



Not Just Childish Games: an Exploration of Different Game-Based Assessments and Discussion of Gamification in Clinical Pediatric Populations

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Abstract

Gamified cognitive tasks are less monotonous and more effective at drawing people's attention when compared to traditional tasks. As such, they may provide more useful and higher quality data when studying cognitive attention processes, especially in children. This proof-of-concept mixed model study examines two remotely administered gamified Stop-Signal Tasks in a clinical pediatric population. Ten children with traumatic brain injury (mean age 12.16 years, range 7–18 years; 50% male) completed ten gamified Stop Signal Task training sessions over two weeks as part of an at-home neuromodulation intervention. The gamified tasks were structurally identical (i.e., both tasks measure reactive response inhibition and the underlying stop-signal task structure is identical) differing only in the mode of presentation: one being an “infinite runner” game in which the player has to lead a fairy through an enchanted forest, and the other a food-sorting game requiring the participant to make quick decisions about the food items presented. Quantitative performance data and qualitative participant feedback were collected. The order of the two games was presented to participants in a counterbalanced fashion. Despite the tasks being structurally similar, and measuring the same construct, participant performance differed between the two tasks. A key factor for this difference in performance was likely driven by self-reported differences in motivation. This study highlights a potential lack of equivalency between different gamified tasks which measure the same construct. Motivational factors alongside differences in game elements may play a role, highlighting the need to tailor game elements to each individual to maximize motivation.

Keywords Gamification · Pediatric population · Game-based assessment · Response inhibition · Stop-Signal

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Introduction

Gamification as a Silver Bullet?

Appropriately measuring cognition in humans is challenging. Outcome measures are selected based on their ability to robustly and validly measure the cognitive outcome of interest, their appropriateness to the population being studied, their sensitivity over time, and their generalizability to the ‘real world’ (Bagiella et al., 2010; Baker et al., 2011; Barak & Duncan, 2006). Many computerized cognitive tasks are often unengaging, which can particularly be a problem in special clinical and/or pediatric populations with attention deficits (Nand et al., 2019), contributing to poorer data quality (DeRight & Jorgensen, 2015). Gamification has been proposed as a potential method to increase engagement and data quality (Wiley et al., 2024).

Characterized by the use of game design elements in non-game contexts (i.e., such as through point scoring systems, levels and leaderboards, challenging goals, and/or storylines), gamification aims to increase motivation through game-like experiences (Cugelman, 2013; Deterding et al., 2011; Huotari & Hamari, 2012; Ip, 2011). Some theories state that gamification increases engagement primarily through intrinsic motivation factors, where others suggest that increased engagement in gamified tasks is not due to increased intrinsic motivation, but rather due to the provision of clear goals and progress indicators. Despite these differences in interpretation and mechanistic underpinnings, it is widely accepted and assumed that gamification has the potential to increase engagement and potentially even performance (Birk et al., 2015; Chan et al., 2018; Friehs et al., 2022; Groening & Binnewies, 2019; Mekler et al., 2013).

The traditional stop-signal task (SST) is used to measure reactive inhibitory control; i.e., the ability to inhibit an already initiated action (Verbruggen et al., 2019). In this task, participants must respond to a 'Go' signal, but withhold their response on a random subset of trials when a 'stop' signal is presented. In the gamified SST created by Friehs et al., participants are required to find their way out of an enchanted forest by pressing the left or right arrow keys in response to a 'magical fairy' ('go' signal), but withhold their response when they hear a simultaneous beep (beware of the evil witch; stop signal) (Friehs et al., 2020). Another gamified stop signal task that was developed by Schroeder et al. uses an alternative game-like storyline (Schroeder et al., 2021). In this task, participants are required to sort food items and animals moving down a conveyor belt into their appropriate bins using left or right arrow keys (go signal) but withhold their response when the conveyor belt flashes and emits sparks (i.e., breaks down; reflecting a stop signal). Although there is some evidence that these gamified tasks can be adapted to fit multiple research needs (e.g., investigating food-based inhibition), it is unclear whether or not these tasks are actually equivalent to each other as a measure of inhibition or in terms of overall participant experience (Gallagher et al., 2023; Kirsten et al., 2023; Schroeder et al., 2021, 2023). Put differently, it raises the question: Are all gamified tasks created equal when they measure the same construct in similar ways? This is especially critical if these tasks are to be used in studies investigating cognitive functioning in sensitive populations such as clinical or pediatric populations.

Games in Pediatric Health Research

Pedagogical research highlights motivation as a crucial factor in student learning (Lumsden et al., 2016;

Mamaril et al., 2013; Nand et al., 2019) and thus the use of gamification is rapidly increasing in clinical research (Lumsden et al., 2016; Schmidt-Kraepelin et al., 2020). Gamification of cognitive tasks has also been expanded into pediatric ADHD populations (Putra et al., 2018), and pediatric traumatic brain injury (TBI) populations, who often show attention deficits (Mateer et al., 1996; Max et al., 2003; Schachar et al., 2004; Schachar & Logan, 1990; Yeates et al., 2005). Gamification may be particularly useful in clinical populations with impaired attention, where increased intrinsic motivation to play may improve engagement with the task and subsequent performance (Craven & Groom, 2015; Peñuelas-Calvo et al., 2022). This can facilitate a robust measurement even in difficult circumstances; e.g., when a participant or patient cannot leave their home or hospital bed. Game-like measurements can be also carried out in a clinical context, e.g., in youth with anorexia nervosa (Schroeder et al., 2024a). It is particularly useful in pediatric populations where family, school and extracurricular commitments increase the burden of travel, and decrease the likelihood of research participation (Charvet et al., 2015). Thus, a game-like intervention or measurement may help address barriers to inclusion (Charvet et al., 2015; DelliFraine & Dansky, 2008).

In this short report, we aimed to understand differences in participant performance according to quantitative and qualitative metrics on two gamified SSTs played as part of a larger clinical trial assessing the feasibility and preliminary efficacy of non-invasive brain stimulation to improve cognitive functioning after pediatric brain trauma. Since the two tasks set out to measure the same cognitive performance parameters we hypothesized that they would result in similar performance and experience. We highlight differences in performance and participant feedback in the context of structural game elements.

Observations from an At-Home Clinical Trial in Children with Acquired Brain Injury using Gamified Outcomes

Sample

Ten children with TBI (mean age 12.16 (SD 2.9) years, range 7–18 years; 50% male) who were 2.16 (SD 3.83) years post-injury completed 10 consecutive weekdays of gamified Stop Signal Task attention training combined with 20 min of transcranial direct current stimulation (tDCS) administered at home. For clinical characteristics and information about the inclusion and exclusion criteria please refer to the Appendix.

Materials and Procedure

The two gamified versions of the SST ('Fairy Game' and 'Sorting Game')¹ were played on alternate days (see Fig. 1). These games were used as cognitive training tasks during non-invasive brain stimulation as part of an intervention to improve attention in children with TBI (Stein et al., Under Review). In the 'Fairy Game' SST (played offline on the study laptop), the participant was required to find their way out of an enchanted forest as quickly as possible, withholding their responses after an inhibition cue. In the 'Sorting Game' SST (played online on the study laptop) items moving down a conveyor belt were required to be sorted into their appropriate bins as quickly as possible, withholding their response after an inhibition signal. Quantitative data related to SST performance (stop signal reaction time [SSRT], go reaction time, error rate) was collected. Sessions were excluded if they did not meet the quality criteria (e.g., race test violations, low accuracy; for more details on the standard analysis procedures see Verbruggen et al., 2019). Qualitative feedback on participant game experiences was collected from participants using semi-structured interviews on the final day of the ten-day intervention.

Results

Behavioural Findings

There were no differences in SSRT, Go RT or Go errors over time within the Fairy or Sorting games. Overall, participants performed significantly better in the Sorting SST compared to the fairy SST, with significantly faster SSRT ($t_{61}=4.5$, $p<0.001$) and lower go error rate ($t_{61}=-4.4$, $p<0.001$). However, Go RT did not significantly differ between games ($t_{61}=-0.73$, $p=0.47$) (see Table 1)². There was a significant association between age and SSRT (Spearman's $\rho=-0.40$, $p=0.03$), and go error rate ($\rho=-0.44$, $p=0.014$) on the Sorting game only, as well as age and Go RT in both games (Fairy: $\rho=-0.49$, $p=0.004$; Sorting: $\rho=-0.51$, $p=0.004$).

Participant Interviews

Variability is fun Semi-structured interviews with participants following the complete study revealed that the

gamified training was well received across participants. In general, participants seemed to enjoy the fact that they could play two games ("*playing two different games was more interesting*" from an 11-year-old female participant or "*I liked playing different games, it would be more boring if I played the same game every day*" from a 12-year-old male participant). Participants gave positive feedback on the diverse number and types of stimuli presented on the Sorting Game ("*I liked the Sorting game better because there were lots of different foods and animals, and it was more exciting*" from a 7-year-old male participant, or "*I liked the Sorting game a bit better because there was more stuff to look at*" from a 12-year-old male participant).

The Story Matters Participants gave positive feedback on the Sorting Game narrative and goals, stating that the goals of the game felt purposeful ("*I liked the Sorting Game because it was more fun, when you sort things out it has more of a purpose*" from a 9-year-old female participant). Some participants liked the feedback element in the Sorting game (a cartoon 'monster' character at the bottom of the screen who would appear happier or sadder depending on participant performance). On the other hand, other participants preferred the Fairy Game because they did not like the cartoon monster feedback element of the Sorting Game ("*I liked seeing the monster get happy and sad*" from a 12-year old male participant), or "*I liked the variety of games. I preferred the Fairy Game because it didn't have a monster getting angry when you got it wrong*" from a 16-year-old female participant).

Several participants also stated that they preferred the Fairy Game, without a particular reason why, and generally referred to it as more fun or 'less boring' (for example a 12-year-old male participant said, "*I liked playing different games because it made it more interesting. I liked the fairy game better because it was less boring*").

Implied In-Game Rewards Several participants were frustrated with the goals and narrative of the Fairy Game, where they stated that they wanted to physically see the 'witch' (a hypothetical narrative element relating to the stop signal) as a 9-year old female participant described: "*I wanted to actually see the witch in the Fairy Game, and I didn't like going around in circles*"). Participants also said they wished to 'make it out of the forest' at the end of the game (i.e., complete the narrative and be rewarded for reaching the goal).

Attention to Technical Details Participants further reflected on the technical elements of the task and the procedure; for example a 14-year-old female participant stated "*I found the Fairy game hard because it was difficult to hear* [when participants were on zoom call at same time as fairy game, the

¹ For more information about the tasks itself please refer to other publications. For the Sorting Game: (Schroeder et al., 2024a; Schroeder et al., 2021, 2023); Schroeder et al., 2024b). For the Fairy Game: (Friehs et al., 2020, 2022; Held et al., 2025; Markiewicz et al., 2024).

² Note that due to logistical problems (e.g., unstable internet connection) the comparison of individual sessions on a statistically meaningful level is not possible.

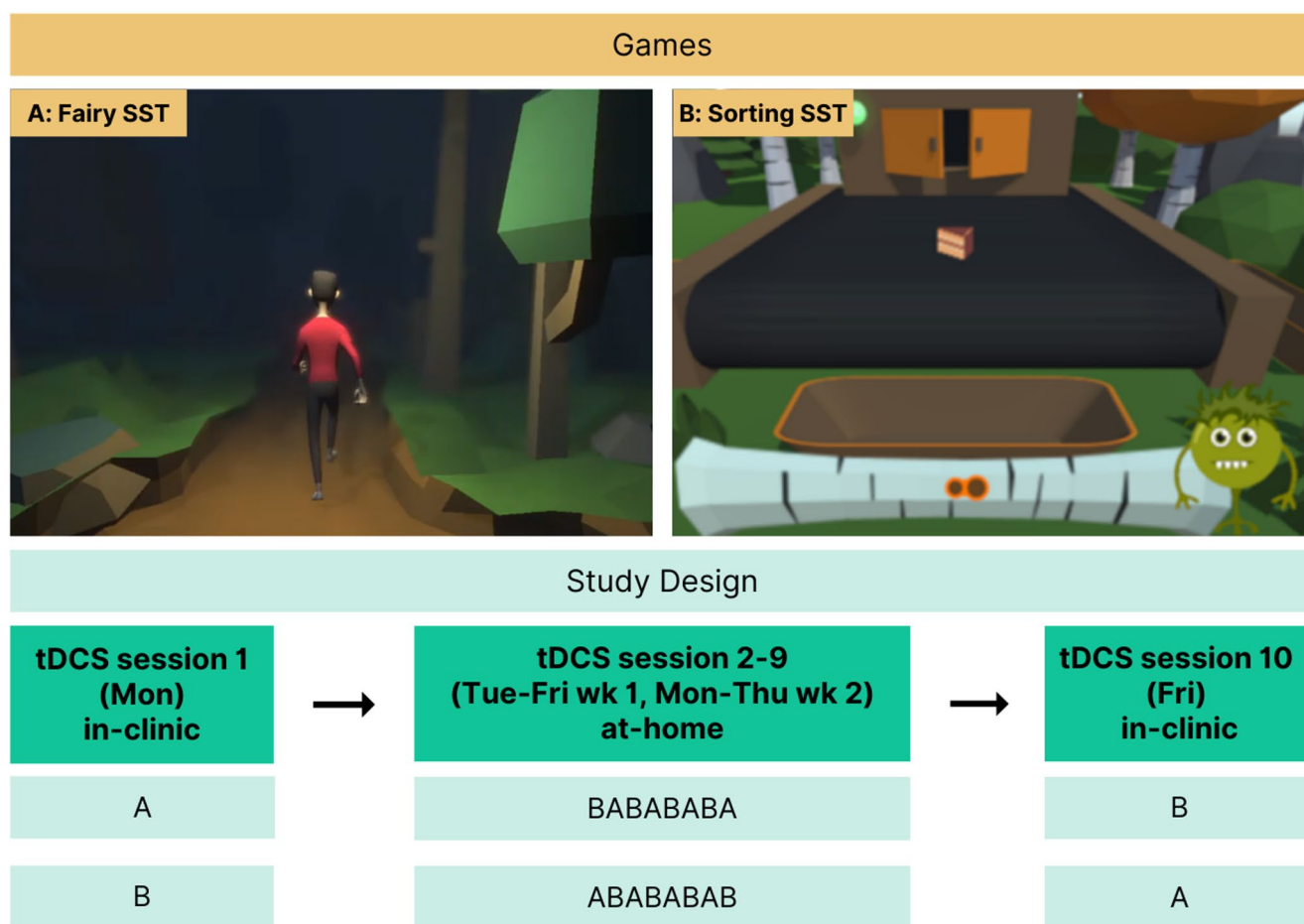


Fig. 1 Flowchart of study design. Top panel: screenshots of (A) ‘Fairy Game’ and (B) ‘Sorting Game’. Bottom panel: Study design. Participants were randomized to play the SST games in one of two sequences

alternating games on each day, e.g., beginning with the Fairy Game, or beginning with the Sorting Game

Table 1 Game performance across SST versions. Means displayed in the table with the standard deviation in brackets

Measure	Fairy SST	Sorting SST	t statistic	p-value
SSRT (ms),	636.4 (236.4)	414.0 (134.7)	4.53	<0.001
Correct go RT (ms)	1051.2 (202.4)	1086.0 (172.3)	-0.73	0.47
Go error rate (%)	0.01 (0.02)	0.03 (0.02)	-4.37	<0.001

SSRT stop signal reaction time, ms milliseconds, SD standard deviation, RT reaction time

auditory stimulus was automatically lowered in volume.] *It would have been nice to have a stop signal that you can see in the fairy game.*” Additionally, a 10-year-old participant said, “*I liked the fairy game better, as it was more predictable than the sorting SST with the speed, and breaks were more predictable*” (referring to where the sorting SST would sometimes change speed due to internet connection speed in participants’ homes).

Discussion: Implications and Reflections

From the Current Study

In our proof-of-concept study, we observed intriguing nuances in participant performance but also their experiences that shed light on the interplay between game design elements and user motivation. Given the structural equivalence between the tasks and the identical task-goal the performance difference is noticeable, especially since they played on consecutive days. It must also be noted that differences in performance were also probably partially driven by differences in game presentation, where the web-based SST was limited by latency of stimulus presentation (e.g., due to issues with participant internet speed); these problems were not present with the offline Fairy SST. Overall, however, the variance in response times suggests a potential link between game dynamics and individual motivation levels.

It is conceivable that the unique mechanics of each game influenced participants' strategic approaches or their eagerness to interact with the game, particularly given the wide range of ages and developmental stages. This seems especially likely given the interview responses by the participants. For example, if a participant is hypothetically 'scared of the witch' or 'wants to confront the witch' in one game and 'does not want to make the monster angry' or 'want to make the monster happy' then approach and avoidance motivation may be triggered (Held et al., 2025). These findings underscore the importance of considering both intrinsic motivation factors and external variables when evaluating user performance in gaming contexts. Future research could delve deeper into understanding how game mechanics and technological constraints interact to shape user experiences and outcomes.

To Future Usage of Gamified Tasks in Clinical Trials

Gamified and home-based cognitive training is intended to increase measurement validity and participant engagement due to a greater motivational pull and a higher likeness to 'real world' attention requirements, which is especially important in assessing and training individuals with attention deficits (e.g., individuals with ADHD) (Lumsden et al., 2016). ADHD is fairly common in pediatric populations, affecting 5.3% of children worldwide, which can interfere with cognitive functioning or development (Polanczyk et al., 2007). Utilizing a somewhat repetitive standard SST including nothing more than white arrows on black screen for half an hour may not lead to a valid measurement of the response inhibition capabilities of an ADHD-affected individual. In line with this, Delisle and Braun (2011) found that changing a standard task to resemble a fast-paced videogame normalized the performance of participants with ADHD, meaning that participants with and without ADHD performed similarly on the gamified task (but differently on the standard task) (Delisle & Braun, 2011).

For future clinical trials and at-home data gathering with gamified tasks we propose researchers pay attention to:

Perceptual Elements Selecting signals important for the task at hand can be difficult depending on the background noise and the situation an individual is in. Future studies should explore the differential effects of stimulus processing on user engagement and performance across various sensory modalities such as auditory, visual, and tactile stimuli. Investigating how different perceptual elements influence gameplay experiences could inform the design of more immersive and accessible gaming interventions. Put differently, if large amounts of auditory information must be processed (e.g., due to constant communication with the experimenter) then another auditory signal from the task

presented over the same speaker used for communication may not be ideal. In this case, cross-modal signals may be more advantageous (Friebs et al., 2024; Markiewicz et al., 2024; Meyerhoff et al., 2018; Soballa et al., 2023).

Motivational Elements The role of motivational elements, including storyline, scoreboards, and feedback mechanisms, should be further examined to elucidate their impact on user motivation and engagement during gameplay; especially when designing games for different age groups. Understanding how these elements contribute to sustained interest and participation in gaming interventions could inform the development of more effective gamified interventions for diverse populations (Mekler et al., 2017).

Outside Influences as Moderating Factors *Researchers should acknowledge and account for external influences, such as environmental distractions and remote supervision, as potential moderating factors that may affect participant engagement and performance in gaming studies. Exploring strategies to mitigate the impact of outside influences could enhance the validity and reliability of research findings. However, the natural environment in at-home interventions generally creates an uncontrollable environment for the experimenter which may detrimentally affect performance (Liebl et al., 2012; Madero et al., 2021).*

Optimal Delivery Methods Investigating the optimal delivery methods for gaming interventions, particularly in non-clinical settings (like homes) is imperative (Cyr et al., 2021; Hauer et al., 2009). Comparing web-based platforms, downloaded applications, and locally cached web-based games could offer insights into the most effective approach for ensuring seamless gameplay experiences while minimizing technical issues and internet-related disruptions.

Consideration for Children When designing gaming interventions for children, it is crucial to consider the cognitive capabilities and gaming literacy of not only the children but also their caregivers that may supervise them during the task. Ideally, feedback can be sought from pediatric patients, their caregivers, and the experimenter in a dialogue format during game design. Ensuring that games are intuitive and understandable for both children and their parents, regardless of their prior gaming experience, is essential for maximizing accessibility and effectiveness. Additionally, studies should address potential adverse effects of gaming, such as frustration, especially in children with preexisting clinical conditions (Brewer et al., 2013). For example, incorporating adaptive difficulty levels or providing additional support mechanisms, could enhance the safety and efficacy of gaming interventions for diverse user groups.

Procedural Considerations It may be necessary to adjust the procedure or give the children some choice to further increase their motivation. For example, a child may be given the option to choose between two games that are equivalent in their nature to increase the perceived autonomy in an that they are not fully voluntary participating in. But even a simple choice between two options may influence motivation and experience (Bowey et al., 2019). Choices hidden from the participant may extend to other aspects of the tasks such as the controls with which the gamified task is played (Markiewicz et al., 2024). Since studies of this nature (i.e. at-home) will include multiple measurements over time, variations in the procedure may introduce noise in the data. Designing games which provide a different experience each day may also increase motivation, for example through a level-based system or by subtly changing the context, environment, narrative or goals of the game each day. However, the reliability of the game must be kept in mind when changing these parameters.

Conclusion

It is important to closely consider the effect of game design elements and user motivation on participant performance. Our study demonstrates that changes in game elements in structurally similar gamified stop-signal tasks can change overall game performance. Future game design should use qualitative feedback to shape perceptual, motivational, and environmental game elements for the population of interest, and in particular, consider optimal delivery methods.

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Data Availability Data and materials can be made available upon reasonable request for research purposes.

Declarations

Ethics Approval and Consent to Participate All participants and their guardians or parents provided informed consent. The study was approved by the local ethics committee of the University of Queensland, Australia.

Competing interests The authors have no conflicts of interest to report.

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