User Engagement in Goodville's Spatial Working Memory Task

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Published online: March, 2023

SUMMARY. This scientific article discusses the use of mobile applications in the assessment and training of spatial working memory using gamification. The article highlights the advantages of using gamified tasks in the assessment of spatial working memory and the benefits of mobile applications in providing a personalized experience for users, offering real-time feedback, and tracking progress.

The article focuses on the Goodville app, which incorporates an emotional wellness module that includes an assessment of spatial working memory. The Goodville Spatial Working Memory task is a gamified implementation of spatial search tasks that take place in a chicken coop.

The aim of the article is to evaluate user engagement in completing the spatial working memory task in Goodville. Data from December 2022 were selected for analysis, where the task was completed 2,124,450 times by 1,305,685 users and the mean number of task passes per day was 66,389.06, with each user completing the task 1.63 times per day on average.

The data shows a high level of user engagement, with a fivefold increase in users who installed the app and completed the task for the first time by the end of December. The dynamics of changes in the increment in the number of users who passed the test in December 2022 demonstrate a positive increment of users who passed on most days. The study shows that there is a pattern in the number of Goodville users who complete the SWM task daily. The maximum involvement is seen on the day of installation, and then the number of task-takers progressively decreases over the following days and weeks. However, the total summary involvement of Goodville users in passing the SWM task during the month progressively increases due to the cumulative summation of users who installed the app in that month. This study provides insights into user engagement, but further research is needed to explore engagement over longer periods and to understand how different factors may impact user engagement.

Key words: Goodville, spatial working memory, mobile assessment, engagement

Working memory (WM) is a crucial cognitive function that involves the preservation and active modification of information, and it goes beyond short-term memory. WM comprises four components proposed by Baddeley: the phonological loop, visuospatial sketchpad, episodic buffer, and central executive. The phonological loop stores linguistic information, while the visuospatial sketchpad stores visual and spatial information. The episodic buffer interacts with long-term memory components, and the central executive controls the other three components (Miura et al., 2017). The theory of visuospatial sketchpad suggests that retaining and manipulating the visual and spatial features of a limited number of objects is vital for cognitive processing. This cognitive ability is commonly referred to as visual-spatial working memory and enables organisms, such as humans, to identify and navigate towards or away from potentially dangerous or beneficial objects (McAfoose & Baune, 2009). Visual-spatial working memory provides significant advantages beyond its practical applications, as it is highly efficient and allows for the recognition of an object's identity and location while navigating through different environments. However, this cognitive process must be adaptable and efficient to ensure accurate and rapid processing under conditions of continual visual input changes (McAfoose & Baune, 2009).

Spatial working memory (SWM) deficits are commonly observed in individuals with various neurological and neuropsychiatric disorders (Van Asselen et al., 2005), including brain lesions resulting from traumatic brain injury or stroke (Karlsen et al., 2021), Alzheimer's disease (Silva & Martínez, 2023), Parkinson's disease (Possin et al., 2008), schizophrenia (Starc et al., 2017), mood disorders (Li et al., 2021), attention deficit hyperactivity disorder (Luo et al., 2019), chronic fatigue syndrome (Dobbs et al., 2001), sleep deprivation (Peng et al., 2020), chronic stress (Conrad, 2010), and substance use disorders (Khurana et al., 2017). Assessing SWM in individuals with these disorders is crucial, and developing interventions to improve SWM deficits in these populations is vital. Working memory can be assessed through a range of tests, including the n-back task, the Sternberg Item Recognition Paradigm, the Visual Patterns Test, the patial Working Memory task, and various additional methods (W. Song et al., 2013). Complex span tasks are commonly used to measure individual differences in working memory, which require participants to both store and process information simultaneously. However, no standard task exists for assessing working memory (Vock & Holling, 2008).

The application of computerized neuropsychological tests has demonstrated significant potential in the evaluation of cognitive function, particularly with regard to spatial working memory (SWM). Computer-based assessments offer extensive possibilities for evaluating SWM, as they can provide standardized and reliable means of measuring cognitive function while also enabling the collection of large amounts of data for research purposes (Wild & Musser, 2014). Moreover, computerized neuropsychological tests can evaluate a broader range of cognitive abilities, reducing floor and ceiling effects, and offering greater flexibility in adjusting to performance levels. This flexibility is particularly important for the assessment of SWM, as it allows for the automatic alteration of task order, presentation rate, and difficulty levels, based on the test-taker's performance. Furthermore, computerized assessments may offer cost savings and greater accessibility, as they can reduce the need for materials, supplies, and trained personnel, and allow healthcare professionals other than neuropsychologists to administer the tests. Thus, computerized neuropsychological tests represent a promising approach for evaluating SWM, with extensive possibilities for enhancing the assessment of cognitive function across various clinical settings (Wild & Musser, 2014).

Gamification has emerged as a popular approach for integrating game-like elements into various contexts, including engineering, education, and psychological assessment. The market for cognitive assessment and training is expected to grow significantly in the coming years, and gamification is predicted to play a major role in this expansion. Gamification has particular advantages in the assessment of spatial working memory, as it can enhance engagement and motivation, leading to better quality data in cognitive tasks. Intrinsic motivation is crucial for long-term engagement, and gamification can satisfy users' needs for relatedness, autonomy, and competence, while also providing extrinsic motivation through rewards and outcomes (H. Song et al., 2020). In addition, gamification can offer an optimal challenge and positive feedback, leading to a state of flow that can improve cognitive function. The use of gamification in cognitive assessment and training is particularly relevant given the global health concern surrounding neurocognitive disorders, which can affect people at any age, and the aging population, for whom maintaining independence and preventing loss of autonomy in activities of daily living is critical (Akoodie, 2020).

Mobile applications have become increasingly popular as a tool for cognitive assessment and training due to their accessibility and convenience. Spatial working memory is an essential cognitive function that plays a crucial role in many daily activities, such as navigation, driving, and sports. Mobile applications can provide an efficient and cost-effective platform for assessing spatial working memory using gamification (Khaleghi et al., 2021).

Gamification in the assessment of spatial working memory using mobile applications can offer several advantages. Firstly, gamified tasks can provide a more engaging and enjoyable experience for users compared to traditional cognitive tests, which can lead to increased motivation and participation. Secondly, the use of game-like elements can enhance user performance by providing feedback and rewards that promote learning and skill development. Thirdly, gamification can provide an objective and standardized assessment of spatial working memory, reducing the potential for subjective bias or errors that may occur in traditional assessments.

Mobile applications that incorporate gamification in the assessment of spatial working memory can also offer a personalized experience for users. They can be tailored to meet individual needs and preferences, allowing users to select tasks that are challenging but achievable, leading to a sense of accomplishment and motivation to continue. Furthermore, mobile applications can provide real-time feedback, allowing users to track their progress and identify areas for improvement (Akoodie, 2020).

The Goodville app is a mobile game that includes a module for assessing various aspects of emotional well-being. This emotional well-being module allows players to obtain a comprehensive assessment of their emotional health dynamically and at their request. During the game, players can evaluate various aspects of their emotional well-being, including the severity of anxiety and depression symptoms, the level of positive and negative emotions, and the quality and duration of sleep. After completing the emotional well-being assessment, players receive feedback in the form of verbal interpretations and visual representations of the state of a certain aspect of their emotional well-being. Notably, Goodville's emotional wellness module includes an assessment of spatial working memory. This assessment is particularly relevant for emotional well-being because there is evidence that emotional disorders can decrease spatial working memory (Li et al., 2021; Vance & Winther, 2021). The Goodville Spatial Memory (GSWM) task is a gamified implementation of spatial search tasks such as the Executive Golf Task (Feigenbaum et al., 1996) and the Box task (Kessels et al., 2004). In Goodville, the task is localized in a Chicken Coop (Figure 1), consistent with the game's farm theme. During the game, the player is prompted to take the test at a specific time.

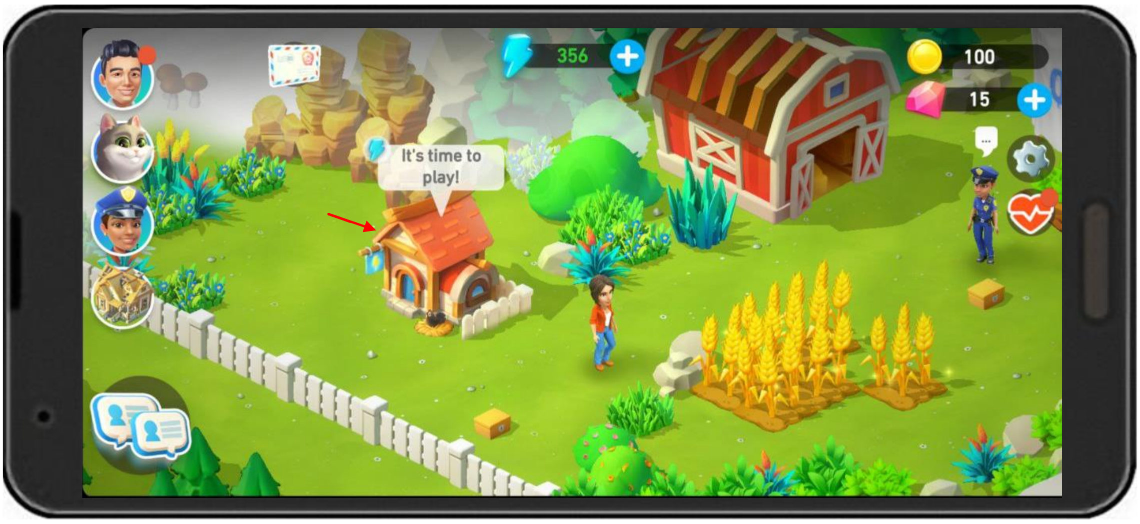

Figure 1. The Goodville Chicken Coop environment featuring the Spatial Working Memory task (marked by a red arrow)

In the Goodville Chicken Coop, the user initiates the task by clicking the "play" button (Figure 2). The maximum amount of energy that can be earned upon completion of the task is also displayed on the screen.

Figure 2. The initial screen before starting the Spatial Working Memory task

The player is given verbal and visual instructions before starting the task, where they are asked to search for eggs under the hens by touching each hen one at a time (Figure 3). The instructions state that the player should not touch hens that have already laid eggs.

When the player touches a hen, it flies up and lands back in place. If an egg was under the hen, it moves to a hole in a column on the right side of the screen. During the task, the player must consistently touch each chicken that has not laid an egg yet.

Figure 3. Instructions for completing the Goodville Spatial Working Memory task

Two types of errors can occur during the task. The first error occurs when the user touches a hen that has already laid an egg. The hen will fly up, crow discontentedly, and a message reading "I've already given an egg" will be displayed. The second error occurs when the user presses a hen that was already touched before without finding an egg. In this case, the hen will also fly up, crow discontentedly, and the message "Don't check on me twice" will appear. The number of hens increases from four to a maximum of eight over three trials. Figure 4 shows a fragment of passing the GSWM task in its final trial.

Figure 4. Example of Passing the Goodville SWM Task on the Final Trial

Upon completing the task, the player receives a reward in the form of game energy, which is necessary to advance in the game. The energy earned by the player in each trial is represented by a column on the left side of the screen. The total energy earned after completing the task is displayed on the final screen (Figure 5). The users can complete the task multiple times, with an interval of 6 hours.

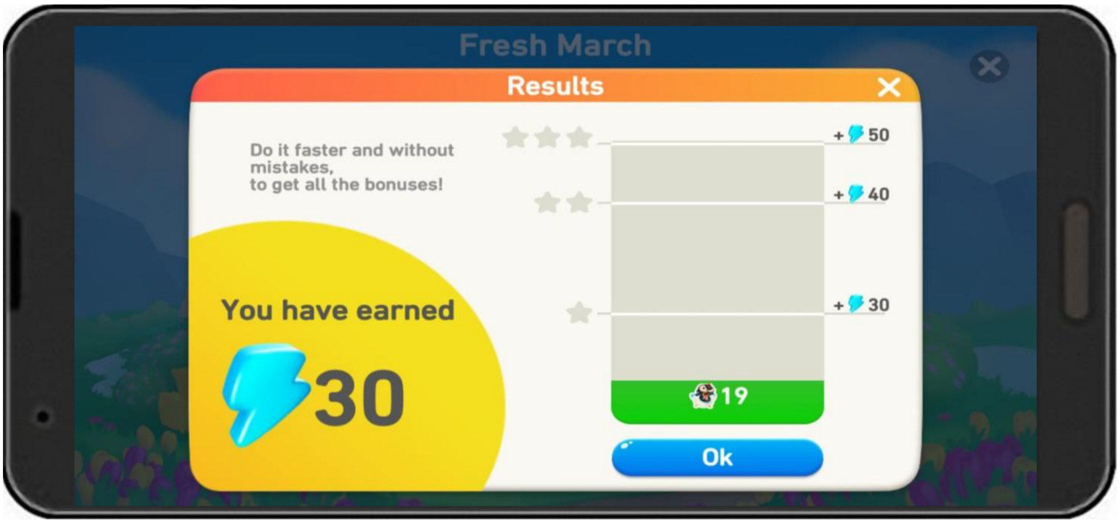

Figure 5. Final Screen of the Goodville Spatial Working Memory task

Since its initial implementation in 2020, a large amount of data has been collected using the GSWM task. The aim of this study was to evaluate user engagement in completing the Spatial Working Memory task in Goodville.

Data from December 2022 were selected for analysis, where the task was completed 2,124,450 times by 1,305,685 users. The histogram in Figure 6 represents the daily distribution of SWM task passes and users in December 2022, with over 60,000 task passes completed by nearly 40,000 users every day except on December 24 and 31.

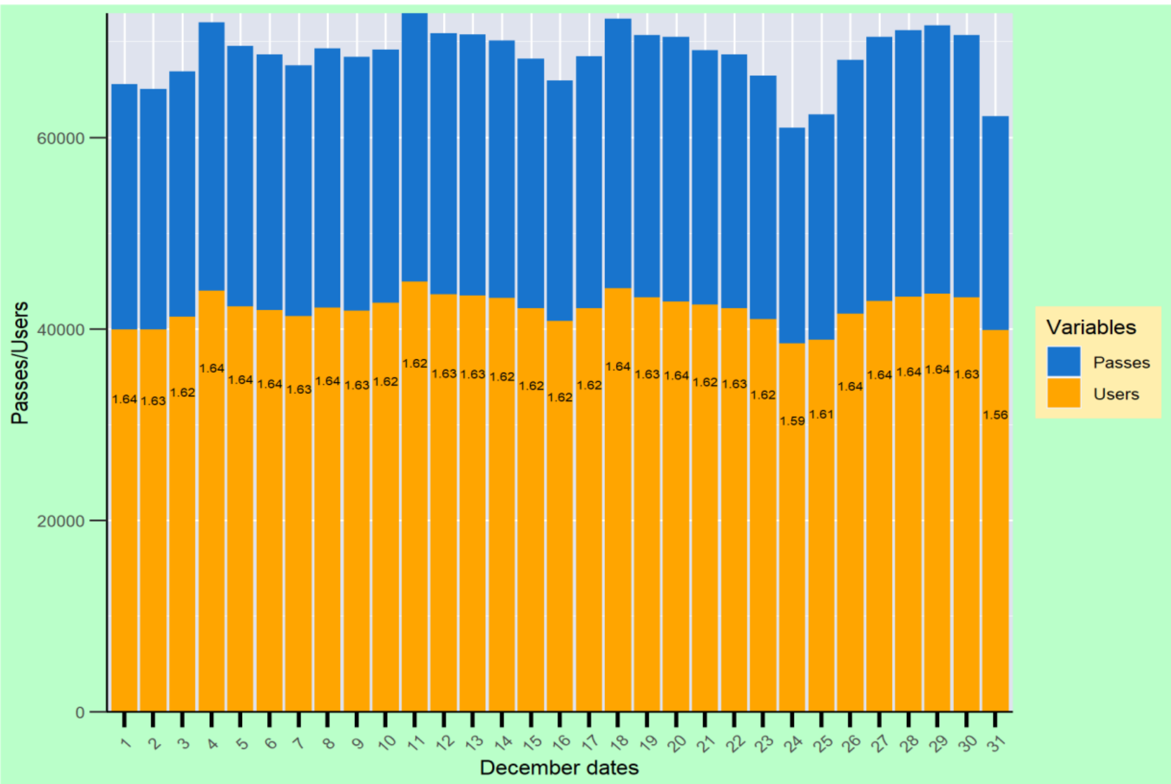

Figure 6. Distribution of Goodville SWM task passes and users by day in December 2022

The mean number of task passes per day was 66,389.06 (with a standard deviation of 11,507.8), and the mean number of users was 42,118.87 (with a standard deviation of 1,561.35). The numbers shown in the histogram bars represent the average number of test passes per user for each day. On average, each user completed the task 1.63 times per day, suggesting that nearly 40% of users completed the SWM task twice a day.

Figure 7 displays the distribution of users who installed Goodville and passed the GSWM task by day in December 2022. Percentages over the histogram bars represent the percentage of users who passed the task out of those who installed the Goodville app on the same date. The histogram shows that a large proportion of users completed the GSWM task on the same day they installed Goodville, with nearly 90% passing the task on the installation day.

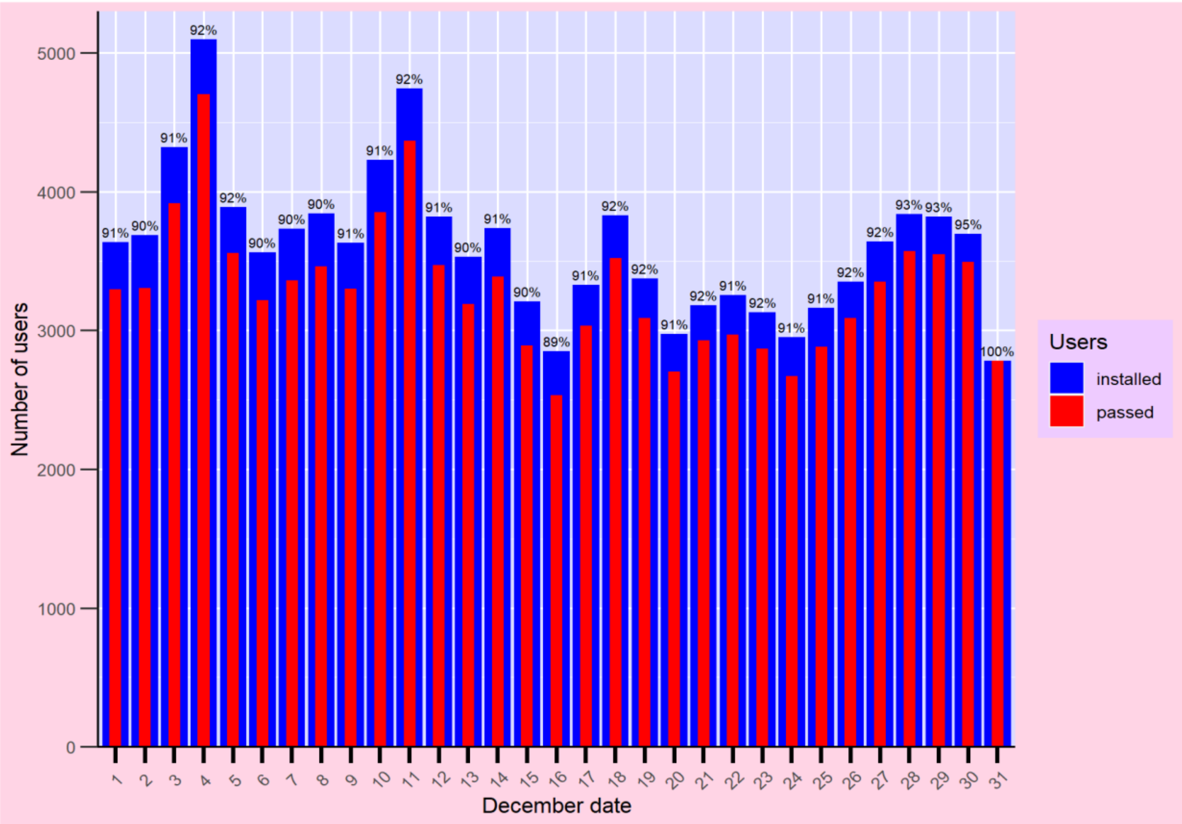

Figure 7. Goodville Installations and Spatial Working Memory Task Passes Distribution in December 2022

The cumulative distribution of users who passed the SWM task, along with those who installed and passed the task on the same date in December 2022, is shown in Figure 8. The orange bars show the number of users who installed the game and passed the task on the same date. As shown in the histogram, the number of Goodville users who installed the app in December 2022 and passed the SWM task increased progressively day by day. For instance, if 3294 users installed the application and completed the task for the first time on December 1, by the end of December, the maximum number of users per day reached 16463 people, which is a fivefold increase. The analysis of the histogram on Figure 8 also shows that, in the first 10 days of December, a significant proportion of users involved in passing the test was due to those who had just installed the application, ranging from 68% to 30%. Then, in the following days, the increase in users due only to those who installed the application and passed the test for the first time was a little over 20%.

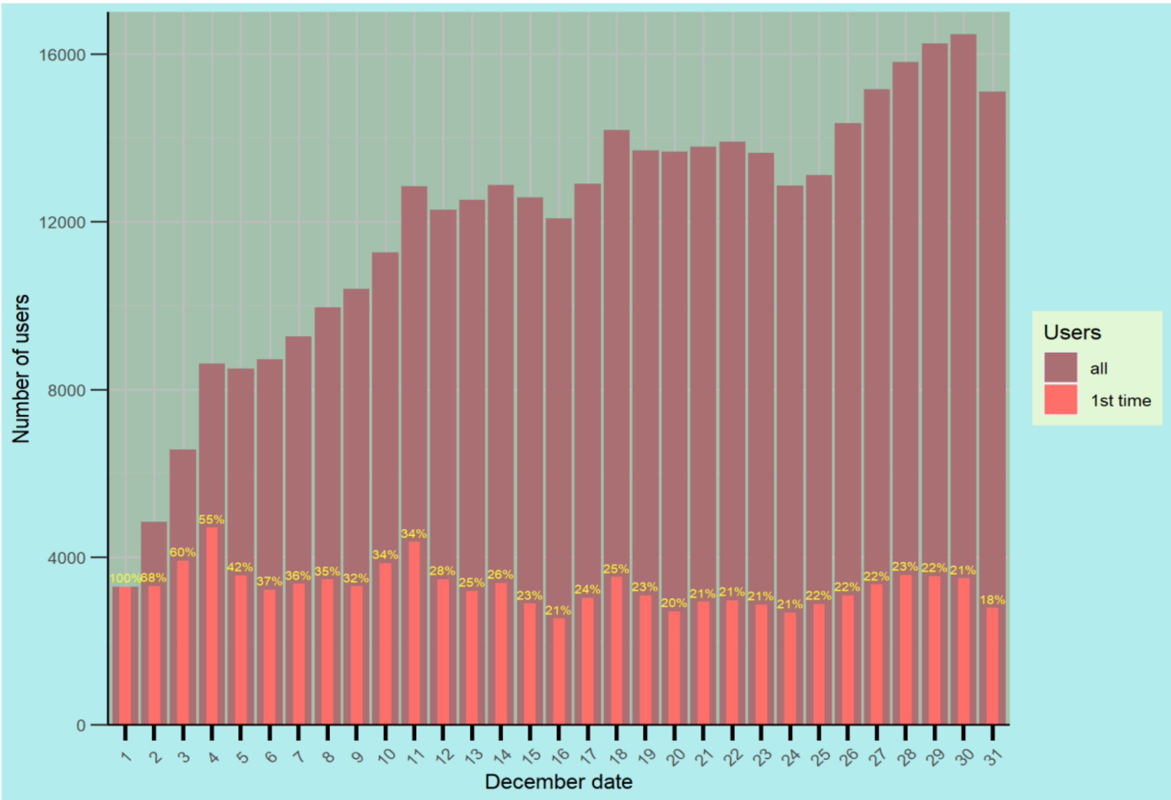

Figure 8. Cumulative distribution of Goodville users who passed the GSWM task and those who installed and passed the task on the same date in December 2022

The graph in Figure 9 shows the dynamics of changes in the number of users who have completed the SWM task. While the average value of the increment was 393.7 (SD = 789.46), it can be concluded that the number of users who installed the application in December and were involved in completing the task changed in the direction of an increase. Analysis of the graph shows that on most days, there was a positive increment of users who passed the SWM task. The peaks of player growth were noted at the end of the week, especially on Sunday, as well as on Monday, December 26, after the Christmas holidays. Negative peaks showing a decrease in user growth occurred on Friday and Monday, with the exception of post-Christmas Monday, December 26, and on New Year's

Eve Saturday, December 31. On Tuesday and Wednesday, there was a moderate and increased positive increment in users completing the task.

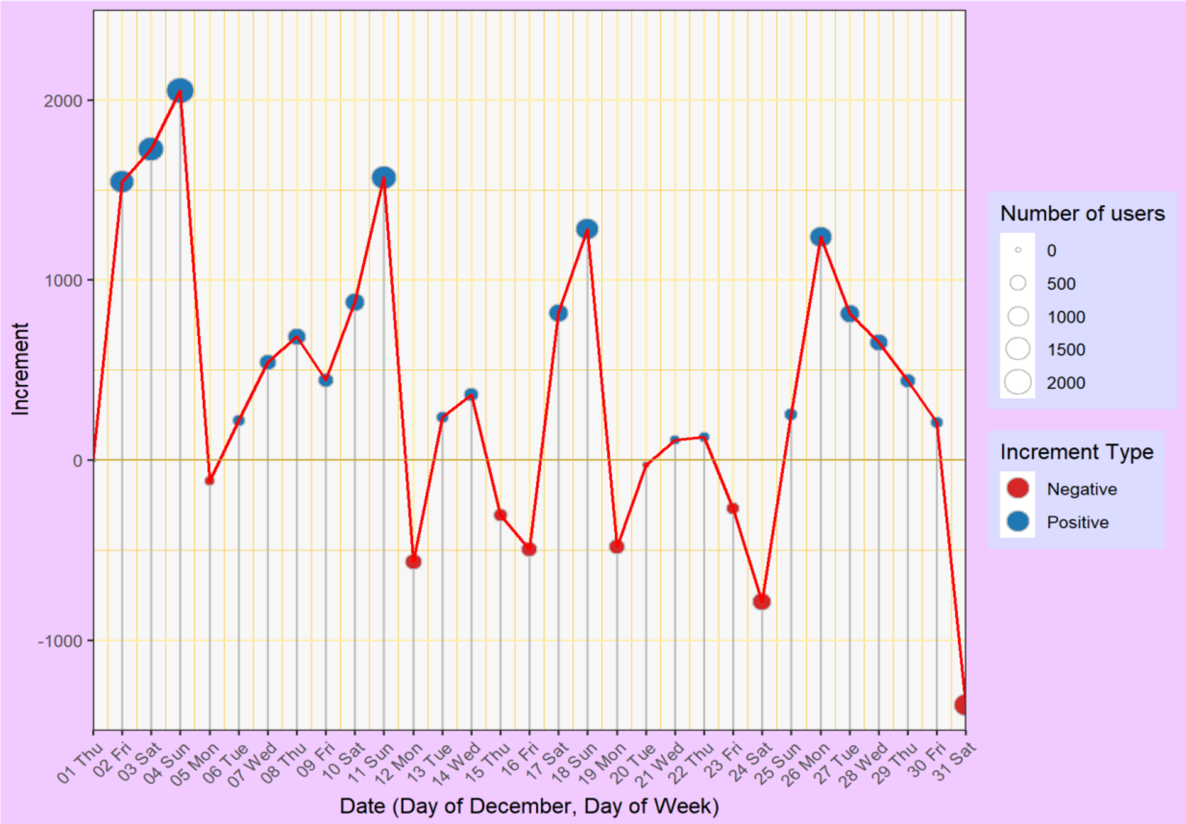

Figure 9. Dynamics of changes in the increment in the number of users who passed the test in December 2022

Figure 10 illustrates this distribution for users who installed the app on December 1 and passed the GSWM task in December 2022. Among the 3635 users who installed the app on December 1, 91% of them passed the SWM task for the first time on this date, as evident from the histogram. December 1 had the highest engagement of users in passing the SWM task. By December 2, more than half of the users had already passed the task. On December 3 and December 4, one-third and one-fourth of the users, respectively, completed the SWM task. From December 4 to December 10, the number of users who completed the task gradually decreased from 25% to 13%. From then on, until the end of December, the number of users who completed the task gradually decreased to 7%. The same pattern was observed for users who installed the app on December 2 and December 3, as shown in Figure 11.

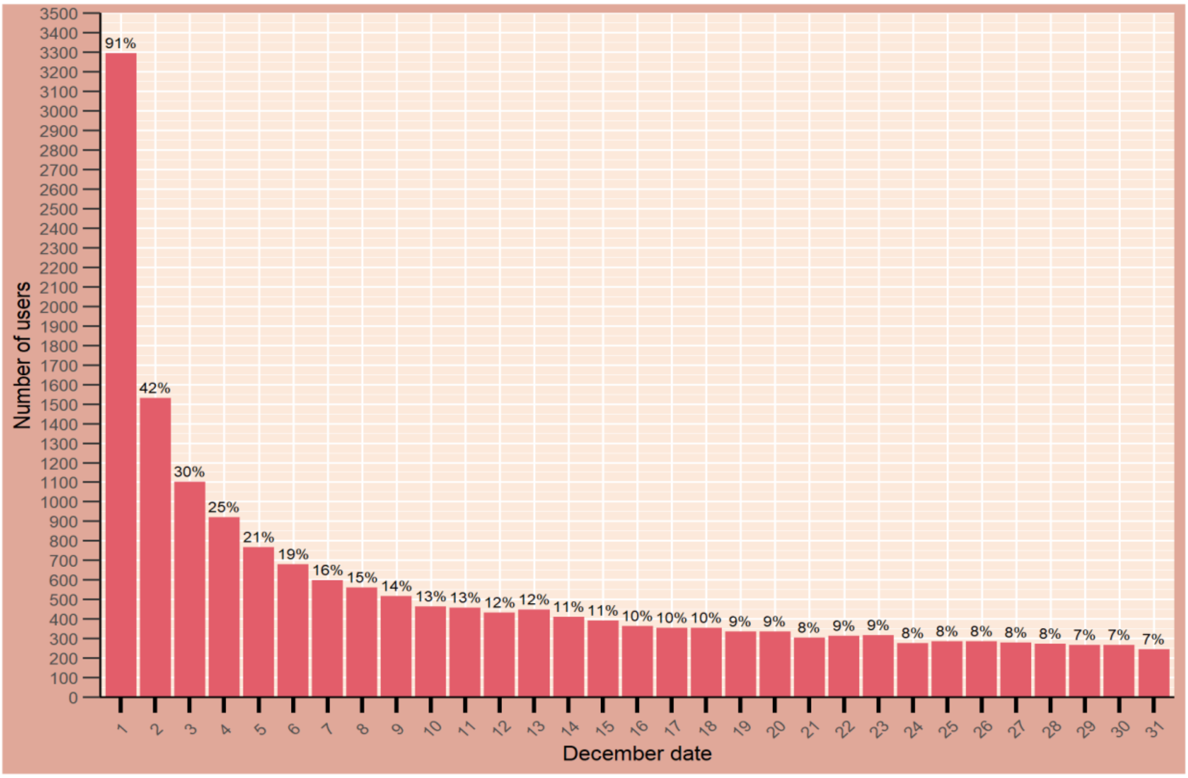

Figure 10. Distribution of users who installed Goodville on December 1 and passed the SWM task by date in December 2022

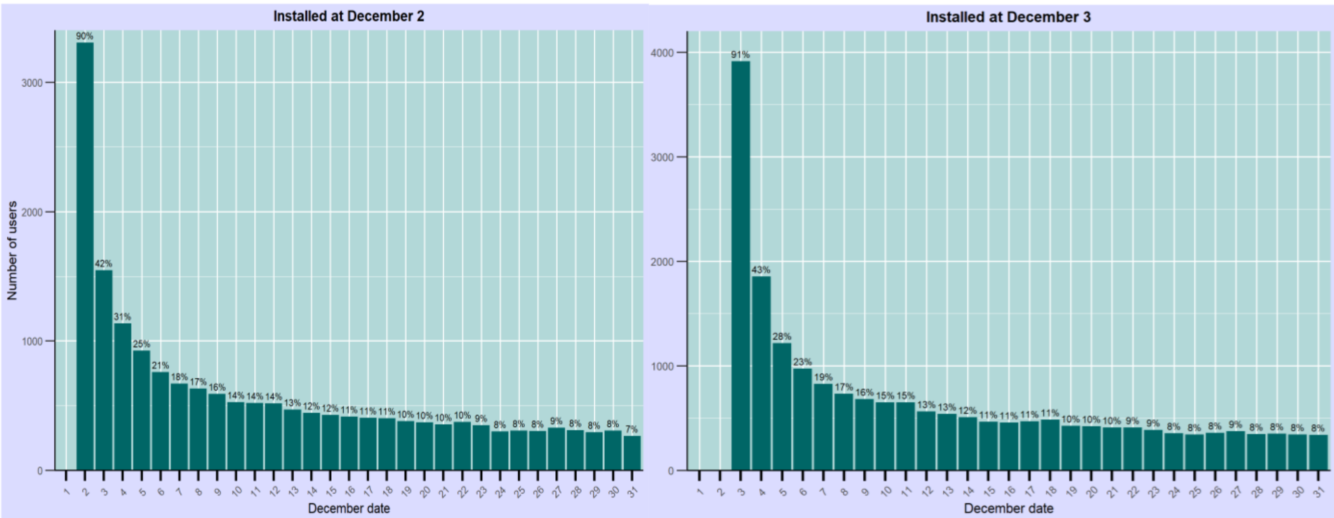

Figure 9. Dynamics of changes in the number of users who passed the SWM task in December 2022 for users who installed the Goodville on December 2-3

This article presents an evaluation of user engagement in completing the Spatial Working Memory task in the Goodville app, utilizing data from December 2022. The results reveal a high level of engagement from Goodville users in executing the GSWM task. Over 60,000 task passes were completed by nearly 40,000 users every day, except for December 24th and 31st. On average, each user completed the task 1.63 times per day, indicating that almost 40% of users completed the GSWM task twice a day.

Analyzing test passes by players who installed the application in December, the number of Goodville users who installed the app and passed the SWM task progressively increased day by day. The dynamics of changes in the increment in the number of users who passed the test in December 2022 demonstrate a positive increment of users who passed the GSWM task on most days, with peaks of player growth noted at the end of the week, especially on Sunday and Monday, December 26th, after the Christmas holidays. Negative peaks showing a decrease in user growth occurred on Friday and Monday, with the exception of post-Christmas Monday, December 26th, and on New Year's Eve, Saturday, December 31st.

The study established a pattern of the dynamics change in the number of Goodville users in daily passes of the spatial working memory task, starting from the day the application was installed. The maximum involvement in passing the task by users who installed the game on a particular day is noted on the same day. In the following 5-6 days, the number of task-takers progressively decreases, and then gradually decreases during the month to 7% of those who initially installed the application. Given the repetitive nature of this pattern, it can be assumed that it is typical for Goodwill users in passing the GSWM task. This is also confirmed by the fact that throughout the whole month, the number of users who installed Goodville and passed the task on the same day was about 90%, which corresponds to the maximum user engagement compared to subsequent days.

Considering that the maximum involvement of users in the GSWM task passing is marked on the day of the application's installation, and taking into account that the game is installed daily by a significant number of users, the total summary involvement of Goodwill users in passing the GSWM task during the month progressively increases due to the cumulative summation of users who installed the app in that month. If we evaluate on the scale of all users who passed the test during December, it can be argued that the relatively constant high frequency of daily task completion is determined by the cumulative addition of small proportions of users who installed the application earlier, in the days preceding December and during December.

In conclusion, this study provides insights into user engagement in completing the spatial working memory task in the Goodville app during December 2022. However, further research is needed to explore user engagement over longer periods and to understand how different factors may impact user engagement.

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