Applications for investigating therapy progress of autistic children

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Abstract—The paper regards supporting behavioral therapy of autistic children with mobile applications, specifically applied for measuring the child’s progress. A family of five applications is presented, that was developed as an investigation tool within the project aimed at automation of therapy progress monitoring. The applications were already tested with children with autism spectrum disorder. Hereby we analyse children’ experience with the games, as a positive attitude towards the application is the key factor enabling practical application of the solutions in therapy. Two evaluation methods were applied: a behavioral study of video recordings of children interaction with the games and on-line behavioral tagging performed during measurement sessions. The paper also outlines the main challenges, encountered during sessions with autistic children. The study might be interesting for both researchers and practitioners applying e-technologies in autistics therapy.

I. INTRODUCTION

Autism is a developmental disorder, that influences the ability to socialize, communicate as well as learning skills [1], [2]. Autistic children have diverse level of deficits in language understanding, speaking and other areas, that make the therapy and education very difficult [3]. Autism is not only a personal or family matter, but a social problem, as the number of children diagnosed with autism rises all over the world. Our motivations to develop e-technologies supporting autistic children lies in a belief, that an appropriate therapy adjusted to the deficits of an individual, may result in independent life for autistic users is described, and the data from interaction sessions is analyzed. Moreover, we report our observations on autistics interaction with tablets and applications. The study might be interesting for both producers of solutions for autistic children as well as for researchers investigating effective methods for ASD support and therapy with e-technologies.

The paper is organized as follows: Section II reports work related to this study and especially previous works on monitoring autistic users performance. Section III presents the study context and study design, including the description of developed applications and their adaptation to autistic users is described, and the conclusions describing future works (Section VII). The paper regards supporting behavioral therapy of autistic children with mobile applications, specifically applied for measuring the child’s progress. A family of five applications is presented, that was developed as an investigation tool within the project aimed at automation of therapy progress monitoring. The applications were already tested with children with autism spectrum disorder. Hereby we analyse children’ experience with the games, as a positive attitude towards the application is the key factor enabling practical application of the solutions in therapy. Two evaluation methods were applied: a behavioral study of video recordings of children interaction with the games and on-line behavioral tagging performed during measurement sessions. The paper also outlines the main challenges, encountered during sessions with autistic children. The study might be interesting for both researchers and practitioners applying e-technologies in autistics therapy.

Moreover, systems and devices might be customized in order to adjust to a unique set of deficits of an individual [4]. This study is performed under the AUTMON project, that aims at development of methods and tools to allow for the automatic evaluation of the therapy progress among children with autism spectrum disorder (ASD) [5]. Therapy monitoring is based on automatic detection of behavioral patterns in tablet and application usage. During the project 5 applications were developed or adjusted to fit the deficits of autistic children. The apps have the potential of being applicable in the therapy progress monitoring. However, the crucial question is: whether the autistic children are eager to use those games. This study aims at verification of this issue. In this paper, the applications and their adaptation to autistic users is described, and the data from interaction sessions is analyzed. Moreover, we report our observations on autistics interaction with tablets and applications. The study might be interesting for both producers of solutions for autistic children as well as for researchers investigating effective methods for ASD support and therapy with e-technologies.

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• eye tracking, which reveals that people with autism rarely focus attention on the area of eyes if compared to other parts of face. It can be used in the early diagnosis of ASD [9], [10], [11];
• automatic analysis of video recordings presenting children performing tasks that are commonly evaluated by specialists [12];
• automatic analysis of individual hand movements when performing tasks, which require indicating objects on a touch screen [13];
• machine learning algorithms applied to predict the state of a person on the basis of information taken from commonly used diagnostic questionnaires [14], [15].

Much more often than in the diagnosis, new technologies are used in the therapy of autism. In most cases, these solutions are computer implementations of therapeutic tools, that usually are in a paper form. There are numerous programs supporting daily activities, allowing for arranging and following procedures that consist of sequences of activities represented as images or text [4]. Sometimes the images are also accompanied by appropriate sound recordings, to help autistic people to communicate and in particular express their needs and desire.

There are also programs that support learning of certain behaviors, e.g. by providing stories illustrating course of typical relationships. Thanks to the new technologies, such scenes can be more interactive and therefore more realistic. Typical interpersonal situations may be also trained using an online chat moderated by a therapist [16]. Other available popular tools improve speech and verbal communication (VOCAs, ang. Voice Output Communication Aids) that read the names of symbols or whole sentences and also support the training of word pronunciation, expressing requests and desires and answering questions. Moreover they encourage spontaneous reactions during interaction with another person.

Very often children with autism spectrum disorders cannot recognize faces among other objects and also are not able to recognize emotions from facial expression. Therefore, numerous tools are created to help to acquire these skills. These include programs that help in learning face recognition and emotions based on facial expressions [17], learning expressing emotions through facial expressions [18] and recognizing emotions of encountered people [19]. There are also solutions, that incorporate special hardware measuring physiological signals to interpret an emotional state of a person, which may be especially valuable information in case of autistic children, who often are not able to show their emotions [20], [21].

Apart from solutions designed for people with autism, there are also some applications supporting work of the therapists, e.g. ABPathfinder or ACE (Autism Curriculum Encyclopedia). They support diagnosis, preparation of individualized educational programs, collecting information about the learning process and its analysis, detection of situations requiring intervention, recommendations for therapy depending on the progress of the skills acquired.
the tablet devices. The solution set includes five games, which allows to gather information about children interactions with the device, using touch screen sensors and gyroscope.

Each game consists of training phase and actual game. During the training phase child may get acquainted with the game concept. At the beginning of training session interactive tutorial is presented. Later child may try to use application by herself/himself. During the whole training therapists should instruct the child and may use either verbal and physical guidelines. Depending on game, training session lasts from 2 to 5 minutes. At any time training session may be terminated by tapping three fingers at the top of the screen.

After finishing training session, actual game, which is used to collect data, begins. In order to obtain the undisturbed results, during this phase, the therapist should not interact with the child. Like during the training phase the session can be terminated, when a child looses interest in the game.

1) Boxes: Boxes is a game designed for warm-up. The goal is to place the balls in boxes by matching corresponding colors, as shown in Fig. 1. The child should touch and drag each out of five balls into proper box. It is very simple, yet allows to measure color recognition, simple instruction understanding and matching ability. It also becomes visible if a child can properly use the touch screen (swipe movements).

2) Sharing: The goal of the second game is to share food among four animated children. Child has to tap on the displayed food article (watermelon, apple, cake) and swipe portions to four plates in front of the children. The game consists of learning phase and identical test phase. This task requires more complex instruction understanding, motor precision, perseverance (the game is all about sharing for 5 min) and to some extend attentional control, as screen is filled with clickable distractors. Distractors are aimed to draw child’s attention and prevent child from completing trials. Trial also cannot be completed if child places the food unevenly (some children are left without their portion) and does not read the mimic cues given by characters (if child doesn’t get his/her portion, his/her face turns sad, while fed children get happy faces). Fig. 2 presents the game screenshot.

3) Cat & Dog: Based on the experimental paradigm of Go/NoGo, the game is intended to be used by older children. Typically developing 3-4 years old’s are not ready to proceed with this cognitively demanding task. Series of stimuli is presented randomly at a fast pace and a child has to react to target stimuli while refraining from reaction to distracting stimuli. For example, in Cat condition, as shown in Fig. 3 a child has to tap the screen as fast as possible when a cat or...

Fig. 2. Sharing game

Fig. 3. Cat & Dog game
meowing sound is presented and inhibit reaction for dog or barking. This task demands prolonged alertness, fast decision making, good perceptual and attentional skills and executive control of intentional actions. It can be used as a measure of impulsivity and control processes. As this game can be frustrating to some children, it is advised to omit the game if the child displays loss of interest and negative emotions (usually auto-stimulatory behaviors).

4) Pinwheel: This game requires some flexibility of mental representation of tablets affordances that were learned in previous games. Performance in Pinwheel game (Fig. 4) is determined by efficiency and speed of learning new ways to use objects, fine motor proficiency, instruction understanding, executive control and attention, inhibition, color recognition and matching and many other basic cognitive abilities. The pinwheel is slowly turning around while a color ball balances at the base of its stem. A child has to flip the tablet (previously only touch screen data were gathered, now accelerometer and gyroscope provide the data) precisely to move the color ball to the corresponding “pinwheel petal”. Should ball fall off the stem, the child has to start over with the next trial, the same happens if the ball reaches wrong petal (for example blue ball hits yellow petal). Patient waiting, anticipatory movement planning and ball control can be challenging for younger users, so the game is recommended for older children.

5) Creativity: Drawing and coloring pictures seem to be the most rewarding, the game for most children. A child has to exhibit a good understanding of the instruction, stability and precision of movement, as well as ability to imitate (mimic) the lines displayed as a prompt. Each step of drawing a picture is shortly displayed on the screen and child’s task is to lead the finger on the dotted line. At the end child gets to color the finished picture – leaving behind even more movement patterns for the analysis. Screenshots of the game are shown in Fig. 5.

C. Study design

Two evaluation methods were applied: (1) a behavioral study of video recordings of children interacting with the games and (2) on-line behavioral tagging during measurement sessions.

The first part of the study was performed before measurements sessions were started and aimed at evaluation of user experience with the games. The second part of the study is performed on-line during each measurement session and this paper summarizes the results as a validation of the chosen approach. The target group in those studies are children aged 3 up to 7 (kindergarten education level), diagnosed (or during diagnosis) with autism spectrum disorder. As children measurements require consent from parents, randomization of selection to sample was not possible. Children were recruited among pupils of ten therapeutic centers in Poland. Parents agreement rate was very high (more than 90%) only few refused to agree that their child would take part in the study.

1) User experience study: This study was aimed at analyzing the experience of the children play. The first step of this study was to find a definition and unambiguous indicators of good UX. Previous research on the subject mentioned: engagement, playfulness and fun as indicators of good UX.
in children [22], [23], [24]. The proper measurement could be made only if a child pays attention and makes effort to interact with tablet and the good UX was defined from that perspective.

Previous studies [25] used some combinations of behavioral observation with survey and interview techniques. This approach was hard to apply in this study, because children with autism are mostly nonverbal or of poor communication skills, so we couldn’t ask them straightforward for their opinions. Sometimes children with ASD present paradoxical mimic or vocal reactions, so to discover their inner feelings and attitudes was a challenge of this study. Therefore in this study behavioral observation was chosen as an investigation tool. Moreover, the gameplay was recorded and analysis were made post-hoc by independent observers. This approach allowed for measuring consistency of manual tagging in order to achieve higher reliability. Steps of the study preparation:

1) An exploratory observation of gameplay was performed resulting in a list of observational indicators of interest and having fun with the games. A small subset of videos of children gameplay were chosen purposefully the ones recorded with autistic children playing the games for the first time. The videos presented two boys (3 and 5 y.o.), while the younger expressed uneasy behavior during gameplay session. Three independent judges (two psychologist with specialization in autism therapy and a naive observer not familiar with the symptoms of autism) were watching videos and listing observational indicators of good/bad experience of play.

2) Behaviors listed by observers in the previous step were clustered into three categories of: engagement, understanding and enjoyment.

3) The three factors were conceptualized and operationalized with three behavioral indicators each forming 9-item behavioral observation scheme.

4) Each item was assigned a five-point discrete scale (1-5) with descriptive explanations assigned to first and last item. As a result an observation sheet was prepared, that was used in manual tagging of the video recordings.

5) Using the elaborated scale and observation sheet, manual tagging of videos was performed by 5 independent observers. Total number of 21 recordings were analyzed.

6) The manual markers from observers were checked against consistency criteria using commonly used Kappa coefficient [26]. The data was used to evaluate the applications using the understanding, engagement and enjoyment criteria.

7) Final results were formulated regarding inclusion or exclusion of the games from the measurement procedure. Some additional recommendations were formulated for the measurement procedure.

Understanding factor characterizes, that the device functions and the games are understandable for a child. First of all, child realizes that tablet screen can be used to interact with the tablet. There is a range of algorithms of interaction (based on set of possible actions provided) that result in successful interaction with the game, meaning when child achieves the goal of the game. Child wins the game if (s)he acquires a final stage of task completion, e.g. feeds all four children, draws a picture, paints a picture etc.) Children may get to win by themselves or with a standardize verbal or motor prompt from the experimenter.

Engagement factor characterizes, that the function of the tablet and the game is engaging, meaning, that tablet and game attracts children attention. If in childs sight, in proximity of his/her hands there is a possibility of engaging. It can be observed how often, regular and persistent is childs interaction with the touch screen.

Enjoyment factor characterizes, whether interaction with tablet results in growth of positive affect symptoms, which were operationalized as laughing and vocal expressions, verbal expressions, mimic expressions and motor and postural expressions (clapping hands, jumping, shrugging). Facial expressions were not observable due to the fact, that video materials were filmed from the chin down (which was explicitly stated in the parent-experimenter agreement for the privacy reasons).

The results of the study are provided in Section IV.

2 Validation during measurement sessions: The second study is off-line observation made during the measurement sessions. A validation procedure was designed with the aim of the comfort of the child. Children are seated by the experimenter at the table with tablet placed on it. The preparatory work (turning on the device, WiFi connection) is done before a child enters the room, so (s)he gets to play the game without waiting. The first part of the procedure is a tutorial session, in which animated prompts are displayed to give children clues on the intended use of the game. If the instruction is insufficient, the experimenter or therapists are allowed to intervene and provide additional motor or verbal instructions. The test phase of the procedure lasts for 5 minutes and ends automatically. In this part, experimenter and therapists are not allowed to interrupt the child or help them in any way. If the child loses interest in the game and walks away, adults can encourage the child to keep up with the game, but no specific instructions should be given.

After the game is finished, the therapists ask a child to give him/her the tablet and they are waiting for the data to be processed and send. In the meantime, the experimenter can offer the child some toys or engage in a small talk. When the data is loaded, next game can be launched. If all of the games (tutorial session + test phase) are completed, the study is over.

The children are supposed to play all five games during the sessions. The detailed criteria used in the usability study were significantly simplified for the measurement stage. From the 9-item scale only 2 indicators were used in the on-line tagging procedure. For each game the following two factors are estimated by an observer: the level of difficulty, which may be 1-easy, 2-adequate, 3-difficult; the level of interest, which may be 0-none, 1-low, 2-average, 3-high. If a child does not want to play a game in spite of some encouragement, 0 is assigned to the level of interest and no value is given as the level of
difficulty. If, for some reasons, a therapist decides not to try to play a game, neither difficulty nor interest are assigned a value. The reasons for children intentional exclusion from play might fall into following categories: a child performed an extremely negative reaction to the game (e.g., fear of sounds); a child is in bad disposition on this specific session day (regular therapist opinion); a child got upset during the study procedure before attempting to play the game.

The difficulty factor corresponds to understandability criteria from the UX study, the interest factor corresponds to engagement criteria from the UX study.

There were multiple reasons for that simplification. First of all, the primal focus of the sessions was to measure the data, not to measure usability. Secondly on-line tagging is much more difficult than video tagging, as multiple activities must be performed simultaneously and there is no possibility to replay the recording. Moreover, the two factors were the most important from the perspective of measurements reliability.

IV. USABILITY EVALUATION OF APPLICATIONS FOR PROGRESS MONITORING

This section provides results of usability evaluation of the applications. Table I presents the distribution of the data analyzed. 21 recordings of nine children have been annotated. All children were boys, aged 3-7. Each of them played from one to four of the created games.

To evaluate the consistency of the annotations done by four observers, kappa coefficient was calculated[26]. The values obtained for all nine behavior indicators defined in section III-C and averaged over all games are shown in Table II. The highest agreement was obtained for engagement, moderate for understanding and the lowest for enjoyment.

To provide final evaluation scores for the three categories (engagement, understanding, enjoyment) the following procedure has been followed independently for each game:

1) in each category the scores for three behavior indicators were summed getting total category scores;
2) the total category scores were averaged over four judges;
3) the obtained recording scores were averaged over all films presenting a given game.

The results obtained in this way are presented in Table III. As there were only two recordings for Boxes, this game should not be considered in the analysis. Sharing received the highest scores for understanding and engagement. Surprisingly, Cat & Dog took the second place in these two categories and the first one in enjoyment. That game seemed to be rather difficult, some of the children did not play it at all. In spite of these obstacles, it turned out to be entertaining. Creativity game received the lowest scores for understanding and enjoyment, Pinwheel for engagement. Although Creativity seemed to be understandable for the children, as most of them intuitively drew lines with their fingers, precise drawing turned out to be quite difficult bringing about the low scores. It can be observed that more understandable games get higher scores in engagement and enjoyment, however the relationship between the variables would require further analysis.

V. ON-LINE TAGGING - EXECUTION AND RESULTS

Eight therapy centers take part in this study. The centers are visited once a month. Each of them has been already visited at least three times. To summarize the results the first three sessions have been taken into account. These are the first three sessions for each child, which is not necessarily equivalent to the first three visits in a center. For example, if a child is absent during session 2, then his results from session 3 are assigned to session 2. Due to some absence rate not all participants have already gathered three data records. From the total number of 42 children, 29 of them were present during all three sessions, 6 - during two sessions and 7 had one session only. The absence rate is typical for the kindergarten children age range.

The results obtained for each game are averaged over all children. The fields with no values are not taken into account in the calculations. The final scores for the levels of difficulty and interest are shown in Table IV.

It can be seen that three of the games (Sharing, Boxes, Creativity) turned out to be much more interesting than other two (Pinwheel, Cat and Dog). Some relation between interest and difficulty may be observed. The more difficult game, the less interesting and vice versa. Boxes and Sharing were the easiest ones. Pinwheel, which requires motor skills while flipping the tablet, and Cat & Dog requiring being focused,
were the most difficult, just as it was expected. Some of the kids were not able to play Cat & Dog at all.

Another interesting observation is the fact that the levels of interest and difficulty do not change much over the time. One might presume that difficulty would decrease as the kids play more. However, it is not the case. Neither the level of difficulty nor the level of interest becomes lower. This is a relevant feature from the point of view of the AUTMON project. It meant that data collected while playing are not affected by confounding factor such as history effect.

VI. SUMMARY OF RESULTS AND DISCUSSION

The aim of this paper was to evaluate, whether the applications developed for monitoring progress of children with autism have a chance to be used in practice. The question was raised, whether the applications are engaging, understandable and enjoyable enough to trigger and maintain child's focus and interaction. Two studies were performed: one detailed usability study based on observation and manual tagging of video recordings and an on-line tagging during first three measurement sessions.

The main results might be formulated as follows:

- understanding, engagement and enjoyment are partially dependent, eg. some children are fascinated with pinwheel although they do not understand the purpose of the game, for the others, if they do not understand a game, they are not interested in it.
- both studies confirmed, that three of the games: Sharing, Creativity and Boxes are mostly understandable for the children; out of the three, Sharing seems to be the favorite game;
- game Cats & Dogs and Pinwheel seems less intuitive and half of the children refuse to use them, however, once a child understands the game, it seems to be engaging,
- although it seemed, that some of the children do remember the games after a month (average time distance between recording sessions), the data do not confirm the history effect, which is convenient for measurement.

All recording and measurement sessions revealed also some qualitative observations:

- Most of the children with autism were eager to use tablets, typical behavior was to grab a tablet in the proximity of hand and to follow it, when it was taken away,
- Most of the children know very well, how to turn the tablet on and how to switch to another game, we have used the parent mode in order to prevent children from switching the games off;
- Some lower functioning children got frustrated, when they did not understand the game;
- Some higher functioning children got bored easily and even though they started eagerly, it was hard to keep them play for longer than a minute;
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- Some higher functioning children got bored easily and even though they started eagerly, it was hard to keep them play for longer than a minute;

Authors are aware of the fact, that this study is not free of some limitations, such as small number of videos analyzed and low consistency of manual tagging for some of the variables. Videos for usability evaluation were taken before the final applications were launched (and the application were corrected afterwards). Children are challenging subjects to follow some of them moved around the room, took the tablet and turned, got off the chair to sit on the floor and so on. From the recorded videos we have chosen for the analysis those, that were the
most complete and had clearly visible actions on the tablet screen.

In this study the main reason for the relatively low consistency is that we have assumed using the common scale for the games. In the future research we are planning to define usability criteria (engagement, understanding and enjoyment) with more detailed behavioural scales separately for each game, which is expected to increase consistency of manual tagging.

Despite some limitations of the study, the performed analysis allowed us to determine, which applications provide experiences positive enough for the child to perform and continue interaction allowing (as a result) to monitor progress. The goal of the study was achieved.

VII. CONCLUSIONS

Our study shows that potential for use of tablet-based technology in children therapy should be considered as more valid and reliable tools emerge. Children are generally enthusiastic about tablets and other mobile devices and this rapture can be utilized in the area of research, diagnosis and therapy. Future works in this discipline should focus on to developing tools for monitoring progress and better means for their evaluation. As our study concludes, its not easy to evaluate in terms of child experience, especially in autistic population, where raters agreement is hard to reach.

Objective measures of therapy progress can bring quality data to the therapy providers. As they have better knowledge of childs state and developmental pace and direction, they can provide adjusted intervention to best fit the individual needs of the child. Autistic children often develop disharmoniously, so they are progressing faster or slower in certain areas of development, say fine or gross motor skills, communication or self-reliance. When these (sometimes minor) differences are recognized and taken into account while planning the intervention a child gets highly personalized and evidence-based therapy. Better therapy means better life for children with ASD, as enormous amount of evidence shows that which type of stimulus to use? 2013.


REFERENCES


