Co-design of a points-based reward system to boost motivation in children and improve adherence to learning serious games

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***Abstract*—Specific Learning Disorders are disabilities that impair the ability to learn, which can be mitigated through timely training. However, administering such training can be challenging due to screening difficulties, including teachers' inadequate training and clinicians' lengthy waiting lists, and to challenges posed by distance modalities and children's low compliance. To improve adherence and motivation, gamification techniques should be used. After a co-design process carried out with clinicians, teachers, and children, we thus added a coin-collection system and an in-game shop to the learning games of the ESSENCE project, and analyzed the trend of the usage and of the performance in the games to verify its impact. 66 children participated in the testing, for a total of 6822 serious games uses. Weekly usage increased after the introduction of both coins and shop (84.0 before, 145.6 after coins, 403.2 after shop), while performance improved significantly after the introduction of the coins, but not of the shop (0.66±0.24 before, 0.86±0.16 after coins, 0.87±0.13 after shop), suggesting that the presence of rewards was enough to improve adherence and lead to better results.**

***Keywords*—serious games, learning, gamification, adherence**

I. INTRODUCTION

Specific Learning Disorders (SLDs) are conditions that cause difficulties comprehending or processing information, and lead to subpar academic performance given proper conditions like age, intelligence, the absence of sensory-motor problems, and an adequate opportunity to learn. As of now, these disorders cannot be cured, but adequate training can alleviate their effects to lessen the impact of the disability on the subject's life. These training activities are especially effective if carried out early in a child's life. Thus, it is important that children are screened from a young age to allow for a timely intervention. To guarantee this, the 170/2010 Italian law [1] mandates that during the first years of primary school teachers are supposed to observe students to check if their evolution in reading, writing, and calculation skills are in line with their peers. If teachers notice that a student's development is subpar, they must try to compensate their difficulties with additional training; if the gap is not filled after the skills enhancement attempt it is likely they have a SLD, and teachers must report the case to the child's family and, eventually, to clinical professionals for further evaluation. This process presents several criticalities, like the teachers' lack of training or the length of waiting lists [2]. In addition to these problems, the lockdowns related to the COVID-19 pandemic impacted not only children's performance and mental health [3], but also SLD management [4]. The screening process, in fact, is much more difficult to carry out remotely, since the observation may not be as effective as in-presence, making it harder for teachers to exploit the benefits of personalized plans without adequate inspection upstream. Moreover, adherence to this kind of training is not guaranteed, as, without enough motivation and the control of a school environment, students may just ignore the proposed exercises, particularly if they find them challenging [5].

The pandemic was, however, a catalyst for technological development to cope with these new challenges, even leading the Italian Ministry of Education to include technological tools in their SLD managament guideline [2]. A recent European project, ESSENCE (Empathic platform to personally monitor, Stimulate, enrich, and aSsist Elders aNd Children in their Environment), is aimed at designing and developing a platform to support vulnerable populations (children and elders) through home-based care. In particular, the portion of the system catered to children includes several modules that strive to enrich every step of the SLD screening. In this work, we focus on ESSENCE's training tools, a set of serious games covering the three areas of learning: writing, reading and mathematics. The games were co-designed with psychologists, child neuropsychiatrists, teachers, and children by gamifying existing exercises.

The gamification process consists in the insertion of game design elements to exploit engagement, human competitiveness and ambition as strategies to make the user accomplish the task [6]. Some examples of gamification techniques are game elements, like points, badges, levels and scoreboards or leaderboards, game dynamics, with interactive elements and decision-making processes, parasocial relationships [7], and rewards [8].

However, gamifying reading, writing, or calculation exercises without distorting the rationale behind them is not an easy task; it means that the gamification features used can barely act on the mechanics and the stimuli, but have to focus on other aspects. To boost motivation in ESSENCE's users, we thus added an element which was external to the games: a system of rewards based on the collection of coins, which can be spent in an in-game shop to customize the main character, Bianchetto.

The central aim of this work is therefore to analyze the impact of the coins system and, later, of the shop, on the usage frequency of the games and on the children's performances in the games.

II. MATERIALS AND METHODS

A. Co-design of the rewards system

The target users of the ESSENCE platform are children attending the first and second year of primary school. One of the main principles adopted in the creation of the platform was that of co-design, which consists in the involvement of the relevant stakeholders in the design process. For the development of the shop, we involved clinicians, teachers, and children that were participating in the pilot testing of ESSENCE and were thus already acquainted with the platform and the games. Firstly, we organized focus groups (FGs) with clinicians and teachers, to identify which gamification factors were, in their experience, the most effective to boost adherence and motivation in primary school children. Then, we organized an in-presence FG with children, during which they were asked questions to investigate their opinions about a system of rewards, their preferences in terms of items to buy in an hypothetical shop, and the way in which they would have liked to customize the serious games experience.

Finally, the shop was developed using Unity 2021.3.8f1 (https://unity.com/).

B. Pilot testing

The ESSENCE project's platform was tested during a pilot testing phase which started in December 2021, and lasted until December 2022, whose protocol was approved by Politecnico di Milano's Ethical Committee n. 04/2021, date of approval March 23, 2021. 66 children participated, 30 females and 36 males; 21 of them were attending first grade, while 45 were in second grade. During the pilot testing, children were given a tablet (Samsung S6 Lite with the Samsung S-Pen) on which we gradually released 21 serious games, which implemented gamified exercises in the domains of reading, writing, and calculation. Even though access to the games was unrestricted, the families of the participants were instructed to monitor the children to avoid excessive usage and to encourage them to use the games once a week under the guidance of a teacher. The coins system was introduced on May 26, 2022, while the shop was introduced on October 24, 2022. For every element of the platform, from the shop to the games themselves, low-fidelity prototypes were used to gather feedback and refine the designs accordingly.

During the pilot testing phase, the serious games logged their results on the ESSENCE servers, recording the children's performances along with the number of coins they earned and the items they bought.

At the end of the pilot testing, the activities in the ESSENCE project were evaluated. Among other questions regarding the project, we asked:

- What did you like the most about the serious games?
- Do you have any suggestions to improve the serious games?
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- Do you have any suggestions to improve the ESSENCE project?

C. Data analysis

Data analysis was performed offline in Python 3.8 (https://www.python.org/).

Our hypothesis aimed to test whether the utilization of serious games increased following the implementation of both the coins system and the shop. We thus extracted the number of entries from the database to compare the frequency of usage before the introduction of the coins, between the introduction of the coins and the introduction of the shop, and after the introduction of the shop.

It is not enough to simply increase the usage of a tool, but its increased usage should lead to an improvement of performances. We thus chose the game that was played the most and which had some sort of quantitative measurement of performance, then computed the Moving Average of its results. We used a Friedman test to compare the distributions of the accuracy in each phase, identifying the phases that differ significantly with a Nemenyi post hoc test. Finally, we used the `ruptures` library [9] to locate change points in the time series. We used the Dynamic programming algorithm in the library, which needs to know in advance how many points to find. We firstly set this parameter to 1 to identify the most relevant change point, then we increased it up to 3 to locate other interesting dates.

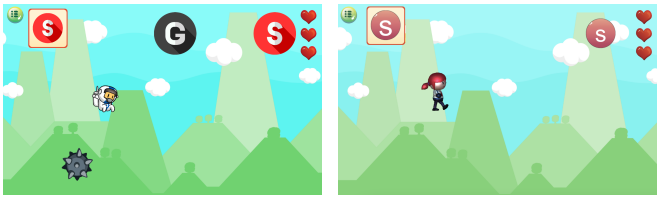
III. RESULTS

A. Co-design of the rewards system

The FG with clincians highlighted the impossibility to distort the serious games' mechanics in favor of gamification. Because of this, the techniques chosen were rewards and customization, which act on factors that are external to the games themselves.

Regarding the children FG, the vast majority of the suggestions that emerged regard clothing, while the remaining ones concern the appearance of Bianchetto (shape of facial features, color of skin). It was thus decided to allow the customization of the character in these two aspects, while ignoring other popular customization options, such as animations, or voices.

The results from the FG were also used to define how to structure the collection of currency. To encourage children to explore all of the games, we introduced three different currencies, one of each learning domain, instead of having just one type of coins. The type of coin is determined by the domain to which the game belongs and is symbolized by an icon coherent with its setting: leaves for reading, which is set in the forest; suns for writing, set in the savannah; droplets for calculation, set in the pond. The number of coins that games grant ranges from 1 to 10, proportional to the child's performance, but never amounting to zero. This was done in accord with the advice of clinicians and teachers, to



(a) (b)

Fig. 1: A screenshot of the game Quick catch **(a)** without the customized character and **(b)** with the customized character.

encourage children who may struggle with some games and avoid feelings of mortification.

Regarding the way in which children wanted to make use of the items bought in the shop, during the FG the idea of seeing the customized character inside the game themselves emerged. Therefore, after the introduction of the shop, we included a dressed-up version of Bianchetto in some of the games. This can be observed in Figure 1.

B. Description of the shop

The final version of the shop can be observed in Figure 2. The coins' values are retrieved from the user's profile, which is stored in ESSENCE's database. We included a tutorial, which is loaded automatically the first time the shop is open and can be then accessed through a button.

Fig. 2: Final shop implementation

C. Pilot testing

By the end of the pilot testing, 3 first-grade children and 2 second-grade children had dropped out of the study because they had changed schools. Because of this, the final questionnaire was filled by 59 children. Regarding the unstructured questions about preferences, we reported the answers in Figure 3. Regarding the suggestions, most children wished either for more games or for more customization options.

D. Impact of the reward system on the adherence and the performance

1) Game usage: The total number of usages of the serious games was 6822. Table I reports the number of usages and the weekly frequency of usage in the corresponding period.

TABLE I: Usage of serious games.

Period	*N. of usages*	*N. of usages / week*
Before coins	1462	84.0
Between coins and shop	3112	145.6
After shop	2248	403.2

(a) (b)

Fig. 3: Word clouds of the preferences of the children regarding **(a)** the serious games and **(b)** the whole project.

2) Game performance: To check if the introduction of the rewards had any impact on the performance in the game, we chose to analyze the results of "Quick catch", a reading game, which was the one that children appreciated the most. It was the second most played game, at 1258 times. We discarded the most played game, "Tunnels", as it did not have an objective quantitative measure of performance, while "Quick catch" had a numerical outcome, namely the accuracy. The average accuracy values can be found in Table II. The results are shown in Figure 4, while the Moving Average of the accuracy can be observed in Figure 4..

TABLE II: Average performance of Quick catch.

Period	*Accuracy*
Before coins	0.66 ± 0.24
Between coins and shop	0.86 ± 0.16
After shop	0.87 ± 0.13

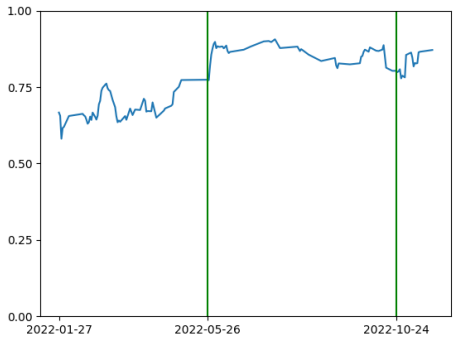


Fig. 4: Plot showing the Moving Average of the Quick catch accuracy, along with the date of introduction of the coins and of the shop.

The Friedman test found the averages of the accuracy were different in the three considered periods (t: 39.18, p-value < 0.001). The post hoc test located differences between the period before the introduction of the coins and the other two (p-value < 0.001), while the introduction of the shop did not generate a significant difference. The `ruptures` library detected the day of the introduction of the coins as a breakpoint in the trend of the accuracy. Conversely, the day of the introduction of the shop was not detected as a change point, not even when increasing the number of breakpoints to look for.

IV. DISCUSSION

Specific Learning Disorders (SLDs) are conditions that impair the ability to process information and cause difficulties during schooling. To strengthen the training, which is necessary to alleviate their effects, we co-designed with teachers, clinicians and children some gamification elements to enrich the serious games of the ESSENCE project. We identified rewards and customization, in the form of coins and of a shop, as adequate techniques. Children tested the serious games during a year-long pilot, at the end of which they filled a satisfaction questionnaire. To verify whether the aforementioned gamification elements contributed to an increment in usage and an improvement in performances, we compared the weekly usages of the games before and after the introduction of the coins and of the shop, along with the average accuracy obtained by users in the most relevant game. We then used the `ruptures` package to identify changes in the trend in this game's accuracy.

The pilot testing included 66 first- and second-grade children, who played the serious games for a total of 6822 times. Looking at the number of uses per week (84.0 before coins, 145.6 between coins and shop, 403.2 after coins) it is apparent that the introduction of the rewards caused an increase in usage frequency, which grew even more after the introduction of the shop.

Accuracy was then taken into consideration, comparing the average results in the three different periods. It emerged that the average accuracy increased over time (0.66 ± 0.24 before coins, 0.86 ± 0.16 after coins, 0.87 ± 0.13 after the shop), although the starkest difference is the one consequent to the introduction of coins. The Friedman test and the Nemenyi post hoc test confirm this, since it emerged that the three periods have different averages of the accuracy (t: 39.18, p-value $<$ 0.001), but only the differences between the first period and the other two were significant ($p < 0.001$). The increasing of performances by itself is surely not enough to impute credit to the gamification elements, since other confounding factors, such as the increasing familiarity with the games and the age of the children, may have influenced this increment. However, when looking for breakpoints in the trend of accuracy, the first point that was detected was exactly the introduction of the coins. This suggests that the impact of the rewards on the performance was strong, and that their introduction was not the sole cause, but a driving force that brought children to engage more with the games, acquiring more familiarity, and achieving better results. Conversely, the introduction of the shop was not relevant. This may be explained by its late introduction, or may mean that children did not necessarily need a way to employ the rewards that they earned during the games, since the satisfaction of collecting the coins was, in itself, a sufficient reason to engage with the games more. However, the shop was particularly appreciated by children, as emerged from the questionnaire, so its importance should not be undermined, particularly because it is plausible that the appeal of the coins' collection came from the knowledge that they would have a way to spend them. It is also important to note that some children stopped caring about the collection of coins after they had acquired the items they were interested in. Consequently, the shop could be a source of further engagement if enriched with more customization options.

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