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Cognitive Evaluation in Sports and Esports: A Comparative Guide to Performance Testing

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ABSTRACT

Purpose: Cognitive processes we use all the time in every aspect of our lives are particularly critical in traditional sports and esports for rapid information processing. While there are existing studies in the literature on cognitive tests conducted with traditional and e-sports athletes, this review aims to synthesize these studies to provide systematic information for sports coaches and athletes on which cognitive performance to develop for each sport, using computer-based cognitive tests.

The tests used in this review article are from PEBL software, which aims to measure cognitive processes that begin with the sensory perception of environmental stimuli, are transferred to short-term memory, and then to task-dependent working memory via attention. The cognitive processes used in this review were examined in five different ways: (1) Attention and Alertness, (2) Inhibitory Control, (3) Cognitive Flexibility and Executive Functions, (4) Memory Systems, (5) Decision Making and Risk, and (6) Time Perception Assessment. This review aims to raise awareness among traditional and esports coaches by serving as a bridge between theoretical cognitive psychology and applied sports sciences. By introducing the cognitive test batteries frequently used in the PEBL battery and discussing the task in detail, this work aims to serve as a resource for developing cognitive assessments and targeted cognitive training interventions for traditional and digital athletes.

Keywords: Sports; Esport; Cognitive processing; Attention; Inhibitory control; Cognitive tests; Cognition

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INTRODUCTION

The Information Processing Loop

Cognition is a fundamental framework that governs the processes of perceiving, processing, and interpreting the environment in which we live (Eysenck, Michael, and Brysbaert, 2018). Whether we are aware of it or not, as individuals we are bombarded every second with countless visual, auditory, tactile, gustatory, and olfactory stimuli from our environment. Sensory memory is where these raw environmental inputs are first received and held for microseconds. While the retention periods here vary by sensory module, they are extremely limited. At this stage, attention plays an important role in selecting the information to be transferred to short-term memory. Modern cognitive psychology draws a clear line between Short-Term Memory (STM) and Working Memory (WM). While STM is a passive stop where information is temporarily held without any changes, with a limited storage capacity (traditionally 7 ± 2), working memory manipulates, updates, and organizes information in real time (Baddeley, 2000). At the core of this system lies the Central Executive, which is critical for executive functions by allocating limited attentional resources, inhibiting task-irrelevant distractors, and coordinating the flow of information. The Central Executive is not merely a storage unit; it drives the active processing dimension of cognition, which is essential for goal-directed behavioral control (Baddeley, 2017; Repovs & Baddeley, 2006). Depending on the nature of the incoming information, the process is divided into two main module-specific lines: Phonological Loop and Visual-Spatial Sketchpad. Understanding these subsystems requires a clear distinction between passive storage and active processing. The 'Inner Ear' within the phonological store and the 'Visual Cache' within the visuo-spatial sketchpad represent passive components, corresponding to traditional Short-Term Memory where information is simply held (Logie, 1995). In contrast, the 'Articulatory Rehearsal Process' and the 'Inner Scribe' are responsible for the active manipulation and updating of information. This active component transforms passive maintenance into true Working Memory performance, a transition that relies on the top-down control of the Central Executive. The Episodic Buffer subsequently integrates this processed information with long-term memory (Baddeley, 2012).

Defining the Framework

The brain has limited processing resources and attention is a mechanism that directs the brain's limited information processing capacity to specific stimuli in the environment by filtering out other irrelevant information (Wickens,2021). Sustained attention and vigilance describe the capacity to continuously monitor the stimulus over long periods of time in order to detect rare but critical target stimuli (Hemmerich et al. 2025). Inhibitory control is the ability to actively suppress, stop, or delay internal impulses, automated dominant responses, or strong external distractors in order to achieve goal-oriented strategic objectives (Diamond, 2013). Cognitive flexibility is the capacity of an individual to dynamically change their way of thinking, mental sets, and behaviors in order to adapt to changing environmental demands, new rules, and unexpected situations (Lee et al., 2024). Executive functions, on the other hand, are an umbrella term encompassing all the high-level cognitive control processes necessary for planning, initiating, monitoring, and flexibly terminating complex, goal-oriented behaviors (Cristofori et al., 2019). Short-term memory is the temporary storage of information in a passive storage without manipulation or reorganization of the information (Chai et al., 2018). In contrast, working memory is a dynamic mental workspace system where information is actively manipulated, updated, and transformed into performing complex cognitive tasks such as planning, reasoning, and problem-solving, going beyond simply holding information in the mind. Working memory is a much broader process that includes short-term memory but also encompasses the management of attention (Hester et al., 2005). Decision-making is the process of combining cognitive, affective, and motivational processes; it involves selecting the most appropriate and adaptive course of action from multiple alternatives, based on an individual's goals, values, emotions, and past experiences (Ganuthula, 2024). Risk assessment, on the other hand, is the analysis of potential gain and loss probabilities in uncertain situations where the outcomes of options are not known with certainty and these outcomes have different probability distributions (Elston et al., 2021).

Since all these cognitive functions are interrelated and closely linked, the tests presented in this review article which were selected from the PEBL battery also do not evaluate a single process in isolation by their nature (Table1). Consequently, the cognitive tests in this study are classified based on their primary evaluated function. The PEBL battery demonstrates high convergent validity when compared to traditional tests (Mueller & Piper, 2014). Furthermore, its executive function, attention, and memory paradigms exhibit stable test-retest reliability (ICC), proving robustly reliable for longitudinal cognitive research (Piper et al., 2012). This review aims to synthesize current studies exclusively administering PEBL tests to traditional athletes and esports players.

Table 1. Cognitive Functions and Tests Utilized in Traditional sports and esports research.

Cognitive Test	Core Cognitive Function	Secondary Cognitive Functions	Example Studies
Attentional Network Test (ANT)	Attention and Vigilance	Inhibitory Control	Chisholm et al. (2010), Starzak et al. (2024)
Psychomotor Vigilance Task (PVT)			Staiano et al. (2024), Horoszkiewicz et al. (2022)
Change Detection		Short-Term Memory, Working Memory	Clark et al. (2011), Grosprêtre & Gabriel (2021)
Stroop Task	Inhibitory Control and Response Selection	Selective Attention, Short-term Memory, Cognitive Flexibility	Huang et al. (2024), Ölçek et al. (2026)
Flanker Task		Selective Attention, Short-Term Memory	Trecroci et al. (2021), Mancı et al. (2024)
Go/No-go Task		Sustained Attention, Short-Term Memory	Gutiérrez-Capote et al. (2024), Mancı et al. (2024)
Trail Making Test (TMT)	Cognitive Flexibility and Executive Function	Working Memory, Selective Attention	Tokgöz et al. (2021), Giatzoglou et al. (2024)
Tower of London (ToL)		Short-Term Memory, Working Memory, Decision Making	Chang et al. (2011), DiFrancisco-Donoghue et al. (2021)
Switcher		Selective Attention, Short-Term Memory	Musculus et al. (2022), Campbell et al. (2024)
Digit Span	Memory Systems		Silvestri et al. (2025), Benoit et al. (2020)
N-Back		Sustained Attention	Song et al. (2024), Imanian et al. (2025)
Choice Reaction Time (CRT)	Decision Making and Risk Assessment	Short-Term Memory	Martínez de Quel et al. (2015), Bickmann et al. (2021)
Balloon Analogue Risk Task (BART)			Keller et al. (2023)
Iowa Gambling Task (IGT)			Sörman et al. (2022)
Time Wall	Time Perception	Focused Attention, Working Memory	Mancı, (2021), Mancı et al., (2023), Mancı et al., (2024)

Search Strategy

Traditional sports and esports, which require high speed, intense visual flow, instantaneous decision-making, and precise timing, are performance fields that heavily utilize cognitive functions (Pedraza-Ramirez et al., 2020). While numerous studies in literature examine athletes' motor skills, training regimens, or overall reaction times, there is a need for a comprehensive guide that systematically and comparatively addresses standardized computerized psychometric tools (Kilci, 2026).

So, we aim to write this review to provide a methodological guide to cognitive performance testing frameworks in the context of sports and esports. These experimental platforms and the core cognitive functions they measure are examined in a systematic hierarchy under the thematic headings of Attention, Inhibitory Control, Cognitive Flexibility, Memory Systems, Decision-making, and Time Perception. So, our primary technique for literature review is a systematic review of recent studies involving traditional athletes and e-athletes, examining the cognitive tests used for each cognitive function. During the review process, priority was given to studies that directly used standard PEBL test protocols and examined only the effect of the relevant test, rather than articles containing test variations or additional assessments. The literature search strategy was systematically organized around five major cognitive domains using specific standard PEBL subtests as the main search criteria: Attention and Vigilance (ANT, PVT, Change Detection), Inhibitory Control (Stroop, Flanker, Go/No-go), Cognitive Flexibility and Executive Functions (Trail Making, Tower of London, Number Letter), Memory Systems (Digit Span, N-Back), Decision Making and Risk Assessment (Choice Reaction Time, BART, Iowa Gambling Task), and Time Perception (Time Wall).

Relevant articles were identified by comprehensive search of the PubMed database and the academic search engines Google Scholar and Consensus. Search queries were created by combining keywords “sports” and “esports” with names of corresponding PEBL subtests. The search results were combined, and gray literature (e.g., conference abstracts and unpublished data) was excluded for the final analysis.

DOMAIN-BASED COGNITIVE ASSESSMENT PARADIGMS

Attention and Vigilance

Attentional Network Test (ANT)

The Attentional Network Test (ANT) is primarily a test that measures attention (Fan et al., 2002), but due to its structure, it also measures cognitive abilities such as inhibitory control and cognitive flexibility. When the ANT structure is examined, there are two phases. First, participants may see cues (star symbols) and its location indicating an approaching target or in some cases, participants see no cues at all. In the second phase, arrows appear on the screen, and the participant's task is to respond by pressing the right or left arrow keys as quickly as possible, depending on the direction the central arrow points (Figure 1a).

Considering the structure of the ANT, it measures three different sub-networks in the brain and can be attributed to Michael Posner's Triad Attention Network Theory (Posner & Petersen, 1989) in terms of Alerting, Orienting, and Executive Control network. The difference in reaction time between situations where cues are given and not given within the test provides information about the brain's alertness capacity, while the location of the cue activates the Orienting network. In the second stage, the Executive network is activated due to the inhibitory control required by the target arrow given with the distracting stimuli.

Within the context of sports Chisholm et al. (2010) found when video game players were instructed to ignore the color information and focus only on reporting the orientation of the target, action video game players responded quicker than non-action video game players. In traditional sport studies, a review by Starzak et al. (2024) examined attentional focus strategies in racket sports. And suggested to enhance novice or low-skilled athletes' performance external focus of attention should be adopted.

Psychomotor Vigilance Task (PVT)

In the study by Dinges and Powell (1985) this task was originally designed to measure simple visual reaction time under sustained sustained operations. Later the task was standardized as the Psychomotor Vigilance Test (PVT), a commonly used measure of sustained attention and vigilance. In the test participants are required to maintain attention while monitoring appearance of a randomly timed visual stimulus and instructed to respond as quickly as possible upon detecting stimulus by pressing a response button. Response times recorded in milliseconds reflect the sustainability of the vigilance, especially during the period when the stimulus is expected. Prolonged response times observed throughout the process directly indicate a decline in performance of attention within the vigilance (Figure 1b).

In the context of sports, Staiano et al. (2024) studied that mental fatigue may cause a perception of increased exercise difficulty even in the absence of physical fatigue and, as a consequence, a decrease in physical, attentional and reaction performance. Horoszkiewicz et al. (2022) examined the differences in psychomotor performance between professional and amateur video game players. Results indicated that professionals outperformed amateurs in cognitive processing speed, reaction time, attentional control, perception, and working memory.

Change Detection Task

The change detection paradigm, which essentially originates from the visual memory literature and was later standardized by Luck & Vogel (1997), focuses on the ability to detect changes within a scene. In this task, participants are briefly presented with a series of visual stimuli, followed by a short delay of period and then a second display. Participants are expected to determine whether any change has occurred in the second display. Changes typically involve color, shape, or spatial location. Visual attention and divided attention mechanisms are active in the encoding process of multiple visual objects appearing on the screen. During the short gap between two stimuli, the encoded information is actively held in visual working memory. The ability to accurately predict whether a change has occurred is tied to limits of the memory capacity. The decrease in performance with increasing object count provides insights into the capacity of working memory and attention (Figure 1c). In a study by Clark et al. (2011), experienced action video game players and non-players were compared on a change detection task. In the experiment participants viewed visual scenes which contained changes and were asked if a change had occurred in the scene. The results indicated that players of action video games could detect changes more quickly and with less visual exposure than non-players.

Grosprêtre & Gabriel (2021) studied the influence of sports experience on change detection in visual scenes. In the study athletes were compared to a non-athlete group. Participants viewed visual scenes with changes and were asked to report whether they saw any differences. The results indicated that athletes, particularly those in open-skill sports, detected changes more quickly and accurately than the non-athlete group.

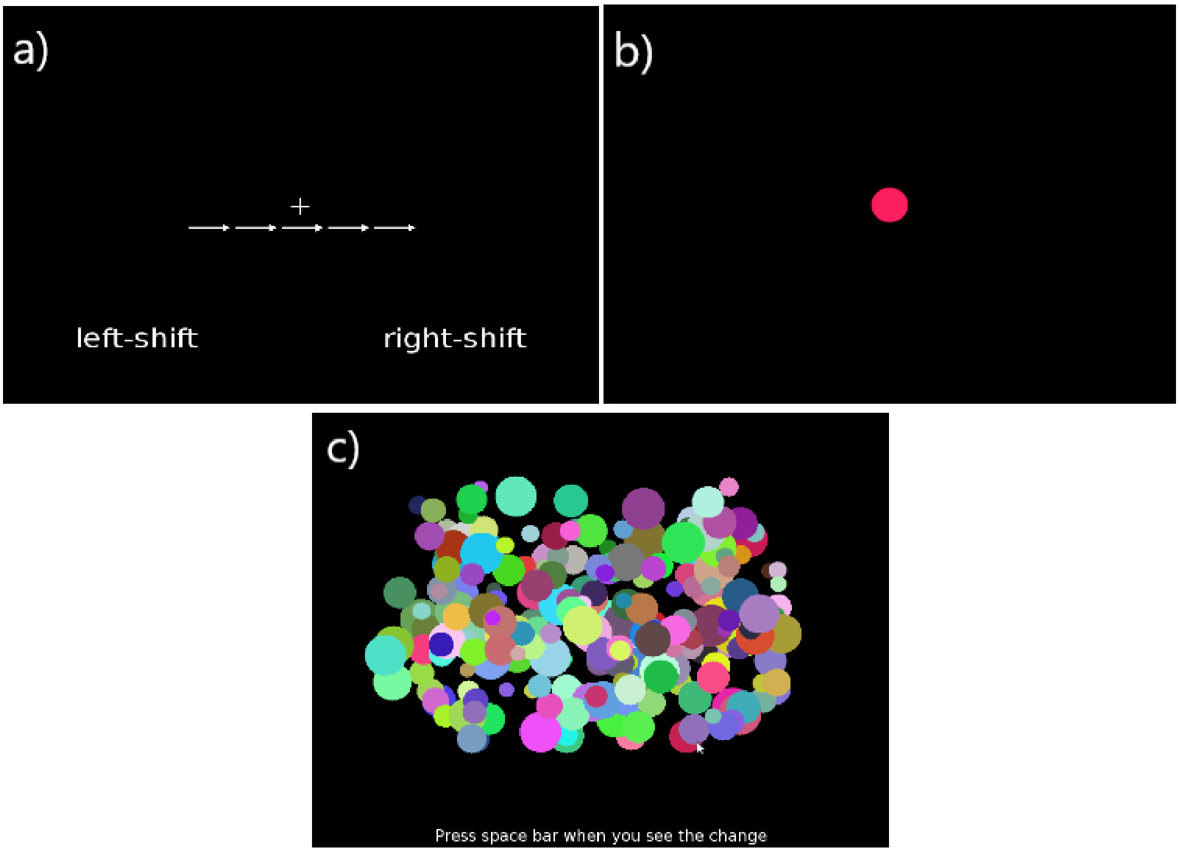

Figure1. Computerized attention paradigms from the PEBL test battery (a) Attentional Network Test (ANT), (b) Psychomotor Vigilance Task (PVT), and (c) Change Detection Task.

Inhibitory Control and Response Selection

Stroop Test

The Stroop test, developed by John Ridley Stroop in 1935, measures the ability to inhibit cognitive interference that happens when the processing of one aspect of a stimulus affects the simultaneous processing of another aspect of the same stimulus. In the test, participants are shown color names written in words of their corresponding colors (congruent) and color names written in words not of their corresponding colors (incongruent). Participants are instructed to name the color of the ink, not the word itself (Figure 2a). In this process, participants need to inhibit their automatic reading tendency and direct their attention to the correct information. Given that people read words automatically, they could have a delay or make an error in naming the colors. The reaction time (RT) difference between congruent and incongruent stimuli primarily reflects the ability to inhibit cognitive interference, and secondarily reflects selective attention, short-term memory, and cognitive flexibility.

Huang et al. (2024) studied cognitive inhibition ability of table tennis athletes and non-athletes. Event-related potentials (ERPs) were recorded during the color-word Stroop and spatial Stroop tasks to examine the brain processes involved in conflicting information. The results indicated that the table tennis players had improved speed and efficiency in particular in the tasks involving spatial attention and conflict resolution of cognition. In addition, athletes displayed reduced cognitive resource utilization during task performance and showed improved neural efficiency.

Ölçek et al. (2026) investigated the cognitive aspects and vestibulo-ocular reflex (VOR) performance of esports and sports athletes. The study assessed the performance of the vestibular system through the Functional Head Impulse Test (fHIT), the visuospatial and short-term memory, the reaction time by Stroop Test and Corsi Block Test, and the functional vestibulo-ocular reflex (VOR) measured through the same tests. Results showed that e-athletes had a faster response time and fewer errors in the Stroop Test and better performance in the visuospatial short-term memory tasks. However, no statistically significant difference was observed between the groups in the performance of the vestibulo-ocular reflex.

Flanker Test

B. A. Eriksen & C. W. Eriksen conducted a study in 1974, in which participants were asked to identify a target letter presented on the screen as quickly and accurately as possible (Figure 2b). However, it was found that incongruent stimuli placed around the target increased reaction times and error rates. This study laid the foundation for what is now known as the "Eriksen Flanker Task" paradigm. Arrow-based version of the paradigm was later developed through studies by E. J. Stoffels and M. W. van der Molen in 1988. In this version, participants were instructed to report the direction of the central arrow as quickly and accurately as possible, while incongruent surrounding arrows were found to increase reaction times and error rates. These findings revealed that participants not only process target stimuli but also automatically process distracting environmental stimuli. Reaction time variation in the Flanker Test primarily measures response inhibition; secondarily, the test reflects selective attention and short-term memory.

The association between cognitive functions and sport-specific physical performance in young female volleyball players was investigated by Trecroci et al. (2021). The study evaluated the cognitive and motor performance levels of the participants. Cognitive measures included tests of executive control and attentional processes such as reaction time, the Flanker task and visual search tasks. Physical performance was assessed by volleyball-specific skills (e.g. , passing, serving and forearm pass accuracy) and motor abilities such as agility, vertical jump performance and balance . Results showed a positive correlation between cognitive functions and physical performance. Specifically, athletes who showed better attentional control, processing speed and reaction time tended to have higher levels of both motor skills and sport-specific technical performance. Mancı et al. (2024) studied the cognitive abilities and differences between people who frequently play multiplayer online battle arena (MOBA) and first-person shooter (FPS) games. Participants completed four computerized cognitive tasks: Change Detection, Mackworth Clock, Timewall and the Flanker Test. The study found that first-person shooter game players showed better sustained attention, faster reaction times and inhibitory control compared to multiplayer online battle arena game players.

Go/No-go Task

The modern Go/No-Go paradigm is traced back to the Continuous Performance Test developed by Rosvold et al. (1956). In later years, Casey et al. (1997) contributed to the development of the task by linking prefrontal cortex activity with inhibitory control, through the use of fMRI. The Go/No-Go task is used in cognitive psychology to assess response inhibition. In this task, participants are presented with a continuous series of stimuli and are required to respond as quickly as possible to a specific type of stimulus ("Go" trials), while withholding any response to another type of stimulus ("No-Go" trials). Performance on the Go/No-Go task primarily assesses motor response inhibition and impulse control mechanisms, while secondarily reflects sustained attention and short-term memory (Figure 2c).

Gutiérrez-Capote et al. (2024) investigated the acute effects of task complexity in basketball on cognitive capacity using Flanker and Go/No-Go paradigms. Results showed that a higher degree of task complexity, particularly in the domain of inhibitory demands, leads to a decrease in cognitive performance, while experience has a positive effect on both response speed and accuracy. The study also indicates the relationship between the acute cognitive effects in sport and the complexity of the task and the cognitive resources of the athlete. Thus, it highlights the necessity of individualizing the demands of cognitive tasks according to the cognitive abilities and capacities of each athlete.

Effects of acute sprint exercise on cognition, gaming performance and cortical hemodynamics were investigated in amateur esports players and age-matched healthy controls by Mancı et al. (2024). Participants were first assessed using the Go/No-Go task, Tracking Test, and Valorant gaming performance measures. After baseline assessments, all participants performed an acute sprint exercise protocol. Cognitive and gaming performance tests were repeated 5 and 30 minutes postexercise. In addition, prefrontal cortex (PFC) hemodynamic activity during gameplay was monitored using Functional Near-Infrared Spectroscopy (fNIRS). Results indicated no pre–post differences in PFC oxygenation levels in either group. Across all sessions, however, amateur esports players performed better than them on both the gaming and tracking tasks. Furthermore, acute physical exercise improved game performance in both groups and esports players showed more accuracy on the Go/No-Go task after exercise.

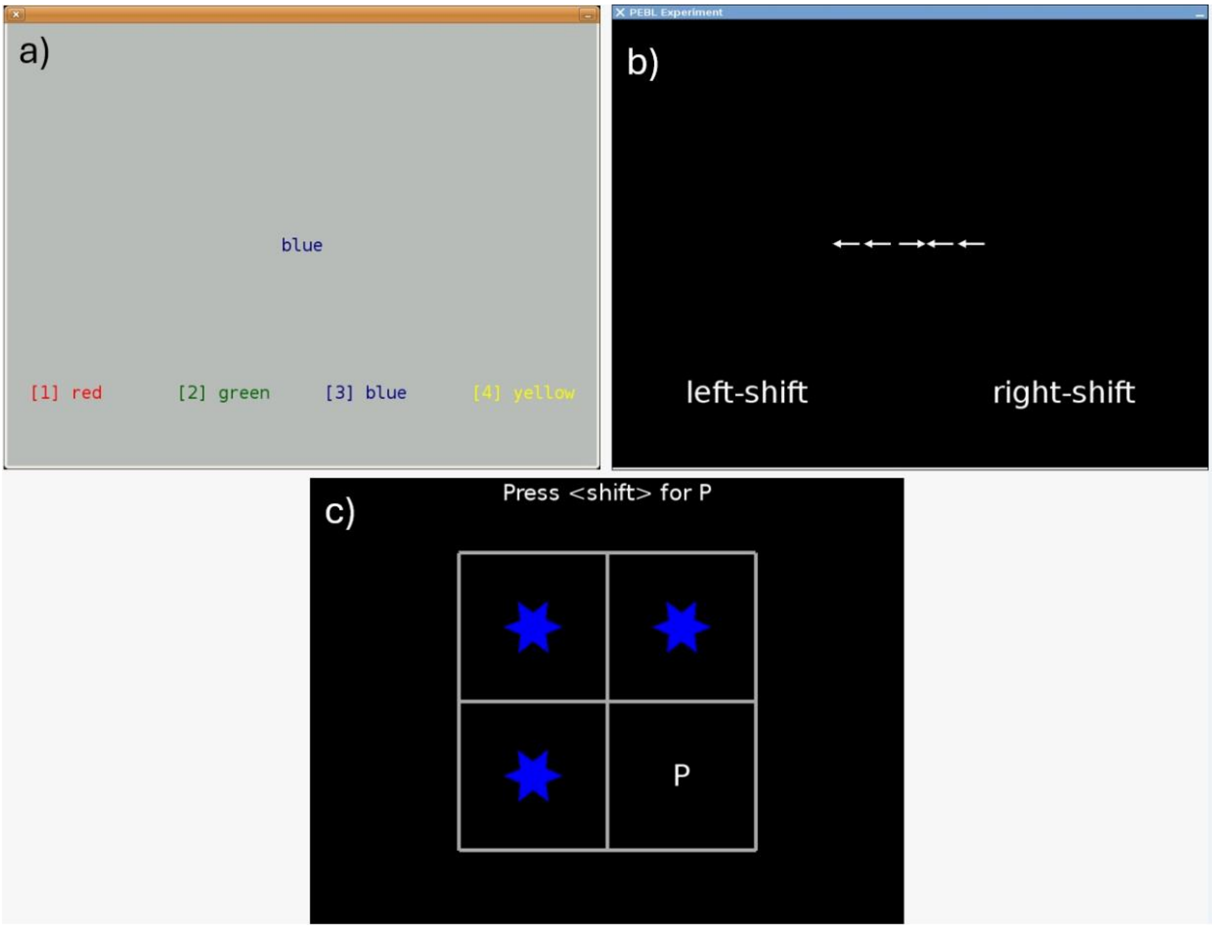

Figure 2. Computerized Inhibitory Control and Response Selection paradigms from the PEBL test battery (a) Stroop, (b) Flanker, and (c) Go/No-go

Cognitive Flexibility and Executive Function

Trail Making Test (Connections)

The Trail Making Test (TMT) is a neuropsychological test originally developed by Reitan (1958) that measures cognitive flexibility, selective attention, and executive functions. The test consists of two parts; in the first part the task of the participants is to connect the numbers in sequential order (1-2-3..) as quickly as possible. In the second part, participants have to connect numbers and letters in sequential order together (1–A–2–B–3–C, etc.). This structure makes the test useful for assessing cognitive flexibility and set-shifting ability. Performance is evaluated based on completion time and the number of errors made (Figure 3a).

Tokgöz et al. (2021) used the Trail Making Test and compared cognitive flexibility, attention, and processing speed of open-skill athletes (football players), closed-skill athletes (track and field athletes), and sedentary individuals. The results demonstrated that there was no significant difference in the performance of participants between football players and track and field athletes. Furthermore, study showed that open- and closed -skill athletes did not differ in attention, processing speed, or cognitive flexibility in the Trail Making Test. When we look at studies with esports players Giatzoglou et al. (2024) adapted the Trail Making Test (TMT) in Virtual Reality (VR) for assessing cognitive performance. The aim of the experiment is to examine the effect of familiarity on cognitive task performance at different levels of gaming experience (high and low). Researchers examined the results in terms of Three VR interaction modes (eye tracking, head movement, and handheld controller) on accuracy and task completion time. Both eye-tracking and head-movement modes showed faster completion times and higher accuracy compared to the controller, however gaming skills did not significantly influence performance in any other mode.

Tower of London

The Tower of London is a neuropsychological task developed by T. Shallice (1982) to assess executive functions. The task consists of rods of different sizes and colored balls, and the participant's goal is to transform the initial arrangement into a target form in as few moves as possible. In the first stage, planning and strategic problem solving involve analyzing the difference between the starting and target positions and mentally sequencing moves before making a physical move. In the second stage, cognitive flexibility, and visual-spatial working memory are effective to evaluate alternative routes while correctly executing the planned moves and memorizing the new positions of the balls (Figure 3b). The Tower of London task primarily measures planning and strategic problem-solving skills, while secondarily reflects short-term memory, working memory, and decision making. In the study Chang et al. (2011) investigated the effects of acute exercise on executive function using the Tower of London task. Participants performed the TOL Task, before and immediately following exercise or a control treatment. . Results indicated that the exercise group showed greater task scores than the control group in planning and problem solving, but not in rule adherence and performance speed.

The study conducted by DiFrancisco-Donoghue et al. (2021) investigated executive function in competitive esports players by breaking up prolonged gaming sessions with short walking breaks or resting periods. Participants were randomly assigned to short walking breaks, resting breaks, or uninterrupted gameplay conditions during 2-hour gaming sessions. Tower of London task, the Stroop test, and an exit survey used as assessment methods. In the Tower of London results, the fastest performance (planning and solution time) was observed in the short walking break conditions, while the slowest performance was found in the resting conditions. There were no significant differences in other cognitive tests, physical measures, or gaming performance outcomes.

Switcher Task

The Switcher Task is a response selection measure based on the classic task-switching paradigm developed by Rogers and Monsell (1995). This task is included in the PEBL 2 software battery and is a standardized tool to explore executive control processes including cognitive flexibility, reaction time, accuracy, and in particular switch cost, which is defined as the difference in performance between task-switch and task-repeat trials . For this particular implementation, a series of objects of different colors, shapes and letters inside them are scattered on the screen. One of these objects is marked with a white circle. The participant's task is to find and report another object that shares the property of the marked object as defined by the active rule currently shown at the top of the screen. Participants have to flexibly shift their attentional focus between these stimulus dimensions (color, shape or letter) depending on the changing rules which is a direct measure of their cognitive flexibility (Figure 3c). Musculus et al. (2022) aimed to develop two soccer-specific cognitive tasks that combine the strengths of the cognitive component skills approach and the expert performance approach. The participants were elite youth soccer players, and standard Go/No-Go and task-switching paradigms were applied in a soccer-based setting. Participants responded to visual stimuli derived from soccer situations, and measures of performance (e.g., response time and accuracy) were obtained. The results indicate that the newly developed tasks may be useful and valid tools to assess cognitive control processes and may be applied by soccer clubs as an evaluation method.

Campbell et al. (2024) compared the cognitive performance of action video game players (AVG) with an age matched control group of non-players and examined changes in performance following cognitive fatigue. Executive functions and attention were studied using the Number-Letter Task (task-switching), Groton Maze Task, and other measures of reaction time and attention. A cognitive fatigue manipulation was also employed, and all tests were repeated afterwards. Video game players performed better on visuospatial working memory and more complex attention tasks, but no significant differences were found on simple attention measures. Moreover, both groups were similarly influenced by cognitive fatigue, which is evidence against a specific resistance to fatigue in video game players.

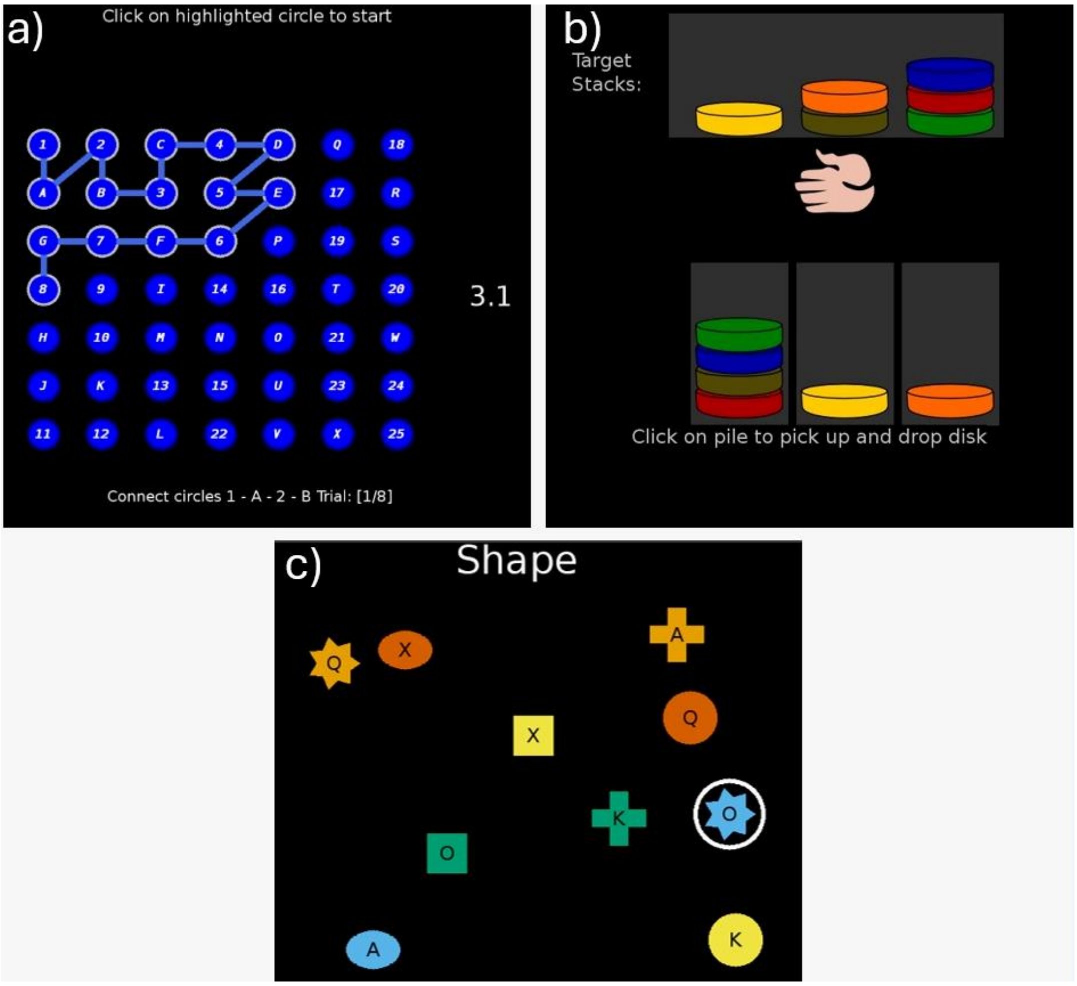

Figure 3. Computerized Cognitive Flexibility and Executive Function Paradigm from the PEBL test battery (a) Trail Making (Connections), (b) Tower of London, and (c) Switchers

Memory Systems: Short-Term and Working Memory

Digit Span Test

The Digit Span Test is a measure frequently used in intelligence tests for the evaluation of verbal short-term memory and working memory capacity. Its foundations were laid by

Joseph Jacobs in 1887 and standardized by David Wechsler in 1939. The test has three main parts. In the first part, the participants are required to report the numbers in the order they are presented. In the second part, they are required to report the numbers in reverse order (from last to first). In the third part, they are required to sort the numbers in the ascending order (Figure 4a). This three-stage test involves not only passive storage of information but also mental manipulation and processing of information. Differences in performance across the three stages indicate primarily short-term and working memory.

Silvestri et al. (2025) studied the effects of open skill (soccer) and closed skill (artistic gymnastics) sports on the development of gross motor coordination and executive functions in pre-adolescent female athletes. Using gross motor coordination and executive function (Flanker/Reverse Flanker; Digit Span) tests, the study found that gymnasts scored higher on physical tests than soccer athletes scored better on the digit span test. Considering the level of expertise, the study concluded that the type of sport and the degree of professionalism within that sport have an impact on the development of motor and cognitive functions. In a study conducted by Benoit et al. (2020) to compare the cognitive abilities of professional esports players with those of non-professional standard video game players and to determine their neuropsychological profiles, the Digit Span, Spatial Span, Stroop Test, Trail Making Test, and 3D Multiple Object Tracking test were used as assessment method. Although no significant difference was found between the groups in the Digit Span results, professional esports players showed higher performance than standard players in the 3D-MOT, Spatial Span, and TMT tests.

N-Back Task

The N-Back Task is a test used to measure working memory capacity and dynamic information updating, particularly in functional brain imaging (fMRI) studies, to examine prefrontal cortex activity. The test was developed by Wayne Kirchner (1958), and it was later standardized for fMRI studies by researchers such as Cohen et al. (1997) and Jaeggi et al. (2008). In the test participants presented with a series of stimuli one per second and asked to press a button when they see a stimulus that is the same as the stimulus "N" (1, 2, 3) steps earlier (Figure 4b). The time constraints between stimulus steps throughout the test provide information about an individual's sustained attention, short-term memory and working memory. Song et al. (2024) studied the working memory performance of professional badminton players in relation to non-athletes and the differences in brain activation (oxygenation) levels at the prefrontal cortex using N-Back Task and Functional Near Infrared Spectroscopy (fNIRS). There were no significant differences in the overall scores of the N-Back tests. However, badminton players showed significantly different activation in the left frontal-parietal attention network (left FPA), right dorsolateral prefrontal cortex (right DLPFC) and left ventrolateral prefrontal cortex (left VLPFC) during the 3-Back test compared to non-athletes. The results indicated that long-term badminton training leads to better performance on high-load working memory tasks.

Imanian et al. (2025) researched the impact of regular esports training on cognitive skills and examined the variations in the development of these cognitive skills when playing alone (Single Player) versus playing in pairs (Co-Player). Participants with no prior esports or intensive video game experience were randomly divided into two equal groups, the Single Player Group and the Co-Player/Team Group. For the development observation, participants were required to participate in an 8-week esports (FIFA) training program. The participants completed the Stroop Task, N-Back Task and Wisconsin Card Sorting Test – WCST before and after training. Both groups showed significant increases in the N-Back Task and Stroop Task test scores, and only the Co-Player group demonstrated a significant improvement in the WCST. Furthermore, there was no significant difference between the Single and Co-Player groups in terms of attention span and working memory development.

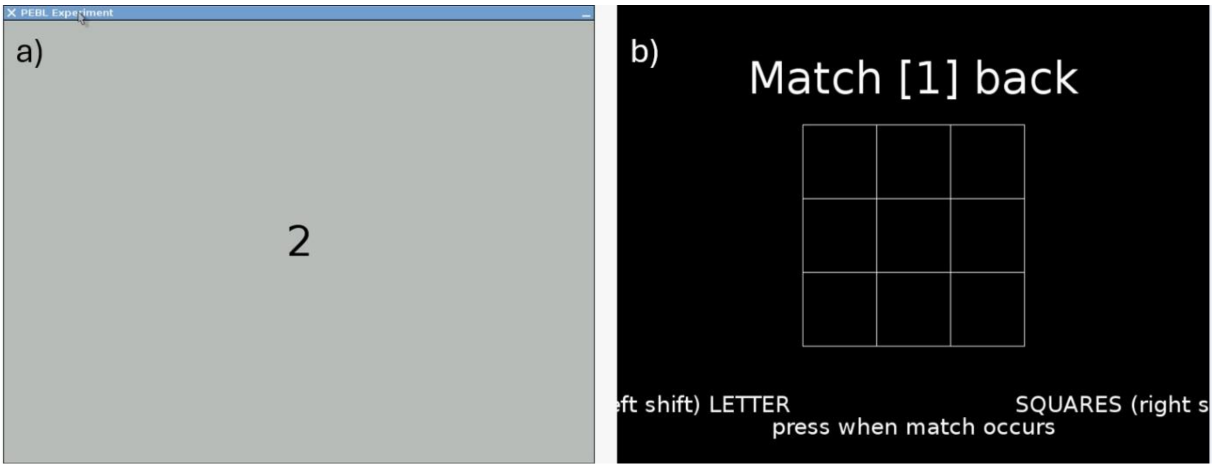

Figure 4. Computerized Memory Systems Paradigms from the PEBL test battery (a) Digit Span, (b) N-Back

Decision Making and Risk Assessment

Choice Reaction Time (CRT)

Choice Reaction Time is a task that measures the decision-making time between the appearance of a stimulus and the correct response (Figure 5a). Choice Reaction Time takes its place in the literature with Donders' (1969) development of the subtraction method (Decision Making Time = Choice RT - Simple RT). The increase in the reaction time provides critical information about information processing capacity and decision-making efficiency.

Martínez de Quel et al. (2015) conducted a study examining whether CRT has a direct relationship with the success levels of elite karate athletes in competitions. In the study participants were divided into two groups: those who had won medals in national or international championships (Successful) and those who trained at a similar level but had not achieved a medal in championships (Less Successful). The results showed no significant relationship between CRT results and the competition success of karate athletes. Furthermore, no statistically significant difference was found between CRT speeds, error rates, and simple reaction time.

Bickmann et al. (2021) aimed to compare reaction times of professional to non-professional esports players and traditional sportspeople in visual, acoustic, and choice reaction tests. No significant results were found between the three groups regarding reaction times and motor reaction; however, players from sports simulations, especially in the acoustic and the choice reaction test, reacted significantly faster than MOBA players.

Balloon Analogue Risk Task (BART)

The Balloon Analogue Risk Task (BART) is a computer-administered experimental task used to measure risk-taking behavior and decision-making mechanisms. Participants are given a virtual balloon and a pump button, as developed by Lejuez et al. (2002). Each time the participant hits the "Pump" button the balloon grows a little, and a small amount of money is added to a temporary fund (Risk Taking). Participants may press the "Collect Money" button at any time to transfer the accumulated temporary money to their permanent fund and end the round (Reward Collection). The more times the balloon is pumped, the higher the chance it will pop (participants do not know when the balloon will pop). If the balloon pops before the temporary money is moved to the permanent fund, the money saved in that round is reset to zero and a new round begins (Figure 5b). The study examined the average number of pumps in rounds where the balloon does not burst, and the participant gets the money. A high average indicates a high risk taking tendency and impulsiveness, a low average indicates a risk averse, overcautiousness.

Keller et al. (2023) aimed to determine the risk-taking behavior of extreme sports athletes, compare their risk-taking behavior to esports players and non-athletes and to investigate the degree to which the Balloon Analogue Risk Task (BART) reflects real-life risk-taking behavior. Participants completed the Balloon Analogue Risk Task (BART), self-reports of general risk-taking , and sport-specific risk taking. The results showed that extreme sports athletes inflated more balloons, burst more balloons and had higher behavioral risk in the BART test, which meant they took more risks than other groups. Furthermore, even when esports players perceived themselves as risk-takers, their performance on the BART did not reflect the same risk-taking behaviors as those of extreme sports athletes.

Iowa Gambling Task (IGT)

The Iowa Gambling Task (IGT) is a method used to measure decision-making, risk-taking, reward/punishment mechanisms, and the ability to predict future outcomes by simulating how we make decisions in real-life situations of uncertainty. It was developed by Bechara et al. (1994) in Antonio Damasio's laboratory. Participants are presented with four decks of cards labeled A, B, C, and D on a computer screen, and in each trial, they are asked to choose a card from the decks and maximize their gains while minimizing their losses. Decks A and B are considered disadvantageous/risky because they offer high gains while resulting in net losses in the long run, and decks C and D are considered advantageous/safe because they offer low gains while resulting in net gains in the long run (Figure 5c). The expected result is that participants show a learning curve of the decks' outcome after the trials and lean towards the more advantageous/safe decks. Sörman et al. (2022) investigated the relationship between skill levels and decision-making abilities in the uncertainty, in order to determine the extent to which the Iowa Gambling Task (IGT) reflects performance groups in the strategy video game Dota 2. Participants performed the Iowa Gambling Task (IGT) and the Cognitive Reflection Test (CRT) as measures of analytical and conscious thinking ability. The parameters to evaluate the players' ability in Dota 2 were medals (league ranks) and MMR (in-game scores). Results showed that players' league ranks (Medals) were a significant predictor decision-making performance on the IGT test, while in-game scores (MMR) were borderline significant. Furthermore, players with high analytical thinking skills (players with high CRT scores) made more rational decisions in the long term in the IGT test and had significantly higher MMR scores in Dota 2.

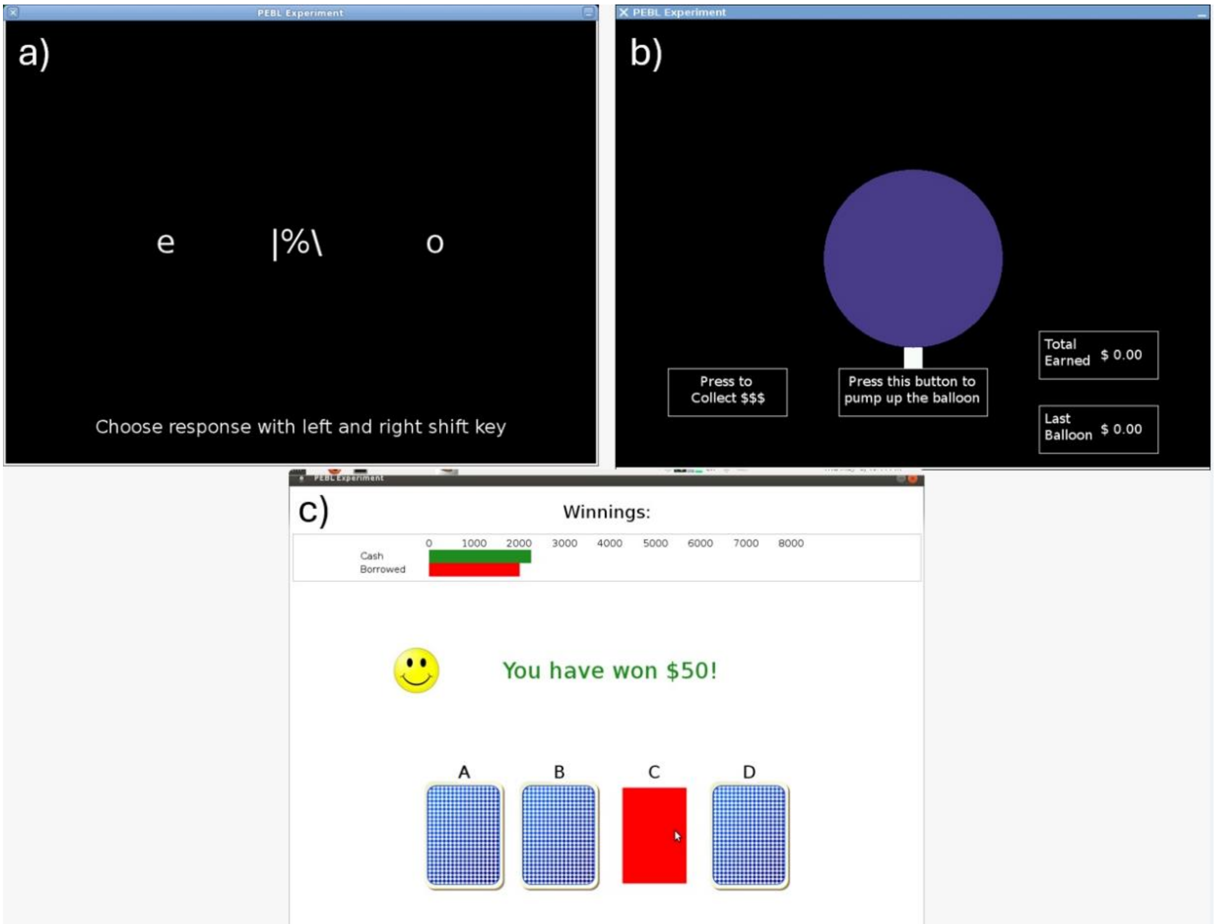

Figure 5. Computerized Decision Making Paradigms from the PEBL test battery (a) Choice Reaction Time (b) BART, (c) Iowa Gambling Task

Time Perception

Time-processing is a fundamental ability (Allman and Meck, 2012) involved in each of the cognitive processes we have discussed so far. While completing all these cognitive tasks, participants need to consciously or unconsciously process information of time as a duration, sequence, or rhythm of stimuli at the millisecond or second level, and this is called "time perception" (Buhusi and Meck, 2005). In both traditional sports and esports, the ability to adjust to the dynamic playing field relies on cognitive functions such as attention, inhibitory control, cognitive flexibility, memory, and decision-making, while a better sense of time will enable a player to perform at a higher level. For instance, an esports player has to anticipate his opponent's move and react at the right moment within a millisecond level. Looking at other examples from traditional sports, a basketball player needs to integrate motor timing with visual-spatial cues to shoot the ball into the hoop at the right time. Meta-analytic results in sports science indicate that blocking the visual information flow at a critical time and enabling the basketball players to anticipate future events with limited kinematic data results in enduring enhancements in timing and decision-making precision (De Oliveira et al., 2006). This temporal occlusion paradigm, employed in research to enhance visual prediction abilities in basketball players, and exhibits notable methodological similarities with the PEBL Timewall task in cognitive psychology literature.

Time Wall Test

The Time Wall is a test designed to evaluate participants' predictive motion capabilities and was first created by Jerison et al. in 1957. In the task, the screen is divided vertically into two halves, with a 2/3 to 1/3 ratio. A small square (the target object) drops within the upper two-thirds of the screen, where participants can observe it, while the lower one-third is blocked by a wall; which participants can observe, while the lower one-third is blocked by a wall; the participant is unable to directly observe the target object's movement. Based on the object's apparent pace of drop and continuous movement within the visible field of view, the participant's task is to react precisely when they think the target object has touched the ground after entering behind the wall (Figure 6). Research using the PEBL battery indicates that in both conventional and esports, proficiency and category type are directly correlated with temporal prediction skills. Elite basketball players demonstrate superior timing accuracy on the PEBL Timewall task in comparison to their amateur and sedentary counterparts (Mancı, 2021; Mancı et al., 2023); similarly, in the realm of esports, types of games (FPS and MOBA) significantly influence the temporal and attention-related performance metrics of athletes on the PEBL battery (Mancı et al., 2024).

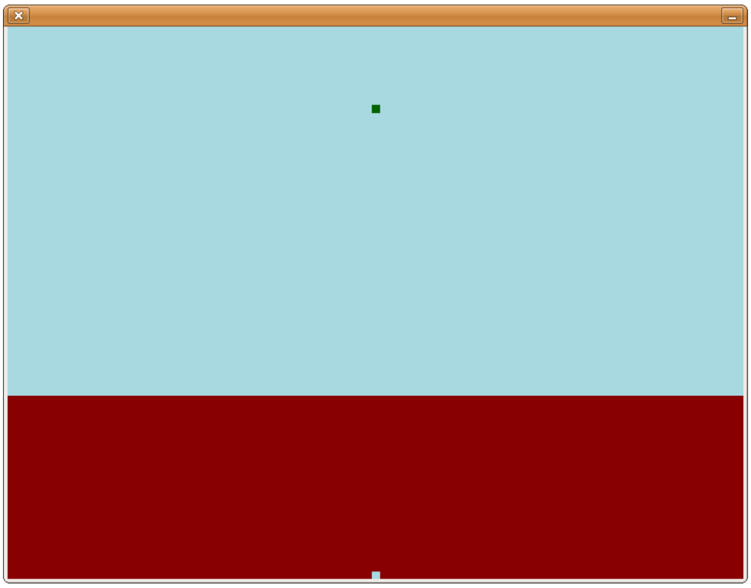

Figure 6. Computerized Time Wall Paradigm from the PEBL test battery

DISCUSSION

Previous literature has investigated a range of cognitive assessments in traditional sports and esports; however, the purpose of this review is to synthesize these findings to provide systematic and evidence-based insights for sports coaches and athletes on optimizing sport-specific cognitive performance through computer-based cognitive testing. The included studies used different samples from different traditional sports disciplines and different video game genres varying in study design, intervention variables and main outcomes. Overall, the results of this review suggest that both high-level athletic engagement and intensive video game experience provide significant benefits to overall cognitive performance compared to non-athletes or casual control groups.

A major inconsistency in the literature reviewed concerns the relationship between laboratory measured reaction times and real world high level competitive success. Several studies have shown that athletes and e-athletes have faster processing speeds and reaction times compared to sedentary controls (Horoszkiewicz et al., 2022; Ölçek et al., 2026). However, this is not necessarily an advantage sport specifically, when comparing highly trained individuals. For example, Martínez de Quel et al. (2015) found no significant relationship between CRT (Choice Reaction Time) speed and the competition success of elite karate athletes, reporting similar results for medalists and non-medalists in non-contextual laboratory tests. Bickmann et al. (2021) detected no differences in pure motor reaction times between traditional sportsmen, professional esports players, and non-professionals.

This apparent difference is explained by the expert performance approach rather than the cognitive component skills approach. In traditional lab testing, it is on “pure” or domain-general reaction time, without a context environment. But in sports it’s about anticipatory mechanisms, about the ability to read situational cues, not raw physical reflexes. For example, high-level karate performance includes anticipating an opponent’s movement based on subtle body adjustments before the strike is fully executed. The assessment does not capture the true cognitive advantage of elite performers in the absence of these high-fidelity sporting requirements.

To bridge this gap and add practical value to coaches, cognitive testing needs to move from abstract tasks to domain-specific environments. Musculus et al. (2022) have demonstrated the successful adaptation of the classical Go/No-Go and task-switching paradigms to soccer-specific visual scenarios. Embedding cognitive demands within familiar sport-specific contexts will offer coaches a more ecologically valid measure of an athlete's functional processing speed. The results suggest that cognitive development in sport should focus on contextual information processing rather than isolated lab performance.

Practical Implications

When we talk about sports, the first terms that come to mind are physical capacity, such as strength, speed, or endurance. However, before physical capacity is sufficient, everything begins with the cognitive processing of the stimulus. Especially with the increasing integration of technology into our lives, esports rely on how quickly information is processed, what decisions are made under pressure, and how well one adapts to changing game dynamics. It is precisely at this point that coaches working with sportsmen can positively impact player performance by selecting assessment tools that target sport-specific cognitive processing and integrating these test results into practical field training.

Each sport (basketball, handball, or esports, etc.) can cause different cognitive processes (attention, suppression, flexibility, or memory) to be used more intensely. This is precisely where coaches' ability to identify appropriate cognitive profiles and match the right test to the right sport can be critically important. For example, in fields like esports, which require high-level cognitive processes such as generating motor responses at the millisecond level, recognizing an opponent's trap moves and instantly halting a planned action (motor suppression), and resolving conflicts under a high level of visual stimulation, identifying the right cognitive abilities and selecting and applying the appropriate cognitive tests to work on them can improve a player's performance.

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