Boosting Cognitive Capabilities through Enhanced States during Gaming

Maria Kozhevnikov
Martinos Center for Biomedical Imaging & Harvard Medical School
Charlestown, MA
mkozhevnikov@mgh.harvard.edu

ABSTRACT

The existence of optimal experiences, in which specific cognitive processes (e.g., attention, perception) are dramatically enhanced for limited durations, has been suggested by phenomenological research (qualitative analysis of narrative data, Csikszentmihalyi, 1975; Maslow, 1962) but overlooked in the domains of cognitive psychology and neuroscience. Csikszentmihalyi (1975) termed such experiences as flow and Maslow (1965) as peak experiences. A recent experimental study (Kozhevnikov et al., 2018) provided the empirical evidence on the existence of enhanced cognitive states (ECSs), similar to the concept of flow, in which dramatic improvements in temporal and spatial aspects of focused attention were exhibited by participants who played 30 minutes of an action videogame (First Person Shooter) calibrated to one's skill level. Moreover, it was demonstrated that an underlying physiological mechanism of ECSs includes parasympathetic nervous system (PSNS) withdrawal-associated arousal. The goal of the current study was to examine activities and experiences under which ECSs could be elicited in gaming contexts. In this study, expert gamers were tested on the attentional blink task before and after playing games of different genres, varying on four game design dimensions (perspective, "adrenaline-rush", immersivity, and collaborative vs. individual context) and two cognitive dimensions (speed of processing and attentional focus). The findings suggest that ECSs are a universal phenomenon that demands focusing one’s attention on a single task from the egocentric perspective and should involve an adventurous “adrenaline-rush” type of activity. The results suggest possibilities for consciously accessing latent resources of our brain to temporarily boost our cognitive capacities on demand (e.g., providing military personnel with videogame training before short-burst missions).

ABOUT THE AUTHOR

Maria Kozhevnikov is a Visiting Associate Professor at Harvard Medical School and Martinos Center for Biomedical Imaging. Maria Kozhevnikov received her Ph.D. from Technion (Israel) jointly with UC Santa Barbara. Her primary faculty appointment is at the Psychology Department, National University of Singapore. Previously, she has held faculty positions at Rutgers University (NJ) and George Mason University (VA). Her research interests focus on examining the neural mechanisms of visual/spatial processing and exploring ways to train visual/spatial skills using innovative technologies and gaming.

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INTRODUCTION

The existence of enhanced mental states, in which an individual is fully absorbed in an activity, exhibiting exceptional perceptual and attentional functioning, colloquially known as “flow” or “being in the zone”, has been extensively described in phenomenological and human-computer interaction (HCI) literature, but had until recently been overlooked in experimental psychology and neuroscience. Phenomenological literature termed these states as “flow” (Csikszentmihalyi, 1975) or “peak experiences” (Maslow, 1962) and has provided striking reports of the state properties such as intense concentration, distraction-less focus, distorted sense of time, and an autotelic sense of self-realization (Csikszentmihalyi, 1975, 1990). These enhanced cognitive states (ECSs) seem to be a universal phenomenon, as they have been reported by experts from a wide range of domains, such as elite athletes (Kotler, 2014), gamers (e.g., in basketball or chess, Csikszentmihalyi, 1975), surgeons (Colaianni, 2020), and visual artists (Nakamura et al., 2002).

Due to the spontaneous nature of the enhanced mental states and the fact that they usually occur during highly challenging situations, it has been extremely difficult to create conditions to capture them experimentally. Thus, there have been only very few experimental studies suggesting the existence of such mental states and their transient nature. In these few studies, significant temporary enhancements on visual-spatial and temporal aspects of attention have been reported as a result of specific styles of meditation, which involve focusing on emotionally significant images of selected people or religious figures (Kozhevnikov et al., 2009; May et al., 2011). Similarly, although not consistently replicated, improved performance on spatial reasoning tasks and temporal aspects of attention, as measured by the attentional blink task (ABT), were observed after listening to a Mozart sonata for 10 minutes. In a more recent study, Kozhevnikov et al. (2018) focused more closely on investigating the cognitive aspects of these enhanced states induced by 30 minutes of playing first-person shooter (FPS) action video games. The elicited states were termed "enhanced cognitive states" (ECSs) and operationalized as transient enhancements in temporal and visual aspects of focused attention, which result from specific environmental conditions (active gaming engagement at an optimally matched skill-challenge level). Furthermore, according to Kozhevnikov et al. (2018), it is psychophysiological arousal [i.e., a withdrawal from parasympathetic nervous system (PSNS) activity towards enhanced sympathetic nervous system (SNS) tone], reflected by a decrease in high frequency (HF) components of the heart-rate variability (HRV) power spectrum, developed during FPS gaming that led to the observed focused attention enhancements.

Despite the preliminary evidence for ECSs, the reports on their existence are sporadic, and it is not clear under what conditions the ECSs could be consistently replicated. Considering the significance of ECSs for advancing human performance, it is important to start formulating scientific models of exceptional cognitive functioning, which could explain the mechanisms allowing an individual to exhibit higher levels of cognitive performance than normally available. The goal of this research was to identify activities and experiences critical for inducing these states and consequently to investigate the common nature of these conditioning pre-ECS experiences. In particular, in the current study, we examine the induction of ECSs in the context of gaming, which, according to cognitive (Kozhevnikov et al., 2018) and HCI (Bian et al., 2016; Raphael et al., 2012) research, might be the only way to induce states of enhanced cognition under laboratory conditions through the simulation of highly stressful or exciting real-world situations. In particular, the current study examines a variety of games from different genres, characterized by differences in game design, including gameplay styles and game mechanics (e.g., shooter, adventure, puzzle-solving, escape rooms) to identify aspects of gaming activities that are critical to access ECSs. We chose games that varied across four different dimensions related to game design, which have been reported to lead to ECSs according to the three different types of studies: a) phenomenological literature based on qualitative analyses of narrative reports describing subjective experiences of these states (usually termed "flow"), b) HCI literature examining conditions leading to the state of flow as a result of the use of technology, based on self-report flow questionnaires, and c) our in-depth pilot interviews with expert video gamers who reported ECS experiences. The four game dimensions examined in this study were:

Perspective

In video gaming, two fundamentally different perspectives from which the player views the scene are typically implemented. These are the egocentric and allocentric perspectives, which rely on egocentric and allocentric spatial frames of reference, respectively. The egocentric reference frame specifies the location and orientation of objects relative to the perceiver (e.g., the object is located “in front of” the perceiver). In contrast, the allocentric reference frame specifies the location and orientation of objects relative to the environment that is extrinsic to the perceiver (e.g., "next to" another object). FPS video games adopt a first-person egocentric perspective where the player views the game environment from the direct perspective of the controlled avatar. In contrast, video games from genres such as real-time strategy (RTS) adopt a third person allocentric perspective, where the game environment is presented to the player either from a top-down or isometric perspective. Previous HCI research suggests that players’ perspective influences the level of engagement and associated arousal, which was more pronounced following the instruction to shoot from an egocentric vs. allocentric perspective (Petras et al., 2016).

"Adrenaline-rush"

The colloquial phrase “adrenaline-rush” is applied to the feeling of exhilaration experienced in highly stressful or exciting situations. A variety of factors might contribute to an “adrenaline-rush” experience, such as a person’s intrinsic motivation, personality traits, or the elements of competitiveness. For this study, to classify the games according to the “adrenaline-rush” dimension, we refer to the level of game violence and elements of survival, as reflected in the game narrative (e.g., life-threatening situations), audio (e.g., screams of pain), and graphics (e.g., virtual blood). According to this classification, “adrenaline-rush” games may vary from low “adrenaline-rush” games, such as safe and emotionally neutral puzzle games (Tetris), to games involving the elements of adventure and survival (e.g., escape rooms), and finally to more violent high “adrenaline-rush” FPS video games. Specifically, the main objective of many high “adrenaline-rush” FPS games includes killing enemy players while avoiding gunfire, where the player is constantly prepared to cope with an emergency under immediate defense reaction pressure. Indeed, HCI literature suggests that the violent content of FPS games, particularly a large amount of virtual blood and screams of pain, may significantly increase arousal (Anderson & Bushman, 2001; Anderson et al., 2010; Jeong et al., 2012).

Immersivity of a Gaming Environment

The act of "looking out" (physical immersion inherent to 3D immersive environments) includes a higher level of interactivity and realism than "looking into" the game scene, as presented on a 2D computer screen. According to HCI literature, more naturalistic environments [e.g., real-world Escape rooms, in which players solve a series of puzzles meeting specific criteria or immersive virtual reality (VR) games] might facilitate the sense of presence, and thus lead to the state of flow, characterized by a deep sense of immersion into the activity (Sherry, 2004). Applying VR as gaming media has been suggested to amplify flow experiences by increasing vividness, interactivity, and telepresence to a greater extent than traditional 2D computer screens (Kim & Ko, 2019). Similarly, in our pilot interview, a majority of gamers reported experiencing more “aroused” or “stimulated” in more realistic Escape rooms, more fully identifying themselves with the game character, and acting directly within the game environment.

Collaborative vs. Individual Game Context

Phenomenological and HCI research on flow has, so far, mainly discussed these as experiences in individuals rather than occurring when individuals are gaming in a team. There are reports; however, that games in a team context, involving direct social interactions, might let individuals experience the state of flow (Lim & Lee, 2009; Raphael et al., 2012). While HCI literature on the role of social interactions in flow is scarce, this literature does show that players are more emotionally immersed and report more enjoyable experiences when playing in a social setting (Gajadhar et al., 2009). Indeed, the flow state has been reported by players to be more pronounced when playing together in each other's physical presence than playing an online multiplayer game without immediate social communication in physical proximity (Gajadhar et al., 2009).

Since most of the activities reported in phenomenological literature (i.e., chess, extreme sports, surgery) leading to the state of flow are time-constrained and require intense concentration on a given task, in addition to the four game design dimensions, we were also interested in exploring how such cognitive aspects of gaming as processing speed (fast vs. slow) and the type of attentional processes (focused vs. divided) might affect the access to ECSs. Different games may vary significantly in terms of the attentional demands involved. For instance, most "action" video games require fast processing speed, high visuomotor coordination, and a high level of focused attention (i.e., keeping the focus on one activity). Other games, however, do not necessitate decision-making under such severe time constraints (e.g., escape rooms) and might require divided attention (i.e., multitasking) instead.

EXPERIMENT

Games

The six games included four video games of different genres, such as *Unreal Tournament* (FPS), *Portal* (Platform), *StarCraft II* (RTS), *Tetris* (Puzzle), and two immersive escape room games, a collaborative physical puzzle game, *Forgotten Temple* [FT(ERG)], and a collaborative 3D immersive virtual reality Escape game, *Abandoned Mine* [AM(VRE)].

All these games had common features, which were emphasized as important in previous phenomenological and HCI research to access the flow state, such as 1) engagement in the activity that requires full attention from players; 2) goal-directed action; and 3) appropriate level of challenge with immediate feedback. We asked 3 professional video gamers and 1 Escape room designer to rate the chosen games according to the four dimensions discussed above (perspective, "adrenaline-rush", immersivity, and collaborative vs. individual context) as well as on the speed of processing and attentional focus. Inter-rater reliability was 86%, but all the raters fully agreed on the classification illustrated in Figure 1, after a discussion.

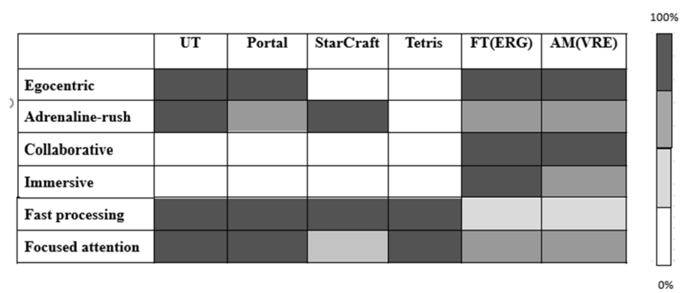

Figure 1. Classifications of the Games according to the Gaming and Cognitive Processing Dimensions

Escape Room Game FT(ERG)

We selected the theme of "the Forgotten Temple" from one of the ERG operators in Singapore (Lockdown room, Figure 2A) for this adventure game. In this plot, a group of treasure-hunters (recommended 3-5 players) are locked in a two-room structure resembling an ancient temple. The goal of FT(ERG) is to find the exit door key in one hour. There are 8 stages of problem-solving, i.e., intermediate goals, each linked to the next in a specific sequence, that lead the players to the key. Teamwork is required to complete the task. Players were given a portable phone and were entitled to a maximum of five calls for hints. FT(ERG) is a fully immersive game happening in a real-world setting.

Virtual Reality Escape AM(VRE)

The collaborative VR game ("Abandoned Mine", see Figure 2B) was set up in a virtual reality equipped room (navigation space 1m^2) with 3D HMD (head-mounted displays), head position, and orientation tracking. In this plot, the Yokon rock mine is closed due to a landslide, with people and gold forever lost inside. According to the legend, since then, the miners are trapped inside to protect the gold as "living-dead". The goal of this adventure VR game is to discover an old corridor that descends into the depths of the mine and then to identify the still working old elevator to get out as quickly as possible under conditions of low oxygen. Due to the limited position-tracking possibilities of this game (the tracked area was only $1m^2$), we considered the AM(VRE) game as partially immersive.

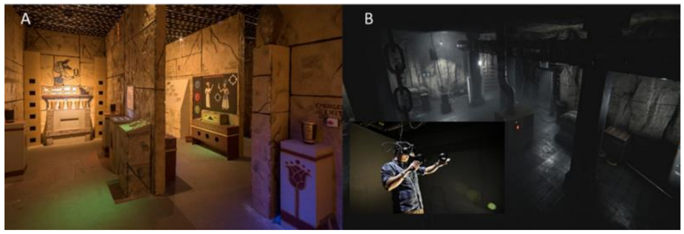

Figure 2. Screenshots of the games FT(ERG) (A) and AM(VRE) (B)

Unreal Tournament, First-Person Shooter: UT

In this study, the first-person shooter game was *Unreal Tournament 2004* (UT2004, Atari see Figure 3A). In this game, the player views 3D graphics on a computer screen from the first-person perspective of his or her avatar. The player must navigate the UT2004 virtual terrain and accurately aim their weapon to shoot enemies by maneuvering with the computer keyboard and mouse while successfully dodging enemies' bullets. The 'Single Player' game mode was set, resulting in an increase of enemies and the geographical complexity of the terrain every time the player meets the requirements of each game level. Additionally, in order to achieve optimal skill-challenge balance according to the kill/death (KD) ratio, i.e., the number of kills and deaths in the game, the difficulty level of the game was adjusted after the player had been gaming for 5 minutes. Specifically, similar to previous research (Green & Bavelier, 2006), the level of difficulty was raised when the participant exceeded a KD ratio of 2:1 and reduced when the ratio went below 1:2. The optimal challenge to skill balance was defined as maintaining a KD ratio within the interval [1:2; 2:1].

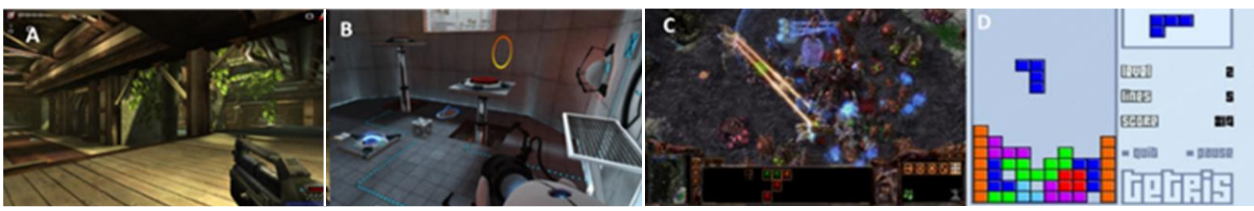

Figure 3. Screenshots of the UT (A), Portal (B), StarCraft II (C) and Tetris (D) Games

Portal

Portal (Valve Corporation, Figure 3B) is very similar to FPS games, where the player also maneuvers the environment from the avatar's first-person perspective. However, instead of shooting/killing opponents in an open (i.e., free to explore) environment, the game involves solving puzzles to navigate the environment, i.e., moving between chambers. Players must fire a gun to aim at two surfaces of the chamber to create a temporary portal between them, to be able to move between these two spatial locations. This game mainly requires spatial manipulations to solve puzzles and it has previously been classified as a puzzle game (Nelson & Strachan, 2009). The difficulty of the puzzles in each chamber automatically increases in complexity as players progress in this game; therefore, it was impossible to manually adjust the difficulty level. Hence, no pre-assessment phase was included in this game, and each participant started the game at the first level.

StarCraft II: Heart of the Swarm

The StarCraft II: Heart of the Swarm (Blizzard Entertainment, Figure 3C) is a real-time strategy (RTS) game in which players take an allocentric bird’s eye perspective of the battlefield. Commands are given via the mouse and keyboard. The game's goal is to establish a base that allows players to gather resources, therefore building military units. Subsequently, these units can be used to secure battlefield areas to gather more resources or destroy the opponents’ units and buildings. Destroying all of the opponents' units and buildings is the overall goal of the game, serving as the equivalence to killing opponents in FPS (Green & Bavelier, 2006; Nelson & Strachan, 2009). The custom game mode was used in which participants played against the computer. Every participant included in this study had achieved at least a Gold ranking on the Battle.net online league, indicating that they were sufficiently skilled to successfully play at high difficulty (i.e., at least level 4 out of 7). Due to the nature of the game (i.e., the game lasts a variable amount of time depending on the strategy used by the player), a pre-assessment phase was not feasible for this game condition. However, at the end of the first game, the experimenter checked if the participant had defeated the computer bot, and if so, the difficulty level was increased by one level for the next game. In cases where the participant had been defeated by the bot, the difficulty level was decreased for the next game session.

Tetris

In this game (Tetris by Palmantics, Figure 3D), geometric shapes made up of four orthogonally connected squares fall one at a time from the top and settle at the bottom of the game area, causing later blocks to stack above previous ones. The player is required to control the location and orientation of landing blocks to succeed. The speed of falling blocks increases as the player proceeds. Eventually, the player will be unable to remove rows fast enough; the game ends when new blocks cannot be added to the top row. The game was then reset back to level 1 for the next round. Tetris was played for as many rounds as possible within the allotted time limit of 30 minutes.

Participants

There were two separate groups (escape and video games), as described below, with a total sample size of 119 participants.

Group 1: Escape Games

The first group comprised 58 participants, age range between 19 and 36 (M = 26.34, SD = 4.12). Participants were recruited through online advertisement for the FT(ERG) real-world collaborative game. To ensure that the participants will experience optimal challenges during escape games, we invited only those who had played at least once in escape rooms and reported to enjoy it. Ensuring players were comfortable to play with each other, the advertisement encouraged them to form a group with their friends. To standardize group performance, we then let the 24 participants (14 male and 14 female) sign up for the FT(ERG) in teams of 4 players each. For the AM(VRE) condition, 34 participants (18 male, 14 female) were recruited and subsequently asked to form teams of 3 or 4 players each. Twenty-eight of these participants reported having had prior exposure to immersive virtual reality and Escape room games.

Group 2: Video Games

The second group included 61 (52 male, 9 female) expert video gamers between the ages of 19 and 30 (M = 22.64, SD = 2.11). All participants in this group were expert video gamers (gaming for at least 1 hour/day, 4 days a week for at least the last 6 months) in the specific games used in this study (i.e., UT, Portal, StarCraft II or Tetris, see Table 1). Participants were assigned the game condition in which they had the most experience. Total video gaming experience ranged between 1 to 17 years (M = 7.29, SD = 4.92). Specifically, the UT group included 16 participants (all male), the Portal group 15 participants (13 male, 2 female), the StarCraft group 15 participants (all male), and 15 participants (7 male, 8 female) were in the Tetris group. In addition, participants were expected to meet a performance criterion as detailed in Table 1 during the game intervention to ensure that they were optimally challenged by the game.

Table 1. Video Game Expertise and Optimal Skill-Challenge Criteria

Game	Expertise Criteria	Optimal Skill-Challenge Criteria
FT(ERG)	Played at least once in ER	Escape within 1 hour
AM(VRE)	Experience in immersive VR and ERG	Escape within 1 hour
UT	Expert video gamer	Maintain Kill/Death ratio between 1:2 to 2:1
Portal	Expert video gamer	Complete at least 15/19 levels in single player mode
StarCraft	Expert video gamer	Defeat bot player at minimum level 5/7
Tetris	Expert video gamer	Attain at least level 5 (no maximum level exists)

Attentional Blink Task (ABT)

The attentional blink (AB) is the phenomenon which occurs as the result of the "temporal limits of the deployment of selective attention" (Dux & Marois, 2009, p. 1683). Two decades of research has suggested that the AB is a robust phenomenon that is likely attributable to a fundamental limit in sequential object processing and that the processing limits evidenced in the attentional blink cannot be directly eliminated by brief exposure to or training on the task (see Tang et al., 2014 for a review). During the ABT, participants viewed a rapid sequence of black letters on a grey background at the center of the screen (Figure 4) and were required to report: (a) the identity of the only white letter (T1) and (b) whether the letter 'X' (T2) was presented after the white letter (50% of trials). Each letter was presented for 16.7 ms, followed by an 83.3 ms ISI.

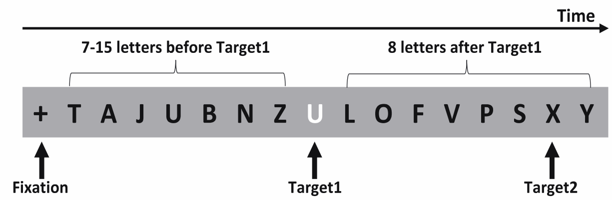

Figure 4. Attentional Blink Task Paradigm

The letter sequence length varied from 16 to 24 letters, with the white letter appearing unpredictably anywhere from the 8th to the 16th position in the sequence. In this experiment, four ABT lags (2, 3, 4 and 7) were applied, where T2 appeared after T1 at the respective lag time (lag-2, 200 ms; lag-3, 300 ms; lag-4, 400 ms; lag-7, 700 ms). The AB window has been identified to be approx. 500 ms (Shapiro et al., 1997), thus while lag-2 to lag-4 fell inside this AB window, lag-7 occurred outside of it. Overall, the ABT consisted of 96 trials (24 trials per lag). The ABT was scored for the accuracy of Target2 (T2) detection given that Target1 (T1) had been correctly detected, denoted as $T2|T1$ accuracy.

Procedure

All participants in group 2 (N = 61) played the corresponding game for 30 min, as the necessary time to access ECS (Kozhevnikov et al., 2018). Due to the nature of the games in group 1, FT(ERG) and AM(VRE) were played for approx. 1 hour. All participants were pre- and post-tested on the ABT, and our setting ensured that all players of group 1 and 2 would be able to perform the ABT immediately after their gaming/escaping to capture the effect of the ECS. Each participant performed an adapted version of the ABT (Raymond et al., 1992), consisting of 96 trials, twice: immediately before and after each session of video gaming.

RESULTS

In group 1 (N = 58), we excluded 3 participants [1 from FT(ERG) and 2 from AM(VRE)] from all further analyses. Two of these participants did not show the expected AB effect (non-blinker (Martens et al., 2006), and another one could not continue to play and withdraw from the AM(VRE) game due to the feeling of motion sickness, resulting in a total of 23 participants in the FT(ERG) and 32 in the AM(VRE) condition. In group 2, a total of 5 participants (1 from UT, 1 from StarCraft, 2 from Portal, and 1 from Tetris) were removed from all further statistical analyses. Two of these participants (from the UT and Tetris conditions) did not show the AB effect, and 3 others (1 from the StarCraft and 2 from the Portal condition) did not meet the performance criterion set during the experiment detailed in Table 1. Thus, the remaining sample in group 2 consisted of 72 participants, of which 22 participants participated in the UT(FPS), 13 in the Portal, 14 in the StarCraft, and 23 in the Tetris conditions.

The FT(ERG) condition had 6 groups of players, 5 of which were able to escape within the allotted 1 hour. One FT(ERG) group included in the analyses requested an additional 15 minutes, after which they could escape successfully. There were difficulties for AM(VRE) groups to escape in the allotted 1 hour, due to the required time to learn operating within VR, i.e., navigate in the game environment and grab objects [which according to AM(VRE) players' reports could range from 10 to 20 minutes]. Thus, we revised our initial criterion to escape in one hour, and all AM(VRE) groups were given an additional 30 minutes to escape (90 minutes in total), during which they were able to escape successfully. We retained all of the AM(VRE) groups in the analysis. However, due to practical constraints (i.e., learning time to operate VR varied between individuals and groups), we could not measure how long it took each AM(VRE) group to escape.

ABT Performance

Considering the exploratory nature of this experiment, we calculated the ABT performance changes as the absolute difference in T2|T1 accuracy between the ABT pre- and post-gaming averaged over lag-2 only, as previous experimental research demonstrated that lag 2 is the most challenging lag to show any improvements (Oei & Patterson, 2015), but when achieved, the improvements on this lag are often the most pronounced (Green & Bavelier, 2003; Nieuwenstein & Potter, 2006). Paired samples t-test (two-tailed) revealed that T2|T1 accuracy at lag 2 was significantly lower than at lag 7, [$t(125) = 19.75$, $p < .001$], replicating the AB phenomenon of sharply impaired performance at lag 2 compared to lag 7 (Dux & Marois, 2009; Shapiro et al., 1994).

To ensure that there was no difference between the pre-test performance between the groups, one-way ANOVA was conducted on the groups' ABT pre-scores. The analysis revealed no significant difference between the groups, $F(5, 125) = 1.09$, $p = .36$. A 2X6 mixed-design ANOVA with Time (ABT pre-test, ABT post-test) as a within-subjects factors and Game [FT(ERG), AM(VRE), UT, Portal, StarCraft, Tetris] as a between-subjects factor revealed a significant main effect of Time [$F(1,120) = 20.93$, $p < .001$, $\eta_p^2 = .15$]. There was no significant main effect of Game [$F(5,120) <1$, $p = .50$], but there was a significant interaction between Game and Time [$F(5,120) = 2.70$, $p = .02$, $\eta_p^2 = .10$]. The changes between ABT pre-test and post-test (ΔABT) for each game are plotted in Figure 5.

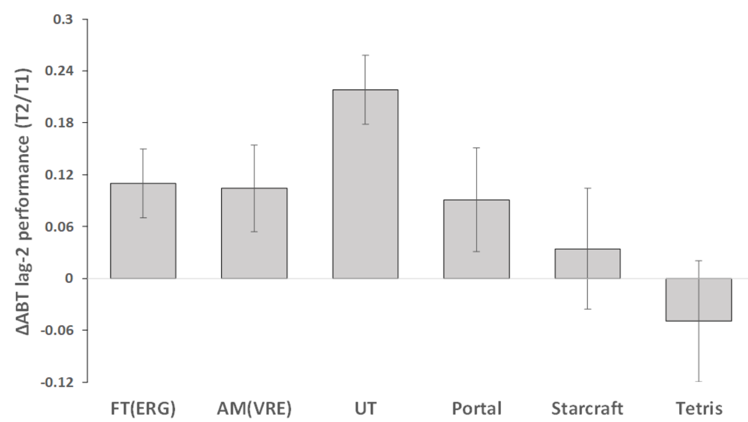

Figure 5. T2|T1 Accuracy Changes from ABT Pre-test to ABT Post-test per Gaming Condition

Follow-up tests (simple effects), comparing the ABT changes between the pre- and post-test, conducted for each game separately, yielded a significant increase in ABT performance for the UT[$F(1,21) = 12.97$, $p = .002$, $\eta_p^2 = .38$], FT(ERG) [$F(1,23) = 12.50$, $p = .002$, $\eta_p^2 = .36$], AM(VRE) [$F(1,31) = 5.72$, $p = .023$, $\eta_p^2 = .16$], and Portal [$F(1,12) = 4.86$, $p = .04$, $\eta_p^2 = .28$]. No significant changes in ABT pre-test and post-test were observed for StarCraft [$F < 1$, $p = .49$] or Tetris [$F < 1$, $p = .67$]. Thus, the largest effect sizes for lag-2 T2|T1 accuracy improvements were observed in UT (20% increase, effect size $\eta_p^2 = .37$) and FT(ERG) (15% increase, effect size $\eta_p^2 = .36$), followed by AM(VRE) and Portal (about 10% increase, effect sizes $\eta_p^2 = .28$ and $\eta_p^2 = .16$, respectively), with no significant changes for StarCraft (3% increase) and Tetris (2% decrease).

As our participants (in group 2) were primarily males, we added Gender as an additional between-subject variable into the above 2X6 mixed ANOVA. However, neither the effect of Gender nor the interaction between Time X Gender was significant, *Fs* < 1. This suggests that our results were not affected by Gender, as it does not play a significant role in accessing the ECSs. For the FT(ERG) condition, we found a significant negative correlation ($r = -.82$, $p < .05$) between the escape time and Group ΔABT, calculated as the average of that group participants' ABT improvements. We could not investigate the relationship between the escape time and Group ΔABT for the AM(VRE) condition, since as mentioned above, it was impossible to control the exact time it took each AM(VRE) group to escape due to different learning curves to operate a VR set for different players**.**

Furthermore, planned contrasts were performed for each game dimension (Perspective, Adrenaline-rush, Immersivity, and Collaborative context) to examine which dimensions contribute to significant ABT improvements. For each game dimension, the mean ΔABT score of each gaming condition was weighted (according to judges' classifications, presented in Figure 1), combined into the two groups, representing the opposite characteristics of the gaming dimension (e.g., first vs. third perspective, collaborative vs. individual game context), and then compared using two-tailed *t*-test. Levene's test was conducted to assess the homogeneity of variance, which yielded $p = .07$, assuming equal variance across the 6 gaming conditions.

For Perspective, the four first-person games [UT, Portal, FT(ERG), and AM(VRE)] were combined (each weighted by +1) and compared with third-person games (StarCraft and Tetris, each weighted by -2). The resulting contrast yielded a significant effect of Perspective, $t(121)=2.98$, $p = .004$, so that first-person perspective games led to significantly greater ABT improvements than the third-person games.

For Adrenaline-rush, the five adrenaline-rush games [UT, Portal, StarCraft, FT(ERG), and AM(VRE)] were combined and weighted by +1,+1/3. +1, +2/3, +2/3, respectively and subsequently compared to Tetris, weighted by -11/3). The resulting contrast was significant, $t(121) = 3.03$, $p = .003$, such that "adrenaline-rush" games led to significantly greater ABT improvements than neutral Tetris.

There was no significant difference between collaborative and individual games [FT(ERG) and AM(VRE), each weighted by +1, were compared to 4 other games, each weighted by -1/2, $t(121) = 1.088$, $p = .23$].

There was also no significant difference between immersive and non-immersive games [FT(ERG) and AM(VRE) weighted by +1 and +2/3 respectively, compared to 4 other games, each weighted by -5/12, $t(121) = 0.76$, $p = .45$].

Similar contrast analyses were performed for cognitive processing dimensions, which yielded no significant difference either between fast and slow processing [4 video games, each weighted by +1/2 were compared to two escape games, each weighted by -1, $t(121)= 0.78$, $p = .44$] or between focused and divided attention [UT, Portal, and Tetris, each weighted by +1, combined with two escape rooms, each weighted by +2/3 were compared to StarCraft, weighted by -13/3, $t(121)= 1.06$, $p = .29$].

DISCUSSION

The results are consistent with previous findings of Kozhevnikov et al. (2018), which showed that playing 30 minutes of action video games produces significant ABT increases, representing a behavioral marker of the ECSs. Furthermore, the results suggest that both the egocentric perspective and the "adrenaline-rush" nature are the most critical gaming dimensions for experiencing an ECS. Indeed, all first-person egocentric games [UT, Portal, FT(ERG), and AM(VRE)] led to significant ABT enhancements, while the allocentric games (StarCraft and Tetris) did not. Furthermore, all the games showing significant increases in ABT were adventurous "survival" games involving at least some "adrenaline-rush" experience.

In addition, according to our results, although "adrenaline-rush" activity is critical, it might not be sufficient by itself, without the egocentric perspective, to elicit the ECS. StarCraft, which was classified as a high "adrenaline-rush" game involving more violent type of activities (i.e., kill enemy units and destroy enemy buildings) than Portal or escape games, did not lead to significant ABT enhancements. Therefore, in order to trigger the arousal level required to access the ECS, it seems critical for the "adrenaline-rush" activity to have direct relevance to oneself, which is facilitated by playing a game from an egocentric perspective.

As for other gaming dimensions, such as immersivity, and collaborative game setting, although they may have facilitated access to ECSs, they were less critical than perspective and "adrenaline-rush". The combination of factors such as the realistic nature of the escape games, their first-person perspective, and the elements of "adrenaline-rush", are more likely to contribute to ABT enhancements during these games. Importantly, our findings are the first to show experimentally that it is possible to experience an ECS not only in individual game settings but also in group game settings. as both collaborative escape room games led to the experience of ECSs.

The results also suggest that the processing speed required by a game is not a critical factor for accessing ECSs. Despite being time-limited, both FT(ERG) and AM(VRE) do not require a fast response from the players compared to the other four video games. These games, however, did lead to ABT improvements, in contrast to Tetris, which did not lead to ABT improvements but required fast processing speed during gameplay. In contrast to long-term video gaming (LTVG) research, according to which only the video games requiring intense speed of processing might lead to improvements on lag 2 (Oei & Patterson, 2015), our findings indicate that speed of processing is not essential for accessing the ECS, suggesting that attentional enhancements due to ECSs and LGVT rely on different mechanisms.

Although, according to the results, the effect of attentional focus on ABT improvements was not significant, the effect of focused vs. divided attention while gaming was not formally controlled for in this experiment. We did not include a game, which would be both first-person and high “adrenaline rush”, and at the same time require multitasking, thus allowing us to isolate the effect of perspective from an attentional focus on accessing the ECS. Future research should examine the importance of focusing attention on a single task vs. dividing it across several tasks in inducing ECS experiences. Anecdotally, in competitive FPS team games such as Counter-Strike: Global Offensive (CS: GO), a designated team member instructs and directs the other players' activities, hence, other players are able to focus on a single goal, e.g., to kill enemies. In a way, this team leader mitigates the multitasking load, e.g., strategy design and implementation. Investigating individual FPS games vs. team FPS games and whether team leaders might be unable to achieve ECSs due to multitasking might shed more light on the importance of the attentional focus dimension.

From a theoretical perspective, the current research provides experimental evidence for the existence of universal ECSs, which might be accessed via playing first-person perspective “adrenaline-rush” games. While there is substantial evidence that LGVT also contributes to improved cognitive performance (see Green & Bavelier, 2003 for reviews), it should be noted that their effects are very different. The enhancement of cognitive functions through LTVG has been reported to be dependent on common demands between the game and transfer task (Oei & Patterson, 2015) and thus limited to the task or performance requiring the same cognitive functions. The current research suggests that the benefits of ECSs to focused attention are generalizable even outside the context of the specific game or activity that brought on the ECS. FT(ERG) resulted in similar ABT improvements to UT, although this game simulates real-world activities immersed in a physical space and does not share many features with action video gaming (fast responses. high visuomotor coordination) that have been previously suggested to affect the performance of action video gamers on attentional tasks (Bavelier & Green, 2019). The implications of the LTVG and ECS studies are also different. LTVG studies inform us that human cognition can be improved over time with specific training that can be generalized to other situations, whereas the ECS research implies that we can temporarily transcend what was assumed to be an ordinary human capacity in cognition under the right conditions and with relevant expertise.

From a more practical perspective, this study proposes a tool (gaming) to investigate ECSs experimentally. Examining ECSs in controlled settings will contribute significantly to behavioral sciences, where the areas of enhanced cognition and exceptional human functioning have been understudied due to difficulties in designing experimental conditions to induce such changes or finding subjects with exceptional cognitive capacities. Unlike other real-world activities that could be rather dangerous (rock-climbing or other extreme sports) or require high levels of expertise (e.g., visual art or surgery), gaming is an activity that not only has the potential to activate ECSs but can also be readily applied and studied under controlled laboratory conditions. In this respect, VR gaming could be the most effective. Not only does it provide a relatively realistic and immersive gaming environment for individual players and teams that can simulate dangerous and highly challenging activities, but it also affords concurrent neurophysiological data collection (Bian et al., 2016) and rigorous control of variables, which is impossible to achieve in the real-world. Finally, although ECSs are transient, a temporary boost in focused attention can nevertheless be utilized to enhance performance dramatically during critical periods. While coaching athletes to set world records is not unusual in sports, no comparable techniques to teach experts to go beyond and above current achievements in their fields exist in cognitive domains (e.g., create an art masterpiece or achieve a major scientific breakthrough), despite numerous reports by members of such professions on their spontaneous experiences of ECSs. Research on ECSs and how to induce them might show how cognitive capacities can be boosted upon demand, potentially resulting in unprecedented levels of human cognitive performance in different domains.

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