Supporting Young High-Functioning ASD Individuals in Learning the Concept of Money

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Abstract. We describe the design of a game-based Web application aimed to support high-functioning individuals affected by Autistic Spectrum Disorder in gaining skills that can help them to understand the concept of money and apply it in practical situations of life. In order to evaluate the effectiveness and usability of the games, a user study involving six medium/high-functioning ASD individuals in their teens and above was carried out. Preliminary results were encouraging and show the potential advantages of such a system for training end users on practical life skills.

Keywords: Accessibility, Autistic 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 [6] 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) [7] and video modelling [8]. 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. [9]). 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 manage 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 [10] 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 abatement of ASD symptoms for HFA (High Functioning Autism) individuals during those developmental periods [11].

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 also associated mathematical skills, which are both much needed by these users [12, 13]. In particular, the goal is to make them understand the concept of money and how to apply it in practical situations so that they can carry out common everyday activities related to it. The set of games is a responsive Web application and is organized in multiple difficulty levels in order to support gradual learning.

In recent years there has been a sharp rise in the number of research work specifically developed for ASD population. However, as highlighted in [14], 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 and, as such, their disability can be less visible to others. We noted that many contributions have focused on children and their learning and developmental related issues [15] because earliest interventions have the highest possibility to achieve the most benefits. Less studies support high-functioning teenagers/early adults in better (and 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). A review of technological interventions benefiting ASD adolescents is reported in [16].

2 The Games

In order to gather relevant requirements we had five meetings with a speech therapist who is involved in educational and therapeutic activities for autistic people in a local health centre. Thanks to her knowledge of needs and requirements 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 would greatly benefit from personalised and motivating computer-based exercises that these users can practice autonomously (e.g. without the direct intervention of the caregiver) even in their familiar settings. The approach used was iterative and we progressed from ideas that were just vaguely sketched out at the beginning, to more refined design concepts which we implemented in prototypes which were discussed during such meetings. This application was designed in a participatory manner, where the caregiver participated in all the phases of the application development (while end users were involved only during evaluation) and we progressively discussed and captured teachers' 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 cope with when they confront with a real life common activity such as managing money. She also pointed out typical difficulties such individuals encounter when interacting with a computer (e.g. difficulties with text comprehension, risk of distractions), as well consolidated strategies therapists use to avoid upsetting their cared users (e.g. avoid to explicitly disagree with them or say 'no' to them), with the goal of smoothly progressing towards the expected learning objective. In addition, we also discussed with the speech therapist the 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.

In the resulting application the home page is composed of three sections dedicated to the main learning objectives (see Figure 1 left): understand and recognise the main currency (banknotes and coins) denominations; learn how to manage money change; learn what can realistically be purchased with a specific amount of money.

Although in each section there are different exercises related to the main theme of the corresponding section, 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 the user what she is expected to do for that exercise. In addition, for all the games there is always available a "Help" button through which it is possible to activate a video that visually shows what to do for solving the game. In addition, while the content of each game changes, the layout of the user interface presenting the various games remains basically the same (e.g. in each page there are buttons to go forward and backward in the application, and a button to exit the application). It is also worth noting that, for simplicity, we only considered showing the front view of banknotes and coins.

The "Money" game was developed to train people in recognizing the different currency notes. As soon as the user enters this "Money" game she can select one of three types of training games: "Image and image", "Image and text", and "Sum" (see Figure 1 right).

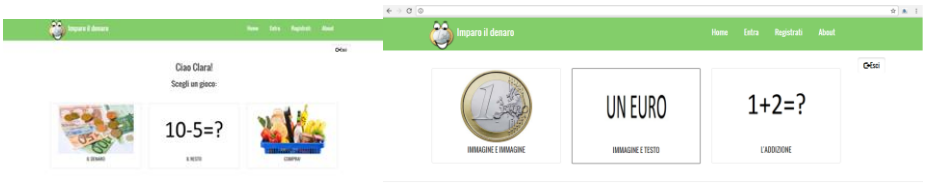

Fig.1: The three main games (left); the three exercises of the "Money" Game (right)

Image and Image. The first game (Image and Image) supports learning how to identify the main denominations and forms of the currency in terms of coins and banknotes. The technique used to support learning of money denominations is the *association*: the page is divided in two rows and the user has to drag each coin or banknote visualised in the bottom row on the corresponding similar coin or banknote shown in the top row (Figure 2 -left). If the user successfully completes the task, then the application shows a yellow smiling emoticon at the end of the exercise. If the user makes an error during the exercise, a smiling red face is shown.

Fig. 2: Money game - *Image and* Image exercise (left); Image and Text exercise (right)

After each try, if the involved coin/banknote is successfully associated, then it is removed from the bottom row of the game. 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 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 in the bottom row and three in the top row).

Smiling faces have been included in all the games of the application, also accompanied by special sounds indicating either an error or a correct execution of the game. A yellow face appears only at the end of a successfully solved game, while a red face appears after each error. After the user makes two errors the position of the images on the top of the page is automatically shuffled so that the user cannot give answer only by memorizing the positions of the images without actually knowing the correct answer (this 'shuffle' strategy also applies to the next type of game).

Image and Text. The second type of exercise included in the Money section is dedicated to image and text associations ("Image and Text"). While the previous game aimed to make people learn how to distinguish the various coins and banknotes, this game is used to make HFA students learn their names. In the game, the user has to drag the coin or the banknote on its corresponding name (e.g. "10 euro"). As you can see from Figure 3 (right), for this game a decimal of euros were presented as "cent", while a currency unit was presented as "euro" (we judged that in both cases these words should be easily understandable by users). This game presented only eight levels of complexity (differently from the previous game, this exercise does not involve the 10 euro banknote but only the 5 euro one).

Sum. This game aims to make the user learn that, by combining coins and banknotes it is possible to obtain further money values. Associations have also been used in this case, with a slight modification: in the top row now the application shows a sequence of coins and banknotes linked by a "+" sign: at the end of this sequence, after an "=" symbol (see Figure 3-left) the image of an open wallet is visualized as well as two buttons: one button (initially de-activated) is for retrying the game, the other one allows the user to explicitly signal that she has finished the exercise.

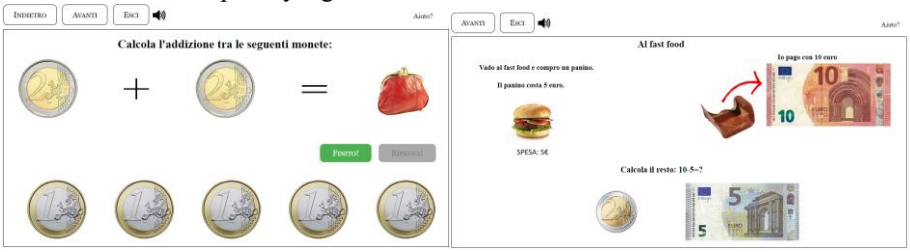

Fig. 3: Money game: Sum exercise (left); Money Change (right)

To solve this game the user has to drag in the wallet the precise amount of currency notes needed to correctly solve the sum and then click on the button used to signal that he finished the exercise. 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 planned, ranging

from the simplest ones (where only two coins are combined) to the most complex ones in which also banknotes are included.

The "Money Change" game is dedicated to learning the concept of money change. Differently from the previous games, at the beginning of this section the user finds a part in which the application asks the user to select a video modelling item of interest and then he can access the game. Video modelling items are videos depicting exemplary behaviour. Then, they generally involve the subject observing 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 well-consolidated behavioural technique which has been shown as being particularly valuable for autistic people. In our case two video modelling elements were prepared (one having a male actor and another one with a female one, to better suit the preference of the user), to show 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 and objects so that users can more easily focus their attention. Focus objects are generally rendered in the video at a reduced speed and by zooming in them. For instance in the videos we prepared, a pen a customer wants to buy was the object of a specific focus. After having selected one video, the user can access the game, which was presented in a problem-like manner. The application shows various scenarios of everyday life, set in different contexts: in each of such scenario there is a purchasing action after which the need of having change occurs. As it can be seen from Figure 3-right, the user has to solve the mathematical subtraction associated with the selected scenario and then select the correct answer, i.e. among the images available in the bottom part of the user interface, select the one representing the solution. Also this game presents eight levels of difficulty.

The "Buy It !" game allows the student to learn what can be realistically purchased with a specific amount of money, by simulating a real situation in which the user has available a specific amount of money, and then she has to select what to buy. At the start of the game the user is presented with a "What can I buy with…" string in the top part of the UI, and then (in the same row) the amount of money considered (the question is further emphasized by an emoticon showing a thinking face, see Figure 4). Then the user has to select among three different images shown in the bottom part of the UI the one actually corresponding to the indicated amount of money. This game was planned as the last one in the series of exercises since it implies that the user has already got skills in the previous exercises. Also this game provides different levels of difficulty, as well as smiling faces to indicate success/error, and a shuffling strategy applied after two errors done by users.

Fig. 4: The *Buy it!* Game

3 Evaluation

We tested the application to understand to what extent it helps user in understanding the concepts associated with money management. The test was articulated in three steps: we submitted a pre-test questionnaire in order to gather data about users' demographics, and then the participants tried the application by carrying out five tasks (each task associated with a type of game). Then, the users had to fill in a System Usability Scale (SUS) questionnaire, for measuring the usability of the application, which consists of a 10 item questionnaire with five response options for respondents, from "strongly agree" to "strongly disagree".

We tested the application with six male ASD individuals (in the following, we use the pseudonyms: Francesco, Jacopo, Gabriele, Giulio, Andrea, Mattia) at the premises of an association supporting them. All of them had been diagnosed with medium/high functioning ASD. Their age ranged from 16 to 22 years (M=18.5; SD=2.2). We recruited participants at adolescent ages and above to test whether our solution was able to make them gain skills that can be useful in practical life. In order to better manage them during the evaluation, we divided them into two groups consisting of 3 members each, according to their age. One group (Francesco, Jacopo and Gabriele) is composed of three early adults (age range 20-22) having all already got their high school diplomas. Their level of use of technological devices was pretty high, the most used device is the smartphone, which is exploited for browsing the Web. As for tablets and PCs, two users use both devices, while 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 having to finish their 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 just occasionally uses the smartphone for calling the mother and he did not have any experience with PCs. The remaining user had low familiarity with smartphones (used only for photos and to browse internet), low familiarity with tablets, and very good familiarity with PCs (used to browse internet and to play games).

The tasks assigned to users were to access and complete every levels of each 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). Each user was allowed to play with each of the five games at maximum for five minutes.

Participants had to use twice the application: 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. The test was conducted at the premises of an association supporting people with autism and it was done by using a Windows-based AMD Quad-Core A8-6410 processor-based laptop having a 15,6" monitor with a 1366 x 768 resolution. Each participant was allowed to interact with each exercise for at maximum 5 minutes. Since they had to solve five tasks, the total duration of the study for each participant was about half an hour.

Task Success. The "Task success" metric is used to verify whether and how users completed the assigned tasks.

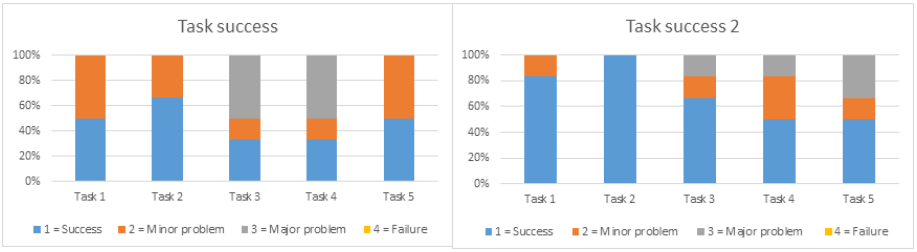

Fig. 5: Task success – First test (left) and second test (right)

Four levels of success 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 at all to solve the exercise. Figure 2 shows two stacked bar charts indicating the success level for each task in both tests. As it can be seen, during the second try we had higher scores than in the first one.

Time on Task. Data related to this metric was collected by using a logging script which was used to enhance the application exploited during the evaluation. We gave a maximum of five-minute time 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 noted down the level that the user was able to reach. Levels reached during the two trails were then compared each other. In this comparison, other factors were also considered e.g. errors done and request for help. The results on this metric gathered in both trails are shown in Figure 6 (left and right). As it is possible to see, apart from one case (associated with lower bound values in Task 2, namely 72 in the second session, and 61,2 in the first session), performance improved over the two sessions.

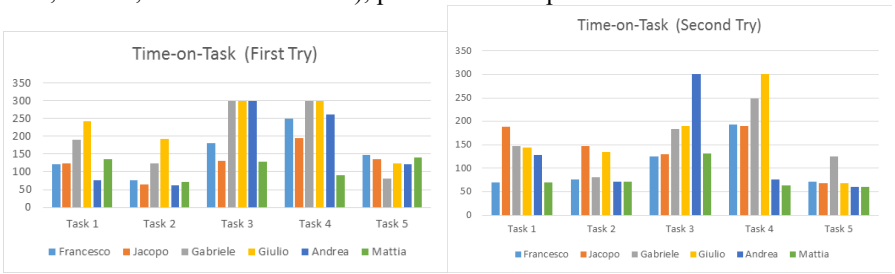

Fig. 6: Time on Task in the first test (left) and in the second test (right)

Errors. We also counted the number of errors done by participants and also in this case overall we had improvements. Indeed, apart from one user (Francesco, who in the first trial made just two errors in the whole test, while in the second session made two errors in the last three tasks), such number decreased between the two evaluation sessions (see Figure 7 left and right).

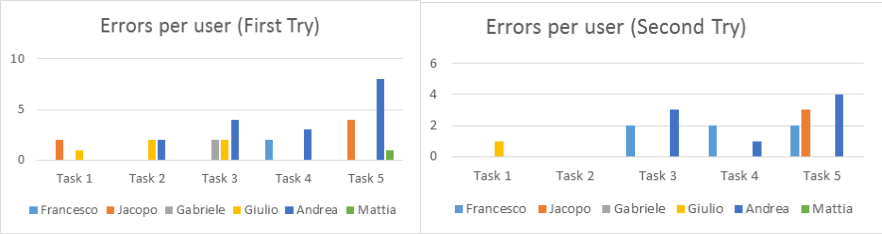

Fig. 7: Errors in the first test (left) and in the second test (right)

Satisfaction. In order to assess user satisfaction we also considered the SUS questionnaire filled in at the end of each session. According to the answers of three participants (Jacopo, Francesco and Andrea) to the SUS questionnaire, the application was not usable (they got 50, 52,5 and 60 scores), while the other three users judged usable the application (their scores were 100, 85, 77,2). Users indicated further remarks about what they most appreciated (or not) in the application. Regarding the first session, the remarks from the group of users including Francesco, Jacopo and Gabriele were that they had some difficulties with calculations (some of them used the calculator during the test). Another problem was connected with reading the textual strings within the "Image and Text" game, which particularly affected the performance of one user. One user indicated the need of having longer time than the allowed time (5 minutes) to solve the games. Another user complained about the smiling faces used in the games. In general users appreciated the application. Users found the "Image and image" and "Image and Text" games as too simple whereas the "Sum" game was found a bit too difficult. During the second session these users carried out the test with much more willingness and some of them showed some progress. Regarding the first session, contrasting judgements came from the remaining users (Giulio, Andrea and Mattia). Two of them evaluated the application as nice but boring, one found the application as both nice 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 because he thought that with the same amount of money it is possible to buy different things within the game. Also Mattia did not appreciate much the sounds. During the second test, two of them showed evident improvements in the performance.

4 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. At <url not provided for anonymity goals> it is possible to access the application developed. A user study was conducted with six high functioning ASD individuals to assess the its effectiveness and usability. Overall, the test shows encouraging results in the potentiality of training high functioning ASD individuals in acquiring skills regarding money management. In addition, being a Web application, it can be used autonomously by users (e.g. without the need of a caregiver) whenever they want, and at their own pace. The results are promising

although additional work to make the application more personalised and adaptive to user's needs, preferences and behaviour should be done in the future.

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