CoASD: A Tabletop Game to Support the Collaborative Work of Users with Autism Spectrum Disorder

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***Abstract*— This paper presents the design and evaluation of *CoASD (Collaborative Game for people with Autism Spectrum Disorder)*. CoASD is a game designed to offer support for collaborative work for users with *Autism Spectrum Disorder (ASD)*. Individuals with ASD have impairments in social communication and behavioral areas, presenting difficulty to perceive, interact, communicate and share with others. CoASD Game has been projected with specific characteristics to support the performance of the required collaborative tasks, as well as to encourage the collaborative work of ASD users with higher difficulties in the affected areas. The game has been assessed upon a group of seven boys with high degrees of impairment. The results have shown that CoASD Game favorably contributes to draw the attention of users to perceive and perform the tasks, motivating them to act and collaborate with their partners.**

Keywords—Autism Spectrum Disorder; Awareness Support; Collaborative Games; Multitouch Tabletop.

I. INTRODUCTION

Autism Spectrum Disorder (ASD) comprehends a set of developmental conditions that emerge at an early age. These conditions are characterized by deficits in verbal and non-verbal communication, social interaction, and restricted behaviors [1]. The term "spectrum" refers to a wide range of symptoms and different levels of deficiencies that people with this syndrome may present. According to the current edition of the Diagnostic and Statistical Manual of Mental Disorders – DSM-V [1], this spectrum is classified in relation to three levels from greater to smaller severity: level 3: "requires very substantial support", level 2: "requires substantial support" and level 1: "requires support". People with level 3 ASD present "*Severe deficits in verbal and nonverbal social communication skills"* that *"cause severe impairments in functioning, very limited initiation of social interactions, and minimal response to social overtures from others*" [1].

This impairment in social communication skills can be justified by the fact that people with ASD have a Theory of Mind (ToM) deficit. ToM refers to the ability of every person to make precise assumptions about the thoughts and feelings of others, allowing us to anticipate what people will say and what actions they will perform [2]. This deficit can be observed in situations such as the lack of awareness of others as partners in social interactions; the fact that they do not act according to the others' actions; the unusual attention to the activities around them and, in general, the difficulty to interpret other people [3]. These aspects affect the ability of such individuals to stablish a relationship with the surrounding world and to take active part in social collaborative activities.

Over the last years there has been a growing development of Co-Located Collaborative Systems for people with ASD, aiming to contribute to the stimulus of their affected abilities. These studies have shown positive results in respect to the stimulus of social interaction and communication skills [4]–[6]. However, most of these studies have been developed for people with less severe ASD or High-Functioning Autism (HFA), and do not mention explicitly the need to offer both awareness and collaboration support to users with high difficulties on co-working, on the typical sense.

In a comprehensive research previously conducted, we investigated matters of how to offer awareness support for users with ASD under face-to-face collaborative systems. This has lead us to propose the conceptual tool 'StrateCSA' [7]. This tool consists of three strategies to support the design of co-located collaborative systems for people with high impairment ASD. The strategies of the StrateCSA suggest requirements for the design of interface elements to encourage workspace awareness, as well as a set of activities to gradually encourage the learning of collaborative process in its three dimensions: Cooperation (actions of the participants within the workspace), Communication (conversation through the exchange of spoken, written, physical or gestural messages), and Coordination (management of participants, activities and resources) [8].

We used the StrateCSA tool to design the CoASD: Collaborative Game for people with Autism Spectrum Disorder that is presented in this paper. We assessed CoASD Game upon a group of seven boys with high severity autism. The results have shown the positive contribution of the game for users, both on the awareness support offered for the performance of the required collaborative activities, as well as on the incentive to collaborate and to interact with the partner through gestural and verbal expressions.

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This paper is organized as follows. In section II we present the work regarding collaborative tabletop games intended for people with ASD. In section III, we describe the design of the CoASD game using the StrateCSA tool. In section IV, we detail the evaluation process of the game in a group of boys in Level 3 ASD. In section V, we present the results obtained. Finally, in section VI, we present the conclusions of this study.

II. Related Work

Co-locate collaborative systems for tabletop designed for people with ASD demonstrate several advantages to contribute positively to the incentive of the impaired abilities of such users. The technology of tabletop interfaces allows the natural interaction of players [9] enabling verbal and non-verbal communication [5] and also the sharing of actions within the workspace [9].

We realized that most of the Co-Located Collaborative Systems are designed for users with less severe ASD (High-Functioning Autism – HFA), and even though these studies present some characteristics to encourage collaborative work, they do not explicitly mention any support for the collaborative performance of its users. Amongst these characteristics, for instance, Roldán-Alvarez et al. [10] highlighted the benefits of turn-based collaborative learning activities in tabletop interfaces. Authors proposed and evaluated collaborative activities in which each user interacts only after the partner finishes his/her task. The authors noticed that the awareness of the others' actions is enhanced when the participants perform the activities working in shifts.

This approach is also taken by [9], [11], [12]. The authors suggest that this strategy motivates HFA users to communicate with partners and pay attention to their turn on taking action in the game [11]. In StoryTable game [12], besides turn-taking, the *Enforced collaboration paradigm* [13] is applied. It consists of enforcing the simultaneous interaction of two or more users on the same interface elements, and this approach is also used in the Collaborative Puzzle Game [13]. The authors suggest that this paradigm improves therapies involving social contact, besides reinforcing the need for collaboration. However, users with more severe ASD needed help from therapists to get involved in the game.

In the *Invasion of the Wrong Planet* game [14], users with HFA work together to eliminate the enemies that are attacking them. The stronger the collaboration, the greater the number of special effects in the game and higher the scores obtained by players. When non-collaborative or dominant behaviors occur, the participants are penalized with lower scores. The authors highlight the positive results of this approach, which leads to social interaction and communication between players. These researchers also point out to the importance of encouraging the collaborative process little by little, never forcing participants to contribute.

In *Joint-In Suite* [15] the authors suggest four games for users with HFA. Such games include what they have called patterns of collaboration, consisting of enforcing the simultaneous interaction of users, attributing different roles for each player and giving to every user the ownership of certain objects to be negotiated. The authors conclude that during the games, users with HFA learned and understood the importance of collaboration [16].

Based on such patterns of collaboration we proposed for the PAR Game [17], [18] a set of four gradual collaboration patterns intended for users with higher levels of severity on ASD. We named such patterns as follows: Passive Sharing (a different role for each user), Active Sharing (exchange of information to share resources), Joint-Performance (simultaneous interaction), and Unrestricted Interaction (free interaction). The Active Sharing pattern was used by [19] in two collaborative games intended for users with HFA. In their pilot study, the authors found out that users showed great enthusiasm in the games. Upon assessment of the PAR Game with youngsters with level 3 ASD, we noticed that these patterns motivate users to interact with others and to gradually engage in the collaborative process. However, we also verify that some users presented some trouble to identify tasks and to easily recognize when, how and whom to collaborate with [20].

This evaluation and a deeper study on this field has lead us to the development of the StrateCSA tool, whose features provide such users with some awareness support for acting in co-locate collaborative systems.

III. Design of the CoASD Game

We used the StrateCSA tool [7] to design the CoASD Game. The StrateCSA consists of three strategies that offer resources to gradually support the practice of collaboration among users. Each strategy includes tasks to stimulate every dimension of collaboration, as well as requirements to guide the design of interface elements.

The first strategy encourages cooperation by suggesting activities that involve resource sharing. This aims to initiate the tasks awareness and to encourage users to identify themselves as responsible for their work. Here, users perform the tasks regardless of identifying that they are involved in a collaborative work. The second strategy encourages communication by suggesting activities that involve resource sharing according to an exchange of information. This aims to introduce the importance of recognizing the role of the partner in the collaborative work. As for the third strategy, it encourages coordination beyond the two previous strategies by proposing tasks that involve simultaneous interaction of users upon elements on the interface. This aims for players to identify the fact that everyone's participation is strictly necessary to achieve a goal, therefore recognizing that they are involved in a collaborative activity.

Following these strategies and working together with therapists from an institution specialized in autism, we designed the CoASD Game. It consists on collaborative work of two players around a multi-touch tabletop. The main goal is to drive a car down a road and park it inside a garage before the garage door closes. The users should together overcome different obstacles presented along the route such as: lack of fuel, car in the need of cleaning, the need to pay toll, and holes along the road. One of the players (user nr.1) takes the role of the car driver and his/her partner (user nr.2) takes the role of the driver's assistant.

CoASD Game consists of three phases, each one with added tasks according to the strategies of StrateCSA. In the first phase of the game the first *strategy* is applied. Here, when user nr.1 reaches an obstacle with the car, her/his partner (driver's assistant) must send her/him the help required (Fig.1.a). User nr.1 must wait until he/she gets help to continue on the route.

The second phase involves the second *strategy* to encourage information exchange. The same shared resources of the previous phase are required, but in this phase user nr.1 must ask for help (Fig.1.b). User nr.2 waits and sends the help required by his/her partner.

The third *strategy* is applied during the third phase of the game. It has the same activities of the previous phases, but simultaneous interaction of both users is required for some tasks. User nr.1 must stop the car in front of a hole on the road, and an alarm is activated. Therefore, it is necessary that user nr.2 helps by pressing a mechanism on the interface to put a bridge over that hole, while user nr.1 drives the car over the bridge (Fig.1.c). When user nr.2 releases the mechanism, the bridge collapses. In this phase, collaborative work is more encouraged.

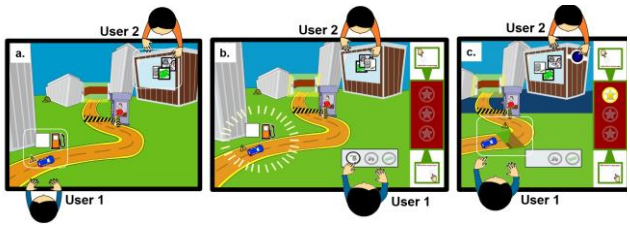

Fig. 1. First (left), second (middle), and third phases (right) of the CoASD game. We used some pictograms from ARASAAC as interface elements. <http://arasaac.org/descargas.php>.

Regarding the requirements proposed in the StrateCSA tool, we designed interface elements to gradually provide awareness support, and thus collaboration support during the three phases of the game. Such gradual support is offered on different levels to slowly bring users closer to the knowledge of collaboration.

According to the StrateCSA tool [7], which takes the approach of cultural approximation to conceive cross-cultural systems as proposed by Salgado and colleagues[1] [21], the collaboration approximation in each phase of the game begins with a medium level of support through the interface elements, but with less contact with the collaborative experience. This level is called *observer at a distance* (OD). Then, the support is increased, and users are guided in their tasks across the collaboration process, so they can feel like a *Guided tour visitor* (GV). Afterwards, less support is provided, and users are more challenged to immerse in the collaborative activity: this level is called *foreigner with translator* (FT). Finally, it is provided the same support that would be offered for users without difficulties to perform a collaborative work, thus, users can feel like a *foreigner without translator (FnT)* in the collaborative experience.

Therefore, for the CoASD Game, the interface features are designed according to the requirements of StrateCSA tool for each level of collaboration (OD < GV < FT and FnT). The intention is to make users interact in the game according to the order of these levels in each phase of the game, hence gradually learning the collaborative process.

In the three phases of the game, only the main elements of the game are kept alike at the four levels of collaboration (Fig. 2). To illustrate, when the car hits an obstacle, other elements are introduced to draw the user's attention to a task that needs to be done (Fig. 2.a). When the car should continue its course, the doors begin to close slowly, and a flashing light is shown around them (Fig. 2.b). When a task is successfully finished users will hear a snatch of a song and recognize it as a sign of victory. In addition to that, the interface shows an animation of the results of the accomplished task, for instance, a person cleaning the car windows, as shown in Fig. 2.c. There is also a pop-up congratulations message to be activated by users to go on with the activity.

During the second and third phases of the game, to highlight and reward the collaboration between participants, there is a chart displaying stars issued for every collaborative action performed, for instance when someone responds to the partner's actions or in simultaneous activities. The star is awarded only when the collaborative task is finished (Fig. 2.d).

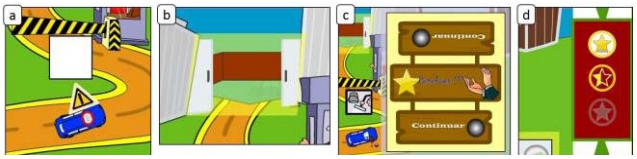

Fig. 2. Game features for collaboration support on levels OD, GV, FT, e FnT. a) flashing warning light and white board to set up the help needed b) flashing lights around the closing doors, c) task successfully performed and d) scoring chart for collaboration tasks achieved

When the activity is finished, the game congratulates the participants on their teamwork with a message that fills up the screen, the victory song and a voice is heard saying: "*wow, congratulations! You have done a great job!*" In case of any mistakes on the task, the screen shows a pop-up message in red accompanied by a sound associated with failure and the voice will say something like: "*[song] try again, what the car needs is a cleaning of its window*". For the second and third phases of the game the message will motivate interaction between users by saying: "*[song] try again, we have to clean the car window*".

Among several features designed for this game, the following ones are some of the most distinguished, according to each level of proximity to collaboration for the three phases of the game. For the level ***observer at a distance*** **(OD)**, the interface shows an avatar moving along the screen over the required tasks and providing users with instructions on what

[1] It is worth noting that this study appropriates the Cultural Viewpoint Metaphors approach, proposed by [21], in a special way and without considering particularly cultural aspects, since this approach is not specifically intended for the type of "culture" intended in this study.

needs to be done (Fig. 3 upper left). The avatar starts by indicating which player should act and proceeds with instructions in short sentences. The instructions are naturally spoken, expressed with emotion and using the sort of language that users can use and easily recognize, such as "*[user name], take the car to the doors, before they close*" or *"Hmm, [user name] the car fuel is finished! Take some fuel and give it your partner"*. At the same time, flashing lights are shown around the task that needs to be done, thus clarifying its identification.

At ***Guided visitor (GV) level,*** which should offer more support, the interface provides visual and audio orientations about what needs to be done (Fig. 3 upper right). Audible instructions include the use of the name of the player who should perform a specific action. The image of a magnifying lens is positioned close to the next task icon. Upon the instructions, it shows how this action should be taken. At the moment an element is touched and dragged, the lens follows the interaction with the user and goes to the point where the object needs to be taken to, showing what players must do. To offer better support on the identification of the task, the elements required for its completion are highlighted, all other elements are darkened, and the player picture is shown. The main objective is to reinforce the idea of being responsible for that task.

When a task is done successfully, the users receive a visual positive feedback highlighted above all other elements on the interface. A picture of both players invites them to press the "continue" icon together, so that they can continue with the activity. At this level, they also receive a congratulations message that is different for each phase of the game. On the first phase the following message is heard: "*[song] God job! you can continue!*". On the second and third phases of the game, the message includes the names of the players: "*[song][user1][user2] you did a great job!*".

At the ***Foreigner with Translator (FT)*** level, when less support but more contact with the collaborative process is needed, there are only audio orientations about what needs to be done. The only visual indication of what object is targeted is a small blue arrow placed beside the tasks, as shown on Fig.3 (lower left). The allow each user to recognize him/herself as the player responsible for a task, the player's picture is shown, and an audio instruction is given, but the name is not heard.

Regarding the congratulations message, the visual positive feedback is not highlighted above the other elements on the interface, it just appears on the screen together with the picture of both players, inviting them to press the icon to continue. The message celebrates their teamwork with the victory song and the same spoken message is heard for every phase of the game: "*[song] Congratulations! You did a great job!*".

At the ***Foreigner without Translator (FnT)*** level, personal instructions are given. Every time a task is presented, the system provides the elements of the game. General information about what to do is offered via an audible message, with no need to show the user picture or to mention any names (Fig. 3 lower right). When a task is successfully done the interface displays a compliments message, but no pictures are shown. For all phases of the game the congratulations message says: "*[song] Congratulations!*".

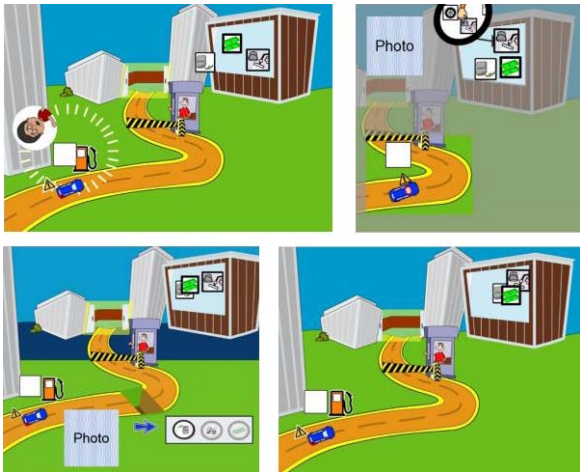

Fig. 3. User interface examples on levels OD (upper left), GV (upper right), FT (lower left), e FnT (lower right).

For the second and third phases of the game, the interface presents a scoring table and a collaboration request panel (Fig.4). On this panel there are two boards, one belonging to each user, displaying photographs of all other team members. When help is needed, the user can request collaboration by activating one of the pictures on the panel. At levels OD and GV, the pictures have indications for their activation. At level OD, when a picture is actioned the system calls the user by the name. At level GV, besides calling the user by the name and activating the elements of the task, the system also activates the player picture, indicating that it is his/her turn to perform. For the simultaneous interactions of the third phase of the game, each correspondent task is emphasized, drawing attention for both players to interact. At FT level the system calls the user by the name, but does not show the signaling over the pictures. At level FnT, the system calls the user by the name, but only activates the elements of the task to be performed.

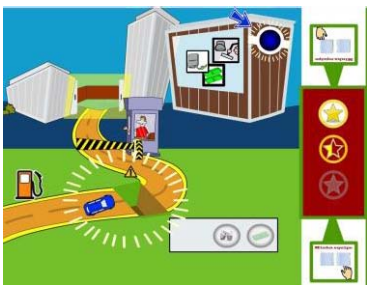

Fig. 4. User interface example of the third phase of the game. At the right-hand side, the center panel shows the scoring table and, at the top and bottom, the spaces with the pictures to summon for help. To protect identities, the photographs have been covered.

For the third phase of the game, at levels OD and GV, there are not only instructions, but also restrictions on the interface elements, so that the interaction on them will occur only at the requested moment. In addition, it includes different colors for the workspace of each user.

IV. ASSESSMENT

We evaluated the *CoASD Game* involving seven children. During the period of the tests sessions there were not ASD girls attending the specialized institute we work with, thus, we evaluated the game involving just boys. It is worth noting that ASD is more commonly diagnosed in boys, with a boys-to-girls ratio of 3:1 [22].

The tests sessions were conducted twice a week over a period of three months. Each test session consisted of one user interacting with each one of the three phases of the game in every level of collaboration support (OD, GV, FT, FnT). Each user took both roles in the game, initially as a driver and then as a driver's assistant. Two GoPro Hero Cameras were used to record the session tests and capture a broader field of view of users interacting on a multitouch tabletop (installed at the Ann Sullivan Institute). Before these tests, we conducted a training stage to provide game instructions and introduce users to the manipulation of the elements on the tabletop interface. The ethics committee of our University center approved the tests before they were performed.

A. Participants

Seven boys with an age range from 5 to 14 years old took part in the tests. To protect their identity, we identified them here as *U1* to *U7*. They are all diagnosed with high impairment ASD presenting great difficulties in social collaborative skills and restricted/repetitive behaviors. *U2, U4, U5*, and *U7* show self-stimulating behaviors; *U7* also presents self-injury; *U4* presents brain malformation; *U5* is also deaf, and *U6* is a boy with both ASD and ADHD (Attention-deficit/hyperactivity disorder). All participants need a lot of intervention from therapists to encourage them to interact with others and to keep this interaction going on.

During each test session, two users participated, always accompanied by a therapist. Six therapists took turns to provide emotional and behavioral support for boys.

B. Research questions

The research questions considered for the evaluation process of this work are presented below:

- Have the elements made available in the game interface (at each level OD, GV, FT, and FnT) contributed as a support for users to perform the required collaborative activities?
- Have the elements in the interface and the activities of the game encouraged the social skills in the participants during the collaborative work?

V. RESULTS

The following results are presented according to the two research questions above.

A. Support for collaboration through the interface elements

In the analyses of the video recordings and field notes performed during the sessions tests, we identified how users perform each task depending on the support provided by the system (interface elements).

We classified the support of the elements provided into three groups: favorable, non-favorable, and undetermined. We denominated 'favorable' the elements most significant for users that helped and guided their interaction, as well as did not interfere in their activity. We called 'non-favorable' the elements that presented some sort of difficulty for users and interfere in their interaction. Finally, we called 'undetermined' those where the interaction of users was not affected, or did not provide enough evidence for the research to precisely evaluate how they contribute. Even so, it has been observed that they contributed together with the other elements and certainly did not disturb the interaction between users.

Table I presents the game's interface elements for collaboration support. The most significant and 'favorable' to users were marked with a "checked" symbol (✓), the 'non-favorable' were marked with the "x" letter, and the 'undetermined' were marked with "-". It was observed that the most of interface elements available on each level OD, GV, FT, and FnT, during the three phases of the game, contributed favorably as a support for the collaboration of the participants. Occasionally it was evidenced that a few participants were confused about some of these elements. However, the other elements involved helped them to carry out the activity.

TABLE I. THE MOST SIGNIFICANT ELEMENTS ON INTERFACE FOR COLLABORATION SUPPORT IN THE THREE PHASES OF THE GAME

Level	Interface elements	U1	U2	U3	U4	U5	U6	U7
OD/GV/FT/FnT	Game sounds	✓	✓	✓	✓	N/A	✓	-
	Custom made images of the game	✓	✓	✓	✓	✓	✓	✓
	Songs to stress victory	✓	✓	✓	✓	N/A	✓	-
	Stars awarded for collaborative work (2nd and 3rd phases of the game)	-	✓	-	-	-	✓	-
	Partner call panel to be used when the partner does not move (2nd and 3rd phases of the game)	✓	-	-	-	-	-	-
	Audio instructions	✓	✓	✓	✓	N/A	✓	✓
OD/GV	User name	✓	✓	-	✓	N/A	✓	✓
	Blockade of elements to be moved (3rd phase of the game)	-	-	-	-	-	✓	-
OD	Flashing lights around the task	✓	✓	✓	✓	-	✓	✓
OD	Avatar	✓	✓	✓	-	-	X	-
GV	Highlighted tasks	✓	✓	✓	✓	-	✓	✓
GV	Parallel instructions (magnifying lens)	✓	✓	✓	-	-	✓	X
FT	Orientation arrow	X	✓	✓	-	-	✓	✓
GV	User photograph	-	-	-	-	-	✓	✓

It was evidenced that the set of images shown, and the sounds heard for each required action helped users to understand when to act. As an example, for the participants, the sound heard when the car hits an obstacle became a signal to stop their current task and give way for the partner to act. It is noteworthy that in the latest tests, even before the sound was played, *U6* and *U3* waited for it when they arrived near the zone of the obstacle, and only after hearing the signal they stopped the car. For the *U4* participant, when taking the role of

driver's assistant, the sound of the car caught his attention to realize that the partner's task had ended. He remained attentive to continue with the activity even without taking any action. In advanced tests, when *U2* took the role of driver's assistant, even after he had learned the game procedures despite remaining very attentive to his partner's actions, he only acted after hearing the characteristic sound.

Upon completion of a task, participants, mainly *U1, U2, U4* e *U5*, could easily recognize required tasks after the compliments messages, when they showed interest to perform. The "victory songs" were an incentive for them to continue their activities, particularly for *U2, U3, U4 e U5*. They celebrated their achievement expressing themselves with applauses, jumps, raised arms, babblings and/or smiles.

The stars awarded for joint interaction during the second and third phases called a lot of attention from *U2* and *U6.* Even during the cooperation-only tasks of the second phase, *U2* remained attentive not only to the events on the workspace, but also to the stars that appeared while the collaborative work was going on. As for *U6*, he remained attentive when the stars were awarded.

At levels OD and GV, it has been noticed that the participants quickly turned their attention to the indicated tasks when called by their names. In most cases to be called by the name was enough support for the player to feel responsible for the task and act accordingly. However, on some occasions it only attracted his attention, without being sufficient to make him do the required task.

The indications provided by the avatar and the flashing lights on the screen at level OD were adequate support for the participants to follow the indications, especially for *U1, U2* and *U3.* For *U1* and *U3,* the avatar was a better location indicative element along the game, since it moves to the place where the actions are required to happen. As for *U2,* the avatar was an important task orientation, for this player only concluded his task after the avatar finished with the indications.

For participants *U1*, *U2, U3* and *U6,* parallel indicators were an important support for the completion of tasks at level GV. For *U3* these elements contributed only to indicate where the task was. For *U1*, *U2* e *U6*, such indicators provided a greater contribution. They observed the actions of these elements very attentively and were guided by them during their performance, as on the interaction example that can be observed in Fig. 5.

Fig. 5. Image sequence of the interaction of a participant supported by the element of guided orientation at level GV.

It is noteworthy that *U2*, besides following the indicated, also babbled back some of the words heard when following the guided instruction. In FT and FnT, it was observed that *U2* sometimes got a bit confused about what was his next step in the activity, making him interfere with the partner's task. The highlighting of tasks above the other elements on GV, was an even better support for all participants. The exception was player *U5,* who always just wanted to act quickly but without paying much attention to the interface, what made him ignore several of the available elements. As for the other participants, this element contributed a lot for them to better understand their tasks and the ones of their partners, as well as helping them act in the appropriate manner at the indicated spots. In addition, they learned the tasks that should be done on the next levels of approach to collaboration.

At *FT* level, the arrow icon indicating the place to perform the tasks was an important support for participants *U3, U6, U7*, who turned their attention to the location shown and worked quickly on the required action.

With regards to the difficulties encountered by 'non-favorable' elements, we observed the case of participant *U6* when, at times, the avatar available on the OD screen called his attention beyond expectations. *U6* kept his attention focused on it without performing any of the tasks. However, other elements like the lights and the audio indications helped him when acting. Participant *U7* encountered some difficulties with the elements of the parallel guidance on GV level, when he tried to get the orientation elements instead of "real" elements indicated. At some points, the same situation happened with *U1* at level FT*,* when he tried to get the orientation arrow icon.

Apart from that, the collaboration request panel (Fig. 4) was the least noticed by the participants. Only *U1* took notice of it at some points. It is worth mentioning that when some participants needed to call the attention of a partner, they did it by using an element owned by them on the interface, as they understood it could help them to achieve the target. For instance, for a participant to receive the required help, he presses the request button again and again until the partner reacts. When the request button is pressed, the partner's name is heard, indicating that it is his turn to perform.

These results suggest the importance of all different elements on the interface for supporting the interaction of each user on various ways. It is important to highlight that they contributed positively to motivate the performance of the collaborative tasks required, even for users *U4, U5,* and *U6* which present other impairments apart from the ASD.

The contribution of the game has also been observed during the analysis of the participants' social interaction behavior, described as follows:

B. Collaborative performance according to social interaction expressions

It was noticed by means of several social interaction expressions between the participants, that both the required tasks in the CoASD game, as well as its elements to collaboration support have raised on the participants the need to interact and to collaborate with their partners. Participants were motivated to contribute to the collaborative activity, by means of encouraging the partner to act, rectifying any actions, celebrating their own or someone else's achievements or by

being attentive to the actions of the partner and answering upon request. These different social interaction expressions were categorized into the following:

a) Following the other's actions

b) Babbling according to the other's actions.

c) Encouraging the actions of the partner

d) Celebrating the actions performed

e) Answering by performing the task

f) Using gestural orientation

g) Using verbal orientation (babbling)

h) Looking at the partner as a means of communication

i) Looking at one element on the interface as a means of interaction

j) Requesting/asking

k) Answering with gestures or babbles

l) Complaining

m)Joint interaction

n) Assisting somebody else's interaction

o) Rectifying the actions of the partner

p) Rectifying with physical contact

Fig. 6. shows that expressions performed most frequently by participants were those categorized as: a), e), and f).

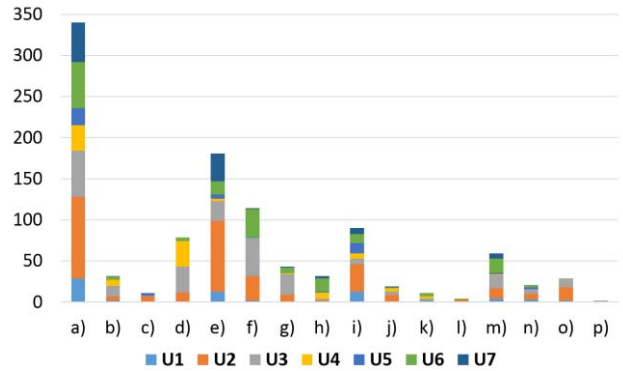

Fig. 6. Number of participants' social interaction expressions towards their partners during the three phases of the CoASD game.

The category stated on the expression "a) to follow the other's actions" was the most frequently found and it was performed by all participants. This expression defines the attention given by the participant to the actions of his partner regardless if it was only to continue with the activity or to answer with another expression to correct, indicate or react while performing his task. The appearance of this expression indicates a high degree of interest and attention towards the action taken, for these individuals are known for losing the track of things quite easily.

We can also notice the high incidence of the expression "f) using gestural orientation", consisting on the gestures used to motivate the actions of their partners. This category includes pointing at elements on the interface using one hand or moving the hands or the head to indicate the position where the action should take place (Fig. 7). This expression received some sort of feedback from the partner either by the visualization of the indicated item or by the accomplishment of the assigned task, which has been categorized as "e) answering by performing the task". This expression was considered only when the action was performed as an answer to a previous request. It became evident that participants that were more supported by the elements in the interface (U2, U3, and U6) (Table I), were also more encouraged to interact with the partner (Fig. 8).

Fig. 7. Example of a participant guiding his partner through gestures.

The participant U5 that was less supported by the elements on the interface to perform the tasks, shows also little interest to interact with his partner (Fig. 8), this can be justified due mainly to the deafness of the participant. However, with the support of the mediator, U5 managed to pay attention to the visual support provided by the game, and then, interact with the partner through expressions categorized into a), and i) (Fig. 6).

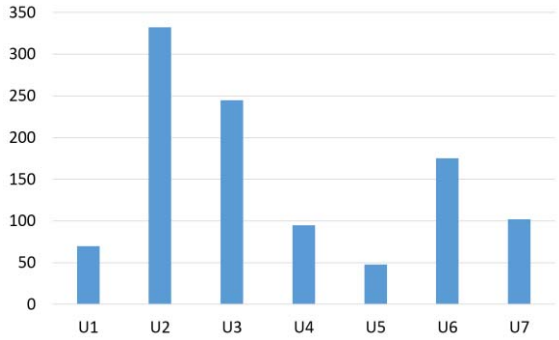

Fig. 8. Number of social interaction expressions performed by each participant during the three phases of the CoASD game.

According to statements from the therapists, both the features of the game and the amount of support offered to the participants contributed on their collaborative work: "*The ones* [features] *that worked were the visual and audio stimuli that functioned as helpers and, at the same time, as a motivation to engage them* [participants] *on the game. The amount of support that was offered to participants had a positive effect on their performance".*

Therapists also highlighted that the participants U2 and U3 showed an improvement over the collaborative work: *"two patients* [U2 and U3] *showed an improvement over this aspect* [collaborative work]. *U2 improved significantly more than U3, to a point when he took the initiative of identifying a problem in the classroom and trying to solve it.".*

Results indicate that the features designed for the *CoASD Game* contributed positively for the interaction and communication between participants, by encouraging them to engage in the activity and coordinate their actions during the requested collaboration process.

VI. Conclusions

The evaluation results suggest that the *CoASD* game, contributed positively to support users on the performance of the required tasks, not only to identify such tasks, but also to raise their interest on collaboration with a partner to achieve the suggested target of the game.

It was evident that both the proposed tasks and the awareness elements available on the interface along all different levels of approach provided the participants with support on the identification of the tasks and on their performance. They also supported the awareness of the actions of their partners, encouraging them to act and to wait as requested and to collaborate when collaboration was needed. The fact that it offers a gradual approach to the collaborative experience, by means of an increase on the number of tasks for every phase of the game, contributed to help them better understand the need to collaborate with a partner.

The availability of different levels of collaboration support (elements on the interface) - evaluated in the order OD, GV, FT, and FnT - has lead participants to an improved collaborative performance, even when interacting on the levels with less support (FT and FnT). Levels OD and GV contributed positively for most participants, both on the support of the collaborative process as well as on the learning of the management of the game, leading them to get more and more engaged on the game. In the future, these levels could be provided according to needs of the participants.

The difficulties faced by some participants when dealing with some interface elements provided, highlights the importance of a careful design of such features. Even being a delicate matter, because of personal commitments of each person, it is an issue that should be taken into consideration.

The results suggest the importance of the availability of support on collaboration for people with ASD. Such support should strengthen their communication and social interaction skills. We stress that collaborative games contribute positively to motivate users with ASD, mainly those with a higher degree of impairment, enabling them to know, identify and learn the act of collaboration, thus providing them with a better inclusion into society. Therefore, we hope future applications with be designed taking that into consideration.

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