ToMtool: An Interactive Multimedia Application to Support Training of Emotion Recognition and Theory of Mind Skills to Children with Autism Spectrum Disorder

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ABSTRACT

Difficulties of people with Autism Spectrum Disorder (ASD) in recognizing and expressing emotions, responding appropriately to them as well as in Theory of Mind (ToM) skills are a core symptom of the disorder. An important gap in the literature concerns structured training in emotions for the development of ToM and subsequently social reciprocity. This paper presents ToMtool, a software tool that systematically supports special education practitioners in helping people with ASD to improve perception of emotional states of themselves and others as well as thoughts and intentions that derive from them and choose an appropriate social response. The application promotes playful learning, personalized to the particular needs of each child. ToMtool focuses on the 4 basic emotions (happiness, sadness, anger, fear) with the possibility of expansion to more complex ones (e.g., surprise, anxiety) and concerns children of developmental age of 4 years and older. The application was developed following a user-centered design approach, involving speech and language therapists, psychologists, and special educators in its development process. To this end, semi-structured interviews and formative usability evaluations of intermediate versions of the application were carried out. A preliminary evaluation study of the ToMtool final version found that it met the users' expectations and also identified issues for further improvement.

CCS CONCEPTS

• **Applied computing** → Education; Computer-assisted instruction; • **Human-centered computing** → Human computer interaction (HCI); HCI design and evaluation methods.

KEYWORDS

Human-computer interaction, User-centered software design, Educational software, Developmental disorders, Playful learning

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1 INTRODUCTION

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition that affects social communication and interaction [22]. People on the spectrum have been consistently found to be less adept at taking another person's perspective (Theory of Mind-ToM) and understanding when others hold a false belief [3, 4]. They may have difficulty with reading emotions and mental states, which in turn may lead to a lack of empathy and social reciprocity [5, 6, 10, 22].

Research into ToM in children and adults with ASD has been prolific over the last 25 years. While the very essence of the concept is subject to ongoing debate, it is widely accepted that ToM deficits are central to explaining the social handicap experienced by people with ASD. Therefore, ToM and its precursors skills, such as eye gaze, joint attention and emotional recognition, are targets for interventions [11].

The recognition of other's emotions, a prerequisite skill of ToM, relies on the integration of emotional cues from various channels including facial expressions, tone of voice and body language and impacts social functioning [25]. Emotion recognition difficulties are well documented core symptoms of ASD and can be a significant risk factor for social exclusion and mental health issues in adolescence [7].

Interventions on ameliorating social impairments in ASD focus either on To*M* or emotion recognition skills. A ToM intervention is explicitly or implicitly based on ToM cognitive model of ASD. One example is using 'thought-bubbles' to teach children with ASD to understand others' thoughts and beliefs by illustrating these in cartoon-like bubbles [23]. Training procedures are also based on corrective feedback, use of imagination, modeling and role-play. In some studies, ToM training was considered as a part of a broader project aiming to develop social skills [12]. Training of emotion recognition skills is mainly computer-based. Those programs focus on emotion recognition from photographs of facial expressions and strips of the eye region, recognition of emotions from facial expressions or interactive guidance to emotions through recognition of emotions and mental states [7].

Although there is abundance of training approaches on ToM and emotion recognition deficits on ASD populations, there is a striking paucity of highly structured methodologies targeting both

skills. Before teaching the attribution of emotions and mental states to others, individuals with ASD need support in recognizing and expressing their own feelings and thoughts as well as their causes. Building up on this knowledge, they can then move on to unravelling the social cues in their immediate social environment, such as family and friends. Thus, an experiential approach might lead to effective social functioning in real life situations.

Computerized environments can be a valuable tool to support this effort [13, 14, 19, 24]. Benefits regard the provision of favorable settings for users with ASD as they can be programmed to be predictable, consistent, and free from immediate social stressors. Users can work at their own pace and level of understanding and lessons can be repeated over and over again, until mastery is achieved. Interest and motivation are usually more easily maintained by individually selected computerized rewards.

This paper presents ToMtool, a computerized environment for supporting special education practitioners' interventions for emotion recognition and ToM skills of children with ASD. The proposed software application supports multimedia stimuli for emotions (image, audio recording, video), employs gamification elements (e.g., electronic sticker), enables interventions personalized to the child's interests and needs, and provides automated performance recording, presentation and extraction of intervention data to facilitate the therapist's practice.

2 ANALYSIS AND DESIGN

ToMtool aims to improve emotion recognition and ToM skills for Greek children on the autism spectrum. The tool focuses on the 4 basic emotions (happiness, sadness, anger, fear) with the possibility of expansion to more complex ones (e.g., surprise, anxiety) and concerns children of developmental age of 4 years and older. This section presents important decisions and information regarding the analysis and design process of ToMtool.

2.1 Software design process

The development of ToMtool was based on the user-centered design for interactive systems as described in Avouris et al. [2]. Real-world user requirements were collected in close collaboration with special education practitioners, hereafter therapists. In specific, speech and language therapists, psychologists, and special educators, all working for many years with children with ASD were involved. We conducted one unstructured and one semi-structured interview with these therapists to define the initial user requirements. Prototypes of the application were developed and evaluated in formative usability studies, which also redefined some of the initial user requirements. Finally, a preliminary evaluation study of the ToMtool final version was conducted.

2.2 Context of use

Training of children with ASD to improve their ToM skills is carried out by specialized therapists. Each session should be personalized to the particular needs of each child, which is also underlined in the related literature [19, 24]. Therapists typically use various means for presenting stimuli to the children, such as images, sounds, and videos. Devices such as computers, tablets and mobile phones are used to view these media. Software used to support the sessions include mainly office suite applications and cloud applications for file sharing. During a session, therapists typically take notes and fill pre-printed forms with various data that monitor the performance of the child (performance or intervention data). After the session, these data are typically inputted in spreadsheet software and various calculations and visualizations are performed.

The intervention process consists of several phases depending on the level of the learner. Each phase has individual steps. At each step the child attends a series of sessions until a specific performance is achieved. When the goal of each step is achieved then the intervention moves to the next step, otherwise the child has to repeat the same step until it is achieved. The stimuli and the type of questions vary greatly depending on the particular needs of each child. Some of the strategies used to encourage the child to continue are using motivational phrases (e.g., "Good job!", "Nice try!") and rewarding systems (e.g., giving stickers for correct answers, playing games of the child's choice at the end of the session).

2.3 User profiles and requirements

Table 1 presents the main high-level requirements of ToMtool for the following user profiles:

- User-learner: age between 4 and 18 with reading and writing skills from none to good, and mental function from moderate to high. Each learner's therapist(s) in collaboration with the parents determine the educational priorities.
- User-therapist: adult, typically with a high level of education and basic knowledge of using computers and software applications.

2.4 Prototypes

In the initial design phase, non-functional prototypes were created and evaluated by end users. Figure 1 shows some representative examples of mockups created with the free version of NinjaMock[1], an online wireframe and mockup tool. Functional prototypes were also created and evaluated by end users throughout the development of ToMtool. These prototypes were created using the software platform and programming languages that were used for the actual end-product (see Section 3.1). Functional prototypes enabled testing of various features that were rather hard to evaluate using non-functional prototypes, such as the gamifications elements (see Section 2.5).

2.5 Gamification elements

Gamification is the integration and use of various game design elements in non-game contexts [8]. Gamification was considered necessary for ToMtool given the user requirement for a pleasant and fun learning environment for children (see Table 1). In agreement with the requirements we collected from practitioners, research has shown [21] that some learners find it difficult to stay motivated in computer-mediated environments. Gamification can help in keeping the learners' interest high.

The following gamification elements are used in the final version of the ToMtool application:

[1] https://ninjamock.com

Table 1: Main high-level requirements for ToMtool

User: Learner (Child/Adolescent)	User: Therapist
1. Personalized learning 2. Pleasant and fun learning environment 3. Application use always with the help of a therapist	1. Custom modification of content easily 2. Multimodal stimuli (image, sound, video) 3. Automated child's performance recording 4. Child's performance data presentation 5. Child's performance data extraction

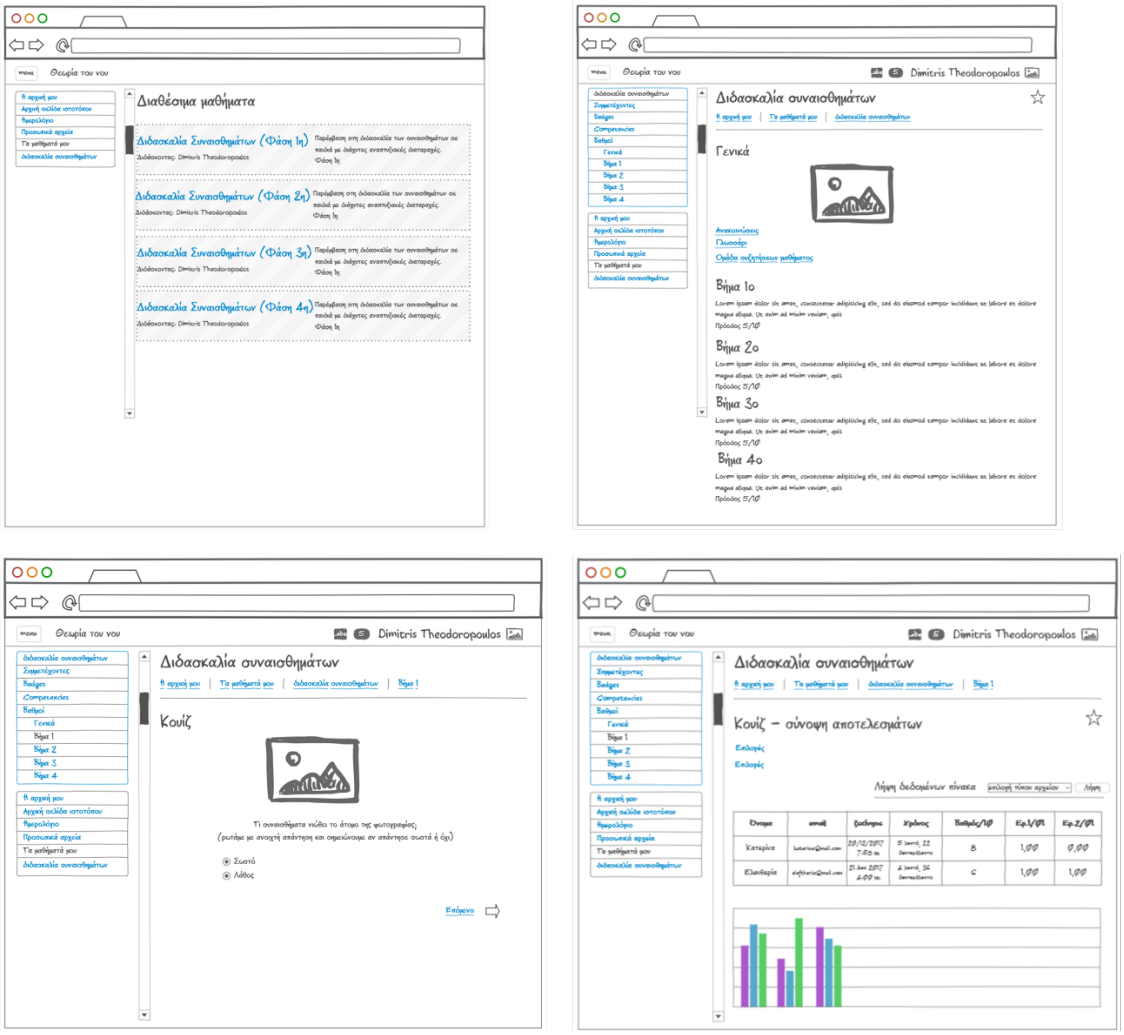

Figure 1: ToMtool mockup examples for the webpages with an overview of the phases (top-left) and steps (top-right) of the intervention process for teaching emotions, a question of an intervention session (bottom-left) and a performance data report (bottom-right)

- The child is rewarded with an electronic sticker for each correct answer per stimuli (Figure 2, left). These stickers can be easily customized by the therapist.
- The child is rewarded with a badge whenever the therapist decides that a certain milestone has been completed. The child is also offered the option to exchange a number of collected stickers for badges after completing a session. These badges are rarer compared to stickers as they represent greater achievements. The badges are added to the user profile of the child and can be easily customized by the therapist (Figure 5, right).

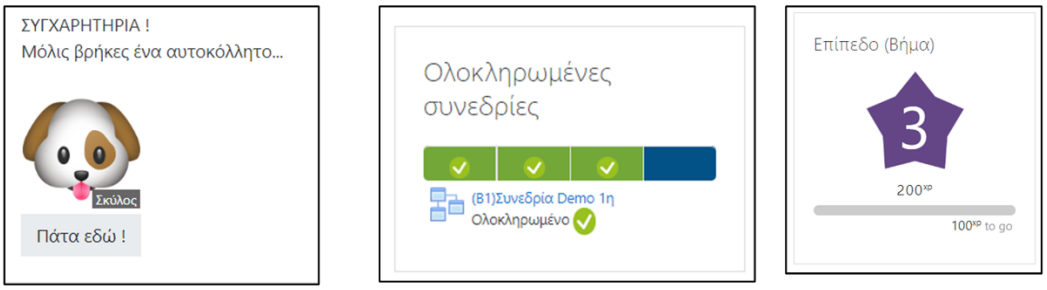

Figure 2: Examples of gamification elements used in ToMtool include electronic stickers (left), progress bar of the completed steps (middle) and a leveling-up system (right)

- The child is offered the option to play an electronic game of his/her choice after each session with the therapist.
- There is a progress bar that summarizes the child's completed steps (Figure 2, middle). This progress bar is constantly displayed in the UI.
- There is a leveling-up approach based on a score that represents the current progress of the child (Figure 2, right). This level is constantly displayed in the UI. The therapist can easily define the number of points required to change a level and optionally specific badges that will be awarded to the child when a certain level is reached.

3 IMPLEMENTATION

3.1 Technologies

ToMtool uses the Apache HTTP server, MySQL for database management and PHP as a programming language. It is implemented over Moodle[2]. We selected Moodle as the development platform because, from the developer's perspective, it saves time and effort as Moodle provides many functionalities that could be immediately used to address some of the ToMtool requirements (e.g., easy customization of any content). In addition, Moodle has many plugins and it is open source, and thus can be easily extended to address any additional user requirements for ToMtool (e.g., gamification). From the perspective of a user-therapist, Moodle provides a learning environment that can be easily customized by them without requiring programming skills, and it is typically an already familiar environment for them.

The following Moodle plugins[3] are also used to implement some of the ToMtool requirements: 1) Completion Progress, 2) Level up, 3) Stash, and 4) Ad-hoc database queries. The "Completion Progress" plugin was used to create a visual representation of the child's completed activities in the form of a bar (Figure 2, middle). For the therapist account, there is an overview of all of his/her students so that it is easy to monitor the progress of all the children. The "Level up" plugin implements the gamification element for the students' leveling-up system (Figure 2, right). The "Stash" is used to showcase the rewards collected by the student, such as the electronic stickers (part of the right sidebar in Figure 3, right). The "Ad-hoc queries" plugin is used to create some custom queries that were required for the implementation of ToMtool functionality, particularly the one related to the intervention data presentation and extraction (Figure 6).

3.2 User flows

In general, there are four main user flows: a) navigate to a specific session, b) run a session, c) customize content, d) manage children's performance data. All actions are performed by the therapist.

A therapist who wants to start a session with a child needs to login with the child's account and then navigate to the desired phase and step of the intervention process for teaching emotions. For instance, the default steps in the first phase are the following: a) perception and naming of basic emotions, b) rating of emotion intensity, c) recognition of emotion based on a scenario, d) selection of socially appropriate behaviors based on a scenario. It should be noted that these steps can be easily modified according to the intervention process decided by the therapist. ToMtool then presents the child's dashboard, which includes information such as the child's name, earned badges, and progress of activities (Figure 3, left). Then, an overview of the intervention phases and steps is presented, along with their current progress. Selecting a step in any phase will show the step overview page (Figure 3, right) which contains: a) introductory information, such as what the child is asked to do for this step (e.g., name the shown emotion), the maximum number of stimuli to be shown etc., b) a list of sessions that can be started or that have been completed, and c) a sidebar on the right that presents gamification elements (level, stickers, completed sessions) and a link to start the data extraction procedure.

A therapist logged in with a child's account may choose to run a specific session. Each session consists of a sequence of questions (e.g., "How does the person feel?" or "Why does the person feel this way?") accompanied by stimuli. Figure 4 presents examples of the various types of ToMtool-supported stimuli, such as image questions, video or audio matching questions. Each time the child answers correctly it is reinforced with a phrase (e.g., Congratulations!!) and awarded with an electronic sticker, and then ToMtool moves to the next question. If the child answers without help then one point for the leveling-up system is also added. If the child gets any question wrong, the same question is shown again but this time with some help (Figure 4, left). In this case the only difference is that if the child answers correctly, then no point is added for the leveling-up system. If the child answers incorrectly when help is

[2]https://moodle.org
[3]https://moodle.org/plugins

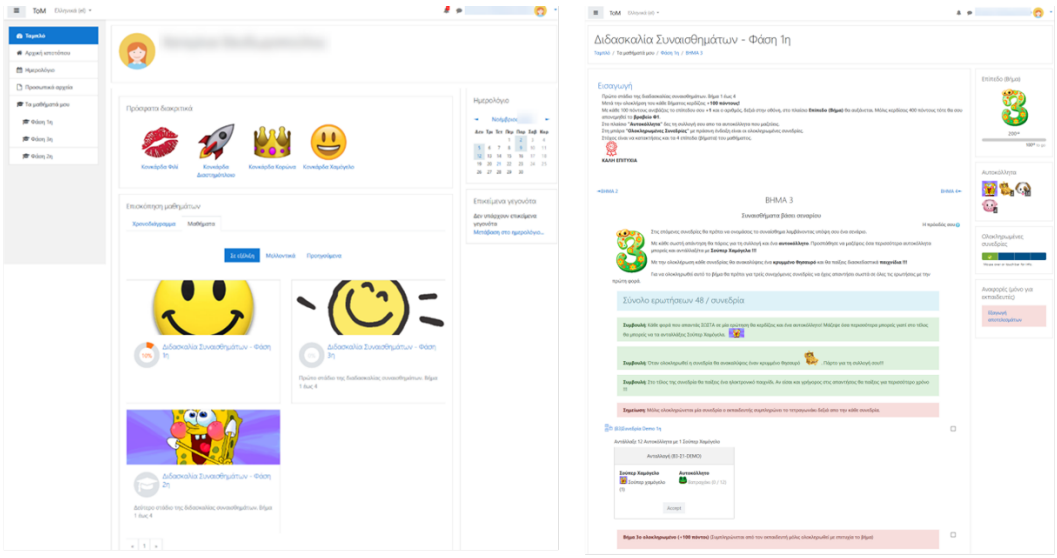

Figure 3: ToMtool user interface examples for the logged-in child's dashboard (left) and a specific step (step 3) in the intervention process of teaching emotions (right)

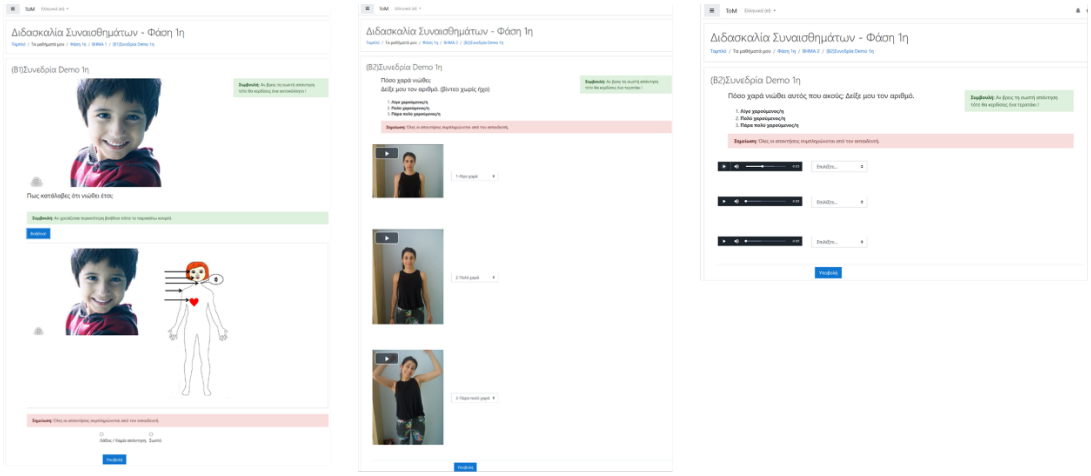

Figure 4: ToMtool user interface examples for different types of questions presented in a session: image question with help showing (left), video matching question (middle) and sound matching question (right)

also present, then the therapist provides the correct answer, and the system moves to the next question. A question is considered mastered only if the child answers it correctly without help. At the end of a session the child is offered the option to play an electronic game for as long as the therapist decides. A session is considered successful only when all questions have been answered correctly without assistance. To master a step the child must succeed in a series of consecutive sessions, as decided by the therapist.

A therapist that uses his/her own account to log in ToMtool is provided with additional rights and functionality. First, a therapist can add, delete, or modify most of the content included in ToMtool, such as the required phases and steps for the intervention treatment, the type of questions and stimuli used in a session (Figure 5, left), the badges used by the system as rewards (Figure 5, right), the icons used for the electronic stickers etc. In addition, a therapist has access to functionality that facilitates account management, monitoring of children's performance (Figure 6, left) and extraction of these data in various formats, such as csv files (Figure 6, right).

4 PRELIMINARY EVALUATION STUDY

The owner of a private business in Greece that offers special education services was involved in a qualitative usability evaluation study of ToMtool. The study participant, hereafter therapist, is a speech and language therapist with an MSc and PhD on children's

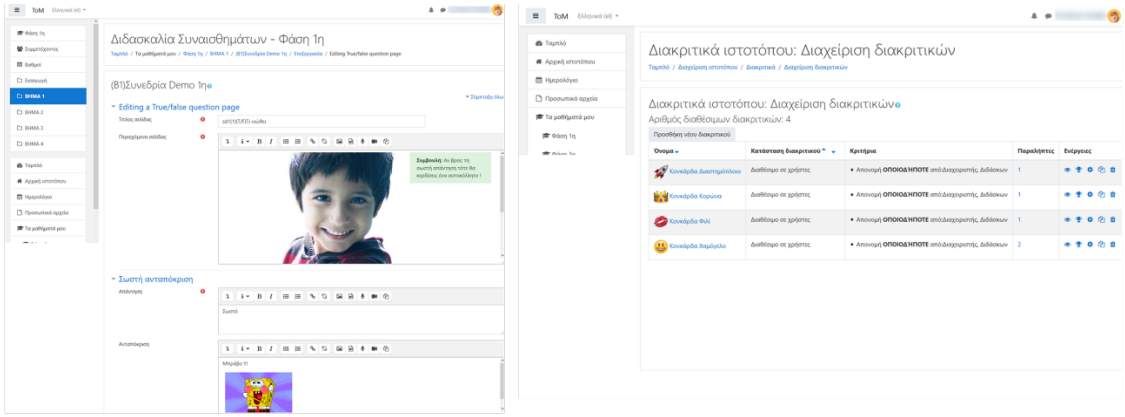

Figure 5: ToMtool user interface examples for customizing the session content (left) and the badges (right)

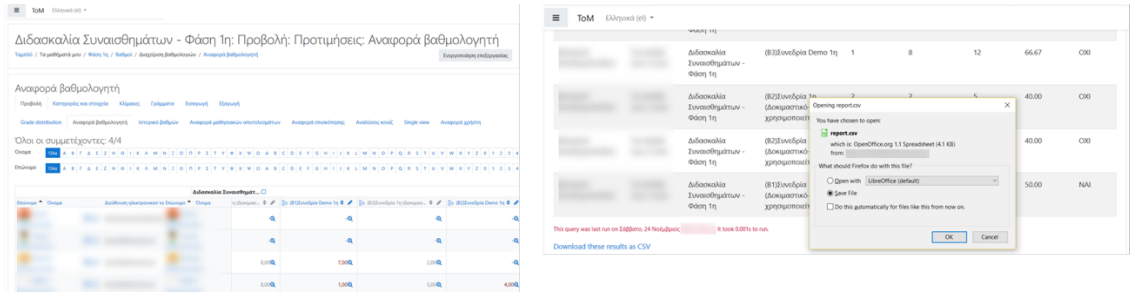

Figure 6: ToMtool user interface examples for children's performance data presentation (left) and extraction (right)

learning difficulties and has more than 10 years of experience with treating children with ASD.

The therapist was provided with access to ToMtool and was asked to perform tasks while thinking aloud [20]. Think-aloud protocols, in which participants verbalize their thoughts when performing tasks, are used in usability testing to elicit insights into their thought processes that are hard to obtain from mere observation [9]. It is a method considered very useful for HCI studies [9]. The think aloud session was performed remotely using video conferencing and screen sharing as the therapist and facilitator lived in different cities. The facilitator also performed a brief semi-structured interview at the end of the session to capture the therapist's views on the tool.

The study found that ToMtool met the therapist's expectations. The therapist reported that the tool "was intuitive and easy to use" and that it can be a "valuable asset to training Greek children with ASD". According to the therapist, the "biggest advantage of this tool is that it supports personalized learning in a way that can be easily followed by a therapist". The gamification elements of the application were also commented favorably, particularly the ones related to immediate positive reinforcement of the child (e.g., electronic stickers). In addition, the therapist mentioned that "the automated recording of the child's performance data is invaluable".

The therapist also provided insights on both improving current functionality and adding new one. First, a delay in loading some webpages was observed, particularly the ones in a session that contained video stimuli. This might be mainly related to the computer machine we used to host ToMtool but should be further investigated anyways. In addition, the therapist mentioned that training would be beneficial for first time users before using ToMtool in their work environment. To this end, a guided-tour of the application or video-tutorials can be produced in the future. Furthermore, the therapist argued that "it would be better if ToMtool also provided the calculations and graphs that are necessary for my work instead of having to extract them and use Excel to do it". Thus, ToMtool could be enriched with functionality that supports presentation of the collected data with graphs, tables and filtering mechanisms. Finally, an undo feature was requested for changes made to the content of ToMtool.

5 CONCLUSIONS

This paper presented ToMtool, a web-based learning environment for training children with ASD in emotion recognition and Theory of Mind skills. Development followed the user-centered software design. Therapists, such as speech and language therapists, psychologists, and special educators, participated in the design and evaluation process.

ToMtool is designed to support learning personalized to the needs of a child with ASD. The profile of the user-learner was designed in such a way that it can be handled by the therapist with the co-presence of the child. ToMtool employs gamification to

address the requirements for positive reinforcement of the child and an overall pleasant learning experience so that the child remains motivated and engaged with the task at hand. The tool also supports the use of multimodal stimuli, such as text, images, audio and video, all of which can be managed by the user-therapist. ToMtool also employs automated performance data recording and provides tools for the user-therapist to inspect and extract these data for further analysis. A preliminary qualitative user study involving one senior and highly experienced therapist found that ToMtool is an easy to use and useful application. The therapist also identified areas where ToMtool could be improved and expanded in future work.

Future works involves conducting a quantitative usability testing of ToMtool involving therapists and children with ASD. In addition, the inclusion of technology to support a learning setting does not ensure the learning effectiveness of the technology-mediated approach. Based on our previous experience [1, 15–18, 26], we plan to conduct a within-subjects study comparing therapists' existing practice for teaching emotions to children with ASD against the new ToMtool-supported intervention practice. Additional ToMtool functionality can be also implemented in the future to address both the existing issues identified in our preliminary evaluation study (e.g., undo feature) and new ones that might be mentioned in future user studies.

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