

Behaviometrics of Digital Games for Children with Autism Spectrum Disorder

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1. Introduction

Autism is a developmental disorder which influences the ability to socialize and communicate. It is not only a matter of families afflicted by autism, but also a social problem, as the number of children diagnosed with autism rises. One of the main problems is a limited access to a support system, especially in terms of early diagnosis, but also therapy. The number of therapy centers and qualified staff is not high enough. Appropriate therapy started as early as possible is essential on the way to independent life as an adult. The paper reports current stage of the project Automated Therapy Monitoring for Children with Developmental Disorders of Autism Spectrum (AUTMON), that aims at development of methods and tools to allow for the automatic evaluation of the therapy progress among children with autism (AUTMON, 2015). The project has been proposed to work out effective methods of early diagnosis and therapy support, which could not only improve the quality of life of people with autism and their families, but also make therapists' work more effective and even reduce the costs of sustained care (Landowska and Smiatacz, 2016).

2. Supporting diagnosis and therapy of autism by computer technologies

One of the autism spectrum deficits is inappropriate (or even no occurring) imitation of gestures, behaviors and movements of others. As educational processes are strongly based on imitation, teaching children with autism might be a challenge in the best of circumstances. Another challenge is an objective and efficient therapy progress evaluation. Therapists use a number of measures, that are based on the observations of behaviors and task performance, as children are frequently non-verbal. The observational metrics are susceptible to subjectivity and it is hard to obtain a highly consistent results, if two or more observers' scores are compared. Therefore a number of computer-aided solutions were proposed to support that might help address the issue of objective and efficient scoring.

Some examples of methods supported by computer technologies may be helpful both in diagnosis and therapy of autism. In the case of diagnosis, most methods are simply computer ver-

sions of questionnaires filled by therapists. More advanced solutions apply eye tracking techniques making use of the fact that people with autism do not focus attention on the area of eyes as most people do (Klin et al., 2002; Jones and Klin, 2013; Saitovitch et al., 2013). Other methods let automatically analyze and evaluate video recordings of children performing tasks usually done during the process of diagnosis (Hashemi et al., 2012). Another interesting solutions has been based on the analysis of hand movements while indicating objects on a screen (Torres et al., 2013). More applications have been proposed and implemented to support therapy of autism. Some of them are computer realizations of tools usually prepared and used by therapists in other forms. An example of such solutions is an application, which lets a therapist prepare detailed plans of all activities for a day to be followed by an autistic person (Landowska and Smiatacz, 2016). Other solutions have been developed to improve verbal communication or enable alternative ones. There are also numerous programs used to train specific interpersonal behaviors, e.g. by presenting example scenes or by moderating a chat (Cheng, Kimberly and Orlich, 2002). Another group of applications supports the process of learning how to recognize emotions and how to show them depending on a situation (Kaliouby and Robinson, 2005; Tanaka et al., 2010; Deriso, Susskind, Krieger and Bartlett, 2012). Although few advanced solutions have been proposed to support the process of therapy, their usage is limited to laboratory environment, because they require special equipment or they have been tested on small groups of patients (Jędrzejewska-Szczerka, Karpienko and Landowska, 2015). There are also various programs for the therapist to organize their work. These programs let prepare individual programs, collect information on the course of therapy, analyze the progress, indicate situations that require intervention and advise some therapy steps.

The original idea of the AUTMON project, which makes it different from the solutions described above, is to support therapy of people with autism by incorporating behaviormetrics taken from tablets via specially designed applications. The main advantage of this approach is the fact that such characteristics might be measured unobtrusively and without any special hardware. Eventually the result of the project would be definition of objective measures used to evaluate the progress of therapy.

3. Automated therapy monitoring with games

AUTMON (Automated Therapy Monitoring for Children with Autism Spectrum Disorder) is a research project aimed at development of methods and tools for automatic evaluation of therapy progress among children with autism spectrum disorder (ASD). It is conducted by a consortium consisting of Gdansk University of Technology, Harimata LTD and Hippotherapy Foundation. The main research question stated in the project is how to use the characteristics measured during the interaction with applications and tablets to evaluate the progress of therapy of children with ASD.

The idea is that a child performing typical tablet-based activities like playing educational games, provides a number of objective and measurable metrics of tablet and game use. Each move on the touch screen, tap, fling or swipe could be recorded and then analyzed. Even more data are available from the gyroscope and accelerometer when a child holds a tablet and moves it.

There are several premises, that support our approach. Children with ASD are usually more than eager to use tablets and digital games. Secondly, tablets are used in some therapy centers as a daily education support. Therapists confirm, that using a digital form of therapy increases motivation of a child to start and follow an educational activity.

3.1. Digital games for the data collection

A group of psychologists, therapists and data scientists has already designed and implemented five games to be used as a data collection tool:

- Boxes is a game where children are supposed to drag balls and place them in the boxes of corresponding colors. Although it is a very simple game it requires understanding instructions, color recognition and matching skills.
- Sharing is a game in which children are required to share food among animated kids. It requires more complex instruction understanding, motor precision, perseverance and to some extent attentional control, as screen is filled with clickable distractors.
- Cat and dog is a game requiring either reacting to randomly presented stimuli which may be images or sounds. Depending on the target a child has either to quickly tap or refrain from reaction. It keeps a player being focused and makes him decide quickly, which can be used as a measure of impulsivity and control processes.
- Pinwheel is a game, in which a ball has to be placed in a petal of a slowly turning pinwheel. The ball and the petal should be of the same color. The ball is controlled by flipping the tablet. Thus, apart from instruction understanding and color recognition, it requires fine motor skills, executive control and attention.
- Creativity is a game in which a child draws imaged by imitating presented lines and filling the shapes with colors. It requires understanding instruction, stability and precision of movement, as well as ability to imitate the lines.

3.2. Behavioral metrics and tool for progress monitoring

After collecting the records a number of parameters are calculated on the basis of raw data. These parameters representing behavioral patterns should indicate the level of selected skills trained during the process of therapy. Some characteristics based on the games' flow might reflect the ability to understand instructions, focus attention, perseverance or self-control. Others would show motor skills, e.g. smoothness and precision of the moves while dragging objects or drawing, the sense of balance and direction changes while flipping a tablet to roll a ball. The characteristics gathered while sharing food might even indicate some interpersonal abilities. One of the investigation directions would be also verification which of the defined parameters might be universal ones and which of them should be adjusted individually for a child.

The authors are aware of the fact that some of the calculated parameters may turn out to be useless in this task, but as in most of the research projects, it is hard to determine which ones, in advance. Thus a thorough analysis should be performed to find out the suitable ones. Various statistical methods, feature selection and extraction procedures and time series analysis would be implemented to solve this challenging research problem.

Based on the findings of the behaviormetrics analysis, an application to monitor the therapy will be developed. One of the considered approaches, is to use the games developed for the data collection, or at least some of them. The application/applications will record and process behavioral metrics and will return the children's progress estimate. As a result, therapists will receive a tool that will support one of the aspects of their daily work.

3.3. Current stage of the AUTMON project

The project has been divided into a stage of data collection, data analysis, integration and evaluation of the solution.

Currently a stage of data collection comes to an end. A number of children from eight therapy centers take part in the project. Each child is supposed to take part in at least five sessions of data collection.

The sessions take place once a month. During each session, while a child plays the five games, all behavioral characteristics are recorded, i.e. data from touch screen, data from sensors (accelerometer, gyroscope) and game flow data. Moreover, the therapists fill detailed questionnaires on the children's progress in different areas of development.

We have already started a task of data processing to obtain behavioral characteristic. The aim of this stage of the project is to find out whether or not there is a correlation between the changes of the gathered behaviormetrics and the changes of the child's progress reported by the therapists.

The application will be validated among children with autism spectrum disorder. The results will be evaluated by therapists. Evaluation stage has not been started yet.

4. Conclusions

Finding objective measures suitable for evaluating therapy progress would let create a system supporting those who diagnose autism and the therapists working with the children. In future these measures could be also applied as optimization criteria in defining the optimal therapy path. Such tool could be helpful in preparing the therapy plan, choosing the type of tasks and their frequency. It might also follow the therapy course, predict its direction and indicate the points which probably require intervention and changing the plan. Obviously it would never replace a therapist, but make his work more effective. Moreover, it could also support the parents in their efforts to objectively report valuable observations to the therapists, which would be especially important in the case of a limited access to therapy centers.

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