Timing Game: Development of a Game for Temporal Perception Research

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Abstract. Introduction: *Temporal perception tasks are traditionally repetitive and time-consuming, often reducing participant engagement and affecting data quality in cognitive research. Serious Games offer a promising alternative to increase engagement while preserving scientific rigor.* ***Objective:*** *This paper presents the development of the* Timing Game*, a Serious Game that adapts temporal perception research into mobile-friendly and engaging minigame formats.* ***Methodology or Steps:*** *The development process involved iterative game design, expert consultation in cognitive science, and user feedback. Two gameplay modes were implemented: (1) Arcade Mode, focusing on isolated temporal tasks, and (2) Story Mode, embedding tasks within a narrative framework.* ***Results:*** *The game demonstrated high user engagement, suggesting improved data quality for temporal perception research. The source code is publicly available to encourage further scientific use and adaptation.*
Keywords *Temporal Perception Serious Games, Game Design, User Engagement, Mobile Gaming, Human-Computer Interaction, Computational Neuroscience*

1. Introduction

Estimating time is a fundamental cognitive ability essential for everyday interactions, involving tasks such as synchronizing with rhythms, reproducing intervals, and recognizing temporal patterns [Paton and Buonomano 2018, Merchant et al. 2008]. Despite their importance, these abilities remain difficult to study due to the need for varied experimental protocols and large participant samples. Traditional laboratory tasks are often repetitive and unengaging, which reduces participant motivation and data quality. In contrast, digital games have long been associated with cognitive benefits, such as improvements in memory, reaction time, and coordination [Granic et al. 2014, Brandão et al. 2010, Brandão and Joselli 2015, Paletta et al. 2020, Goldstein et al. 1997, Adachi and Willoughby 2013]. Serious Games, in particular, have shown promise in influencing behaviors, knowledge, and health outcomes [Becker 2021].

The *Timing Game*, originally prototyped by [Santos et al. 2021], was designed to investigate temporal perception using participatory methods [Santa Roda and Moraes 2012]. However, the initial version lacked narrative and polished visual design, which limited user engagement. This paper presents a novel version of the *Timing Game* that integrates a compelling time-travel storyline and improved user interface into a 2D mobile platform. The game introduces two modes—Arcade, focused on isolated temporal tasks, and Story, centered on a narrative-driven experience—each designed to support specific cognitive functions. This redesign

aims to enhance player engagement and increase the reliability of collected data, thereby contributing to temporal cognition research and potentially supporting studies involving conditions such as Parkinson's and Huntington's disease [Paton and Buonomano 2018]. Key contributions include (1) a complete redesign of the original game, (2) a development process grounded in expert feedback, and (3) a proposal for scientific data collection via engaging gameplay.

In contrast to the initial prototype, our version of the *Timing Game* represents a substantial evolution. Beyond visual and narrative enhancements, it features the complete implementation of nine scientifically grounded minigames, a modular and configurable gameplay system for research use, and a data collection pipeline suitable for experimental studies. These improvements transform our prototype into a functional research tool. While this work focused on validation through expert review, future efforts will involve formal experimental validation with participant groups.

2. Related Work

Timing abilities encompass duration discrimination, rhythm synchronization, and temporal pattern recognition, underpinned by distributed neural mechanisms across cortical and subcortical regions [Paton and Buonomano 2018, Merchant et al. 2008]. Taxonomies by Coull and Breska identify distinct attentional and motor timing subsystems [Coull and Nobre 1998, Breska and Ivry 2016]. Serious games leverage intrinsic motivation through narrative and feedback, demonstrating efficacy in cognitive training and data collection [Granic et al. 2014, Becker 2021].

Integrating scientific tasks within engaging gameplay can mitigate the traditional trade-off between experimental control and ecological validity, as demonstrated in prior work on spatial navigation and memory games [Hyde et al. 2016, Chaiwong et al. 2021]. Titles such as *A Maze Game with Singing Interface to Fight Dementia* [Chaiwong et al. 2021], *Sea Hero Quest* [Hyde et al. 2016], and *MindLight* [Schoneveld et al. 2020] illustrate how gameplay can support cognitive assessment and treatment.

The *Timing Game* builds upon these foundations by applying Serious Game principles to the field of temporal perception research. Designed to ensure scientific validity while maintaining high user engagement, it introduces two gameplay modes—Arcade and Story. These modes provide distinct experiences that facilitate reliable data collection and enhance participant involvement, thereby contributing meaningfully to both cognitive research and game-based assessment practices.

3. Development

3.1. Game Design and Development Process

The updated version of the *Timing Game* builds upon the original prototype [Santos et al. 2021], shifting from a functional but rigid structure to an immersive and visually cohesive experience. The visual style was upgraded from 8-bit graphics to a hand-drawn cartoon aesthetic inspired by popular media such as *Rick and Morty* and *Among Us* [InnerSloth 2020], with simplified animations to preserve the validity of time-based tasks. The user interface was designed as a physical

space—resembling a time machine built from everyday items—enhancing immersion while maintaining clarity for cognitive experiments. Menus, HUDs, and controls were streamlined for accessibility across player types. A consistent visual language was applied, using metal plates, chains, and crystal motifs throughout.

The game features two modes: *Story Mode*, which embeds minigames in a time-travel narrative, and *Arcade Mode*, which presents them independently (Fig. 1). This dual-mode approach addresses the need for both immersive engagement and targeted experimentation. The narrative places players of a scientist trapped in a malfunctioning time machine, tasked with solving technical issues and collecting temporal crystals to return home. The game world unfolds within a spaceship-like environment (Fig. 2), with each minigame mapped to a specific section of the ship.

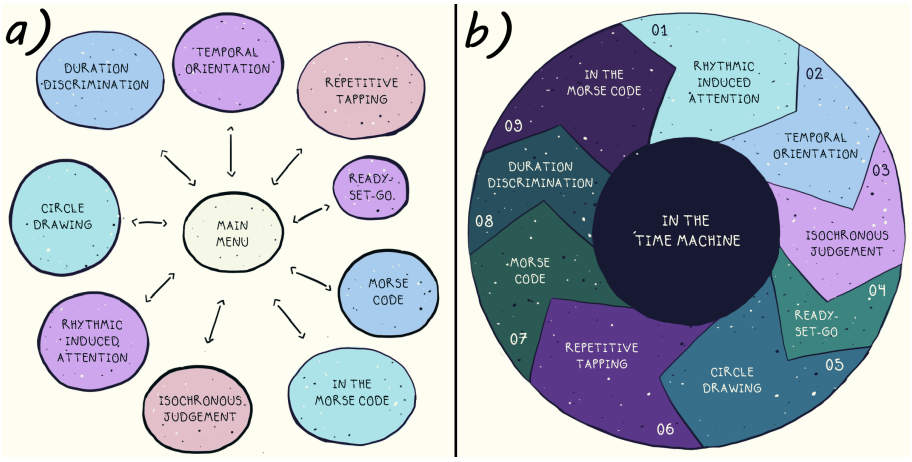

Figure 1. Diagram of Arcade Mode (a) vs Story Mode (b)

3.2. Scientific and Narrative Integration

The development followed an iterative methodology grounded in participatory design [Santa Roda and Moraes 2012], incorporating feedback from a neuroscientist specialized in temporal perception. Over eight alignment meetings, each minigame was tested, refined, and validated to ensure both scientific rigor and usability. Improvements included adjustments in cue timing, interface clarity, scoring systems, and narrative alignment. Each of the nine minigames—such as *Rhythm-Induced Attention* [Breska and Ivry 2018], *Temporal Orientation* [Coull and Nobre 1998], and *Isochronous Judgement* [Grube et al. 2010]—was restructured to align with experimental parameters and to engage players meaningfully (Fig. 3).

The data collection system was implemented using Unity's authentication and Google Drive integration. Minigame data is stored as JSON files, each named according to a standardized format, enabling organized data collection for future cognitive studies. This redesign not only ensures scientific reliability but also improves player retention and data richness, demonstrating the potential of Serious Games in experimental research. A video presentation of the game is available on YouTube[1].

While formal validation with a broad participant sample is out of the scope of our study, the current version prioritizes methodological preparedness and technical

[1]https://www.youtube.com/watch?v=xBIwBxlBSZM

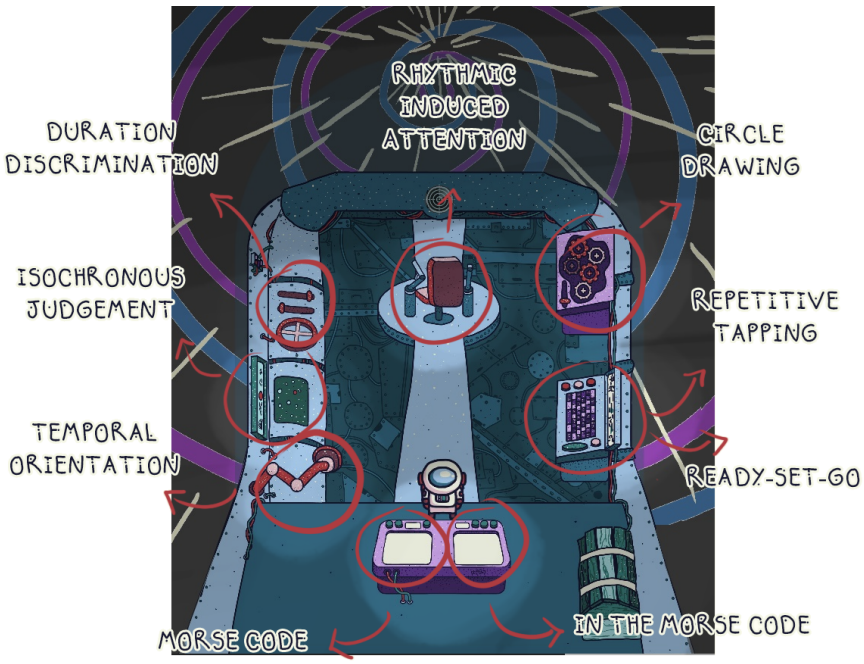

Figure 2. The Time Machine environment and the spatial distribution of all minigames.

reliability. The collaborative design process with a domain expert ensured that each minigame remains scientifically faithful and suitable for future experimentation. Controlled validation studies, such as proof-of-concept evaluations and data consistency analyses, are planned as part of upcoming research phases.

4. Conclusion

This study presented the development of the *Timing Game*, a 2D mobile game originally prototyped by [Santos et al. 2021], which evaluates temporal perception through minigames embedded in a time-travel narrative. The novel version introduces a complete narrative, a cohesive interface, and gameplay improvements designed to enhance user engagement and data reliability. We collaborated with a neuroscientist specializing in temporal perception, who contributed to the game design and the initial game validation.

The interdisciplinary nature of this work required close collaboration between developers and neuroscience experts. Understanding scientific principles was crucial to ensuring both accuracy and engagement. Each minigame was redesigned to align with cognitive theory while maintaining its visual appeal and scientific validity.

The main challenge was unifying the minigames under a cohesive narrative and improving their aesthetic and functional consistency. Enhancements included new animations, a refined UI, and immersive storytelling—all of which contributed to sustained engagement and richer data.

Compared to existing Serious Games for cognitive research, the *Timing Game* stands out by focusing specifically on temporal perception, a domain often overlooked in game-based assessment tools. While previous cognitive training games exist, few have

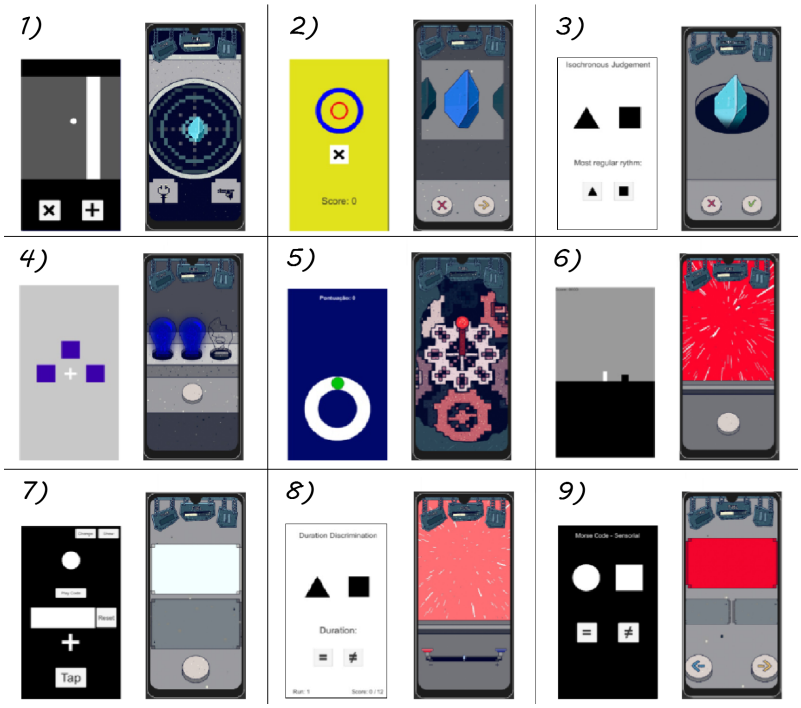

Figure 3. Comparison between initial and final versions of the nine minigames [Santos et al. 2021]. Left images show the early prototypes; right images show the final designs. Descriptions: 1) Rhythm-Induced Attention; 2) Temporal Orientation; 3) Isochronous Judgement; 4) Ready-Set-Go; 5) Circle Drawing; 6) Repetitive Tapping; 7) Morse Code; 8) Duration Discrimination; 9) In The Morse Code.

systematically integrated scientifically validated temporal tasks into a narrative-driven experience. The game offers a unified platform that combines multiple validated tasks, a customizable testing environment, and a narrative structure designed to foster sustained engagement. Additionally, it introduces a scalable data collection pipeline. This approach aims to bridge the gap between ecological validity and experimental rigor in neuroscience research.

For future work, improvements include integrating user metadata (e.g., age, gender) via a pre-game questionnaire, refining each minigame through controlled testing, and enriching scientific content. Enhancements such as scoring systems, cutscenes, and broader deployment (e.g., Google Play) will further increase the impact, supporting temporal perception research in an accessible and engaging format. Another important future work is the large-scale application of the game for scientific purposes.

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