

Original Article

## Impact of Playing Action and Puzzle Video-games on Attention and Executive Function: A Comparative Study

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### Abstract

**Background:** Video-game play has been shown to significantly affect visuo-spatial cognition, working memory, executive functions and information processing speed. However, scientific literature comparing the cognitive functions in players of different video-game genres is very limited.

**Objectives:** Aim of the present study was to assess and compare the impact of playing action or puzzle video-games on response speed, sustained attention and executive functions in young adults.

**Materials & Methods:** Fifty players each of action video-game (AVG) and puzzle video-game (PVG) were recruited from medical undergraduate batches of the Institute. Cognitive functions were assessed by using Letter cancellation test (LCT), Trail making test A and B (TMT-A&B) and Ruff figural fluency test (RFT).

**Results:** Players of AVG took significantly less time ( $p < 0.05$ ) to complete both LCT and TMT-A as compared to players of PVG. However, they had significantly higher ( $p < 0.05$ ) LCT errors in comparison to puzzle video-gamers, as their number of omissions and commissions were more. Performance of both the groups was comparable in TMT-B task. PVG players were able to draw significantly more ( $p < 0.05$ ) number of dissimilar patterns in RFT as compared to AVG players.

**Conclusion:** Results indicate that playing action or puzzle video-games had a differential impact on cognitive functions of gamers. Response-speed was better in AVG players whereas, sustained attention and executive functions were better in PVG players. Given that both sustained attention and executive functioning skills underpins many areas of our lives including occupational, social and educational settings, future efforts aimed at improving these critical abilities through specific genres of video-game play can surely be explored.

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### Introduction

Cognition refers to the set of all mental abilities and processes involved in the acquisition, storage, retrieval and use of information. It includes basic

cognitive processes like attention (both, focused and divided), as well as, higher cognitive abilities such as, executive functions, perception and information processing (1). Focused attention refers to the capacity to attend to only one source of information while ignoring other incoming stimuli. It also encompasses sustained attention, which is the ability to maintain a directed attentional focus over an extended period of time (2). Executive function represents a complex range of cognitive functions that are not only important for responding in an adaptive manner to novel situations, but also involves planning and selecting strategies that organize goal-directed actions. It consists of a family of top-down processes including updating of working memory, behavioral inhibition and task-switching (3).

Video-gaming has become one of the most common pervasive recreational activity worldwide. Survey based studies in various countries from across the globe have found that, on an average, more than fifty percent of the population play video-games regularly (4). Recently our country has been ranked at 22<sup>nd</sup> position in the list of highest revenue-generating countries of the world from gaming-related businesses. Several factors such as, increased availability of internet and low-cost smartphones in the country have played a significant role in this boom in gaming. Notably, more than half the mobile phone Indian gamers have been found to be below 24 years of age (5). This emerging trend highlights the importance of exploring, not only the potential effects that video-gaming may have on psychosocial behavior, but also on the cognitive functions of an individual.

There is increasing evidence to show significant effect of playing action video-game on both, basic perceptual skills as well as, higher levels of cognitive abilities. Improvements in specific cognitive domains like attention, visuo-spatial cognition (6), working memory, information processing, task-switching, and decision-making (7) have been linked to action video-game (AVG) play. Recently, few studies have put forth evidence of improvements in cognitive performance following training in non-action video games also. Enhancement in mental rotation skills in young children (8) and improved executive control

abilities in older adults (9) after training in strategy video-games have been shown. However, inconsistent results in the occurrence and replication of positive impact of video-gaming on cognition have also been reported (10). For instance, in one of the previous researches, impact of all genres of video-games was studied together and it was reported that the total amount of time spent in video-game play predicted poorer attention of the subjects in the classroom (11). This indicates that not all genres of video-games are likely to affect the cognitive functions equally, nor are all the effects likely to be positive.

Some researchers have raised another pertinent point that, not only the length of video-game experience but, also the nature of that experience could have a bearing on the manner in which different genres of video-games may influence the cognitive functions of an individual (12). This stems from the fact that different genres of video-game have considerable qualitative differences due to their inherent mechanics of game-play and the in-game tasks which a player must attend to, for achieving game-success (13). Despite the growing consensus amongst researchers regarding the possibility that video-game genre might influence cognitive abilities to a different extent, there is still limited availability of scientific literature in which the video-game genre has been compared (14)

Present study was therefore, conducted with the aim to assess and compare the impact of playing action or puzzle video-game on response speed, sustained attention and executive functions in young adults.

## Materials and Methods

This observational study was conducted in the department of Physiology, Maulan Azad Medical College, New Delhi. Approval of ethical committee of the institute was obtained prior to commencement of study.

### Subjects

100 subjects were recruited based on their responses to a gaming questionnaire, administered to medical undergraduate students of the Institute after obtaining their informed signed consent. Subjects were divided

into two study groups having fifty subjects each, based on our recruitment criteria. AVG group comprised of action video-game and PVG comprised of puzzle video-game players.

- o **AVG players** were required to have played three or more hours per week of first-person shooter (FPS) games in the past six months and one hour or less of PVG per week during the same time frame. They should have also rated their expertise on AVG as >1 and for PVG as <1 on Likert scale.
- o **PVG players** were required to have played three or more hours per week of physics-based puzzle games in the past six months and one hour or less of AVG per week during the same time frame. They should have also rated their expertise on PVG as >1 and for AVG as <1 on Likert scale.

Those who did not play either of the genre of digital video-games under consideration or, played other genres of video-games like adventure, real-time strategy, role-playing, racing, and multiplayer online battle arena for one hour or more per week were not included in the study. Those students who were on any medication that could have affected cognition were also excluded from the study. The subjects did not have any neurological, musculoskeletal, sleep related or psychological disorder at the time of inclusion and conduct of the study.

#### Video-game Genre

**Action video-game:** Genre includes diverse subgenres such as fighting games, shooter games and platform games. First-person shooter games (mortal combat game, counter-strike and call on duty) are played from the first-person perspective of a single protagonist who is generally charged with combating enemies while navigating through a three-dimensional environment. Players are placed under a sufficiently high level of perceptual, cognitive and motor load as they have to either immediately attack enemies with little down-time between battles, drive or maneuver at a fast-pace or quickly and accurately respond to unexpected, multiple, rapidly changing

stimuli, thereby, emphasizing primarily on peripheral processing of information (6).

**Puzzle video-game:** This genre usually involves some level of abstraction and may make use of colors, shapes, numbers, physics or complex rule. Physics-based PVG's demand high levels of planning, problem-solving and reframing and players have to use game's physics to complete each puzzle (10). Within each set, as player progresses, levels become more difficult, convoluted and new contraptions are introduced which alters the game-play. For some levels, there may also be timing requirements, so speed and fast movement are sometimes but, not usually important. Physics-based games include cut the rope, where's my water and angry birds.

#### Gaming Questionnaire

Questionnaire was completed twice, once as part of a department-level screening exercise that was used for recruitment and once, at the time of cognitive function testing. This self-report video-gaming experiences questionnaire included two parts:

**Part A** comprised of questions on basis of which subjects were grouped into the two study groups. First question asked subjects to respond as yes/no to whether they played video-games. If subjects responded "yes" to the first question, they were then required to respond as yes/no to whether they played the following genres, namely, AVG (first-person shooter games), PVG (physics-based) or others (adventure, real-time strategy, role-playing, racing, and multiplayer online battle arena). In the next question, subjects had to rate their perceived level of expertise on each of the game mentioned above via 4-point Likert scale expertise ratings (0=have never played, 1=novice, 2= intermediate, 3= expert). Fourth question pertained to the platform used for gaming purposes.

**Part B** pertained to questions on gaming behavior of subjects and had five questions. First three questions asked them to indicate the number of hours spent playing each genre of video-games (to which they had responded as yes in previous part) on a typical weekday (Question 1: Monday through Friday) or

weekend (Question 2: Saturday and Sunday) and during a week (Question 3: Number of hours of Q1+Q2). Next two questions inquired about the age (in years) at which subject started playing video-games and duration since playing (in number of years) respectively.

### Cognitive Function Tests

Subjects reported to laboratory at same time of the day. All tests were done between 1-2p.m. during lunch-break. Paper-pencil-based versions of cognitive function tests were administered and scored as per standard manuals.

#### A). Letter cancellation test (LCT) (15)

LCT response time reflects speed of visual scanning and information processing whereas; number of omissions and/or commissions and accuracy percentage are used as measures of sustained attention (15). Subject was presented with capital English alphabets in which target characters ('C' and 'E') were randomly interspersed (Total targets=108). Score was time taken in seconds by subject to actually perform this task. Omissions were total number of target letters (C and E) which were missed and Commissions were total number of wrong (non-target letters) cancellations done. Accuracy percentage was computed by using the formula:

$$\frac{\text{Total number of target characters (108)} - \text{number of errors (Omissions+Commissions)}}{\text{Total number of target characters (108)}} \times 100$$

#### B). Trail making test (TMT) (16)

It comprises of two task components, TMT-A and TMT-B. TMT-A required the subject to draw lines and connect circled numbers in a numerical sequence from 1-25, whereas, TMT-B involved connecting circled numbers and letters in an alternating alpha-numeric sequence (i.e., 1-A-2-B to 13-L). Score was time taken to complete the task (in seconds) including time for correction of errors. TMT-A provides a measure of visual scanning, psychomotor speed and target-directed motor tracking, and is administered first in sequence. TMT-

B, in addition to these low-level cognitive processes, also provides measure of task-switching and mental flexibility. Corrected TMT-B scores (TMT-B minus TMT-A) were derived to isolate set-switching cost. Difference in performance between task-repeat and task-switch measure is known as switch cost and, is thought to be indicative of functioning of various executive control processes ranging from attention-shifting, goal-retrieval, task-set reconfiguration and response-inhibition (17).

#### C). Ruff figural fluency test (RFT) (18)

This test assesses nonverbal fluency of a subject, which is an indirect measure of cognitive flexibility. RFT consists of 40 boxes having five dots each on a sheet of paper. Objective was to draw dissimilar/unique pattern in these boxes by joining the five dots. Scoring was done by considering total time taken by subject in seconds and number of total dissimilar patterns including unique rotations (considered to be the hall mark in strategic approach) drawn. Number of repeated designs was counted as preservation errors and these yielded a negative score. Net total number of dissimilar patterns drawn was finally computed by subtracting number of preservation errors from dissimilar patterns.

### Statistical Evaluation

Data collected was analyzed using SPSS version 20. Gaussian fit of data was checked using Lilliefors corrected Kolmogorov-Smirnov Test. Test-retest reliability analysis of gaming questionnaire was done using Pearson's correlation. Group-wise descriptive statistics of gaming behavior was expressed as Median (Interquartile range) and of cognitive function test scores as Mean±standard deviation (SD). Inter-group statistical comparisons were done using Mann-Whitney U test. A value of p<0.05 was considered significant for all tests.

## Results

There was no statistical difference in mean age of action (18.82±0.90 years) and puzzle video-gamers (19.12±1.08 years). Gender-wise distribution of subjects in AVG (M:F=41:9) and PVG (M:F=24:26)

was significantly different  $\chi^2=12.70$ ,  $p<0.001$ . Test-retest reliability analysis of gaming questionnaire was acceptable ( $r=0.76$ ).

### Gaming Behavior

Descriptive statistics of gaming behavior of all subjects in two study groups is given in Table I. There was a significant difference ( $p<0.001$ ) between two study groups for both, the age at which subjects started playing digital video-games and number of years since they were playing them. (Table I).

### Cognitive Function Test

Descriptive statistics of cognitive function tests of all subjects is given in Table II. There was a statistically significant difference in two study groups for mean LCT time, number of omissions and commissions ( $p<0.05$ ) as well as, for the accuracy

TABLE I: Gaming Behavior of Action video-gamers (AVG) and Puzzle Video-gamers (PVG). Values are Median (Interquartile range).

Gaming Behavior	AVG(n=50)	PVG (n=50)
Hours / Weekday	5 (2-10)	5 (2-8)
Hours / Weekend	3 (1-8)	3 (1-9)
Hours / Week	8 (4-14)	7 (4-15)
Starting Age (Years)	8 (4-15)	11 (3-18)*
Duration of Gaming (Years)	10 (2-13)	7 (1-15)*

\*p value  $<0.05$  significant, compared to action video-gamers.

percentage ( $p<0.01$ ). Statistically significant difference ( $p<0.05$ ) in mean TMT-A scores of subjects in the two study groups was also seen. There was a significant difference ( $p<0.001$ ) between the subjects within same study group for mean TMT-A and TMT-B response times. This difference was observed in both AVG as well as, PVG. There was a significant difference ( $p<0.05$ ) in mean net number of dissimilar patterns drawn by action and puzzle video-gamers (Table II).

## Discussion

Primary objective of our study was to assess and compare the influence of playing action or puzzle video-games on response speed, sustained attention and executive functions of young adults. As there are myriad sub-genres in both AVG and PVG, those subjects who played either, FPS action-games or physics-based puzzle games were recruited in respective groups. To ensure further homogeneity within a study group itself, gamers with intermediate or expert skill levels were only included.

There was a significant difference in gender distribution of two groups, with males far outnumbering females in playing AVG. However, PVG group had almost equal number of male and female players. This observed, uneven gender distribution between the study groups is in conformity with previous works and seems to simply reflect a

TABLE II: Cognitive Function Test scores of Action video-gamers (AVG) and Puzzle Video-gamers (PVG). Values are Mean $\pm$ SD.

Cognitive	Function Test	AVG(n=50)	PVG (n=50)
LCT	Time (Seconds)	73.36 $\pm$ 18.42	84.26 $\pm$ 28.55*
	Omissions	1.88 $\pm$ 1.79	1.18 $\pm$ 1.27*
	Commissions	0.72 $\pm$ 0.97	0.38 $\pm$ 0.60*
	% Accuracy	97.02 $\pm$ 2.46	98.39 $\pm$ 1.66**
TMT-A	Time (Seconds)	52.72 $\pm$ 12.23	59.30 $\pm$ 13.83*
TMT-B	Time (Seconds)	83.36 $\pm$ 21.06	88.28 $\pm$ 20.63
Corrected TMT-B	Time (Seconds)	30.64 $\pm$ 17.28	28.98 $\pm$ 15.16
	Time (Seconds)	188.40 $\pm$ 58.03	182.26 $\pm$ 51.66
	Number of Patterns	39.86 $\pm$ 0.73	39.82 $\pm$ 0.90
RFT	Number of Perservations	3.26 $\pm$ 2.766	2.18 $\pm$ 1.78
	Number of Dissimilar patterns	36.60 $\pm$ 2.94	37.64 $\pm$ 1.96*

\*p value  $<0.05$ , \*\*p value  $<0.01$ , significant, compared to action video-gamers.

LCT: Letter cancellation test.

TMT-A and TMT-B: Trail making test A and B respectively.

RFT: Ruff figural fluency test.

universally well-known effect in which, males have been found to be inherently more interested in playing action video-games. Females on the other hand have been found to mostly opt for non-action, intellectual, creative or fantasy games (19).

Prior studies have shown that usually, video-gaming begins in early childhood and tends to continue throughout adulthood (20). Observation of median age at which subjects started playing video-games in present study also follows a similar trend. It is noteworthy that AVG players began gaming at a significantly younger age and were gaming for a greater number of years as compared to PVG players. However, both study groups were comparable in terms of time spent in video-game play across weekdays, weekends or per week. It has been seen that individuals usually assess the amount of free time available to them and subsequently decide as to how they should spend it (21). Since, all subjects in this study were undergraduate medical students of same institute and were pursuing a highly demanding course, they had almost equal number of hours available for leisure activities. This could account for the similarity observed in gaming time between them.

Findings of LCT in current study indicate that playing AVG led to a comparatively poorer sustained attention as compared to playing PVG. However, both LCT response time and TMT-A scores indicate that playing AVG led to faster visual scanning, psychomotor speed and information processing as compared to PVG play. These observations corroborate with earlier works that have shown general speeding of perceptual information processing using different trial protocols and continuous performance tests (14, 22). Positive effect on short-term visual capacity coupled with decrease in performance on a sustained attention task has also been reported to be significantly greater in action as compared to non-action video-game players (19). However, in contrast, some studies have shown that relatively short video-game training sessions led to improvements in visual attentional skills of non- video-game players (9).

Playing video-games of different genres had an equivalent effect on shifting aspect of executive

function as measured by TMT-B scores. Both gamer groups had comparable switch costs and therefore, it cannot be said that playing action or puzzle video-games has a superior effect on mental flexibility. In past, only one cross-sectional study has compared video-game players of two different genres (first-persons shooter and real-time strategy players) (14). They also reported that both their gamer groups had comparable switch costs. However, some prior researches have reported reductions in switch costs following training in either, action (6) or puzzle video-games (10). Therefore, before we attempt to extrapolate our findings to general population, further statistical validation is needed to compare these cognitive skills in players of different game-genres.

RFT data of current study indicates that playing PVG had a beneficial impact on non-verbal fluency as subjects in this group were able to generate greater number of dissimilar visual patterns in comparison to AVG players. Non-verbal or figural fluency is typically assumed to assess planning, cognitive flexibility, problem-solving and fluency of generation of visual patterns without repetition, above and beyond contributions from motor speed (18). Ours is probably one of the first studies to objectively measure and compare cognitive flexibility and problem-solving skills in action and puzzle video-gamers by using a non- verbal fluency test. Till date, very few studies have addressed the link between video-game play and problem-solving. Positive relationship between strategic video-game play and self-reported problem-solving skills has been put forth (23). However, due to disparity in various methodological factors including different video-game genres and study design, it would be imprudent on our part to conjure up any similarities without further replication.

Taken together, our results of comparison between two video-game player groups indicates that cognitive abilities were differentially influenced, depending on genre of video-game (AVG and PVG) being played. Different genres of video-game seem to place differential ability requirements on the players due to their inherent mechanics of game-play and in-game tasks. For instance, playing physics-based puzzle games requires a wide variety of higher-level cognitive functions to achieve success and progress

to next levels. Unlike AVG's, these games give ample time to the players for mentally representing challenging puzzle, formulating and evaluating action plans and, if need be, even revising ineffectual plans. Prior studies which had used neuroimaging techniques have shown that, dorsolateral prefrontal and anterior cingulate cortices are involved in such complex cognitive planning (24). Considering the fact that subjects in our study were playing PVG's since many years, this may have produced plastic changes in these executive control networks, which in turn, could have led to better sustained attention and non-verbal fluency in them. In contrast, FPS action video-games allows player to interact with virtual game environments which are not only exciting and challenging but also, intrinsically stimulating and perceptually appealing. Previous research has shown that reward centers in brain such as ventral tegmental area and nucleus basil is are extremely active when individuals play AVG. Interestingly, these areas also play a large role in producing plastic changes in sensory areas. Moreover, it has also been demonstrated that roughly same amount of dopamine is released in basal ganglia when playing an AVG as when methamphetamines are injected (25). Increased availability of various neurotransmitters (dopamine and serotonin), coupled with plastic changes in these areas, could have induced facilitation of neural processes leading to alerting effects, faster response speed as well as, better visuo-spatial cognition in action video-gamers as compared to puzzle video-gamers.

Reliance on self-reported gaming behavior could have led to biasing and cross-over amongst study groups and was a limitation in this study. Longitudinal studies may be undertaken in future to compare the impact of different genres of video-games on wider range of cognitive skills. Given that both sustained attention and executive functioning skills underpins many areas of our lives whether in occupation, social or educational settings, future efforts aimed at improving these critical abilities through specific genres of video-game play can surely be explored.

In conclusion, our results indicate that playing first-person shooter action or physics-based puzzle video-games had a differential impact on cognitive functions of gamers. Response-speed and information processing was better in AVG players whereas, sustained attention and executive functions were better inPVG players. To the best of our knowledge, such a comparison in cognitive abilities of action and puzzle video-game players have never been explored before in a single study.

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### Conflict of interest

None

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