Real world example of these positive improvements come in different forms. Tests of reaction times of action video-game players show that performance improved by more than 10 percent compared with before they took up gaming. Game playing seems to confer the ability to make correct decisions under pressure. One study revealed that laparoscopic surgeons who were also game players were able to complete surgeries more quickly while retaining the necessary precision in the operating room. Game-playing surgeons appeared to work more efficiently, not just faster (Bavelier & Green, 2016). Action video games can be demanding on a person's cognition. Many action games require that the player focuses on a variety of different tasks at once as well as keep tabs on different components of the game mechanics. Generally, these video games require additional attention, working memory, and executive functions of the players (Boot, Kramer, Simons, Fabiani, & Gratton, 2008). Action video games follow a certain format; (i) a fast pace involving severe time constraints for decisions and motor responses; (ii) a high degree of perceptual and motor load which taxes working memory and goal directed actions; (iii) a dynamic mixture of highly focused attention and vigilance with a widely distributed focus of attention; and (iv) a high degree of distraction and clutter in the gaming environment (Kowal, Toth, Exton, & Campbell, 2018). Following this format, only certain types of video games seem to have this effect on participants. In theory, action games should be able to enhance different cognitive effects.

A meta-analysis conducted by Wang, Liu, Zhu, Meng, Li, & Zuo (2016), consisting of twenty studies, found that healthy adults achieve moderate benefit from AVG (Action video games) training in overall cognitive ability and moderate to small benefit in specific cognitive domains. In contrast, young adults gain more benefits from AVG training than older adults in both overall cognition and specific cognitive domains. In addition to this, two meta-analysis consisting of 72 studies and 318 comparisons concluded that video games significantly improved information processing. quasi-experimental studies (*d* = 0.61, 95% CI [0.50, 0.73]), and true experiments (*d* = 0.48, 95% CI [0.35, 0.60]) (Powers, Brooks, Aldrich, Palladino, & Alfieri 2013). These meta-analyses show that there is evidence suggesting that there is a way to cultivate our cognitive abilities through video games. It would be possible to improve our cognitive performance and research in this field should be continued.

Based on this research, the current study attempted to see if there is any possibility of improving upon a participant's problem solving. Previous research states that there is a moderate link between a person's cognition and exposure to video games. Particularly action video games. The scale previously mentioned before; (i) a fast pace involving severe time constraints for decisions and motor responses; (ii) a high degree of perceptual and motor load which taxes working memory and goal directed actions; (iii) a dynamic mixture of highly focused attention and vigilance with a widely distributed focus of attention; and (iv) a high degree of distraction and clutter in the gaming environment (Kowal, Toth, Exton, & Campbell 2018), helped to determine what video games were chosen in order to get the most out of participants. The hope was to see if we can establish a way to improve on participant's cognition. As for the tasks to measure participant's cognitive abilities, we used the AX-CPT task, the Eriksen Flanker task, and the N-Back task.

The AX-CPT task (Appendix 1, Fig 1) is frequently used as a cognitive control task to examine context processing and goal maintenance (Washington University 2019). In this task, participants viewed a sequence of letters. There were 4 letters in each trial. Participants decided if the probe is a target (cue = A, probe = X) or not. IF the probe was a target, then participants pressed the 'E' key; if it is not a target then they pressed the 'I' key. Throughout the sequence of letters, there were distractor letters. The AX-CPT has not been used to contrast action video game players and non-video game players. Some studies, however, suggest that AVGP might outperform NVGP on this type of cognitive control task. Previous studies have found that in tasks similar to the AX-CPT have found that action video game players were able to respond to the task more quickly without the losing accuracy. (Cardoso, Kludt, Vignola, Ma, Green, & Bavelier 2016). The hope was that this task can uncover any differences between the different groups based on previous research.

The Eriksen Flanker task (Appendix 1, Fig 2) is an interference task where different inputs compete with the target, slowing the participants response speed (Eriksen 1974). In this variant of the Eriksen Flanker task, participants were asked to match the direction of the arrow shown in the middle of the screen with the provided keyboard as quickly as they could. There will only be two directions an arrow can appear, either left or right. The Eriksen Flanker task requires participants to respond to stimuli that is 'flanked' by irrelevant stimuli, the irrelevant stimuli can still affect their response. Often times the effect is a slower response time, but it can even cause the participant to answer incorrectly (Eriksen 1974). Previous research suggests that people who play video games may be able to extract task relevant information more efficiently while better suppressing irrelevant, potentially distracting sources of information (Bavelier, Green, Pouget, Schrater 2012). By running this task, we hoped to see if there are any differences in performance between groups.

The N-Back task (Appendix 1, Fig 3) is a task that focuses on working memory. In this task, participants had simple images appear one at a time. Participants clicked whenever they saw an image that previously appeared 2 images ago and ignore all others. If the participant did not click when an image appeared 2 images ago, then the system marked them as incorrect as if they did click on an incorrect image. Previous research suggests that video game players will be able to correctly ‘click’ on the image that appeared 2 items ago, but also have fewer ‘false alarms’ (Cardoso-Leite, Kludt, Vignola, Ma, Green, & Bavelier (2016). If we are successful, the implications for this could be useful for future research. The previous research suggests that this study will yield positive results.

This study attempted to figure out whether or not a person’s cognitive abilities can be temporarily improved upon. This study focused on only temporary cognitive improvement and was not measuring whether or not their cognitive abilities are improved on long term. Participants were exposed to three conditions; high intensity video games (Variable 1), low intensity video games (Variable 2), or classical music group (control). All three conditions were given a set of three tasks (AX-CPT task, Eriksen Flanker Task, and N-Back task) (See appendix 1 for tasks). The three tasks were treated as separate dependent variables. These tasks were measuring working memory, information processing, context processing, and goal maintenance. In theory, participants should’ve been able to perform better if they are stimulated with a high intensity video game.

Hypotheses

The cognitive abilities of the participants were measured by a set of three tasks in which participants worked on and completed. In this study, I predicted that participants exposed to high intensity video games would’ve been able to see an increase in their ability to perform mental activities. I anticipated that participants exposed to a high intensity video game were able to not only complete the tasks quicker, but also have fewer mistakes.

For participants that were exposed to a low intensity video game, I predicted the following. Participants should have a close if not equal problem-solving abilities to those who are in the control group, but the low intensity group should have done slightly better. In theory, low intensity video games should not stimulate the participant as much and so the results should not vary by much from one another.

Lastly, I also predicted that participants with previous experience playing video games would score higher than those who do not have as much experience. Participants who had previous experience should be able to pick up the game mechanics much quicker than the rest and in theory should have been able to become more actively stimulated.

Method

Participants

The participant group consisted of 30 males from Saint John's University that were provided by PRIA. 10 participants were assigned to each condition using block randomization.

Design

This study was an Independents groups between subjects' experiment with three conditions. The three conditions were; high intensity video game, low intensity video game, and the classical music control group.

Materials

For this study, I utilized three tasks. The three tasks were the AX-CPT task, Eriksen's Flanker Task, and the N-Back Task. (See appendix 1 for tasks). These tasks were treated as three separate dependent variables. These tasks were administered to all three groups. The tasks were also given in the following order: AX-CPT task, Eriksen Flanker task, N-back task. The AX-CPT task was measuring context processing and goal maintenance. It was also coded to last for 6 minutes. The Eriksen Flanker task was also measuring information processing. This task consisted of 20 trials and lasted 1 minute. Lastly, the N-back task measured working memory. This task ran for 70 trials and lasts 2 minutes. The purpose of these tasks was to measure the cognitive abilities of the participants. By administering these tasks to all three groups, we could see whether or not being stimulated by video games actually had any effect on the participant's cognition.

The video games were administered to the participants with a computer. The two games that was used were; DOOM (2016) and ABZU (2016). Both games are vastly different from one another in terms of what participants were encountering in game. ABUZ is a calming experience in which participants would simply explore the ocean with no in game threats. While DOOM was a hectic game that required the player to be constantly aware of their surroundings while avoiding in game threats. ABZU was given to the low intensity group. DOOM was given to the high intensity group. Both groups were exposed to each game for 15 minutes each.

There was also a set of headphones for the participants in group c, classical music control group. There was a laptop with a set playlist of music that they will be listening to. They were not allowed to change the song and listened to classical music for 15 minutes. Its purpose was to give this group the same amount of time, but they were exposed to a neutral stimulus.

Lastly, there was a questionnaire (See appendix 2 for questionnaire) that would determine the amount of experience each participant had with video games. The questionnaire also contained questions about whether or not they have played the games given previously as well as their experience with video games. The purpose of this was to determine if participants with more experience with video games had any overall effect on the scores. In addition to this, participants who had more video game experience should have been able to become more invested with the game mechanics during their play time. This may or may not have altered their performance overall and it is important to have accounted for that.

Procedure

The experiment itself ran for about 35-40 minutes per participant. Participants completed a consent form as well as the questionnaire. The questionnaire attempted to figure out how much experience the participants have had with videogames. We expect that participants who have had previous experience with video games will perform better overall than those who have had little or no experience. This was a small 3 question questionnaire. Afterwards, participants were brought to the computer in which they were exposed to their designated stimulus.

There were three groups. Group A; who was exposed to the high intensity video game, DOOM. Group B; who was exposed to the low intensity video game, ABZU. Group C; who was exposed to the classical music (neutral stimulus). All three groups had participants taken into the lab room without their belongings; in order to reduce distractions. Groups A and B were given the remote to play the games and were given the basic instructions on how to move, interact, and control the game. Once directions on how to play were given, participants were on the clock for 15 minutes.

In order to have a consistent experience for both groups; both games were set to a set of boundaries. Group A, exposed to DOOM, were set to an endless arcade mode in order to have no interruptions. Group B, exposed to ABZU, were set to the initial exploration point. This way both groups had a constant experience while experiencing their intended stimulus level; high or low intensity.

Participants in Group C, classical music control group, sat in a room to listen to well-known classical music for 15 minutes. In order to have them listen to it with no other kind of stimulus, the music had no lyrics.

Once participants were finished with their 15-minute session; participants were then given the three tasks. The first task given was the AX-CPT task. Participants were asked to read through the instructions, and once they finished reading instructions the researcher clarified any questions regarding the task. Afterwards participants worked on the actual task. This task had been previously adjusted to last only 6 minutes and had the three phases last 2 minutes each. At the four-minute mark (2 phases), there was a progress report which lasted for 5 seconds before continuing to the final phase for two more minutes. Afterwards participants moved onto the next task, the Eriksen Flanker Task.

For this task, participants worked through cognitivefun.net. A preprogrammed task was available for use. This task ran for approximately 1 minute, depending on the speed of the participant. Participants were asked to read the instructions and were asked whether or not they have any questions regarding the task. From there the researcher clarified anything pertaining to the task. Once they finished, scores will become available and the researcher wrote down the results and moved onto the final task, the N-back task.

Participants were once again working through cognitivefun.net for the N-back task. The N-back task was using the version in which participants had to recall the item that appeared 2 items ago. Participants were told to view the provided demonstration on how the task worked and afterwards participants were asked if they had any questions regarding the task. Participants were also told that they must only work up until they reached trial 70, a predetermined trial number. Overall, the task ran approximately 2 minutes. Once they finished, scores were available, and researcher wrote down the results. Finally, participants were debriefed and thanked for their participation with the experiment.

Results

The results were analyzed using SPSS. For this research we used separate A-Nova analysis to compare different groups and their scores on each task. One-way ANOVAs were used to compare the performance of the three groups: high intensity, low intensity, and classical music control group. If there was a significant F, I would have used a Post Hoc T test to analyze the results.

For the AX-CPT task, the % correct of the trials were analyzed. An ANOVA test was used to compare the results: F (2, 24) = .34, P= .71. There were no significant differences between the three groups. No Post Hoc T Test was used for these results.

For the Eriksen Flanker (Same Arrow Direction), the % correct and average response time were analyzed. An ANOVA test was used to compare the results. For the % correct; F (2, 24) = 1.18, P = .32. There were no significant differences between for the three groups for how many the participants were able to get correctly. For the average response time; F (2, 24) = 1, P = .38. There were no significant differences for the three groups for how quickly they answered to each trial.

For the Eriksen Flanker (Different Arrow Direction), the % correct and average response time were analyzed. An ANOVA test was used to compare the results. For the % correct; F (2, 24) = 2.19, P = .13. There were no significant differences between for the three groups for how many the participants were able to get correctly. For the average response time; F (2, 24) = 2.30, P = .12. There were no significant differences for the three groups for how quickly they answered to each trial.

Lastly, for the N-Back task, the # of times a participant responded, the % correct, and the average response time were analyzed. An ANOVA test was used to compare the results. For the # of times a participant responded; F (2, 24) = .45, P = .64. There were no significant differences between the three groups. For the % correct; F (2, 24) = .27, P = .76. There were no significant differences between for the three groups for how many the participants were able to get correctly. For the average response time; F (2, 24) = .53, P = .59. There were no significant differences for the three groups for how quickly they responded to each trial.

Discussion

In this study, I predicted that participants exposed to high intensity video games will be able to see an increase in their cognitive abilities. I anticipated that participants exposed to a high intensity video game will be able to not only complete tasks quicker, but also have fewer mistakes. The results did not support my prediction. None of the three groups did significantly better or worse when it came to speed and accuracy.

I also anticipated that participants who are exposed to a low intensity video game; will perform better than the classical music control group and the high intensity video game group will perform the best. The results did not support my prediction. The high intensity video game group had similar scores to the low intensity and control group.

Lastly, I predicted that participants with previous experience playing video games would score higher in general. Participants should be able to pick up game mechanics quicker and therefore be more actively stimulated. The results show no real difference in cognitive ability when having video game experience.

The results did not support my prediction that participants exposed to high intensity video games would be able to perform better on the cognitive tasks than those in the other two groups. There were no significant differences among the three groups on any of the tasks.

This study had weak external validity. The small sample size in this study created low power, making it impossible to reach valid conclusions from the results. Almost all participants were recruited from the Introductory Psychology classes at the College of Saint Benedict and Saint John’s University through a voluntary system. Participants were not very representative of the wider population. Overall, the study had weak statistical validity. The internal and construct validity were strong for this experiment. The experiment was straightforward and well controlled, and participants were given clear instructions. The tasks were also based on previous research conducted.

The study of video games effects is a recent byproduct of the massive technological expansion within the last forty years. As stated before, some studies have been conducted regarding the use of video games to see if there is any improvement in an individual's cognitive abilities, but there have been varying results. Studies conducted by Cardoso et al. (2016) suggest that video game players may outperform people who do not play video games in certain cognitive tasks. These studies were the basis for this experiment.

The results of this experiment were not consistent with previous video game studies. This is more than likely due to the low power of the study. From this study, we cannot say whether or not video games have had any sort of effect on a person's cognitive abilities, whether positive or negative. We do not know if there simply is no effect on an individual's cognitive abilities. We also do not know if simply not playing video games and playing video games has any affect since all of the participants have played video games. We also do not know if there is any long-term effect as a result of this study. The focus of this study was to see if there were any short-term effects of video games. There was no intention of measuring any long-term effects of video games. I believe that the results of this study would have been more consistent with previous research if there was more time to collect more data from a larger group of participants. If this was done, then I believe that there would have been results similar to the previous research.

Moving forward, there should be an experiment that tests the differences between people who play vs those who did not play video games. Also, this experiment should be revisited, but it should be conducted on more than just 27 individuals. This experiment should also be recreated in a way that allows for a measure of long-term effects of video games instead of being limited to short term effects. I also suggest that there be more tasks that measure a wider range of cognitive abilities as well as extending the current tasks. For the AX-CPT, task to be the original twenty minutes instead of the modified six minutes. For the N-Back task, I suggest the task measure three items before rather than the modified two in order to complicate it. Lastly, the Eriksen Flanker task should be extended to have more than simply twenty trials at the discretion of the researcher. Overall, future research regarding this experiment should measure a larger number of tasks as well as a larger number of participants.

References

Batty G.D., Deary I.J., & Macintyre S. (2006). Childhood IQ and life course socioeconomic position in relation to alcohol induced hangovers in adulthood: the Aberdeen children of the 1950s study J. Epidemiol. Community Health, 60, pp. 872-874

Batty G.D., Deary I.J., & Macintyre S. (2007). Childhood IQ in relation to risk factors for premature mortality in middle-aged persons: the Aberdeen Children of the 1950s study *J. Epidemiol. Community Health, 61*, 241-247

Batty G.D., Deary I.J., Schoon I., & Gale C.R. (2007). Childhood mental ability in relation to food intake and physical activity in adulthood: the 1970 British cohort study *Pediatrics, 119* (2007), e38-e45

Batty, G. D., Deary, I. J., Schoon, I., & Gale, C. R. (2007). Mental ability across childhood in relation to risk factors for premature mortality in adult life: The 1970 British Cohort Study. *Journal of Epidemiology & Community Health, 61*(11), 997-1003. doi:10.1136/jech.2006.054494

Bavelier, D., Achtman R.L., Mani M., & Föcker J. (2012). Neural bases of selective attention in action video game players *Vision Research. 61*, 132-143

Bavelier, D., & Green, C. S. (2016). The Brain-Boosting Power of Video Games. *Scientific American,315*(1), 26-31. doi:10.1038/scientificamerican0716-26

Bavelier, D., Green, C. S., Pouget, A., & Schrater, P. (2012). Brain plasticity through the life span: Learning to learn and action video games. *Annual Review of Neuroscience*, *35*, 391–416. https://doi.org/10.1146/annurev-neuro-060909-152832

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

Cardoso-Leite, P., Kludt, R., Vignola, G., Ma, W., Green, C., & Bavelier, D. (2016). Technology consumption and cognitive control: Contrasting action video game experience with media multitasking. *Attention, Perception & Psychophysics*, *78*(1), 218–241. https://doi.org/10.3758/s13414-015-0988-0

Córdova-Palomera, A., Fatjó-Vilas, M., Kebir, O., Gastó, C., Krebs, M. O., & Fañanás, L. (2015). Polymorphic variation in the epigenetic gene DNMT3B modulates the environmental impact on cognitive ability: A twin study. *European Psychiatry*, *30*(2), 303–308. https://doi.org/10.1016/j.eurpsy.2014.11.011

Del Carmen Ruiz, J., Quackenboss, J. J., & Tulve, N. S. (2016). Contributions of a child's built, natural, and social environments to their general cognitive ability: A systematic scoping review. *PLoS ONE*, *11*(2). Retrieved from http://ezproxy.csbsju.edu/login?url=http://search.ebscohost.com/ login.aspx?direct=true&db=psyh&AN=2016-08874-001&site=ehost-live&scope=site

Christensen, G. T., Rozing, M. P., Mortensen, E. L., Christensen, K., & Osler, M. (2018). Young adult cognitive ability and subsequent major depression in a cohort of 666,804 Danish men. *Journal of Affective Disorders,235*, 162-167. doi:10.1016/j.jad.2018.04.035

Eriksen, B. A. & Eriksen, C. W. (1974). Effects of noise letters upon identification of a target letter in a non-search task. *Perception and Psychophysics, 16*, 143-149.

Green C.S. , & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature*, 423 (6939), 534-537

Kokkinakis, A. V., Cowling, P. I., Drachen, A., & Wade, A. R. (2017). Exploring the relationship between video game expertise and fluid intelligence. *Plos ONE*, *12*(11), 1-15. doi:10.1371 /journal.pone.0186621

Kowal, M., Toth, A. J., Exton, C., & Campbell, M. J. (2018). Different cognitive abilities displayed by action video gamers and non-gamers. *Computers in Human Behavior,88*, 255-262. doi:10.1016/j.chb.2018.07.010

Michelon, P. (2016). What are Cognitive Abilities and Skills, and How to Boost Them? https://sharpbrains.com/blog/2006/12/18/what-are-cognitive-abilities/

Powers, K. L., Brooks, P. J., Aldrich, N. J., Palladino, M. A., & Alfieri, L. (2013). Effects of video-game play on information processing: A meta-analytic investigation. *Psychonomic Bulletin & Review, 20*(6), 1055-1079. doi:10.3758/s13423-013-0418-z

Wang, P., Liu, H., Zhu, X., Meng, T., Li, H., & Zuo, X. (2016). Action Video Game Training for Healthy Adults: A Meta-Analytic Study. *Frontiers in Psychology,7*. doi:10.3389/fpsyg.2016.00907 Boot

Washington University in St. Louis (2019). *AX-CPT Task | Dual Mechanisms of Cognitive Control*. http://pages.wustl.edu/dualmechanisms/axcpt-task

Table of Means

TASKS	HIGH	LOW	CONTROL
AX-CPT Task % Correct	.93	.87	.91
Eriksen Flanker Task (Same) % Correct	100	98.14	100
Eriksen Flanker Task (Same) Avg Response Time	598.6 ms	580.8 ms	1249.5 ms
Eriksen Flanker Task (Different) % Correct	95.44	87.55	97.2
Eriksen Flanker Task (Different) Avg Response Time	680.89 ms	742.78 ms	840.67 ms
N-Back Task # of times responded	26.44	28.44	29.56
N-Back Task % Correct	55.09	59.54	61.88
N-Back Task Avg Response Time	980.44 ms	898.89 ms	949.89 ms

Appendix 1

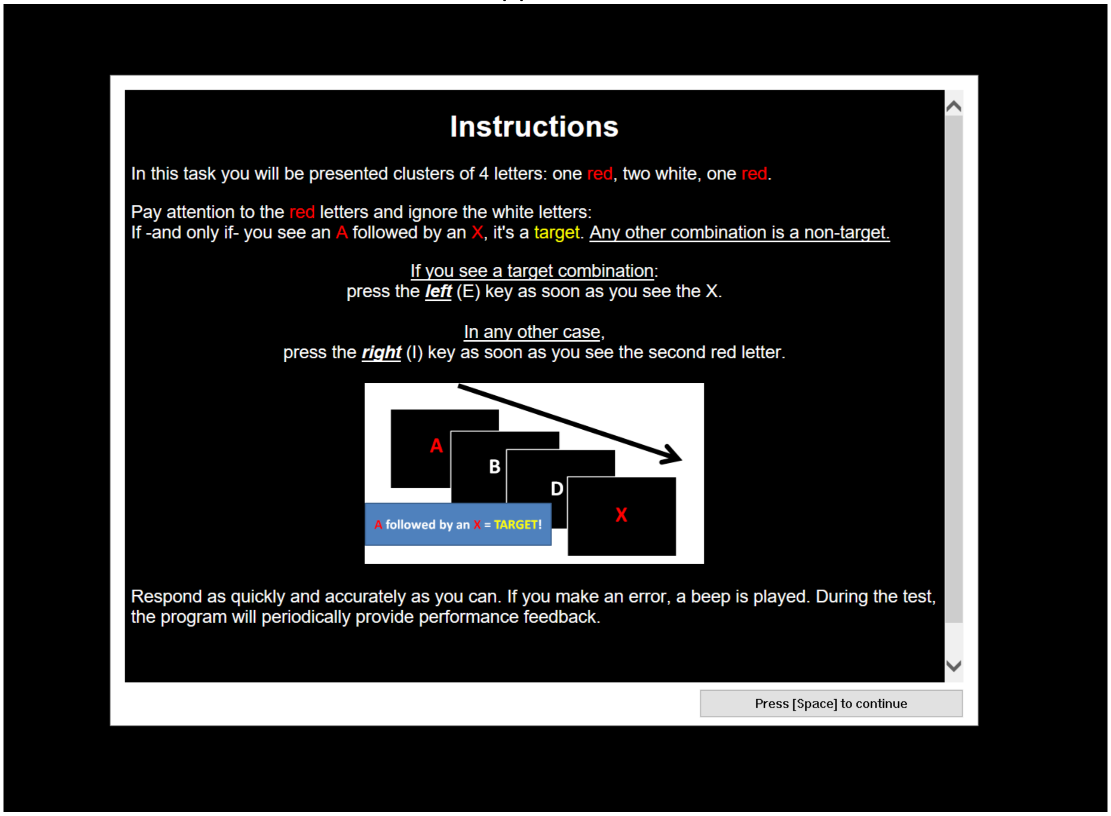

Fig. 1

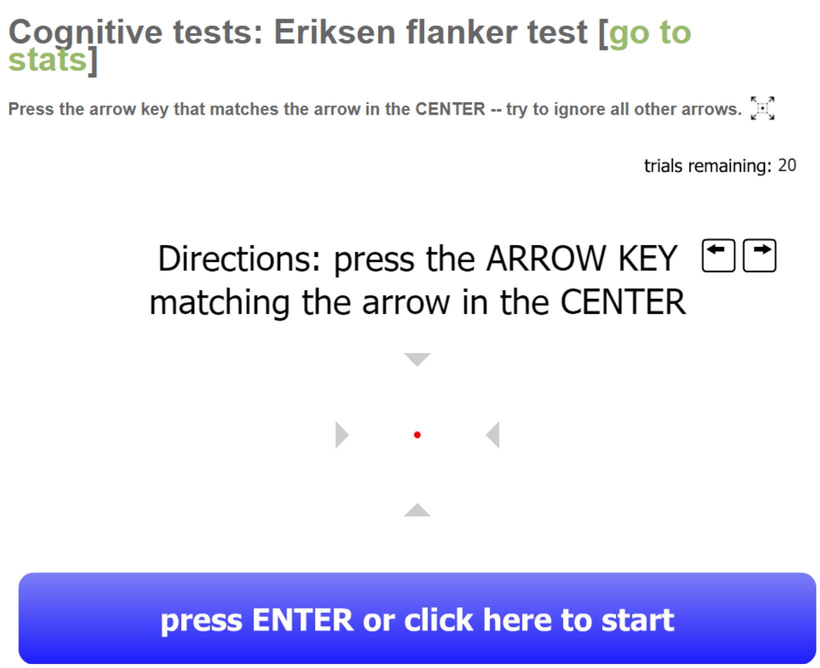

Fig. 2

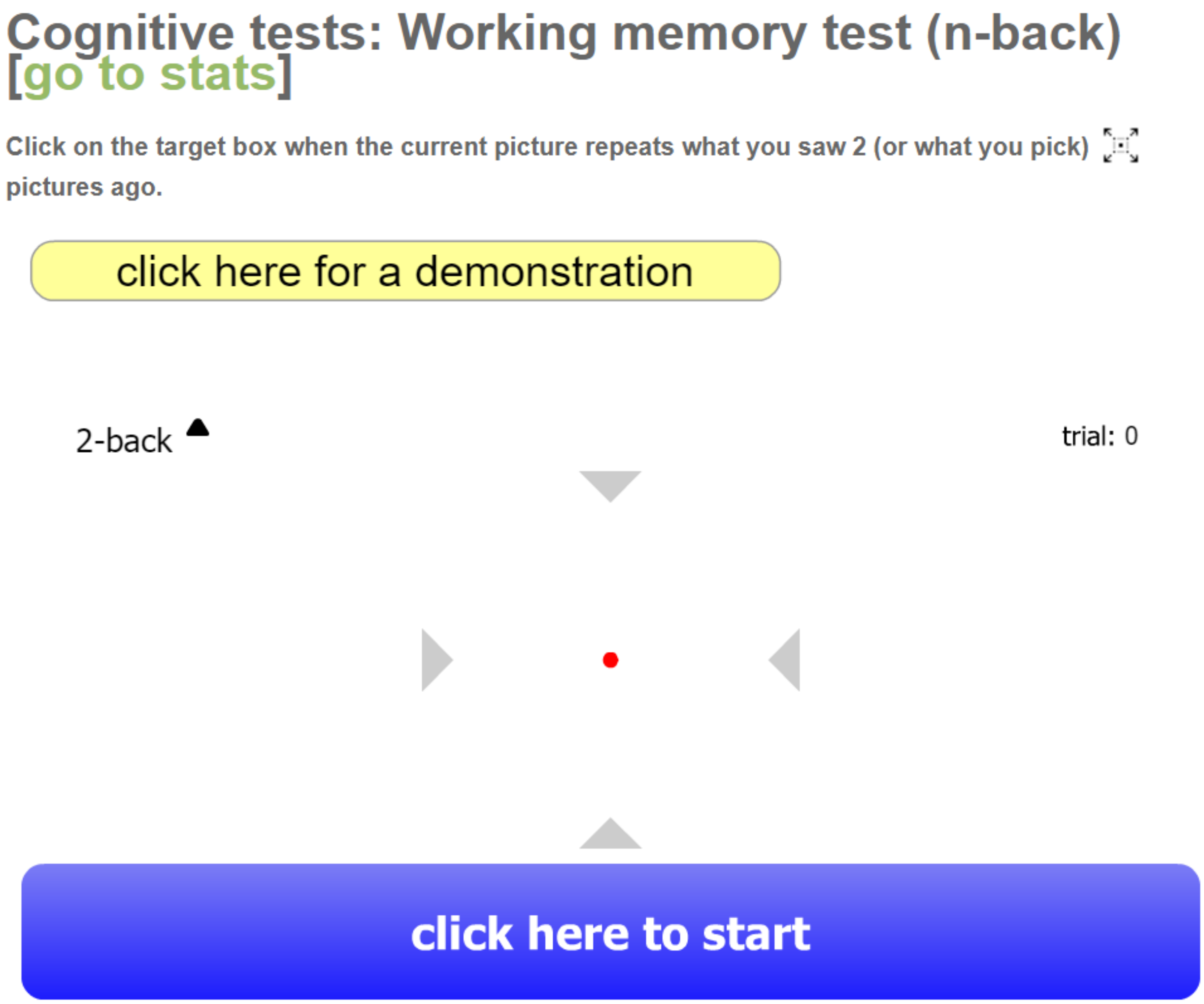
Cognitive tests: Working memory test (n-back) [go to stats]
Click on the target box when the current picture repeats what you saw 2 (or what you pick) pictures ago.
click here for a demonstration
2-back
trial: 0
click here to start

Fig. 3

Appendix 2

Questionnaire:

Have you played video games before? _________________

How experienced are you with video games?

1	2	3	4	5	6	7

1=Never played 7=Very experienced

How many hours of video games do you play a week? _____________