The Design of Web Games for Helping Young High-Functioning Autistics in Learning How to Manage Money

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Abstract. We describe the design of a Web-based game application aimed to support high-functioning individuals affected by Autism Spectrum Disorder in gaining skills that can help them understand the concept of money and apply it in practical life situations. In order to evaluate the effectiveness and usability of the games, a user study involving six high-functioning ASD individuals in their teens and above was carried out. Preliminary results were encouraging and showed the potential advantages of such a system for training end users on practical life skills. We report on the redesign of the application that has been performed taking into account also the feedback gathered in the empirical validation. During the redesign we also added a more realistic game involving interaction with a vending machine, a tool that is commonly used by teenagers to buy snacks or drinks.

Keywords: Accessibility, Autism Spectrum Disorder, Serious games, Web

1 Introduction

Autism Spectrum Disorder (ASD) refers to a broad range of neurodevelopmental disorders characterized by difficulties with social communication and interaction as well as restricted, repetitive and stereotyped patterns of behaviour [1]. While the exact ASD causes are unknown, it is believed that both genetic and environmental factors play a role in its development [2]. The term "spectrum" refers to the wide range of symptoms and levels of disability in functioning that affected people could display. Across it, three levels of functioning (low, medium, and high) are identified according to the severity of the disorder and thus the extent to which quality of life is negatively impacted. People who are affected most are called "low functioning", and they have quite severe impairments in all the three areas of reciprocal social interaction, communication, and repetitive behaviour.

On the other extreme there are those whose quality of life is impacted less ("High Functioning" or HF): although they have a close to normal IQ (some even exhibit exceptional skills in specific areas), and language development can be normal, they have reduced social relationships connected with difficulties in starting or maintaining a conversation, deficits in emotional expression and recognition, limited range of interests, as well as troubles with organizational skills and abstract thinking.

There are many evidences [3, 4] that interactive technologies can be valuable tools in supporting computer-based learning of the core problematic areas of ASD (e.g. communication, affective and interaction skills). Indeed, currently there are several technological solutions for supporting autistic people [3]: it has been noted that many individuals on the spectrum have a natural affinity with computers [5] due to the predictable and repeatable nature of technology that can create controlled environments, and which thus appeals to those who feel relieved by stability and routine. In addition, people with autism have strong visual processing skills, making them good candidates for approaches such as Augmentative and Alternative Communication (AAC) [6] and video modelling [7]. However, in spite of the growing attention paid to developing assistive applications for autistic people, we noted that so far most tools mainly address children developmental disabilities (social, cognitive, emotional, motor) within the ASD spectrum (see e.g. [8]). This may be due to the fact that earliest interventions (even starting from childhood: a first diagnosis can usually be made by the age of two) can give the highest chances to improve the core behavioural symptoms of autism. Thus, most work has concentrated to this age range. Less attention has been dedicated so far to other groups of autistic individuals which might need to gain different types of skills. This is the case of ASD adolescents and early adults, especially those characterised by a high functioning level. For such people, interventions might be needed helping them to achieve a more autonomous management of practical problems of daily living, for instance managing money and purchasing things, which can involve non-trivial aspects in cognition (recognize currency notes), decision-making (decide whether the object and the cost are congruous) and even mathematical competences (calculate exact change). The motivation of the lower interest that this category of users has attracted so far may be the fact that their high functioning nature makes their condition less visible to society, often leaving them with no support for coping with their real life problems [9] during their transition to early adulthood. Such challenges, often connected with e.g. increased demands of social relationships, self-determination/self-efficacy and more independent living, make adolescence and young adulthood one of the most difficult developmental periods in the life of these individuals. This situation is also exacerbated by the fact that public services tend to decline for ASD individuals after they leave high school, which is in turn frequently associated with substantial reduction (or even absence) of daytime activities such as higher education or work, and a disappointingly reduced decreasing of ASD symptoms for HFA (High Functioning Autism) individuals during those developmental periods [10].

To alleviate these issues, we have designed and developed with the support of relevant stakeholders and users a set of games aimed at helping HFA autistic adolescents and early adults to more autonomously manage their life, more specifically to learn money management and associated mathematical skills, which are both much needed by these users [11, 12].

In particular, the goal is to make them understand money-related concepts and how to apply them in practical situations, so that they can carry out everyday activities related to it. The games have been organised in a responsive Web application with multiple difficulty levels to support gradual learning. The paper is organized as follows: next section presents related work, then in Section 3 we describe relevant requirements that have driven the design of the application and how they were gathered. Section 4 presents the implemented prototype while Section 5 reports an evaluation conducted with six HFA individuals. Section 6 describes how the application was redesigned according to the feedback collected during the test. Finally, we conclude with some remarks and plans for future work.

2 Related Work

In recent years there has been a sharp rise in the number of research work specifically developed for ASD population. However, as highlighted in [13], everyone diagnosed with the ASD disorder is remarkably different. Thus, on the one hand it is extremely difficult to make generalizations, on the other hand developing new software and technologies for this incredibly diverse population is really a challenge.

In the autism spectrum scale of functioning levels, HFA people represent the sub-group who get the least severe form of disability, generally characterized by the absence of language and cognitive impairments. As such, their disability can be less visible to others. We also noted that many contributions have focused on children and their learning and developmental related issues [14] because earliest interventions have the highest possibility to achieve the most benefits. Less studies support high-functioning teenagers/early adults in more autonomously managing their everyday life by means of training them in skills that can be generalizable and transferable to practical everyday situations (e.g. shopping) [20]. Another issue that should be taken into account when addressing HFA individuals is the fact that, although they do not show any specific problem on language, they often exhibit deficits in basic mathematics instructions and calculations [17, 18], which can have implications in practical situations such as money computation. The problem of training ASD people on shopping skills has been considered in Kirana [22], a gesture-based application that simulates a real world scenario to teach practical skills to individuals with developmental disabilities. The findings suggest that applications that employ gesture-based interaction to simulate real world scenarios in a safe and controlled environment can provide learning that is translatable from virtual worlds to the real one. However, differently from our case, the range of people considered in their tests was very variegated because it included individuals with Down syndrome, mental retardation, autism, and cerebral palsy.

In [23] an application aimed at assisting autistic teenagers in organizing their lives and enhancing the communication between autistic teenagers and their caregivers is proposed. In [24] authors focus on the fact that adolescents with ASD often have enhanced spatial cognitive abilities but less efficient hand-eye coordination. Thus, their main research question is to understand whether adolescents with ASD perform 3D interaction tasks differently than typically developed adolescents. To address this question, they present a user study including adolescents without ASD (used as controls) paired with adolescents with HFA. Participants performed a series of basic 3D rotation and translation matching tasks. Results suggest that the ASD group's deficits in hand-eye coordination may have influenced their 3D interaction performance more than their spatial ability did. While this work gives insight into the usability of 3D interaction for adolescents with ASD, it focuses on a peculiar type of applications and, as such, their results cannot be easily transferable to more common user interfaces such as Web applications, which we considered in our solution.

3 Requirements

In order to define appropriate requirements, we involved relevant stakeholders in the process, mainly speech therapists and psychologists with experience providing care to ASD people.

In particular, we had five meetings with a speech therapist involved in educational and therapeutic activities for autistic people in a local health centre. Thanks to her knowledge of the needs of autistic people, we were able to collect several requirements that have driven the co-design and development of the application. We started by identifying current gaps, focusing on topics and skills that are currently difficult to teach (or are not taught at all) to HFA people in their teens or above with traditional methods, and the potential benefits that personalised and motivating computer-based exercises can bring to such people, also because they can practice them autonomously (e.g. without the support of the caregiver) even in their family settings. The approach used was iterative and we progressed from ideas just sketched out at the beginning, to more refined design concepts which were then implemented in prototypes that we discussed during such meetings. As such, the application was designed in a participatory manner: caregivers (e.g. the speech therapist) participated in all the phases of the application development (while end users were involved only during evaluation) and we progressively discussed and captured caregivers' reactions to the application we were going to develop. In particular, during such meetings the speech therapist provided us with useful insights about typical challenges HFA users have to face when they confront real life activities such as managing money. She also pointed out typical difficulties such individuals encounter when interacting with a computer, for instance difficulties with text comprehension and risks of distractions. In addition, she also reported typical strategies that therapists use to avoid upsetting their users in their care while smoothly progressing towards expected learning objectives. For instance, they try to avoid explicitly disagreeing with their patients or saying 'no' to them, also because HFA individuals do not have advanced coping strategies to deal with frustration and regulate their emotions. In addition, we also discussed with the speech therapist typical exercises that trainers usually provide to HFA users in order to improve skills they are in need of, and which currently are often carried out by interacting with paper-based tools with the help of caregivers.

Other requirements arose from discussions with psychologists/educators that helped us recruit HFA people for the test: we also involved them to get further requirements, so that their feedback could inform the development. For instance, a requirement clearly identified by them was to introduce clear specifications of what the user is expected to do at the beginning of each game session.

Moreover, in creating software applications for disabled users, it is crucial to follow certain already established accessibility guidelines and principles. Thus, in order to gather further requirements, we checked the literature for existing sets of guidelines [25, 26, 27] specific for developing applications for people with ASD, since users with autism may have a different worldview than designers. Indeed, for this group of users it is particularly important that the user interface design aims to reduce the software complexity and create an easy, natural, efficient and enjoyable environment to work with. For instance, among the guidelines that we applied, there is the need to simplify texts, which we exploited when explaining what the user should do to solve the exercise (this text was also accompanied by a corresponding audio to provide users with an alternative interaction channel). To improve the readability of the Web user interface, we also used clear fonts and avoided background images.

To sum up, the requirements we identified in the end were the following ones:

- *The visual channel as the primary modality*. The Web application should be mainly visual. In general, the number of elements in the page (e.g. text elements) should be kept at minimum to limit the sensorial stimuli, so reducing the possibility of users' distractions
- *Support for help*. Help should be provided to users so that they can be aided in critical points or when they are stuck in the application (e.g. by explaining what they have to do for proceeding in the game, how to interact with it)
- *Multimodal rendering*. Textual elements appearing in the game should also be rendered vocally in order to better support people having difficulties in reading. More in general, the system should provide alternative ways of interactions.
- *Explain complex procedures*. Complex activities should be explained by thoroughly demonstrating and highlighting the key points, also dividing them in smaller chunks. One example is the change concept, which was explained by using a video modelling technique.
- *Highlight key aspects*. It is important to highlight key elements in the application (e.g. adding a border around images on mouse hovering) so as to make them more visible. Another technique that was used in our case was to use colours as a supplementary means to better emphasise some information.
- *Support personalisation*. Due to the large variability in skills presented by autistic people, tutors should have the possibility to personalise the application to better cope with the specific needs and characteristics of the user at hand (e.g. customize the feedback by selecting between sounds or emoticons according to the user preferences). Different levels of personalisation should be allowed to the two types of users of the system (tutors and students)
- *Support a number of learning objectives connected with the concept of money*. This requirement covers a number of sub-goals: recognition of the different coins and banknotes not only in terms of their visual properties (e.g. colour, shapes), but also in terms of their name and actual value; support understanding the things that can be reasonably and realistically be bought with a specific amount of money; support learning the mathematical concepts of addition and subtraction which are needed to completely master the concept of money [21].

Starting from these requirements, we designed the application that we describe in the next section. The application was developed using standard Web technologies and it used responsive design to make it effectively rendered on different devices.

4 The Games

The resulting application was organised in such a way to reflect the main learning objectives that we identified (see Figure 1, left part): recognise the main currency denominations (banknotes and coins); learn how to manage the change due; learn what can realistically be purchased with a specific amount of money. For simplicity, we only considered showing the front view of banknotes and coins.

For consistency reasons some elements are common to all the exercises of the application. For instance, before the user starts to play the game, the application shows a text (accompanied by an audio) explaining what the user is supposed to do to solve that exercise. In addition, for all the games there is a "Help" button through which it is possible to activate a video that shows what to do for solving the game, by showing an example of use that considers values different from the ones involved in the game, so as not to provide solutions to the exercises. In addition, each page contains buttons to navigate through the application (e.g. go forward/backward), and a button to exit.

Smiley faces have been included in all the games of the application, also accompanied by special sounds indicating either error or success. A yellow smiley face appears only at the end of a successfully solved game, while a red unhappy emoticon is shown after each error. After the user makes two errors the position of the images on the bottom of the page is automatically shuffled so that the user cannot give answer by memorizing the positions of the images. The shuffling strategy was applied to all the games in this section except for the *Sum*, since in this game the coins rendered on the bottom are all the same, thus, applying a shuffling strategy would not bring about any change. The decision to not shuffle on the first error was suggested by the therapist, with the aim of providing users with a (simpler) "second possibility" to solve the game by themselves, while at the same time reducing the likelihood of failures.

The "**Money**" game was developed to train people in recognizing different currency denominations. When the user accesses this game, s/he can select one of three types of included games: "Image and image", "Image and text", and "Sum" (see Figure 1, top part). Image and Image presented 12 levels of difficulty, the other ones only 8 levels. This was done because the speech therapist suggested trying to have the same number of difficulty levels for each game in the same game section ("Money" in this case). Since 8 was the maximum number of combinations allowed by the "Image and Text" exercise, we decided having 8 levels, with the only exception for the "Image and Image" exercise, where at least 12 levels were needed to show all the considered coins and banknotes (from 1 cent to 10 euro).

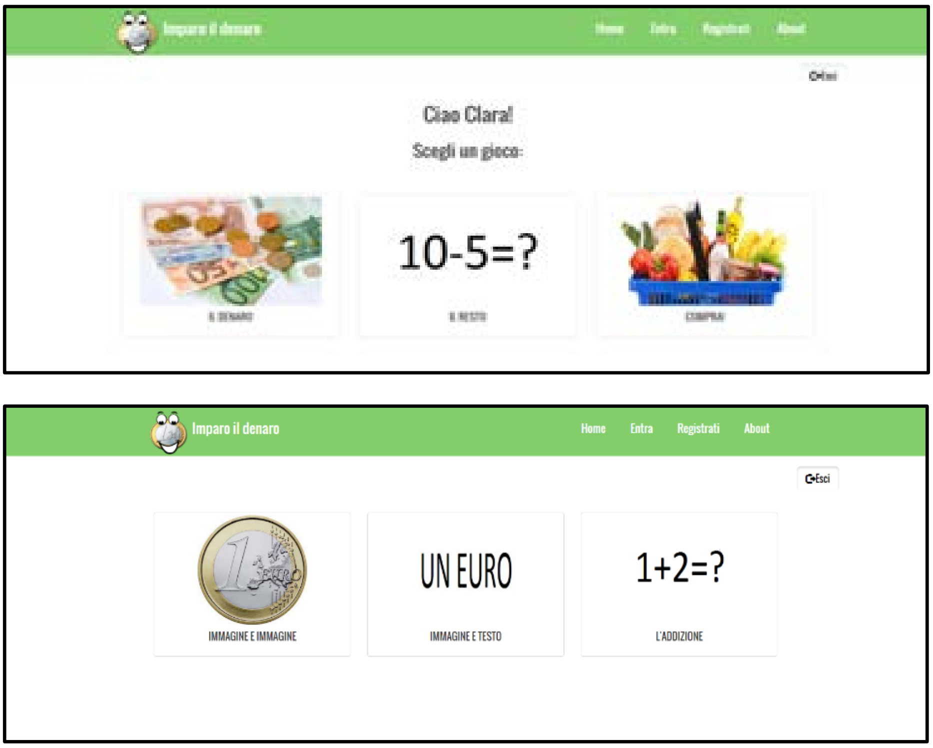


Fig. 1: On the top: The three main games. On the bottom: The three types of exercises included in the "*Money*" game.

Image and Image. The first game (Image and Image) supports learning how to identify the main currency denominations and forms in terms of coins and banknotes. The technique used to support learning of money denominations is *association*: the page is divided into two rows, and the user has to drag each coin or banknote visualised in the bottom row onto the corresponding similar coin or banknote shown in the top row (Figure 2 -left). If the user successfully completes the task, the associated coin/banknote is removed from the bottom row, and then the application shows a smiling yellow emoticon at the end of the exercise. If the user makes an error, a smiling red face is shown. This game presents twelve levels of increasing difficulty, i.e. the games become more challenging as soon as the user progresses in solving them. The level of difficulty is connected both to the number of elements to associate (i.e. the higher the number, the more difficult is the task), as well as to the similarity between the elements contained in the two rows. Once the user selects the "Image and image" game, the user has to solve the first level (the simplest one), which presents only three images (one in the bottom row and two in the top row). Each level of this game presents a series of 4 games having the same difficulty. The second level presents overall five images (two in the bottom row and three in the top row). The last level includes six images (three at the bottom and three at the top).

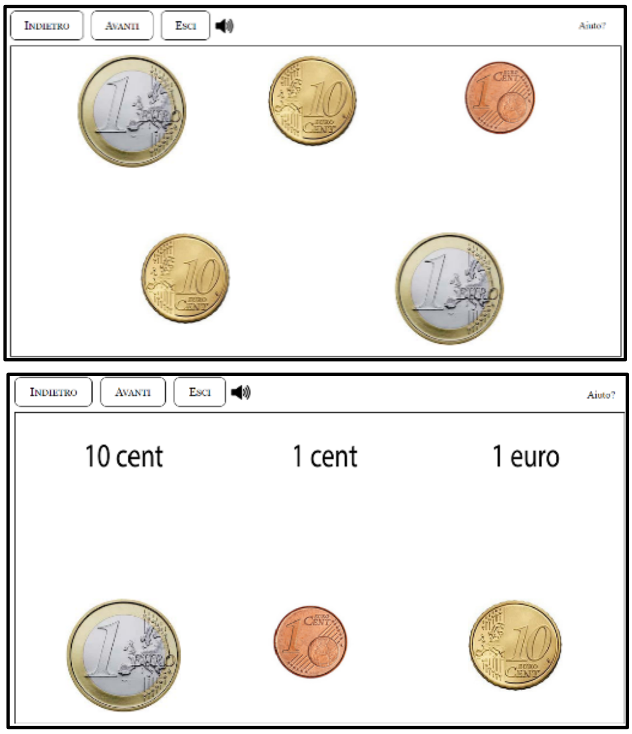


Fig. 2: Money game - *Image and Image* exercise (on the top); *Image and Text* exercise (on the bottom).

Image and Text. While the previous game aimed to help people learn how to distinguish the various coins and banknotes, this game is aimed to aid HFA students to learn their names by using image-text associations: the user has to drag the coin or the banknote on its corresponding name (e.g. “10 euro”). As you can see from Figure 2 (bottom), in this game decimals of euro were presented as “cents”, while the currency unit was presented as “euro”. This game has eight levels of complexity.

Sum. It aims to help users learn that, by combining coins and banknotes, it is possible to obtain further money values. Also in this case we used associations. In the top row the application shows a sequence of coins and banknotes with an in-between “+” sign, while at the end of this sequence, after the “=” symbol (see Figure 3-top) the image of an open wallet is visualized, with two buttons available: one (initially de-activated) to try again the game, the other one to signal that the exercise is finished.

To solve the game, the user has to drag in the wallet the precise amount of money needed to correctly solve the sum and then select the “Finish” button used to signal that the user has completed the selection of coins. If the exercise is correctly solved, a smiling yellow face will appear, otherwise a red face will be shown and the “Retry” button will be enabled. Also in this case, various levels of difficulty have been provided, ranging from the simplest one (where only two coins are combined), to the most complex ones in which also banknotes are included.

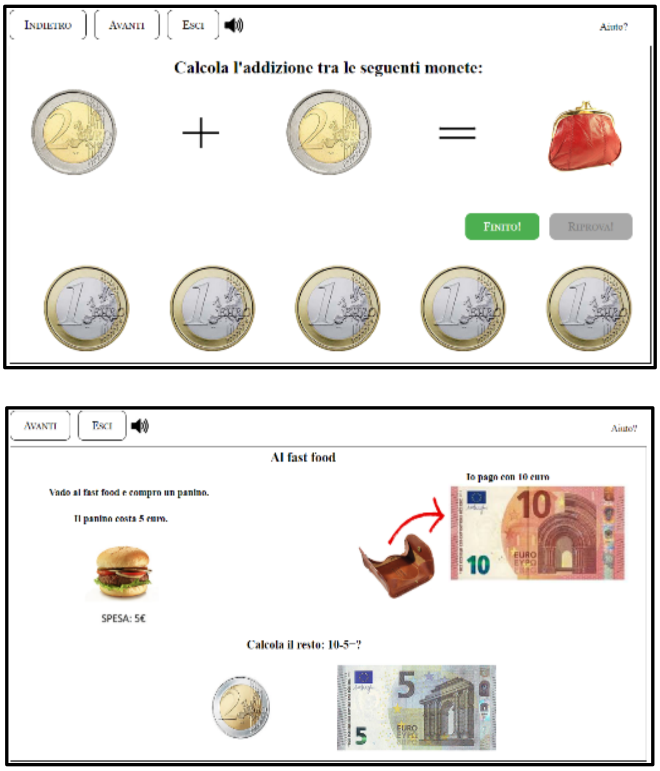


Fig. 3: Money game: *Sum* exercise (on the top); *Money Change* (on the bottom).

The “Money Change” game is dedicated to learning the concept of money change. Differently from the previous games, at the beginning the application asks the user to select a video model [7] of interest and, only after this, s/he can access the game. Video models are videos depicting exemplary behaviour: the user is expected to observe a videotape of a model doing the task (or the skill) the teacher wishes to teach, and then such model is subsequently practiced and imitated. Video modelling is a behavioural technique which has been shown as being particularly valuable for autistic people. In our case two video models were prepared, one having a male actor and another one with a female one, to better suit the preference of the user: both of them showed how potential customers should behave to buy items in a stationery store. During such videos some ‘focus’ elements were also used to emphasise key steps/objects on which users should concentrate their attention (‘focus’ objects are generally rendered in the video at a reduced speed and by zooming in them). After watching the video, the user could access the game, which was presented in a problem-like manner.

The application shows some scenarios of everyday life, and in each of them there is a purchasing action implying a change: the user has to solve the mathematical subtraction associated with the considered scenario (see Figure 3-bottom) by means of selecting, among the images available in the bottom part of the user interface, the one representing the right solution. In the videos we built, a customer wanted to buy a pen. Four 'focus' elements were used: i) the hand of the shop assistant when s/he says how much the pen costs (in this case: 1 euro). While providing the customer with the information about the cost of the pen, the shop assistant indicates with his/her finger the '1' number; ii) the second focus element is centred on the pen, which is concretely given to the customer in order to better reinforce the concept of purchasing; the remaining two focus elements are both directed towards the money: iii)the customer gives to the shop assistant 5 euros to pay the pen and then there is a zoom on the banknote and on the gesture of the customer while providing the money; iv) the last focus element is on the change that the shop assistant gives to the customer, to emphasise that, before exiting the shop, the customer should take the change. Also this game presents eight levels of difficulty.

The "Buy It!" game allows the student to learn what can realistically be purchased with a specific amount of money, by simulating a real situation. At the start of the game the user is presented with a "What can I buy with…" text in the top part of the UI, together with the amount of money considered. The question is further emphasized by an emoticon showing a thinking face (see Figure 4).

Fig. 4: The *Buy it!* game.

Then the user has to select among three different images (shown in the bottom part) the one that should correspond to the indicated amount of money. This game is the last one in the series of exercises since it implies that the user has already got the skills needed to solve the previous ones. It provided different levels of difficulty, smiling faces to indicate success/error, and a shuffling strategy applied after two user errors. In such games, we purposefully tried to include objects that could be of interests of such people (e.g. objects they could reasonably like to have), so as to make them learn skills helping them in deciding whether they would afford to buy something that they would like, so progressively understanding and getting a sense of what can be reasonably be bought with a specific amount of money.

5 Evaluation

We tested the application to assess to what extent it helps users in understanding the concepts associated with money management. The test was divided into three steps. We first submitted a pre-test questionnaire to gather demographic data. Then, the participants had to carry out five tasks (each task associated with a type of game) using the application. Finally, they had to fill in a System Usability Scale (SUS) questionnaire [16], for measuring the usability of the application. SUS is a 10 item questionnaire with five response options for respondents, from "strongly agree" to "strongly disagree".

We tested the application at the premises of an association supporting ASD individuals. The test involved six male HFA individuals, indicated in the following with a set of pseudonyms: Francesco, Jacopo, Gabriele, Giulio, Andrea, Mattia. All of them had been diagnosed with high functioning ASD (although some of them presented traits that would better locate them towards the lowest edge of the high-functioning level). Their age ranged from 16 to 22 years (M=18.5; SD=2.2). In order to better manage the participants during the evaluation, we divided them into two groups consisting of three members each, depending on their age.

One group (Francesco, Jacopo and Gabriele) was composed of three young adults (age range 20-22), all having a high school diploma. Their level of use of technological devices is high, the most used device is the smartphone, exploited for browsing the Web. Two users use both tablets and PC devices, one user never used tablets and he uses the PC just few times a week. All of them use such devices to browse the Web and play games. The three remaining users (Giulio, Andrea and Mattia) are teenagers (16-17 years old) still finishing secondary school. Their familiarity with devices was rather varied. While one user was particularly familiar with technology (having even some knowledge of JavaScript), another user occasionally uses a smartphone (e.g. to call his mother) and he did not have any experience with PCs. The last user had low familiarity with smartphones (used only for photos and Web browsing) and tablets, and very good familiarity with PCs (used for Web browsing and games).

The tasks assigned to the users were to access and complete every level of the five games developed in the application (Task1: Money/Image and Image game; Task2: Money/Image and Text game; Task3: Money/Sum game; Task4: Change game; Task5: Buy it! game). Participants had to use the application twice: the second try was carried out one week after the first one. This was done to understand whether any improvements in using the application could be detected over time. For evaluation goals, the web application was enhanced with a logging tool (implemented in JavaScript), which was mainly used to log user interaction times during the test. The test was done by using a Windows-based laptop having a 15,6" monitor with a 1366 x 768 resolution, and a AMD Quad-Core A8-6410 processor. Each participant was informed that he would be allowed to interact with each exercise for at maximum of 5 minutes. Since they had to solve five tasks, the total duration of the study for each user was about half an hour.

Task Success. The "Task success" metric is used to verify whether and how users completed the assigned tasks. Four success levels were identified: we assigned a "1" score if the user did not have any problem, "2" when just a small problem was found (e.g. two slight errors occurred and then the user was able to continue the interaction), “3” when the user made more severe errors, and “4” when the user was not able to solve the exercise at all. Figure 5 shows two stacked bar charts indicating the success level for each task in both tests. During the second try we obtained higher scores than in the first one.

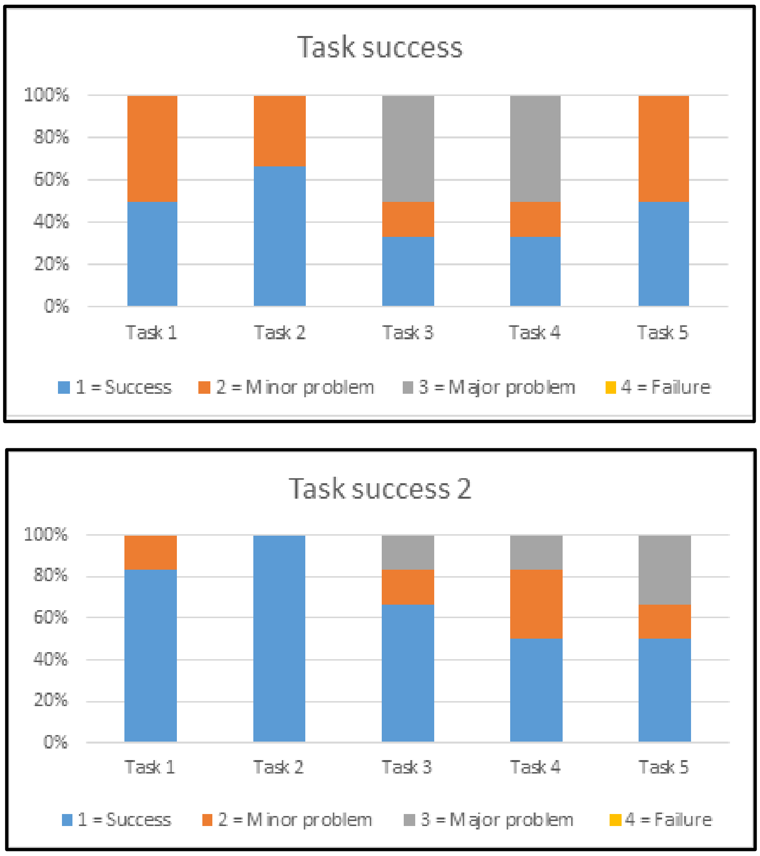
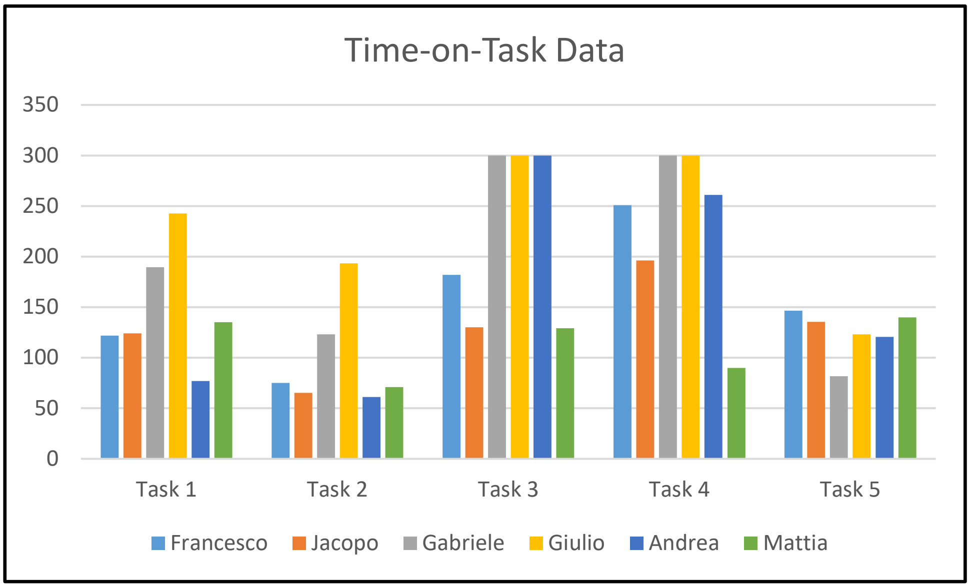


Fig. 5: *Task success* – First test (top) and second test (bottom).

In particular, in the second trial, we had a higher number of tasks successfully carried out by users, and the number of errors due to major problems were less than in the first trial. Only for the last task (task 5) a few major problems occurred in the second trial and not in the first one. This happened mainly because Francesco was a bit tired and considered the game easy, thus he did not pay sufficient attention in the task performance.

Time on Task. Data related to this metric was collected by using a logging script, mainly to record interaction times.



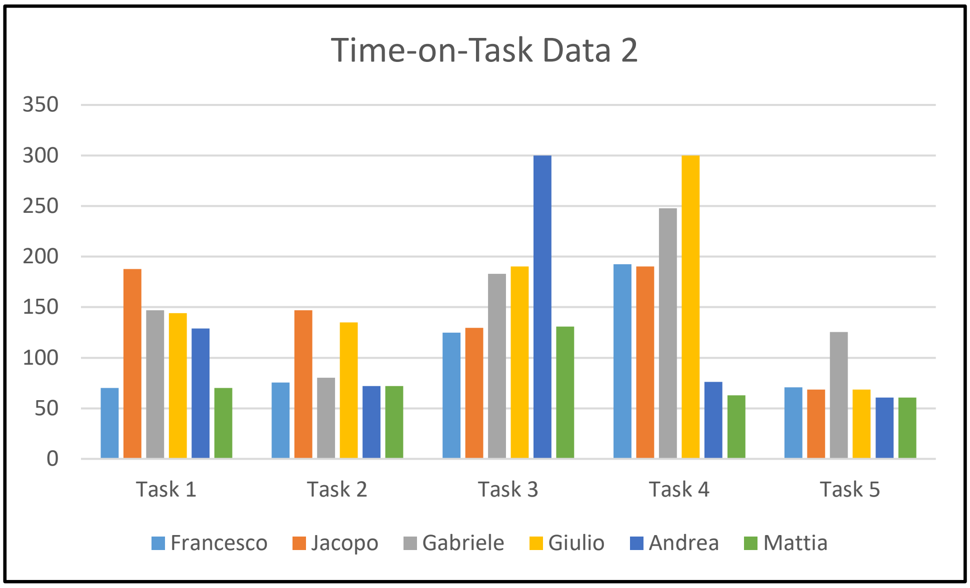
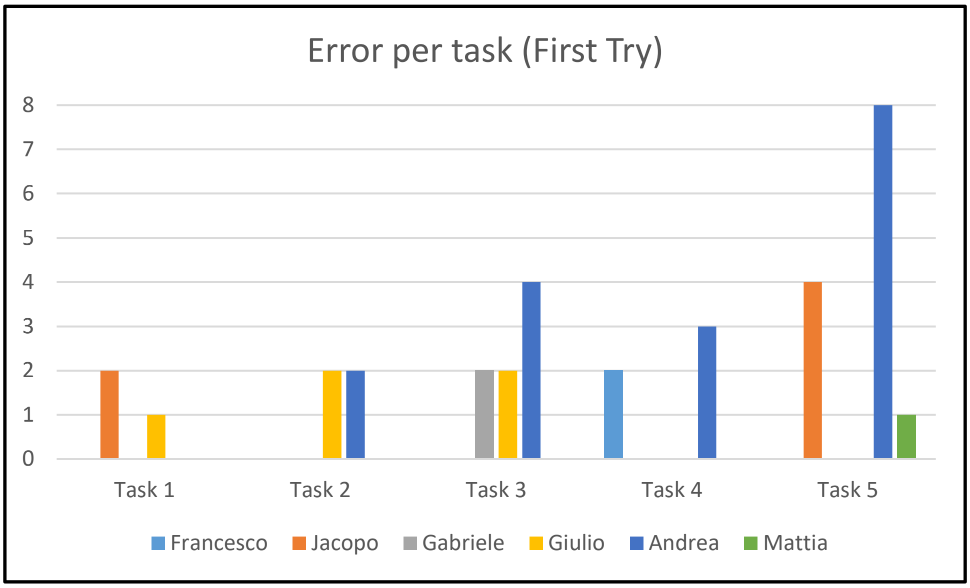


Fig. 6: *Time on Task* in the first test (top) and in the second test (bottom).

We gave a maximum of five minutes to solve each task, and then we verified whether in this interval of time the user was able to solve the exercise. If not, the evaluator recorded the last level reached by the user. Levels reached during the two trials were then compared to each other. In this comparison, other factors were also considered, e.g. errors made and requests for help. Regarding the levels reached, we obtained improvements in this metric for all the tasks over the two tests.



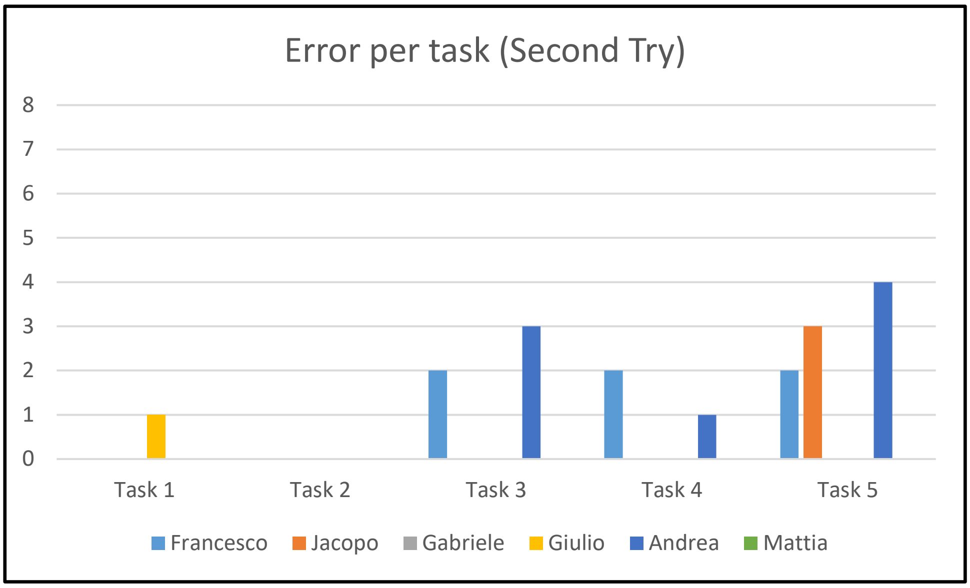


Fig. 7: *Errors* in the first test (top) and in the second test (bottom**)**

For task1, task2, and task5, all users reached the maximum level in both tests; for task3 and task4, four users (out of 6) reached the maximum level in the second test; the remaining two users (namely: Andrea and Giulio) both reached the penultimate level in one task and the last level in the other one. This also confirmed the fact that the 5 minutes assigned for completing each task was overall reasonable. The results on the task performance time metric gathered in both trails are shown in Figure 6 (top and bottom), where the X axis refers to tasks and Y axis refers to time on task in seconds. Lower and upper bounds were also calculated on such data: apart from one case associated with lower bound values on Task 2 (namely: 72 seconds in the second session and 61.2 seconds in the first session), time on task improved overall between the two sessions.

Errors. We also counted the number of errors made by the participants and also in this case, overall, we obtained improvements, since it decreased between the two evaluation sessions (see Figure 7 top and bottom). The only exception regarded Francesco, who in the first trial made just two errors in the whole test, while in the second session he made two errors in the last three tasks. In the execution of the second test, the moderator reported that Francesco, probably due to his previous experience with the application (in the first try), may have felt a bit overconfident, which in the end could have compromised the resulting accuracy in solving the games.

Satisfaction. In order to assess user satisfaction, we administered the SUS questionnaire, which was filled in by users at the end of each session. According to Jacopo, Francesco and Andrea, the application was not very usable (they got 50, 52.5 and 60 scores respectively), whereas the other three users judged it usable (the scores were 100, 85, and 77.2). In this regard, the moderator noticed that, while filling in the questionnaire, users seemed a bit tired and not very motivated to spend time and effort on an activity which was not strictly related to using the application.

In the first trial the group composed of Francesco, Jacopo and Gabriele showed difficulties with calculations (some of them even used the calculator during the test). Another problem was connected with reading the texts included in the "*Image and Text*" game, which particularly affected the performance of one user. Just one user indicated the need for more time to solve the games (i.e. longer than the allowed one: 5 minutes). Another user complained about the smiley faces used in the games. Users found the "*Image and Image*" and "*Image and Text*" games too simple, whereas the "*Sum*" game was found a bit too difficult. During the second session some of them showed some progress.

Regarding the other group (Giulio, Andrea and Mattia), contrasting comments came from them in the first trial. Two of them evaluated the application nice but not particularly engaging in some points, whereas one found the application both valuable and stimulating. Giulio and Andrea had problems with calculations (in the *Sum* and *Money Change* games). Mattia had just one concern in the *Buy it!* game as he thought that different things shown in the game could be bought with the same amount of money. Mattia and Francesco did not appreciate the provided audio feedback much. During the second test, two of them showed evident performance improvements.

6 Revised Application Design

A revision of the application design was motivated by the comments received through the user test, which encouraged us to make some changes, since not all users were completely satisfied. For instance, some users felt a bit annoyed by the sounds that were provided as positive or negative feedback (although other users did not express any particular negative feeling about such sounds). However, taking into account the peculiar diversity that characterizes ASD individuals, we judged it relevant to add for the tutor the possibility to personalize the application according to user preferences. To this goal, within the tutor page showing the information associated with the students, we included a checkbox (see Figure 8) to activate (or deactivate) the playing of such sounds for each user. This setting did not affect the vocal support provided in the game to explain the students the tasks to do, which was provided in any case. In addition, the tutor can select specific audio files to use in the games, as well as set the most suitable volume level, according to the preferences of the concerned user.

Another aspect that was involved in the customisation is the colour of the pages. Although we did not gather any specific comment in the user test on this aspect, we judged it useful to add it in the customisation support. By default, the application has a white background, a neutral colour chosen to avoid bothering or distracting users. However, taking into account that ASD individuals can show specific (and sometimes atypical, see e.g. [19]) preferences or aversion for some colours, we gave the tutor also the possibility to change the colour of the games based on the user preferences. To do this, a colour selection palette has been added to the tutor page: when the tutor chooses a specific colour, the background colour of the panel containing the images of the game changes, whereas the background colour of the whole page remains unchanged. Another customization option that we gave to tutors was the possibility to choose specific images for providing positive and negative reinforcements. By default, they are colorful (happy and unhappy) smileys, but tutors can choose other images (i.e. from their local disks).

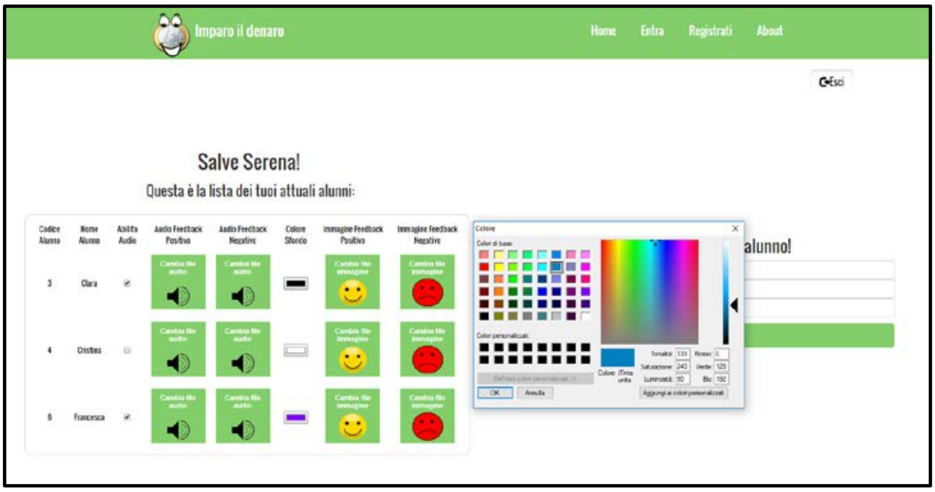


Fig. 8: Support for customization.

An additional modification was the inclusion of a further game to assess the capability of users to exploit the skills learned through the application in more realistic settings. Indeed, HFA individuals have problems with abstract ideas and conceptual thinking, with difficulties in generalizing what they learned from one setting to another one. Thus, teaching through multiple examples across various settings in which skills can be used should help them in applying learned concepts to different situations and more easily making connections between the various learned abstract concepts (connected to e.g. maths and money) and their concrete experiences in everyday situations. As such, we judged it relevant to offer such students another scenario in which they could practise the acquired money-related skills. Following the suggestion of the speech therapist, we considered the interaction with a vending machine as the scenario for the additional game we developed for the application, since vending machines (to buy e.g. soft drinks or snacks) are very popular among adolescents who are at a stage in life in which they experience increased autonomy, even in terms of some discretionary availability of money. Thus, this was judged a relevant situation for HFA teenagers/early adults to be confronted with.

The structure of the new game mostly exploited the visual modality to facilitate ASD learning. When the student accesses the game, the image of a vending machine is rendered, showing various types of products, i.e. chips, chocolates and drinks. By selecting one of the various images representing the products offered by the machine, the corresponding identification number associated to each product appears. When the user finds an item s/he is interested in purchasing, s/he selects the related image, types the associated identification number by using the numerical keypad, and then selects the button to confirm the entered number. At that point, various coins appear below the image of the product. We decided to use only coins because it is more common to insert them in a vending machine than banknotes. Above such coins there is the image of the product that the user selected, accompanied by its price. In order to purchase a product, the user must enter the appropriate amount of money.

The game has various levels of difficulty, associated not only with the number of coins needed to purchase a certain product (i.e. for basic levels users need to insert just one coin), but also with the fact that when users enter too much money, they must indicate how much they would get as change. Although this does not completely reflect what typically happens with real vending machines, it was included as a further exercise to practise the concept of change due. In particular, in case of simple games the user has the possibility to insert two types of coins: one is correct and the other one is wrong. When the user enters the correct amount, a green tick appears next to the slot indicating that the student has provided the correct answer, otherwise a red cross appears. For the games that provide the opportunity to get the change there are two types of amounts that the user can enter, one "wrong" and one right. Since there are various coins to be inserted, every time the user drags the coin into the slot, a counter appears above the slot showing the amount the user has currently inserted in the machine. When the amount entered by the user is higher than the actual price of the product, the following sentence appears: "You have entered <amount entered>. How much change is due?". Under this sentence two types of coins that correspond to the change appear, one is right and one is wrong. When the user provides the right answer, the green tick appears next to the correct coin, otherwise a red cross appears next to the wrong coin.

Fig. 9: The vending machine game.

Regardless of the difficulty of the game, when the user has to insert the coins in the slow, the slot is visualised as enlarged and, to further draw user attention towards it, an arrow indicating the slot also appears.

The techniques used for supporting the game are matching and selection. In order to insert the amount inside the vending machine, the user should drag the coins into the slot, imitating also a real gesture. Instead, when the user has to indicate the change, the answer modality is different because in this case s/he has to select the correct coin.

The new game added to the application was designed to continue the initial training through which users can learn the various sizes of money and their names. At the end they can test the skills acquired using the vending machine, an instrument that they can really use in their daily life.

7 Conclusions and Future Work

In this paper we present a game-based Web application aimed at supporting high functioning ASD people in their teens and above to gain practical life skills connected with money management. A user study was conducted with six high functioning ASD individuals to assess its effectiveness and usability. Overall, the test shows encouraging results in the potentiality of training high functioning ASD individuals in acquiring skills associated with money management. In addition, being a Web application, it can be autonomously exploited by users whenever they want, and at their own pace, without the need of being supported by caregivers.

The results gathered in the user tests, while promising, encouraged us to revise the design of the application, by including a customisation support for enabling tutors to configure specific settings according to which the application is adapted. In addition, a further game was included to make students practise the learned concepts in a scenario that resembles a situation which they should be familiar with. The redesigned application has not been empirically validated.

For future work, we plan to conduct further user studies to assess the effectiveness and usability of the redesigned application, and to carry out additional work to make the application more personalised and adaptive to user's needs, preferences and behaviour. We also plan to evaluate whether and how students will actually be able to apply the skills acquired through the games in real contexts. Indeed, it is a well-known issue that ASD people who undergo specific learning interventions typically do not show the ability to generalize and transfer the learned skills to novel, different, practical situations of real life. Thus, further studies (e.g. with larger samples, including control groups, lasting longer treatment periods) are needed to attain deeper knowledge of the efficacy of such computer-based interventions in supporting users' ability to apply the learned money-related concepts to practical real-life contexts, and to understand the long term effects of such interventions to assess whether changes remain stable in time. In such future tests, we also plan to consider other types of evaluation tools, even in combination with each other, e.g. video recording, eye tracking, to have more comprehensive information on user behaviour, while avoiding relying too much on user-reported data.

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