Motion-Based Touchless Interaction for ASD Children: a Case Study

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ABSTRACT
Autism spectrum disorder (ASD) has become the fastest growing disability in the United States in 2013. The disorder is characterized by a triad of symptoms related to lack of social interaction, deficits in the acquisition and expression of language, and repetitive patterns of behavior often accompanied by sensorimotor impairments. In our research, we explore the use of motion based touchless games for ASD children and develop innovative tools that can be autonomously used by teachers/therapists in school classes or therapeutic activities. The paper describes the design and preliminary evaluation of "Pixel Balance", a motion based touchless game conceived to promote imitative capability, body schema awareness, and social skills in ASD children.

Categories and Subject Descriptors
K.3.0 [Computers and Education]: General; H.5.2 [Information Interfaces and Presentation]: Multimedia Systems, User Interfaces

General Terms
Design, Human Factors

Keywords
Autistic children, learning, motion-based touchless interaction

1. INTRODUCTION
Autism Spectrum Disorder (ASD) is a range of complex neurodevelopment disorders characterized by social impairments, communication difficulties, and repetitive and stereotyped patterns of behavior often accompanied by restricted motor capabilities.

In recent years, a rapid growth in the development and use of assistive technology has significantly improved access to education for children with autism. Special attention has been given to tablet devices and related applications that help them behave more independently in their classrooms [7].

This variety of applications helps children in the spectrum to learn by focusing on their visual learning styles, rather than forcing them to adjust their own method to the classroom. Autistic people are frequently sensitive to sound and show difficulty processing auditory information, so gaining information through reading, pictures and videos is easier for them than listening to lectures [6].

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Kinect, a low-cost device that is now incorporated in many houses, adds a kinesthetic component to visual learning. Some studies [4][5][11][13], by showing that bodily experience can affect learning and comprehension, suggest the fundamental necessity to consider the importance of physicality from a developmental psychology perspective [20]. Bodily experience, through its actions in a situated context, can be considered crucial in the development of cognitive and behavioral skills and in the processes of construction of meaning [14][15].

Furthermore most existing technologies for autistic children combine the potential of motion-based touchless paradigm per se with the educational effectiveness of gameplay [6][17][18]. Game-based activities promote attention, increase the capability of selecting relevant information (abstraction and customization), and augment the willing to complete the required tasks (rewarding) providing control of the rate of learning [8][9].

This work describes the design and preliminary evaluation of a motion-based touchless game called "Pixel Balance". It tries to offer opportunities for encouraging social interaction, developing communication and imaginative thinking, and increasing children's body awareness ability to perform a variety of activities needed for daily life.

From a HCI perspective, this study suggests the necessity of carefully considering the importance of physical activity when we design technologies for children. This claim is particularly relevant in the design of learning and therapeutic technologies, since these fields, by addressing specific psycho-pedagogical issues, need to be carefully aligned with a proper understanding of the crucial factors involved in children development.

The empirical data gathered in this experiment show improvements in terms of game play autonomy and performance, enhancement of motor skills, and pinpoint positive effects also in the social sphere.

2. ELICITATION PROCESS
The elicitation process has been articulated as a bi-directional knowledge sharing process between the design and technical staff and the educational/therapeutic at Centro Benedetta D' Intino (hereinafter CBD) and at Associazione Astrolabio (hereinafter AA) (two therapeutic centers in Milan and Florence that are collaborating with the project). Our technical team needed to deeply understand the characteristics of children for whom their games are built while domain experts – neuropsychiatric doctors, language therapists, motor therapists, and educators– had to understand potentials and limitations of motion-based touchless games for autistic children. Requirements elicitation hence comprised the following three main types of activities.

Observing children's activities *without motion based touchless technology:* This activity implements the principle of Contextual Inquiry: understanding what is happening in people's real life context, what works, what doesn't, where the opportunity lies, and what value of our technology can be brought into people's lives.

We attended as observers 5 afternoon sessions at CBD in which 10 autistic children participated in their normal activities at the center. All sessions were videotaped and videos were discussed with CBD experts.

Observing children playing with motion based touchless commercial games: These activities aimed at gathering empirical evidence of the potential benefits of the general paradigm of touchless motion-based gaming for autistic children. Starting from these activities, we derived strengths and weaknesses for our intended target of commercial products. To this end, five commercial Kinect games were selected for these activities, in cooperation with therapists. In particular the game *Rabbids Alive & Kicking,* was chosen thanks to its distinctiveness of body imitation and schema awareness, scope of our case study.

The games were installed in the two centers for a period of two and a half months and were used overall by 15 children - 10 at CBD and 5 at AA - who were videotaped, collecting over 30 hours of videos of children's activities. The material gathered was analyzed and discussed in focus groups (see below). The details of this study are reported in [2][3].

Focus groups: Focus groups were undertaken to analyze the data gathered in the above mentioned activities, and then in joint meetings involving both teams.

3. GOALS

The game is designed to promote imitative capability, body schema awareness and social skills in ASD children. Goals are mainly classified, respectively associated to learning goals, in the motor, cognitive, and social dimension.

Motor Skills

Providing audio-visual stimuli associated to each movement promotes different motor skills such as body awareness and its limits, movements regulation and coordination, postural control and auto-regulation, balance and gross motor skills (walking, jumping…). A number of studies [13][15][16][22] highlight that a person, focusing on the task and on the effects of his movements, may unconsciously disrupt the coordination of a number of automatic (reflexive and self-organizing) processes that normally control the movement.

Cognitive Skills

Cognitive skills are used in all types of play. Any activity where the child uses, expands or questions what he/she knows or has learned is using his cognitive skills. This could happen in block play, reading and acting out a story, science activities and fine motor play such as our game.

Since autistic children show limited cognitive capability [10][12], our goal is to promote imitative skills (avatar), body consciousness (itself and in the space) and abstraction ability.

Social Skills

Most touchless games can be developed for being played by both a single individual and two or more persons without changing game logic. However, moving together in front of a display and performing independent or complementary tasks do not necessarily triggers social interaction. This is especially true for autistic children [21] who do not engage with others spontaneously. Social interaction must be supported "by design", with multiplayer tasks that are explicitly conceived to promote and exert social skill such as communication, strategy planning and joint attention [1].

4. DESCRIPTION

The goal of this game is to create body postures that mimic closed shapes shown in the virtual world. The child is realistically mirrored on the screen and he must find the correct movements to "fill" the shape, maximizing the area that is "covered" by his body. This activity requires the child to identify the proper body schema and to keep the posture for a predefined time frame. The activity ends when the shape is fully covered or after a given time frame (Figure 1).

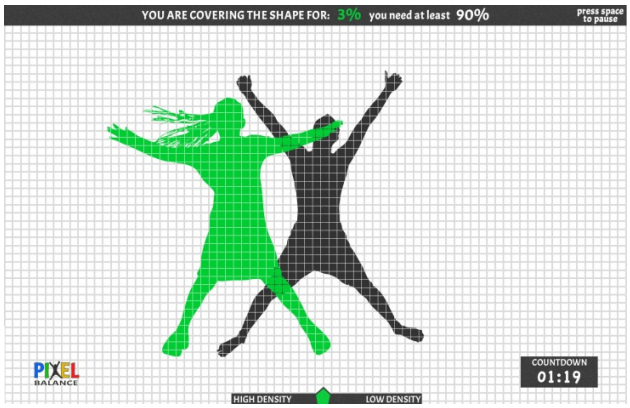

Figure 1: Single player activity.

Once successfully accomplished an activity, a 3 seconds video reward is shown and the task can be repeated within the same level or selecting the next one.

The game can be played in single player or in multiplayer mode (Figure 2). During this second modality, players have to collaborate to match together the shape on the screen. This modality is well accepted during group time where collaboration is a priority and shared strategy planning is requested.

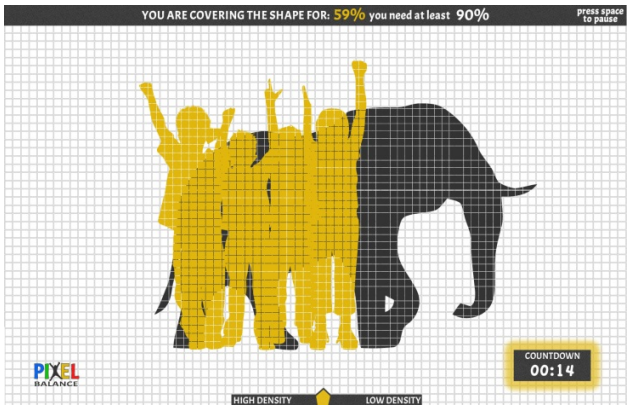

Figure 2: Multi player activity.

Games' graphic is easy and linear and facilitate the child attention in doing the task instead of graphical details. According to [19] each child should follow its own tailored program with its own favorite and personalized settings.

Customization

Pixel Balance is entirely customizable and always editable from the therapist before and during the treatment. Each game's parameter is easy to set (i.e. shape to match, steady duration, time limit…). Furthermore therapists can easily create new levels and new shapes to imitate (Figure 3). There are two main modalities to create a shape: paint mode and photo mode. In the paint mode,

one has to draw a figure with the mouse while in the photo mode one can easily shoot a photo of herself. Both modalities can be mixed and a shoot photo can be subsequently edited in the paint mode (Figure 3).

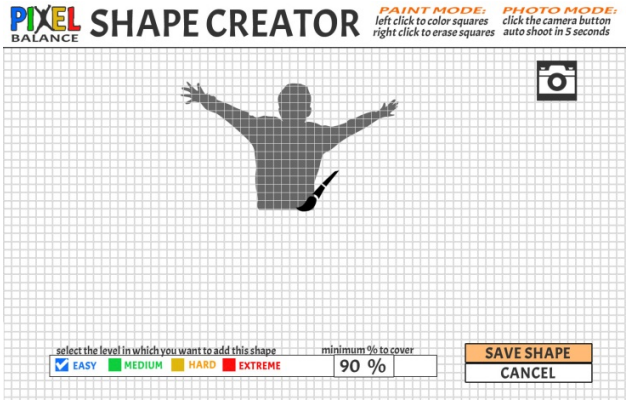

Figure 3: Shape creation tool.

Customization gives the chance to support child development exploiting strengths and refining weaknesses as [19] suggests.

Comparison with Alive&Kicking "Wet Terror"

Since Alive&Kicking with "Wet Terror" focuses on the entertainment, the game offers a great ludic experience, while "Pixel Balance", through the playful experience, tries to elicit different skills such as collaboration, motor and body awareness inside a therapeutic setting. Table 1 summarizes the main differences:

Table 1: Comparison between Wet Terror and Pixel Balance

Elements	"Wet Terror"	"Pixel Balance"
Penalties	yes	no
Matching %	Default	Customizable
Graphic dimension	3D	2D
Graphic type	Rich	Simple
Background	Default	Customizable
Game area	Part of the screen	Whole screen
Sounds	Default	Customizable
Player's color	Red	Customizable
Maximum time	Default	Customizable
Reward	Image	Video (3s)
New Levels	no	yes
Edit and Order Levels	No	yes

Table 1 show the main differences in the graphical aspects and customization scopes between both games.

5. EMPIRICAL STUDY

Five medium-low functional children have been recruited for the testing phase (males, aged 6-8 years) to regularly attend sessions with our game. During the entire testing period, parents have been warned not to let children play with motion-based game console such as Nintendo Wii nor Xbox with Kinect.

The study was performed at the therapeutic center AA of XX [2]. The group had been analyzed along a 3-months period (from October to December 2013); and for each session children played 10 minutes with the game, gradually increasing the level of difficulty. Meetings were video-recorded, using two cameras placed in front of and back to the child, respectively and simultaneously capturing his movements and the game visual interface. A total of 5 hours of video recording were collected.

During the game session, the therapist was sitting or standing aside the child and outside the Kinect sensing area, taking notes and intervening when needed. All sessions took place in the same room without modification of the environment settings.

The game was set with a starting homogeneous setup among the children. After the first meeting each child received his own therapeutic trend (preference assessment [19]). In each session, the child had to start from the level which he had played the previous session, with the goal to redeem confidence and reach a satisfactory concentration level. At the end of each level an animated reward was shown gratifying and encouraging the child. Game's configurations are divided in 5 levels with growing difficulty. Table 2 summarizes the experiment configurations used in the game. Each level gradually increases his difficulty and consequently adds effort on cognitive and motor activities of children. In particular levels L4 and L5 add additional complications. L4 focuses on improving static balance skills while L5 involves motor planning abilities, since most of the figures to be simulated in this level do not have a human shape (Figure 2).

Table 2: Pixel Balance configurations

Level	Coverage	Pose time [sec]	Game time [sec]	Additional difficulties
1	60%	2	30	No
2	60%	2	30	No
3	70%	3	30	No
4	80%	3	30	Static balance
5	90%	3	40	Abstraction

6. RESULTS AND DISCUSSION

In order to evaluate game performances, we propose a weighted score called *Global Weighted Score* (GWS) which represents an average weighted score depending on the following game parameters:

*Pixel Balance GWS = (Difficulty_Level * Pose_Time * Coverage_Threshold * (1- Final_Time / Max_Time)*

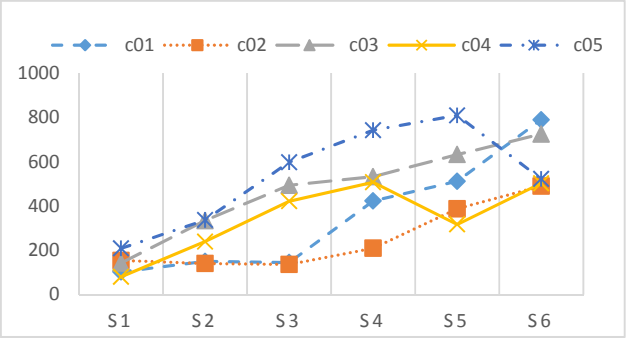

Figure 4: GWS average per session.

Where the *Steady_Time* denotes the time in which children have to maintain their position to cover the shape; *Coverage_Threshold* corresponds to the percentage of the shape players have to cover in order to win; *Final_Time* represents the time spent to correctly cover the shape and *Max_Time* characterizes the total available time for a specific level. Our findings show that the time for completing the task at a specific level of difficulty decreases with the treatment. After a first initial phase, children began understanding different new and creative strategies and combining them to complete the tasks. Global Weighted Score (avg. per session) increases over the time for all the children with predictable fluctuations (Figure 4).

Table 3: % completed levels along 6 sessions

	Levels				
Sessions	L1	L2	L3	L4	L5
S1	83%	100%			
S2	97%	97%	76%	33%	
S3	75%	93%	88%	48%	
S4	81%	80%	86%	44%	17%
S5		100%	93%	44%	39%
S6			67%	55%	35%

Table 3 shows the percentage of successes for each level (L1-L5) along the six sessions (S1-S6). Levels are gradually completed with a noticeable improvement along the entire evaluation period. Fluctuations of percentage trends confirm the fact that levels are peculiar to each personal individual skill even though activities of each level are equally distributed (homogeneous). Overall 328 (71%) activities have been successfully accomplished among 456 in total.

7. CONCLUSIONS

The systematic analysis of the qualitative data gathered during the study (video recordings, therapist's and observers' notes, feedbacks from parents) is still ongoing. Still, some facts have already emerged that are worth to be mentioned.

The bidirectional eye triangulation that eventually occurs during play between the child, the therapist and game screen has been repeatedly noticed. This behavior was considered very positive by therapists taking into account that the marked impairment in eye-to-eye gaze is a typical symptom of social interaction deficits which characterizes autism.

The motor skills involved in this game are lower, with respect to commercial games, but the game is more demanding from a cognitive perspective. As results demonstrate, "Pixel Balance" positively promotes the development of self-awareness and self-regulation, imitation skills, and the capability of planning body schema and postures (Section 6).

Finally, the overall comments by parents were very positive. After the study, a mother reported evident improvements in her child's motor skills and in the execution of daily tasks at home, and a more positive attitude towards social play with peers. By word of mouth the positive effects of the "game-based treatment" spread among families attending the therapeutic center. Many parents of subjects who were not involved in the treatment asked explicitly to organize an additional study and to have their children involved.

Pixel Balance also challenges balance, eye-hand co-ordination and reflexes. The graphics and sounds give this the semblance of a competition and even provide a score at the end of each run. It becomes a social event when many children participate together.

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