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 Autism 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 · 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.

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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 modeling [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 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 [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 abatement 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 also associated mathematical skills, which are both much needed by these users [11, 12]. 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 everyday activities related to it. The games have been organised in a responsive Web application with multiple difficulty levels 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 [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 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 [14] 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 [15].

2 The Games

In order to gather relevant requirements, 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 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 which would greatly benefit from personalised and motivating computer-based exercises that these users can practice autonomously (e.g. without the support of the caregiver) even in their familiar 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 were discussed during such meetings. As such, the application was designed in a participatory manner: caregivers 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 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 explicitly disagreeing with them or saying '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.

Thus, the resulting application was organised in such a way to reflect the three main learning objectives that we identified (see Fig. 1, left part): 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. For simplicity, we only considered showing the front view of banknotes and coins.

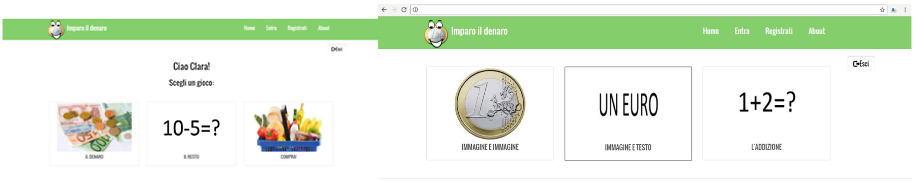

Fig. 1. Left: the three main games. Right: the three types of exercises included in the "Money" game

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. In addition, in each page there are buttons to navigate through the pages of the application (e.g. go forward/backward), and a button to exit.

The "Money" game was developed to train people in recognizing different currency notes. When the user accesses this game, he can select one of three types of included games: "Image and image", "Image and text", and "Sum" (see Fig. 1, right part).

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 (Fig. 2-left). If the user successfully completes the task, the associated coin/banknote is removed from the bottom row of the game and then the application shows a smiling yellow emoticon at the end of the exercise. If the user makes an error, a sad 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

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

"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).

Smiling faces have been included in all the games of the application, also accompanied by special sounds indicating either error or success. 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 bottom 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. While the previous game aimed to make people learn how to distinguish the various coins and banknotes, this game is aimed to make HFA students 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 Fig. 2 (right), 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 make 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 Fig. 3-left) the image of an open wallet is visualized, with two buttons available: one (initially de-activated) to try again the game, the other to signal that the exercise is finished.

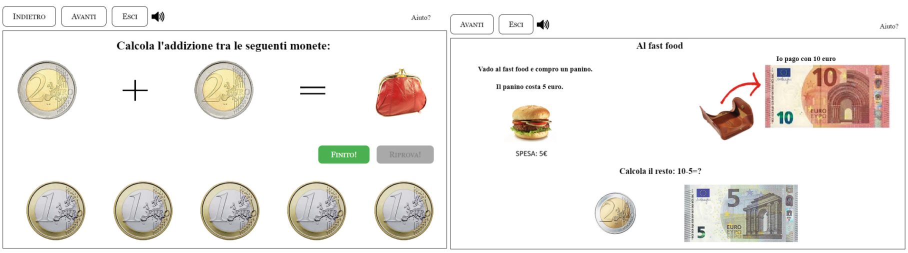

Fig. 3. Money game: sum exercise (left); money change (right)

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 click on the button used to signal that the exercise is finished. 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 designed, ranging from the simplest one (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 the application asks the user to select a video modeling [7] item of interest and, only after this, he can access the game. Video modeling items 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 modeling is a behavioural technique which has been shown as being particularly valuable for autistic people. In our case two video modeling 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/objects on which users should focus their attention ('focus' objects are generally rendered in the video at a reduced speed and by zooming in them). In the videos we built, the object of a specific focus was a pen that a customer wants to buy. After having watched 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 Fig. 3-right) by means of selecting, among the images available in the bottom part of the user interface, the one representing the right 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. 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, as well as the amount of money considered (the question is further emphasized by an emoticon showing a thinking face, see Fig. 4).

Fig. 4. The *Buy it!* game

Then the user has to select among three different images (shown in the bottom part of the UI) 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's errors.

3 Evaluation

We tested the application to assess to what extent it helps users in understanding the concepts associated with money management. The test was articulated in 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, which consists of 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 ASD individuals. In the following, we use a set of pseudonyms to indicate them: Francesco, Jacopo, Gabriele, Giulio, Andrea, Mattia). 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). In order to better manage the participants 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), all having a high school diploma. Their level of use of technological devices is pretty high, the most used device is the smartphone, 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 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 the smartphone (e.g. to call 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 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 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 done by using a Windows-based laptop having a 15.6” monitor with a 1366 × 768 resolution, and a AMD Quad-Core A8-6410 processor. Each participant was allowed to interact with each exercise for at maximum 5 min. 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.

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 at all to solve the exercise. Figure 5 shows two stacked bar charts indicating the success level for each task in both tests: during the second try we had higher scores than in the first one. 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.

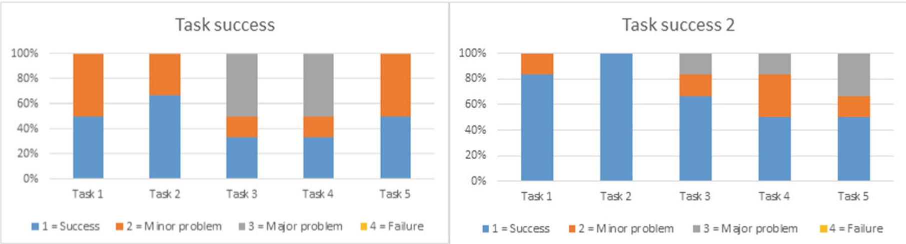

Fig. 5. Task success – first test (left) and second test (right)

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 recorded the last level reached by the user. Levels reached during the two trails were then compared each other. In this comparison, other factors were also considered e.g. errors done and requests for help. The results on this metric gathered in both trails are shown in Fig. 6 (left and right), 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 s in the second session and 61.2 s in the first session), time on task overall improved among the two sessions.

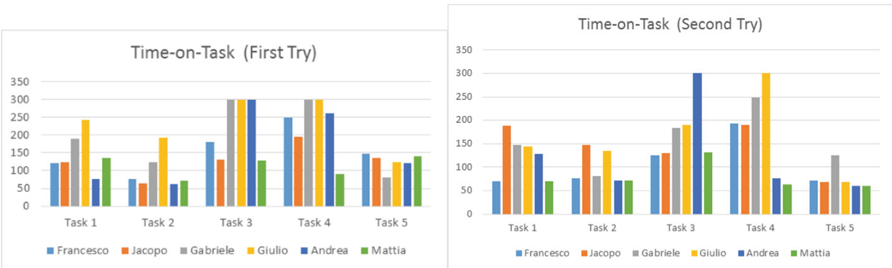

Fig. 6. *Time on Task* in the first test (left) and in the second test (right)

Errors. We also counted the number of errors done by participants and also in this case, overall, we had improvements. 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 Fig. 7 left and right).

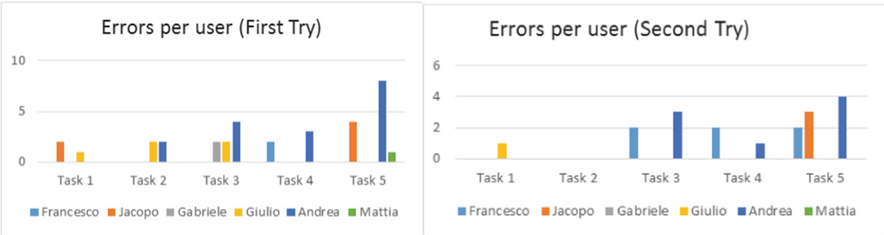

Fig. 7. Errors in the first test (left) and in the second test (right)

Satisfaction. In order to assess user satisfaction, we considered 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, 77.2). To this regard, the moderator noticed that, while filling in the questionnaire, users seemed not much motivated and also a bit tired. In general, users appreciated the application. In the first trial the group composed of Francesco, Jacopo and Gabriele highlighted 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 to solve the games than the allowed one (5 min). Another user complained about the smiling faces used in the games. 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 some of them showed some progress.

Regarding the other group (Giulio, Andrea and Mattia), contrasting judgements came from them in the first trial. Two of them evaluated the application nice yet boring, 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 with the same amount of money it is possible to buy different things in the game. Mattia did also not appreciate much the provided audio feedback. During the second test, two of them showed evident performance improvements.

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. 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 regarding money management. In addition, being a Web application, it can be autonomously exploited by users 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, as well as further empirical studies to better evaluate it.

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