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Paykan: Virtual reality gaming as a therapeutic tool for target panic disorder

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ABSTRACT

The detrimental effects of stress and anxiety on mental and physical health are well-documented. In the context of professional athletics, high levels of pressure and anxiety can lead to a decline in performance and a regression in well-honed skills, a phenomenon known as performance blocks. While traditional methods have been employed to mitigate these blocks, recent studies have demonstrated the efficacy of digital approaches, especially virtual reality and serious games, in addressing mental and physical disorders. The application of digital treatments to target panic, a specific type of performance block which is a prevalent issue among professional archers, remains understudied. Furthermore, the relationship between personality traits and treatment efficacy remains unclear. This study reports on the findings of a formal user study involving 30 archers over a four-week period. A comprehensive system was designed and developed, integrating a virtual reality game as the software component alongside the necessary hardware, serving as the medium for treatment. Additionally, a tailored questionnaire addressing target panic was formulated to facilitate data collection. The results reveal a statistically significant difference between the proposed method and traditional approaches, as well as a strong positive correlation between achievements in the digital environment and real-world performance. The findings suggest that digital treatment can be a viable tool for archers experiencing target panic disorder, and that certain personality traits, such as conscientiousness, are closely tied to treatment effectiveness.

1. Introduction

Throughout life, individuals encounter various stressors that can trigger negative mental and physical reactions, leading to sensations of disappointment or anxiety. It is of paramount importance to develop and implement effective techniques for managing stress and anxiety to maintain overall health. Research has shown that stress impacts professional athletes in different aspects as well, potentially causing a decrease in concentration [1], heightened proneness to sickness and injuries [2–5], decline in sports performance [6]and even the possibility of ceasing participation in sports altogether [7].

Elite athletes typically execute well-rehearsed abilities with ease and minimal deliberate thought [8]. However, they are subject to intense pressures that can jeopardize their personal and professional welfare [9]. Such pressures may lead to anxiety and create obstacles in performance commonly referred to as performance blocks [1], which are recognized across various sports such as golf [8,10], trapshooting [11] and hurdling [12]. These blocks manifest psychologically, impeding one's execution of certain motor sequences that often results in involuntary movements like jerks or tremors known as 'the yips' [13,14]; in archery, a similar condition is termed 'target panic'. To overcome and reduce performance blocks, both physical and psychological aspects of the problem must be addressed [15,16]. Traditional and mostly non-digital approaches to ameliorate performance blocks are restricted, time-consuming and require special prerequisites. There is an apparent need for holistic solutions.

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Virtual reality (VR) and serious video games provides repeatability and safety in immersive virtual settings close to actual environments. These unique features have been utilized extensively in interventions for mental and physical disorders [17–19]. For instance, Cnossen et al. [20] examined the influence of serious virtual reality games (SVRGs) interventions on the performance and situational awareness of elite female football players. Their findings indicate a significant and positive correlation between stress-coping strategies and the athletes' overall performance, highlighting the effectiveness of VR interventions in shaping stress mindset. Ongoing technological advancements are enhancing the accessibility of VR tools and devices, enabling researchers to examine the effects of immersive interventions in both clinical and non-clinical scenarios. However, research is still limited regarding how VR treatment techniques affect performance blocks and specially target panic reduction and the extent to which individual characteristics, such as personality traits, modify their effectiveness. Several research endeavors have utilized the Big-Five standard personality questionnaire to examine the connection between personality traits and the success of Immersive treatments. An illustration of this is the findings by Han et al. [21], which revealed several significant and moderate relationships between the personality traits of the participants and the stress-alleviating effects of VR interventions. In the same vein, archers need to utilize a standard questionnaire to evaluate their target panic level. Regrettably, no standard questionnaire was accessible for measuring target panic, necessitating authors to devise a questionnaire tailored for this specific objective.

Despite the established effectiveness of interactive digital interventions for a variety of disorders [17–27], to the best of the authors' knowledge, there has been no use of VR and serious game-based treatments for improving target panic. Considering that this study is one of the first of its kind, it faced several challenges such as identifying suitable venues for experiment administration, setting up the required hardware in the natural environment of archers training, and convincing archers with target panic disorder to participate and stay in the long-term study. Furthermore, in the absence of a pre-existing suitable system for treatment purposes, researchers undertook the task of creating a functional system from the ground up with guidance from both national and international coaches. The architecture of the system consists of an SVRG as the application and the associated hardware required for its functionality. To facilitate this, a touch-sensitive shooting mechanism was designed and deployed, characterized by its minimal latency. This mechanism was specifically devised to replicate the sensation of utilizing an actual recurve bow, ensuring a flawless fusion of tangible and virtual components. As a result, this integration amplifies the overall immersion required for an engaging intervention. By assembling a multidisciplinary team consisting of game developers, HCI and electronics experts, archery researchers, and coaches, this research project tried to address the challenges at hand. The valuable input received from the archery community further contributed to its administration.

The aim of the present study is to examine a novel and affordable intervention designed to assist archers in overcoming target panic while enhancing overall performance through the use of SVRG. Addressing the aforementioned gaps in knowledge, we pose the following research questions:

- How effective is the designed SVRG on the improvement of archers' target panic disorder, compared with the real-world traditional methods?
- To what extent are individual profile factors, such as personality traits, linked to the effectiveness of intervention targeting the improvement of target panic?
- Is there a link between in-game and real-world achievements, indicating a positive correlation?

The study addressed the research questions through a formal user study involving 30 athletes conducted over a four-week period. Data was collected using a designed questionnaire and subsequently analyzed using statistical methods. The results demonstrated a statistically significant difference between traditional methods and the proposed digital treatment, confirming the effectiveness of the SVRG intervention.

Furthermore, the study explored the influence of individual personality traits on treatment efficacy, utilizing the Big Five Personality Traits questionnaire. The findings indicated that certain traits, such as conscientiousness, had a significant relationship with the effectiveness of the treatment. Additionally, the research examined the correlation between in-game achievements and real-world performance, revealing a positive relationship between digital and real-world outcomes. These findings are thoroughly justified and discussed in the study.

2. Background

2.1. The yips

Performance blocks are phenomena well-articulated by Crampton and Adams [28] as the sudden incapacity to perform a skill, potentially derailing an athlete's career trajectory. While nomenclature differs from sport to sport, the attributes of performance blocks remain consistent. They exhibit both physical symptoms like dystonia and psychological symptoms such as anxiety or the feeling of choking during performance. Excessive anxiety regarding competition is not desirable, yet complete calmness may not be the best approach either. Nervousness is a common reaction when a person is involved in a significant event and aims to perform well. Many athletes mention that the absence of pre-competition nervousness could indicate a diminishing importance of the event to them. Nonetheless, high levels of anxiety and a sense of choking can still hinder their finely tuned skills during their professional years [29]. Investigations into these disturbances have focused on the cognitive mechanics at play when performing under duress [30–32]. Eysenck and colleagues [32] postulate that the distraction caused by pressure detracts attention from the task towards irrelevant stimuli—including worries about potential outcomes—which creates a dual-task scenario where task execution and anxiety compete for cognitive resources, consequently impairing performance. Another theory suggests that the heightened self-consciousness brought on by performance pressure intensifies focus on monitoring each step of skill execution which disrupts fluidity [33,34]. Attention directed towards execution can disrupt ingrained, procedural performance and lead to performance impediments [33,34]. There is a consensus among theoretical perspectives that the manner in which athletes handle performance pressure is fundamental to their behavior related to performance. The recent framework by Clarke, Sheffield, and Akehurst [13] lends support to this view by categorizing the 'yips'. Their framework suggests that athletes may encounter performance blocks in various ways, depending on their physical and psychological symptoms and the specific environmental pressures they face.

It is estimated that target panic affects upwards of 40% of archers [35]. However, definitive prevalence rates remain elusive due to the reluctance of many to openly discuss it [36]. Target panic represents a sport-specific manifestation of the yips and has thus far received scant scholarly focus. By perceiving target panic and the yips as phenomena emerging from the transitional spaces of liminality—rather than attributing them solely to distinct aspects of mind, body, or environment—the complexities connecting these entities become apparent [37].

2.2. Individual variations

The phenomenon of performance blocks is a subjective experience that varies from person to person, as delineated in the research of Roberts et al. [38], Byrne et al. [39], and Laborde et al. [40]. These individual variations have been examined through assessments that are either typological or trait-oriented in nature. Such evaluations have been instrumental in forming the foundation of the Big-Five personality framework, which delineates the principal dimensions along which personal variances occur [41]. Recent scholarly reviews on performance blocks, including those by Hill et al. [42]and Clarke et al. [13], underscore the imperative of further investigation into the role of personality traits as predictive indicators. This research is critical to identify individuals who may be more prone to performance blocks like target panic. Furthermore, there exists an opportunity to investigate the relationship between the efficacy of interventions for target panic and personality traits, utilizing the Big-Five personality model as a theoretical lens.

2.3. Current solutions

Professional archers' recollections concerning target panic reveal a significant diminishment in their enjoyment of archery. Attempts to mitigate these symptoms through equipment modification often led archers to adopt less desirable shooting techniques. Such circumstances have compelled many archers to abandon the sport entirely, resulting in losses that extend beyond a simple pastime. For athletes, this means forfeiting an outlet for emotional expression, a community for social engagement, and an integral part of their identity [35]. These impactful changes underscore the importance of innovative methods for rekindling a positive association with the sport of archery. Traditional approaches to help athletes overcome target panic—including physical approaches: aiming drills, adhering to a consistent shot routine and practicing near the target, psychological approaches: goal setting, imagery, self-talk, and relaxation [36], or a combinations of physical and psychological techniques: such as SPT-Drill method and imagery [37,43]—are recognized but can pose challenges due to their demanding nature, time commitment, and prerequisites such as access to specialized facilities. It is imperative that all athletes, including archers, are granted equal rights on the field and during practice sessions [44]. However, the techniques mentioned above can be particularly challenging for disabled archers. This highlights the necessity for more inclusive, cost-effective, and easily accessible solutions.

2.4. SVRG

When compared to traditional treatments, digital interventions, particularly those utilizing VR, offer a range of advantages in terms of cost, safety, and accessibility. The implementation of digital technologies eliminates the need for costly physical resources, making these treatments more affordable and economically viable [45]. Furthermore, the controlled and simulated environments provided by VR ensure a safer experience for individuals, reducing the likelihood of adverse events. Additionally, the accessibility of digital treatments allows individuals to overcome geographical and logistical barriers [46], enabling them to receive therapeutic interventions regardless of their physical location. Recent studies have shown that virtual reality exposure therapy (VRET) and serious video games could potentially provide advantages alongside traditional treatments in common mental health disorder such as depression [47,48], phobias [22,26], attention deficit hyperactivity disorder (ADHD) [23,25], post-traumatic stress disorder (PTSD) [24,27], stress and anxiety [49–51]for athletes and normal people.

SVRG can be implemented in either 3DoF or 6DoF. It is quite common to use a 6DoF Head Mounted Display (HMD) device for sports education and training [52–55]. However, depending on the specific requirements of different sports, HMDs can be combined with other tracking techniques. For instance, Ferrer et al. [56] developed a VR system to assess and enhance the read-the-game ability of soccer players. Their research revealed that a high level of immersion and presence can be achieved by incorporating full body interactions, which involve the integration of head and body movements through the use of an HMD and kinetic body tracking. Proper integration of VR technologies in sports education, training, treatment, and rehabilitation offers numerous advantages to athletes, enabling them to enjoy their physical activities while harnessing the power of technology. Moreover, individuals with disabilities can now engage in sports training without the constraints imposed by traditional solutions [57]. Some research studies have attempted to replicate archery sport through SVRG for training [58,59], yet none have specifically tackled target panic disorder or other performance blocks. This is why the present study places particular emphasis on examining the impact of a digital intervention in enhancing target panic by leveraging immersive technologies.

3. Methods and materials

3.1. Participants

The statistical population encompassed all archers in *** (removed for anonymity) city specializing in recurve archery, the most popular branch of archery and the sole discipline featured in the Olympics. Inclusion criteria involved the presence of target panic, which was measured using a researcher-made questionnaire, absence of visual impairment, and no impairments in the use of VR. Following initial oral interviews with athletes and coaches from archery clubs, 42 archers displaying symptoms of target panic were identified. A target panic questionnaire was then administered to confirm the presence of target panic according to a standard definition, revealing that 30 out of 42 individuals exhibited target panic. Subsequently, participants were randomly allocated into two evenly sized groups. To ensure participant retention throughout the long-term study, those who completed the experiment were incentivized with a six-month club membership fee. Nonetheless, 8 individuals (5 from the experimental group and 3 from the control group) withdrew from the experiment. To maintain comparable sample sizes in both groups, data from 2 individuals in the control group were excluded at end of the sessions. The experimental sessions have concluded, and the findings are presented for a total of 20 participants, comprising 11 males and 9 females. The mean age of the participants is 19, with an age range spanning from 14 to 32 years.

3.2. Target panic questionnaire

In addition to conducting oral interviews, this study required a standardized method to identify individuals experiencing target panic in a scientific manner. Furthermore, a tool was needed to measure the extent of target panic, which is a subjective phenomenon. To address these needs, the researchers carried out a pilot study in collaboration with archery coaches from both national and international backgrounds. The aim was to determine the most significant symptoms exhibited by athletes with target panic. Once a draft questionnaire was prepared, it was shared with the coaches for further refinement. Eventually, a 5-point Likert scale questionnaire consisting of 13 questions was finalized and its validity was confirmed by both the coaches and professionals involved. Subsequently, the reliability of the custom-made questionnaire was assessed. Based on the results of Cronbach's alpha [60] ($N = 30$, $\alpha = 0.761$), the questionnaire items were found to exhibit good internal consistency. According to the coaches, agreeing to questions two, six, eight, nine and eleven was the criteria for entering the study. The questionnaire can be found in the Appendix.

3.3. The design of "Paykan"

In this research a custom-made system called "Paykan" was used as the intervention tool. Paykan is consisted of two parts:

3.3.1. Software prototype

A 3D first person shooter archery video game with two levels (Fig. 2); the design of the levels, target placement and overall flow of the game were done under the supervision of the archery coaches while considering the necessary elements of an entertaining game. The game was built using unity3D 2022.1.24f1 and had interaction with the hardware part via Bluetooth. In the first level of the game, players find themselves in a fortress facing a sturdy door that prevents them from moving forward. To unlock the door and progress to the next level, players need to solve a set of puzzles. Within this level, players will notice yellow circular targets positioned on the walls to their left and right. The main task is to aim and shoot at these targets. Hitting the targets accurately will cause them to shrink and follow specific paths. The ultimate objective is to match the targets in a certain pattern, which then unlocks the door. Moreover, the first level of the game is equipped with wooden targets and figures that have been specifically designed to enhance the aiming skills of players. As players progress to the second level, they will encounter an assortment of sizable wooden crates and barrels positioned at varying distances between 5–10 m, mirroring the conventional practice range for combating target panic.

Each destruction of these targets triggers the emergence of smaller replicas in the same location. Additionally, there are two mobile targets that offer a dynamic challenge, replicating real-life training scenarios. Through the incorporation of these elements, the game not only provides entertainment but also serves as a training ground for archers aiming to refine their technique and overcome the prevalent issue of target panic.

3.3.2. Hardware prototype

Considering the project advisors' strong focus on upholding the authenticity of the shooting technique, it is essential that any extra components added to the bow, which are not inherent to the natural shooting process, be designed to be lightweight and intangible. Consequently, researchers opted to develop an interface utilizing a real recurve bow and arrow. Various methods, such as employing an IMU to track arrow movement or utilizing a laser detector to monitor arrow release, were explored. However, these techniques proved to be error-prone and lacked the necessary stability for shooting [61]. It is imperative that the shooting system replicates the genuine shooting experience, ensuring that the digital arrow release and physical feedback from the bow are synchronized. This synchronization is crucial to maintain the user experience and prevent users from experiencing excessive vibration, noise, or unwanted arrow release [62]. After considering all the errors and requirements, a touch-sensitive shooting system [63] was ultimately developed. This system utilizes a straightforward yet efficient mechanism, wherein a thin aluminum foil is positioned on the string precisely where the fingers are placed. This aluminum foil acts as one plate of a capacitor, while the fingers serve as the other plate. In this method, the dielectric constant changes upon touching the sensor, which in turn alters the capacitor's charging time. This variation in charging time is detected and measured using the following procedure.

An Arduino microcontroller (such as the Arduino UNO R3) is utilized in this approach. The mechanism operates as follows:

- Two Arduino pins are defined, one as an input and the other as an output.
- A high-value resistor (ranging from 1 to 10 megaohms) is placed between these pins to regulate the sensor's sensitivity.
- An aluminum foil is connected to the input pin, serving as one of the capacitor's plates.
- The output pin generates a voltage signal (HIGH or 1), causing the capacitor to charge.
- The microcontroller determines the capacitor's charging time by measuring the number of clock cycles (16 MHz for Arduino UNO, with each cycle equating to 0.0625 microseconds). To enhance accuracy, the algorithm records the charging and discharging times across 40 samples, calculates the average, and then transmits the output. The sample size is selected through testing various values to achieve an optimal balance between precision and speed.
- When the user's fingers touch the sensor, the dielectric constant changes, resulting in an increased capacitor charging time.
- Once the input pin voltage exceeds a predefined threshold (approximately 2.5 V), the input pin state switches to HIGH (1), indicating touch detection.
- After detecting the touch, the output pin is set to LOW, discharging the capacitor and repeating the process cyclically.

The charge/discharge cycle is executed across 40 samples, with each sample taking approximately 10 to 100 microseconds, depending on capacitance. Assuming an average duration of 50 microseconds per sample, sensor data is received every 2 ms. The received data is averaged every 15 ms before processing (0 for no touch and 1 for touch) and transmitted wirelessly via Bluetooth to the system (software part) to accurately determine the release timing of the digital arrow.

To facilitate data transmission, the HC-05 Bluetooth module is used, operating with a serial communication protocol (UART) at a baud rate of 9600 bits per second. The final data transmission speed per sample remains below 2 ms. Furthermore, a 15-millisecond delay is implemented for data averaging, reducing environmental noise. This delay remains imperceptible to humans, as it is under 20 ms. The use of wireless communication ensures that data is transmitted in real-time without the requirement for physical connections, thus enhancing the overall flexibility and user-friendliness of the system (Fig. 3).

3.4. Study design

The duration of this study spanned 4 weeks, during which 2 sessions were conducted per week. Throughout this period, the control group exclusively underwent training using traditional methods (see section 2.3) aimed at enhancing target panic. In contrast, the experimental group received training that incorporated the designed SVRG in addition to the conventional techniques. Data collection involved the utilization of a custom-made questionnaire, real-world shooting scores, in-game data, and the Big Five personality test [64]. With the exception of the initial session, which had a fixed play time of 20 min, individuals in the experimental group were granted the freedom to play the game for as long as desired and engage in target shooting according to the game's procedures and levels. To prevent any potential interference, both groups trained at separate clubs equipped with comparable amenities and facilities.

3.5. Hypotheses

The primary objective of our research is to examine the impact of utilizing SVRG on enhancing target panic, in comparison to conventional approaches. Previous research has indicated that employing serious games and virtual reality interventions can be just as beneficial as real-world methods in addressing certain mental and psychological conditions. Nevertheless, the influence of digital interventions on performance blocks in sports, particularly in relation to target panic and archery, remains largely unexplored. Regarding our research questions in the introduction section, we put forth the following hypotheses:

H1. The developed SVRG has a positive effect on improving archers' target panic disorder and proves to be more effective than traditional methods.

H2. Personality traits including conscientiousness, neuroticism, agreeableness, openness and extroversion are associated with the efficacy of the SVRG intervention for improving target panic.

H3. A positive correlation exists between scores attained in the game and those achieved in real-world settings.

3.6. Devices and study space

In this study, an HTC Vive was employed as the VR head mounted display (HMD), accompanied by two Vive controllers. The HMD is equipped with a Dual AMOLED 3.6′′ diagonal display, which offers a resolution of 1080 x 1200 pixels per eye (2160 x 1200 pixels combined) at a refresh rate of 90 Hz. Additionally, it provides a field of view spanning 110 degrees. To facilitate tracking, an outside-in tracking system was utilized, consisting of a pair of Vive base stations v1. The designated play area was set up as a 3.5 m x 3.5 m room-scale configuration. For enhanced portability, the base stations were affixed to tripods with adjustable heights (Fig. 1). Considering the need for flexibility and mobility, the virtual experience was executed on a VR ready laptop powered by Microsoft Windows. The laptop was equipped with a Core i7 12650H CPU, 16 GB of DDR5 RAM, and a NVidia GeForce 3070 RTX graphic card with 8 GB VRAM.

3.7. Procedure

At the commencement of the study, each participant was provided with a concise overview of the study procedure (Fig. 4) and protocols. If they had a clear understanding of the information presented, they were requested to read and sign a consent form. Subsequently, they were instructed to complete the pre-test questionnaire, which focused on target panic, and their real-world shooting score was recorded. Following this, they engaged in a 20-minute session of playing the game, during which their in-game score and other relevant data were documented. For the rest of the sessions, participants were given the freedom to play the game without any limitation, and their in-game data continued to be recorded. Upon completion of eight game sessions, equivalent to a month's duration, the participants were asked to fill out the same questionnaire they had completed prior to the start of the experiment (aka., the post-test), and their real-world shooting score was once again measured. Additionally, a separate questionnaire consisting of 50 Likert-type questions pertaining to personality traits was administered. However, due to the time-consuming nature of this process and in order to prevent participant fatigue and potential negative effects on their responses, the completion of the final questionnaire was postponed until the following week. Participants who successfully and thoroughly completed the study were rewarded with a six-month club membership fee.

3.8. Measures

The present study employed various methods for data collection. Firstly, a custom-made target panic questionnaire was utilized, consisting of 13 questions on a 5-point Likert scale. The scale ranged from 1, indicating complete disagreement, to 5, indicating complete agreement. All the questions in the questionnaire were designed to assess the presence and severity of target panic symptoms in individuals and had the same direction (The higher the score, the higher level of target panic the individual has). This questionnaire was used in both the pre-test and the post-test.

To explore the potential relationship between in-game and real-world progress, the participants engaged in 8 sessions of playing Paykan. Throughout these sessions, different data points were recorded, including play time, total arrows fired, missed shots, and successful shots.

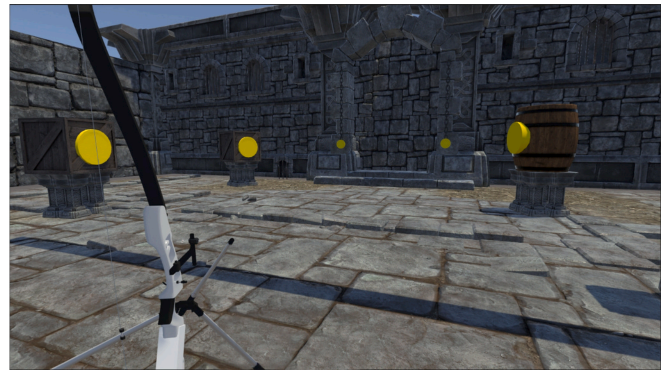

Fig. 2. Screenshot of the game environment. The player must aim and shoot at fixed and moving targets and earn the necessary points to go to the next stage and complete the objective.

Real-world scores were measured both before and after the intervention sessions using a regular recurve bow and arrow, without any additional enhancements. To ensure a natural training environment for the athletes and minimize any disruptions, both the game sessions and the real-world scores capturing took place in archery clubs. This approach aimed to maintain the study situation similar to the athletes' usual training settings.

Participants' personalities were measured using the Big Five personality traits model to see if personality affects how well the intervention works. A 50-question survey was used for the study. Each question is rated from 1 (disagree) to 5 (agree) and has a positive or negative score to figure out the person's personality type. The Big Five model describes personality with five main factors: agreeableness, extraversion, conscientiousness, neuroticism, and openness. Agreeableness is about how kind and cooperative a person is. Extraversion shows how much a person likes to be around others. Conscientiousness means how organized and careful someone is. Neuroticism is about how often someone feels bad emotions. Openness is about how much a person likes to try new things.

4. Results

Various methodologies and statistical tests were utilized to examine the gathered data and respond to the research inquiries. The selection of these analytical techniques was contingent upon the characteristics of the data, relevant literature, and the specific demands of the hypothesis being investigated.

4.1. The level of target panic

The present study required a statistical technique that could effectively compare means from both experimental and control groups while

Fig. 1. Paykan's Outside-In tracking system with Room-Scale play area.

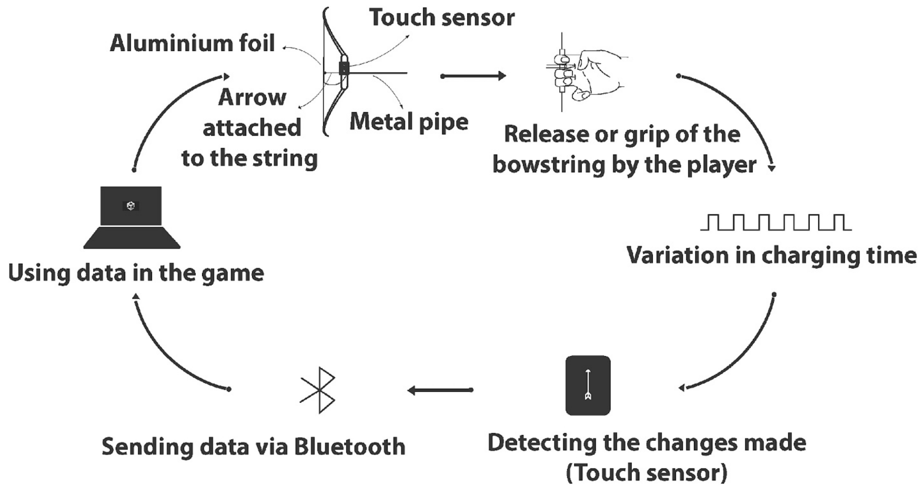

Fig. 3. Touch-sensitive shooting mechanism.

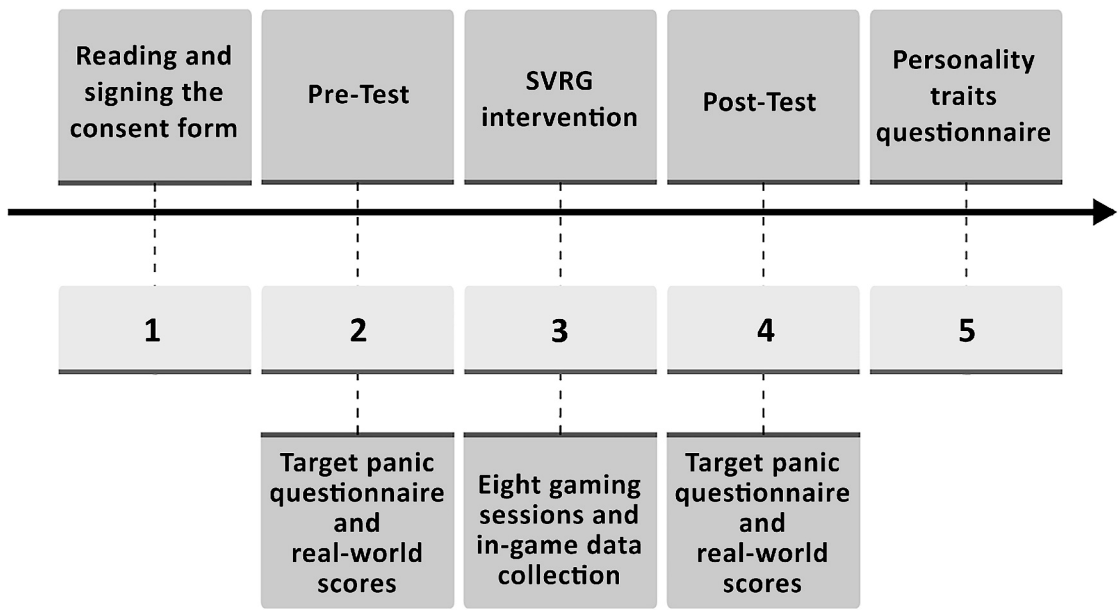

Fig. 4. Study procedure overview. (1) Initially, participants were required to review and sign the consent form. (2) Subsequently, they were directed to complete the pre-test questionnaire, with their real-world shooting scores being documented. (3) Following this, participants underwent 8 intervention sessions, during which their in-game data was collected. (4) Upon completion of the intervention sessions, they were asked to fill out the post-test questionnaire, and their real-world shooting scores were recorded once more. (5) Finally, participants were instructed to complete the Big Five Personality Traits questionnaire.

accounting for pre-existing differences between them. To elucidate the influence of the independent variable (the system) on the amelioration of target panic, pre-test scores were treated as covariates, and Analysis of Covariance (ANCOVA) [65] was employed as the primary method of analysis. Prior to conducting ANCOVA, the fundamental assumptions underpinning the analysis were meticulously verified. In order to determine the normality of the datasets, the Shapiro-Wilk test [66] was applied, as it is particularly suitable for small sample sizes. The results confirmed that the data across all four datasets adhered to a normal distribution (pre-test control: $p = 0.251$; pre-test experimental: $p = 0.597$; post-test control: $p = 0.408$; post-test experimental: $p = 0.440$). Furthermore, the assumption of homogeneity of regression slopes was upheld ($p = 0.382$, F (1, 16) = 0.809), ensuring that the relationship between the covariate and the dependent variable was consistent across groups. Additionally, there was no significant difference between the control and experimental groups' pre-test scores ($p = 0.939$, F (1, 18) = 0.006, $\eta_p^2 = 0.000$), indicating baseline equivalence. By incorporating the pre-test scores as a covariate, the ANCOVA results, depicted in Fig. 5, revealed a statistically significant difference between the control group (M = 38.70, SD = 3.33, N = 10) and the experimental group (M = 35.80, SD = 2.85, N = 10) in the post-test scores ($p = 0.006$, F (1, 17) = 9.651, $\eta_p^2 = 0.362$).

4.2. *The effect of personality traits*

The present study explored the interplay between personality traits, as assessed by the Big Five personality traits questionnaire, and the effectiveness of a novel digital treatment designed to alleviate target panic.

To achieve this, linear regression analyses were employed, utilizing scores from a custom-made target panic questionnaire alongside data derived from the Big Five personality dimensions. A significant positive correlation was identified between the trait of conscientiousness and improvements in target panic ($\nabla = 0.288$, $r = 0.597$).

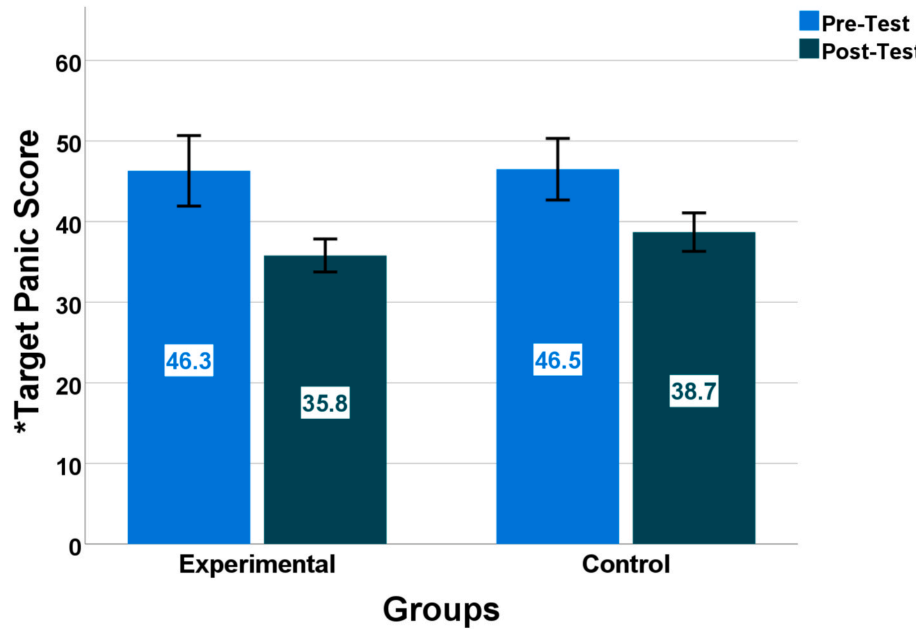

Fig. 5. Findings from target panic pre-test and post-test questionnaires, including the means and error bars representing a 95% confidence interval. By considering the pre-test as the covariate, it was found that there existed a significant difference between the control and experimental groups in the post-test. *The higher the target panic score, the higher the symptoms of the disorder.

This finding suggests that individuals who score higher on conscientiousness are more likely to experience notable improvements in their target panic symptoms following the digital treatment. Additionally, the trait of neuroticism also showed a moderate positive association with target panic improvement ($\nabla = 0.202$, $r = 0.427$). This indicates that individuals with higher levels of neuroticism may still benefit moderately from the digital intervention. In contrast, the traits of agreeableness and openness displayed weaker associations with target panic improvement ($\nabla = 0.093$, $r = 0.201$ and $\nabla = 0.155$, $r = 0.279$, respectively). These results suggest that while there is some positive relationship, it is not as pronounced as with conscientiousness and neuroticism. Interestingly, the analysis revealed no substantial relationship between extroversion and target panic amelioration ($\nabla = 0.002$, $r = 0.006$). Each personality trait was subjected to individual linear regression analysis, with the resulting estimated slope coefficients (∇) and Pearson correlation coefficients (r) illustrated in Fig. 6.

4.3. The connection between the game and the real world scores

To examine the potential connection between scores obtained in the SVRG and those obtained in real-world scenario, linear regression and Pearson correlation analyses were conducted. Real-world progress was determined by subtracting the pre-test real-world scores from the post-test real-world scores. Similarly, in-game progress was measured by subtracting the scores recorded in the first session of treatment from the scores obtained in the last session. The outcomes, as seen in Fig. 7, demonstrated a strong positive correlation between in-game scores and real-world scores ($\nabla = 1.864$, $r = 0.717$).

5. Discussion

The findings from the user study indicate that the implemented SVRG has had an impact on the individuals involved. The results from the extended treatment period demonstrated a favorable influence on managing and enhancing the symptoms associated with target panic disorder. This section will delve into the justification of the results and the characteristics of the findings, as well as explore the potential benefits of utilizing digital tools such as Paykan in mental and physical interventions.

5.1. Paykan, as an SVRG, is effective in ameliorating target panic symptoms

Based on a comprehensive review of existing literature and empirical studies, a hypothesis (H1) was formulated to assess the effectiveness of a novel digital intervention in mitigating target panic disorder. To rigorously test this hypothesis, an extensive user study was conducted, employing a robust inferential statistical method. The results from this

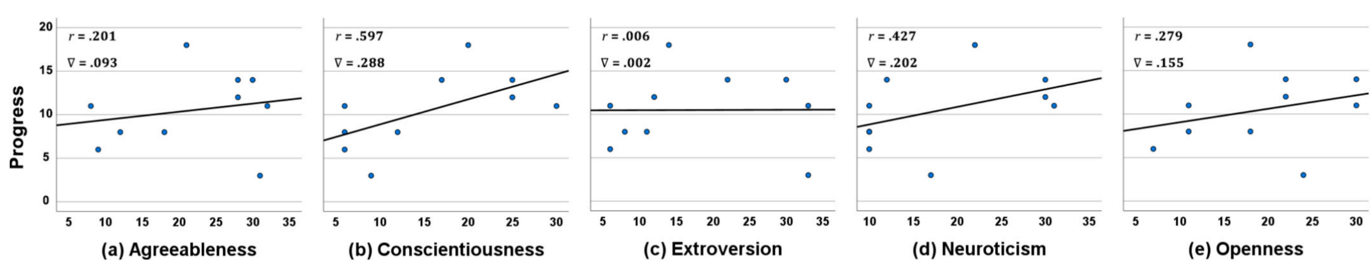

Fig. 6. The results of the linear regression analysis for each personality trait are displayed, along with the corresponding slopes (∇) and correlation strengths (r). The correlation strengths are classified into four categories: Strong ($r \geq 0.6$), Moderate ($0.4 \leq r < 0.6$), Weak ($0.2 \leq r < 0.4$), and Very weak ($r < 0.2$). The progress is measured by the difference between the pre-test and post-test results, indicating the level of improvement in target panic disorder. The findings indicate a relationship between the personality profile and the efficacy of the treatment.

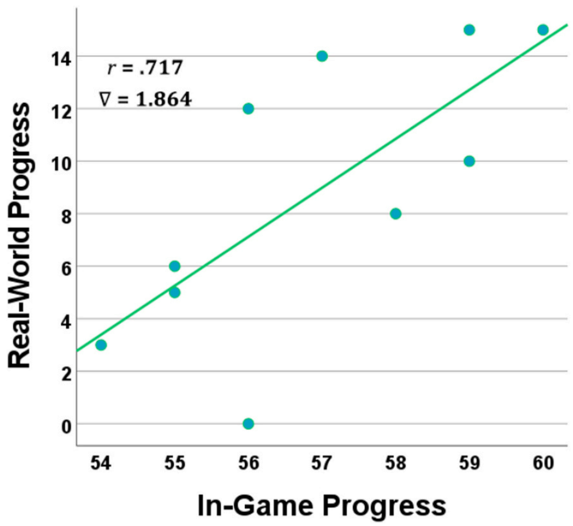

Fig. 7. The outcomes of linear regression and Pearson correlation analyses demonstrated a strong positive correlation between in-game and real-world scores.

study revealed a statistically significant difference between the control and experimental groups over the course of eight treatment sessions. Specifically, the analysis of covariance yielded a substantial effect size ($\eta_p^2 = 0.362$), which underscores the efficacy of the digital treatment in alleviating symptoms of target panic. Consequently, the null hypothesis was rejected, thereby supporting the alternative hypothesis (H1) and indicating a significant positive impact of the digital treatment on reducing target panic. These findings not only affirm the effectiveness of the intervention but also highlight the promising potential of digital treatments in addressing performance blocks such as target panic.

Further insights were gathered through post-study interviews with participants, which provided a deeper understanding and justification of the results. Notably, except for one participant in the experimental group, all reported that the immersion and sense of presence experienced during the VR training sessions significantly enhanced their engagement with the digital environment. This experience aligns with previous studies [20,49] which emphasize the importance of immersion in treatments for mental disorders in context of sport. Immersion and the sense of presence emerged as critical factors, with participants indicating that the gamified process of training redirected their focus from the technical aspects of shooting to the enjoyment of the activity itself. This phenomenon is consistent with findings from earlier research [32–34,36], which suggest that avoiding dual-task scenarios—where task execution and anxiety compete for cognitive resources—is crucial in helping athletes manage nervousness and anxiety effectively. Beyond its applications in the sports community as a versatile training tool, the digital intervention offers significant benefits for disabled individuals. One participant, a para-archery athlete, highlighted the practical advantages of the intervention, noting that it eliminated the need for additional effort typically required in traditional training settings. This allowed the athlete to conserve energy for the shooting process itself, rather than expending it on ancillary tasks. This observation is corroborated by Sunyoung and Seungae's study [57], which advocates for the equitable benefits of immersive digital training for both able-bodied and disabled athletes.

The study's findings provide robust evidence supporting the efficacy of digital interventions in reducing target panic disorder. The immersive nature of the digital environment not only enhances engagement but also facilitates a focus on the intrinsic enjoyment of the activity, thereby mitigating anxiety and performance pressure. Furthermore, the inclusive nature of the intervention ensures that disabled athletes can benefit from the training without additional burdens, promoting equitable access to effective treatments across diverse athlete populations.

Although immersive solutions like Paykan provide substantial benefits to users, observations and participant interviews revealed minor challenges linked to the inherent limitations of virtual reality VR technology and its hardware. Specifically, these challenges include motion sickness and the weight of VR headsets.

Among the 30 participants who completed the study, three reported experiencing nausea after several minutes of VR headset use, particularly during high-motion or fast-paced activities. In some cases, this discomfort necessitated temporary removal of the headset. Additionally, four participants with susceptibility to muscle fatigue noted that the headset's weight exacerbated their discomfort, requiring intermittent breaks to complete the session. Despite these issues, all participants successfully finished the intervention, and the challenges did not compromise the overall study outcomes.

To mitigate these concerns in future long-term studies, the use of lighter headset designs is recommended. Furthermore, implementing motion sickness reduction strategies—such as higher frame rates [67,68] or MR instead of VR [69,70]—could enhance user comfort and engagement.

5.2. *The influence of individual profile factors on the efficacy of the digital intervention for target panic*

The second hypothesis of this study delves into the intricate relationship between individual profile factors and the efficacy of the designed SVRG as a therapeutic intervention for target panic. In order to examine this hypothesis, a combination of linear regression analysis and Pearson correlation coefficients was employed. The findings exhibited a robust positive correlation between the trait of conscientiousness and the level of progress in alleviating target panic symptoms. This suggests that individuals who score higher on conscientiousness—characterized by traits such as responsibility, organization, and diligence—tend to achieve more substantial improvement following the treatment sessions. To further validate this relationship, the results were discussed with a cohort of experienced archery coaches. Almost unanimously, the coaches concurred that diligence is a critical determinant of success, irrespective of the training modality. This consensus underscores the notion that individuals with higher levels of conscientiousness are predisposed to greater improvement due to their inherent diligence and structured approach to training.

Additionally, the trait of neuroticism exhibited a moderate positive association with target panic improvement ($\nabla = 0.202$, $r = 0.427$). This indicates that individuals with elevated neuroticism levels, who are typically more emotionally unstable, could still experience moderate improvements from the digital treatment. This finding is particularly intriguing as it suggests that even those who are more prone to anxiety and emotional fluctuations can achieve meaningful progress through SVRG.

Conversely, the traits of agreeableness and openness demonstrated weaker associations with target panic improvement. The analysis indicated that these personality dimensions, characterized by tendencies towards cooperation and creativity respectively, do not significantly influence the efficacy of the digital treatment for target panic. Furthermore, extroversion, defined by sociability and assertiveness, showed no significant relationship with the level of improvement. This implies that extroverted individuals do not experience differential outcomes from the digital intervention compared to their introverted counterparts.

Collectively, these findings underscore the importance of considering individual personality traits when evaluating the efficacy of digital interventions, particularly those aimed at mitigating performance blocks as outlined in previous research [38–40]. The significant role of conscientiousness highlights the potential for tailored therapeutic approaches that leverage specific personality characteristics to enhance treatment outcomes. By integrating personality assessments into the design and implementation of such interventions, practitioners can develop more personalized and effective treatment plans. This personalized approach not only enhances the therapeutic efficacy but also ensures that interventions are more responsive to the unique psychological profiles of each individual.

5.3. The real world and the digital experience influence each other

The investigation into the effectiveness of the designed SVRG on target panic improvement (H1) employed rigorous statistical methodologies. To further explore the quality of the connection between the real and virtual environments, a third hypothesis (H3) was established. H3 concerns the extent to which achievements in the digital experience reflect accomplishments in real-world scenarios. Linear regression and Pearson correlation analyses were utilized to examine this relationship, and the findings revealed a robust and statistically significant correlation. These results suggest that progress in digital domains is meaningfully associated with tangible achievements in real-world settings. This strong association implies that skills and achievements in digital game environments can potentially translate into real-world competencies, supporting the use of virtual scenarios in psychophysiological interventions and highlighting the positive influence of digital training on real-world improvements.

Although similar findings have been corroborated by other research [45,47–51], the results from post-study interviews further solidify these conclusions. Many participants reported that the interactive and engaging mechanism of shooting in the virtual environment, Paykan, allowed them to shoot as many arrows as they desired without worrying about the process of retrieving arrows or the number of available arrows. This anecdotal evidence is supported by data recorded during the training sessions (Fig. 8). On average, archers shot 107.47 arrows during each session of playing Paykan, a figure that is notably higher than the average number of arrows shot in a comparable timeframe in real-life conditions. This increased practice volume in the virtual environment may contribute to the observed improvements in real-world performance.

5.4. Limitations and future works

The findings of this study were systematically presented and substantiated. However, as with any research, certain limitations and challenges were encountered, which could be addressed in future investigations.

Within this research project, a serious virtual reality game (SVRG) was meticulously designed and developed as the primary intervention tool. The game's scenario, mechanics, and dynamics were crafted under the guidance of experienced coaches, resulting in a prototype. This tool demonstrated potential as an effective medium for treating target panic.

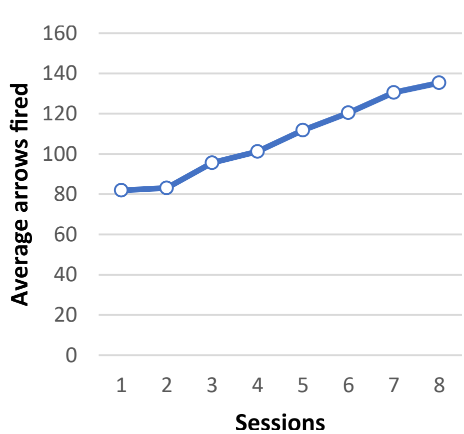

Fig. 8. The number of fired arrows increased over time, indicating an improvement in the shooting process.

However, the development of a fully functional SVRG requires a dedicated team comprising artists, programmers, engineers, and sports professionals. Enhanced game procedures and improved graphic quality are anticipated to yield greater therapeutic outcomes.

To evaluate the hypotheses, 30 archers exhibiting symptoms of target panic participated in the study. Despite offering incentives, the longitudinal nature of the research led to participant attrition. Future studies are advised to collaborate closely with sports organizations to better manage and retain participants throughout the experimental process.

In this study, a custom questionnaire was developed to assess individuals' levels of target panic, a subjective phenomenon that cannot be quantified explicitly. The necessity for a subjective measurement tool was acknowledged; however, the reliability of the data could be enhanced by incorporating physiological measures such as heart rate monitoring and Galvanic Skin Response (GSR). Additionally, these data could facilitate the integration of a responsive feedback loop within the game scenario, allowing for the customization of the experience to accommodate each individual's unique circumstances. Moreover, to gain a deeper understanding of the impact of personality traits on treatment efficacy, a standardized personality questionnaire was employed. Future research could enhance intervention effectiveness by tailoring the game settings according to personality profiles, thereby creating a more personalized treatment approach.

While the main objective of this research was not to evaluate user experience in virtual reality therapeutic tools, both observations and verbal interviews highlighted certain challenges and limitations regarding user experience that should be taken into account in comparable studies:

- Large Dimensions of Virtual Reality Headsets

One of the primary challenges in using VR headsets in archery, particularly in the recurve style, is the relatively large size of these devices. In the standard archery stance, the archer must fully draw the bowstring and anchor their hand firmly beneath the chin, a position known as the anchor. A bulky headset may hinder proper execution of this movement, negatively impacting accuracy, balance, and shooting stability.

- Excessive Weight of Headsets and Muscle Fatigue

VR headsets are often relatively heavy, which can lead to muscle fatigue and discomfort in the neck and surrounding areas during prolonged use. This issue is particularly significant for archers, who must maintain a stationary or standing position for extended periods. Therefore, it is recommended that users take short breaks at regular intervals, for example, every 20 min, to remove the headset and rest.

- Dizziness and Headaches in Some Users

Prolonged use of VR headsets may cause symptoms such as dizziness, headaches, or nausea in some individuals, particularly those with no prior experience with this technology. These reactions are typically due to a sensory mismatch between visual inputs and the body's vestibular system (referred to as "sensory conflict"), which can adversely affect the user experience.

6. Conclusion

This study explored the efficacy of a serious virtual reality game as a therapeutic intervention for target panic, a specific form of sport performance block. A formal investigation was performed with the participation of 30 archers, during which data was collected over a span of four weeks. Various statistical methods were applied to analyze the data. In order to study the alleviation of target panic in archers, responses gathered from a custom-designed questionnaire were analyzed through ANCOVA. The findings demonstrated a statistically significant difference between traditional methods and the proposed digital treatment, thereby affirming the effectiveness of the virtual reality intervention.

In addition, the study evaluated the association between distinct personality traits and the effectiveness of therapeutic interventions. The results from linear regression analysis indicated that certain traits, especially conscientiousness, significantly affect treatment success. The study further investigated the relationship between achievements within the game and performance in the real world, employing the same statistical approach, demonstrating a positive correlation between virtual and actual achievements.

Overall, these findings suggest that serious virtual reality games can serve as a viable treatment option for target panic, with implications for personalized treatment strategies based on individual personality traits. The positive correlation between virtual and real-world achievements further underscores the potential of digital interventions in enhancing athletic performance.

Moreover, the study opens avenues for future research into the long-term retention of therapeutic benefits and the scalability of virtual reality interventions across different sports and performance-related anxieties. Given that target panic shares psychological similarities with other performance block, such as the "yips" in golf or "choking" in competitive sport, the findings may extend beyond archery, suggesting broader applications in sports psychology. As XR technology continues to evolve, its role in mental training and performance optimization could revolutionize how athletes and practitioners address psychological barriers in sports.

CRediT authorship contribution statement

Hesam Sakian Mohamadi: Writing – review & editing, Validation, Project administration, Conceptualization, Visualization, Software, Methodology, Data curation, Writing – original draft, Supervision, Formal analysis. **Faraz Bakhshi:** Software, Visualization, Data curation, Project administration. **Yoones A. Sekhavat:** Validation, Writing – review & editing, Conceptualization. **Mallesham Dasari:** Conceptualization, Writing – review & editing, Validation. **Kazem Gobadi Ansaroudi:** Project administration, Resources. **Mahdi Ahmadzadeh Haji Alilou:** Software, Visualization, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

None

Appendix

Target Panic Questionnaire

ID:

This questionnaire is designed to measure the level of Target panic in archers. All questions have been designed under the supervision of archery experts and international archery coaches.

Please choose the option that best matches your experience:

No.	Question	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	I am always worry and feel a lot of stress about the conditions of the competition.					
2	I am not able to keep the site pin in line with the target when aiming.					
3	I get extra vibration when aiming.					
4	I am pessimistic about the conditions of the competition.					
5	I'm always looking for a reason for my failures.					
6	I doubt when aiming.					
7	I am not interested in participating in competitions.					
8	In stressful situations, I cannot maintain my control over aiming and shooting.					
9	I feel that I have a long delay when deciding to shoot.					
10	I feel that the delay in the moment of releasing the arrow has a negative effect on the shooting.					
11	I usually worry about my lack of success when shooting.					
12	The joy of shooting has decreased in me.					
13	Despite continuous training, I don't feel improvement in control and stability in shooting.					

Data availability

Data will be made available on request.

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