A Proposed ASD-Centric Framework: The Case of ASDAPT

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Abstract. As the number of individuals diagnosed with Autism Spectrum Disorders (ASD) rises, the need for providing one-to-one treatment increases significantly. ASD is a complex lifelong disorder that has an intense impact on a person's development predominantly demonstrating strong deficiencies in many types of social behavior, social imagination and communication. Although people with autism share some common characteristics, no two individuals are the same. In this regards, computer-based treatment approaches should always be emphasizing on the abilities, individualistic characteristics and preferences of a person with ASD. In this paper, we propose an ASD-centric adaptation and personalization framework, namely ASDAPT, that utilizes an extended user profile which attempts to capture inclusively the attributes that could formulate a strong basis for the apt identification of an individual with ASD. Main aim of ASDAPT is to provide a unified adaptive approach to the learning process over a computer-based environment for children with ASD, discussing implementation considerations, taking place during the dynamic adaptation process, supported by a real life case scenario.

Keywords: Adaptation, Personalization, Autistic Spectrum Disorder, Computer-based Education.

1 Introduction

The developmental challenges and associated problems in children with Autism spectrum disorders (ASDs) vary widely [1]. Symptom presentation and degree of impairment can diverge not only among individuals but also within the same individual over time [2]. Autistic people often interpret situations differently from non-autistic people and struggle with new, unpredictable and ambiguous environments. Although children with autism share some common characteristics, no two individuals are the same. In addition, the pattern and extent of difficulties may change with development. They might develop learning disabilities and/or psychiatric disorders, such as depression and anxiety. The manifestation of autism can change with age, as patterns of atypical behavior and impairments become more or less marked over time, while the actual capacity in any one individual may fluctuate at

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different times and in different circumstances. Early identification of young children with ASDs can lead to earlier entry into intervention programs that support improved developmental outcomes [3]. Continuous education and treatment is considered vital for children with ASD, even though it is generally agreed that no single intervention will suit all autistic people, and that any intervention can have negative as well as positive effects. In recent years, the use of multidisciplinary approaches in the treatment of individuals with ASD is flourishing, with Human Computer Interfaces (HCI) technology and computer science to be really emerging [4]. Information and Communication Technologies (ICT) and computer-based systems are considered really promising as an educational medium which can convey the instructional methods and learning interventions' approaches in a more efficient way. Nevertheless, there are some negative points that can many times blur these views of acceptability, such as fear that while children with ASD interact with computers will be further isolated from their social interactions and the surrounding environment they are living in [5], many systems provide insufficient error control and inappropriate audio feedback on error [6], many interfaces are not easily customized to the needs of a child with ASD, there is lack of comprehensive technology-based analysis tools that can measure the overall progression of a person's development [7], etc.

In any case, given this dynamic nature of diagnoses over time for autistic children as well as the unpredicted behaviors and responses on particular sensor stimuli, the computer-based systems should support the treatment method in a user-centric and dynamic manner, adapted always on the unique individuals' with ASD current state and characteristics. A research area that has put huge amounts of effort to identify the peculiarities of user groups and design user-centric methodologies and systems that could deliver an adapted and personalized content are the ones of Adaptive Hypermedia and (Web) Personalization. Main concern of the developed technological paradigms is to alleviate navigational difficulties and present the content based on the characteristics that are defined in the user profile of each person [8, 9]. It has been shown that the incorporation of human factors and individual differences in the adaptation process increases users' information assimilation, satisfaction, academic performance, accuracy and efficiency during navigation, etc. [10]. User profile is the key component of such systems that holds all the information based on which particular adaptation and personalization rules and schemas are applied for the appropriate content reconstruction, annotation and/or enhancement. Even though the abovementioned considerations are mostly applied in non-specialized educational and/or training systems, it is evident that the convergence of these paradigms can suggest a cohesive and strong basis for the development of sound ASD-centric systems. The effectiveness of the interventions applied in a child with ASD requires a multidisciplinary approach not only as far as their apt identification (based on the diagnosis) is concerned but also at an implementation level. In this respect, main scope of this paper is to propose an ASD-centric adaptation and personalization model, namely ASDAPT. It utilizes an inclusive user profile for persons with ASD and together with the appropriate technological components and concepts derived from the ASD sector, could provide a user-centric interaction maximizing the efficiency during a goal-directed ASD therapy.

2 The Importance of the User Profile in ASD-Centric Systems

One of the key technical issues in developing personalization applications is the problem of how to construct accurate and comprehensive profiles of individual users and how these can be used to identify a user and describe the user behaviour. In computer-mediated ASD systems several types of information concerning a child with ASD are present, such as: general information, the individual's preferences and domain knowledge, and the history [11]. All these data can assist experts to visualize and analyze some results coming from the activities-based interaction of a person with ASD and consequently modify and adapt any defined treatment directives, resources or functional rules. However, to our knowledge, most of the approaches are not utilizing all the components of a profile under a common representation schema but rather in heterogeneous platforms and mediums, either computer-based or hard-written/coded. The accurate, inclusive and unified definition/representation of the user profile is of paramount importance when building ASD-centric systems since its components and subsequent information will trigger the adaptation and personalization process determining the level and type of adjustment with regards to a given treatment for an individual with ASD in a cohesive and contingent manner. An enhanced ASD-centric user profile toward that direction should comprehensively incorporate most of the information that are considered vital for the treatment of a child with ASD and which are extracted from various diagnostic tools, interviews, observations, etc. Such components could be: (a) *Traditional Characteristics* represent probably the most stable component (in terms of dynamic value change) of the profile and include elements such as: Name, age, sex, ethnicity, interests, assessment method, therapists (roles), treatment history (i.e. interventions applied), etc.; (b) *Clinical/Diagnostic Medical Records* involve the initial diagnosis for ASD, any differential diagnosis, and medication (if applied). Clinical/medical assessment (or clinical assessment) for intervention planning derives from diagnostic evaluation in which established medical diagnostic criteria (DSM-IV-TR – [12]) are used to make a medical diagnosis of a person with ASD; (c) *User Perceptual Preference Characteristics (UPPC)*, which have been primarily discussed in [13], formulate a three-dimensional approach to the problem of building a user profile that include: (i) users' cognitive style, (ii) their visual and cognitive processing efficiency (including parameters like control of processing, working memory span, and visual attention), and (iii) their emotional processing (a pluralistic construct which is comprised of two mechanisms: Emotional arousal (since is correlated with the learning performance), and emotion regulation), during the interaction process with the information space. A challenge is to identify whether these factors can be effectively evaluated and have an adequate applicability on ASD adaptive computer-mediated learning environments, other than the conventional eLearning environments that have initially successfully implemented; and (d) *Intervention Assessment Records (personality characteristics)*, refer to the capture of the diversity in expression of symptoms and levels of functioning among individuals diagnosed with ASDs [14]. Assessment for intervention planning builds on the diagnostic evaluation by further describing the strengths and concerns of the child that fit within the diagnostic category [15].

3 A Proposed ASD-Centric Adaptation and Personalization Framework – ASDAPT

Generic computer-based intervention training methods rely on presenting information to a group of users/students with the expectation that all students will adapt to the teaching style and pace of the instructor. However, it has been shown that people have different cognitive traits, and adapting the presentation method to match the learning style of an individual can improve the learning process [16]. More importantly, in the ASD domain, the ability of a child to acquire and comprehend information can vary during the presentation because of changes in his/her underlying cognitive state (i.e., level of attention, information overload, level of anxiety, etc.). The ability to dynamically adapt the pace, order and type of information in real-time during a presentation would allow an ASD computer-based learning system to optimize the learning process by presenting just the right amount and type of information at the right time. Nowadays, there are many attempts of identifying appropriate ASD computer-mediated intervention environments but in many cases teachers and therapists have experienced low usability and flexibility during interaction; the high complication of these systems most of the times presupposes an extensive training, time consuming set-up and customization (especially for the parents), while in many cases they are expensive [17]. Based on the above considerations, a proposed ASD-centric adaptation and personalization computer-mediated model namely ASDAPT (Autistic Spectrum Disorders Adaptation & Personalization Treatment framework), will be presented, trying to convey the essence and the peculiarities encapsulated.

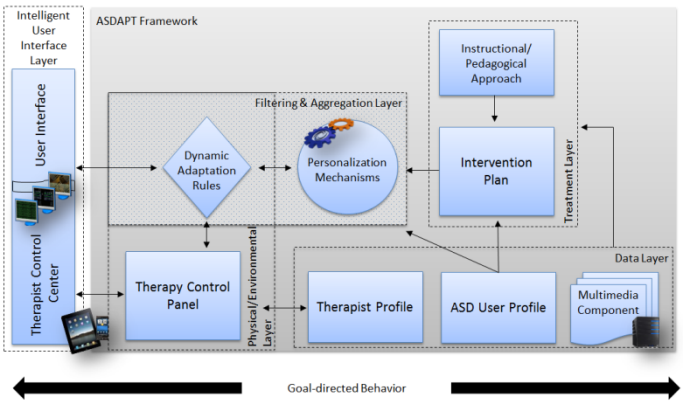

Fig. 1. The ASDAPT Framework

The proposed model consists of 5 interrelated layers: the *Intelligent User Interface*, the *Physical/Environmental Layer*, the *Filtering & Aggregation Layer*, the *Treatment* Layer and the *Data Layer* (see Figure 1). The particular layers are further composed of components that are interoperable and integrated under the generic ASD-centric adaptation and personalization schema, ensuring continuous exchange of data and flow of information. In the application context, our model aims to bring flexibility and

modularity in the individualized treatment of the child with ASD. Each task implemented by our model is adapted to each child, is reproducible, extensible and evolutive following a specific intervention scenario defined by the expert therapist (Goal-directed Behaviour).

3.1 The Intelligent User Interface Layer

This is the first layer and the "entry" point that the child with ASD (also referred hereafter as *user*) and the therapist (or care team) interacts with the system. It accepts multi-device requests enabling the attachment of various devices on the infrastructure. It directly communicates with the Filtering & Aggregation Layer exchanging multi-purpose data. It is comprised of two components: the *User Interface* (UI) and the *Therapist Control Center* (TCC). The UI is used for displaying the raw or personalized and adapted provider's content (i.e. treatment content) on the user's device, upon therapists' decision and his extended ASD user profile, by giving his/her credentials. The corresponding profile will be loaded onto the server and according to his/her individual characteristics and preferences the content of the provider will be reconstructed (based on the mapping personalization rules existing in the Personalization Mechanisms component and device characteristics). The TCC component is a touch screen interface dedicated to the therapist during intervention session, loaded onto his device (i.e. laptop, tablet, handheld). This environment allows the therapist to interfere to the pace/progress of the treatment anytime through the system (e.g. in case a child starts at some point during treatment problem behaviors), and to keep any notes with regards to an incident or reaction of the child to a particular stimuli, since the two environments (UI and TCC) are fully synchronized.

3.2 Physical/Environmental Layer

This layer is directly connected with the Intelligent User Interface Layer and the Therapist Profile component and consists of two components: the *Therapy Control Panel* (TCP) and the *Dynamic Adaptation Rules* (DAR). The Therapist is the person that works together with the user throughout the whole process of the intervention at a particular session. The Therapist Profile is a component that belongs to the Data Layer, and keeps all the information the Therapist currently undertakes during a treatment session with a child with ASD. The fact that such a child's treatment presupposes a multidisciplinary team of care around him, many times is the case where a diversification of approaches or different progression data should be stored for reusability at a later stage, within the sessions of one Therapist and between Therapists for analysis and further decision making with regards to a case. Hence, the Therapist Profile keeps updated data of the last sessions' progression, as well as all the records and activities undertaken using the TCP. The Therapist observes the whole procedure and takes dynamic decisions through the TCP for alternative progression routes as needed. Through his/her dedicated devices and interface can influence the delivery of content with further reinforcement or repetition of particular activities. The monitoring of user's behavior might be physical and/or computer-based through the DAR

component, where all the adaptive control parameters are stored. Through this component (which also belongs to the Filtering & Aggregation Layer) the system, with the use of machine learning and prediction algorithms, keeps a balance of adaptive interaction and leverage the prompting to the user given its dynamic context.

3.3 Filtering and Aggregation Layer

The Filtering & Aggregation Layer is the core layer of the ASDAPT framework and includes all the mechanisms and algorithms through of which dynamic adaptation and personalization based on the ASD user profile and the individual intervention can be achieved. It consists of the *Dynamic Adaptation Rules* and the *Personalization Mechanisms* (PM). It includes all the instances of the components of the proposed ASD-centric User Profile for a particular child with ASD (discussed in the section above), as well as others device/channel and contextual data. It is directly communicating with the Intelligent User Interface Layer, the Treatment Layer, where the provider's treatment multimedia content is formulated, and the Data Layer where the actual verification and profiling for the user is taking place. Once the whole processing has been completed it returns the adapted results to the child. The two components of this layer are responsible for the implementation of the following personalization notions: (a) Content Presentation (or Adaptive Presentation) – It adapts the content of a page (based on child's with ASD treatment approach) to the characteristics of the user according to the ASD user profile and the personalization processing by conditionally showing, hiding, highlighting or dimming fragments on a page; (b) Content Alteration (or Adaptive Content Selection) – When the child interacts with a particular content, that is, related information to its profile, the system can adaptively select and prioritize the most relevant items; and (c) Link-level Manipulation (or Adaptive Navigation Support) – It provides methods that restrict the child's interactions with the content or techniques that aid the user in its understanding of the information space, aiming to provide either orientation or guidance (i.e. adaptive link, adaptive link hiding /annotation). Orientation informs the user about its place in the information space while guidance is related to a user's goal based on a given task by the therapist.

3.4 Treatment Layer

The Treatment Layer concerns the actual treatment approach that the child with ASD will follow through the computer-based system, and has been decided by his dedicated care team. It communicates with the Data Layer and the Filtering & Aggregation Layer, and is composed from the *Intervention Plan* (IP) and the *Instructional/Pedagogical Approach* (IPA) components. The IP is mainly related to the combination of individualistic intervention approaches that will be applied to the individual with ASD (i.e. development of communication, cognitive development, etc.), based on his unique characteristics, strengths, qualities and personality traits. This plan is liable to dynamic personalization and adaptation based on the ASD user profile. Responsible for this is the IPA component that provides the environment with design enhancements that enable the delivery of structured teaching and learning activities

that help children with ASD to understand the world as an organized, predictable place where they can succeed, rather than random events and disconnected objects that inevitably overwhelm or confuse them. The elements of structured teaching are: a) organization of the physical environment, b) predictable sequence of activities, c) visual schedules, d) routines with flexibility, e) work/activity systems, and f) visually structured activities [19].

3.5 Data Layer

The Data Layer (DL) is the base layer of the ASDAPT framework that contains the access-control data (for security reasons), all the information regarding the user profile, the transition mechanisms and the databases of the multimedia content or multimedia-based services as supplied by the provider without been through any further manipulation or alteration. It includes three components: the *Therapist Profile*, the *ASD User Profile* and the *Multimedia Component*. The Therapist Profile and the ASD User Profile have been discussed in previous sections. The Multimedia Component is based on metadata describing the content (data) available (i.e. the intervention learning programs). In this way a common understanding of the data, i.e. interoperability, openness, is achieved. The data manipulated by the system is described using metadata (based on predetermined ontologies) that comprises of all needed information to unambiguously describe each piece of data and collections of data, implemented in a transparent manner removing any data duplication and the problem of data consistency. This provides semantic interoperability and a well-structured description of data. This component is directly related to the Therapy component providing the most optimized personalized multimedia content result.

4 Implementation Considerations – A Real Life Case Scenario

The ASDAPT system, which is currently under development, adheres in flexibility, scalability, robustness, openness and customization requirements ensuring interoperability and integration of modules driven by the particularity of each case scenario. The ASDAPT framework's implementation encapsulates, among others, a prototype application, called ABCD SW, that is a didactic software for autistic children compliant to ABA (Applied Behavior Analysis), a methodology that can often favor learning for ASD persons. ABA intervention with child with autism is based on Augmentative and Alternative Communication (AAC) and Discrete Trial Training (DTT). Specifically, the ABA principles have driven the process of the system's design and development (i.e. providing content and design insights given the contextual characteristics of the ASD domain). ABCD SW conceptualization has been described in [19], analyzing the first version of the application developed using participatory design with therapists and caregivers, necessary for reaching reliable results. The whole dynamic adaptation process is enabled by rules which will be created considering the impact of the attributes of the ASD User Profile (i.e. cognitive and emotional factors, intervention assessment records, performance and acquired knowledge on the specific educational

tasks, etc.) on the information space and in more general terms on the treatment content delivered over a system.

A preliminary summary of selective generic adaptation mechanisms for tasks that are applied to specific needs and features of the subjects with ASD is described below. Basic tasks of computer-based educational systems for children with ASD may include: matching, discrimination, receptive/expressive communication skills and advanced task such as ordering academic sequences, puzzle, and mathematic operations. The subject interaction history is collected by the system that automatically records each action on the user interface (percentage of success, percentage of error, time elapsed, etc.), and by the tutor that for each trial adds other information not automatically detectable, such as type and percentage of prompt or comments on a trial (child that does not collaborate, a problem behavior, etc.). The adaptation mechanisms may be triggered based on specific permanent or temporary child needs. At each instance the tutor can dynamically interfere to the computer-based learning process by activating adaptation features (pressing keys or pushing buttons on his device – TCC) such as: (a) Jump to a previous/next level (to tune the sequence of trials according to child learning pace); (b) Provide a positional/indicative prompt (to offer a higher level of prompt according to child abilities); (c) Activate the visualization of the discriminative stimulus (instruction) as label/word (or gesture) – to offer a more accessible task; and (d) Reset the trial if ambiguous items are presented on a given moment or if there is a specific item disliked by the child (the choice of distracters is random – this personalization action allows to match specific child preferences). In addition, the tutor might regulate the velocity of the trials according to child needs. Usually the rhythm is fast to avoid the chance for the child to have "free time" that might be used for self-stimulations. The tutor-activated rules have priority over configuration and system-based mechanism ones.

To further support the abovementioned statements, we consider the case of Alice (for ethical and confidentiality issues, the name, age and/or any other characteristics that could reveal the real identity of this person have been altered). Alice is a 6 years old low-functioning girl non-receptive and non-verbal. These data (contained in her user profile) set the program to visualize the discriminative stimulus as a capitalized word (such as COMBINE or TOUCH) up in the center of the page. Alice is a visual learner at a primary school, thus ASDAPT system proposes all programs involving words. Since she is not verbal the expressive program is adapted to her abilities offering a choice between 3 words (as alternative to pronunciation of the name of the object). One other characteristic of Alice is that often losses attention. For recalling her attention the tutor provides indicative prompt. She needs extended level of prompt (the tutor records this data trial by trial). ASDAPT system acknowledges this situation and thus responds accordingly, adapting to Alice ability the pace of the trials and lowering the difficulty. For instance, if Alice is executing a matching image-image in an extended trial (a source element must be dragged to an equal target element in a choice of three items), ASDAPT provides a positional prompt (the target element is approached to the source element) to favor the drag and allow Alice to have a higher probability to carry out an independent successful trial. Then the positional prompt is gradually faded by the system in the next trials. Main objective is to maximize

effectiveness and efficiency of use, in terms of information assimilation, learning performance, satisfaction and usability for individuals with ASD.

5 Conclusion

The structural integration of human factors and individual differences in the design, development and evaluation of adaptive processes is expected to provide an unprecedented framework for ASD adaptive applications and inclusive computer-mediated treatment for persons with ASD. Several computer-mediated platforms have been developed placing emphasis on the design of intelligent human-computer interfaces for such individuals. However, to our knowledge, there is no model that proposes an approach that takes into account a comprehensive ASD user profile as well as adaptivity technical considerations under a unified user-centric treatment framework. In this regards, this paper proposes an ASD-centric adaptation and personalization model that utilizes 5 interrelated layers and is based on an inclusive ASD user profile which maintains vital information for a person with ASD; and together with the appropriate technological components and concepts derived from the ASD sector aims to deliver an apt user-centric treatment result. Furthermore, it presents a real life case scenario, discussing practical implementation considerations. It has to be clarified that the proposed ASD-centric model is open and expandable, accommodating any further elements that are determined based on the unique case and diagnosis of an individual with ASD. An approach that could lead to a generalization of a user profile and/or model in the ASD domain would be out of scope as it is generally appreciated. However, the particular suggestion attempts to stress emphasis on the accuracy of definition and inclusiveness of data under a common schema that will allow the apt adaptation and personalization of any intervention and content through computer mediated interaction. Such systems could be extremely beneficial for enriching the lives of children with ASD and allowing them much greater ability to explore and understand the outside world.

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