Defining an Interaction Model for Users with Autism: Towards an Autistic User Model

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Abstract. The consideration of Human Factors is an integral part of the design and development of any software system. User Models are used to represent the user's characteristics in a computational environment, forming an integral part of Adaptive Interfaces, by enabling the adaptation of the interface to the user's needs and attributes. In this paper we describe a proposed user model based on Executive Functions and a description of the planned case study, being users with Autism Spectrum Disorder.

Keywords: User modelling · Adaptive interfaces · Usability · Accessibility · Autism spectrum disorder · Executive functions

1 Introduction

Currently, the consideration of Human Factors has become of extreme importance in the design and specification of any software system for the reason of the huge impact that they have on the usability of the software and the efficiency in which the user can accomplish the tasks in the software.

All human beings have a series of attributes or characteristics, being: physical, cognitive, demographic, among others; that in one form or another affect how we perceive and interact with the world around us, including electronics and software. This is especially true for users with some form of disability, since it is necessary a profound understanding of the user's impaired capabilities and how will they affect interaction with the software or electronic device, in order to achieve a user experience adapted to that particular user. Such is the case with persons with Autism, which have some of these abilities impaired, such as generativity, motor, and attention. In addition to having a series of impairments, no two persons with Autism are the same, making the development of software for them especially difficult for the reason that it not might be usable for many, if not most, of them.

Due to the varying degree of user capabilities, a software can me more or less usable in comparison to another user, resulting in being impossible to achieve a uniform level of usability, accessibility and user satisfaction. One of the ways of dealing with the problem of usability and user experience is the integration of usability engineering practices in to the software development life cycle, such as the activities of user and task analysis, and prototyping [1].

Another possible solution is the use of Adaptive User Interfaces, which are capable of adapting itself to the user's characteristics and needs [2]. One of the essential parts of

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an Adaptive Interface is the User Model. User Models can be considered the abstract representation of the user characteristics in a computational environment [3], which is used in order to achieve the adaptation needed. Due to the wide variety of electronic devices and users with differing characteristics, there hasn't been a single generic user model definition, although there is research towards that goal [4, 5]. Also there is no consensus on what are the elements of the user interface to be adapted, what design patterns, what characteristics to consider of the user and how it affects the adaptivity of the interface, each software developer implements their own interaction rules based on experience and some guidelines.

In this paper we present the proposal of a PhD thesis that presents a user model that focuses on Executive Functions, adapting the user interface to measurements of said functions, and the subsequent reasoning for the case of study being developed.

2 Adaptive Interfaces

As software systems become more complex with added functionality, the diversity of the user base also increases, which means accommodating all the wide range of user characteristics becomes a daunting task, impacting usability and acceptance of the software and general user satisfaction. Adaptive Interfaces were first developed as an answer to this predicament by dealing with four mayor concerns [6]:

- A system is used by users with different requirements.
- A system is used by a user with changing requirements.
- A user works in a changing system environment.
- A user works in different system environments.

The architecture of Adaptive System can vary to a certain degree depending on the range of adaptation decided. As shown in [7], an Adaptive System consist of three basic models, each one having a direct impact of the adaptability of the system:

1. ***User Model***. Represents the characteristics of the users, such as cognitive characteristics and domain knowledge.
2. ***Domain Model***. Represents the functionality and tasks that the user can accomplish.
3. ***Interaction Model***. Defines what are adaptations possible based on Domain Model, system characteristics and the User Model.

Depending on the system being developed it is possible for the need of more than one of each model. There is no requirement for Adaptive Systems to possess the three modules or to have only one of each.

Although Adaptive User Interfaces do help deal with the problems preciously mentioned, they have their own pros and cons when using them. According to Lavie et al. [10], in order for an Adaptive Interface to achieve the level of adaptivity desired, it is necessary to consider the following factors:

- *The task that the user must accomplish.* Analysis of the task and all the actions needed for the user to accomplish said task.
- *The user and his characteristics.* User attributes that are considered necessary for the task and interaction with the software system.

- *Level of adaptivity that wants to be achieved.* It can range from manual to fully adaptable and customizable, to fully adaptive and the level in between.

Of particular importance is the definition of what are going to be considered routine tasks, since Adaptive Interfaces are not optimal for non-routine tasks, since the user must relearn the interface each time that the interface is adapted. Another drawback concerns on how the system collects user feedback in order to adapt, and the fact that there is no methodology to determine when and how the adaptation should take place [10].

There is room for improvement in Adaptive User Interfaces by enhancing the predictability (if the user can predict the adaptation) and accuracy (percentage of time that UI elements are contained in the adaptive area) of the adaptivity algorithms used. In [11] it is shown that improving those two factors greatly affected user's satisfaction, but accuracy only affected user performance or utilization of the adaptive interface. The study showed the importance of the adaptivity algorithm as an essential element in contributing toward system usability and user satisfaction.

With the focus on user characteristics it is easy to see why Adaptive Interfaces can help in solving the problem of usability with a varied user base, but first, an important part of any adaptive system must be defined: the User Model, in order to determine what user characteristic will be considered, and more importantly, what adaptations are possible based on the data contained in the User Model.

3 Executive Functions

Executive Functions are an umbrella term for the set of cognitive processes necessary to accomplish goal-oriented tasks, this includes: planning, sustained attention, working memory, inhibition, self-monitoring, self-regulation and initiation carried out by the frontal lobes of the brain.

The concept of Executive Functions is one that defies a formal definition, since research in this area often gives contradictory results, generating lack of clarity and controversy when trying to define the nature of executive functions [12]. Although there are discrepancies researching the nature of Executive Functions, the definitions proposed coincide in the fact that Executive Functions function as processes where cognitive abilities are used in goal oriented tasks [12].

3.1 Overview of Some Executive Function Definitions

One of the earliest notions of Executive Functioning was by Pribam [13] in studies related to the function of the pre-frontal cortex, and later by Baddeley and Hitch [14] as the term "central executive" when referring to a part of their proposed Working Memory Model. Previous work by Luria [15] gives support of the importance of the frontal cortex and frontal lobes in Executive Functions by analyzing the abnormalities present in patients with frontal lobe damage, such abnormalities included: impaired ability to evaluate their behavior and actions, and goal directed mindset.

In subsequent years, numerous studies and research was done pertaining the pre-frontal cortex and frontal lobes and Executive Function. Numerous definitions were proposed, but with some research yielding opposing results a formal definition has not been possible. For example: In Godefroy et al. [16] puts in doubt the notion that all the control processes for Executive Functions were in the frontal lobes by submitting patients with lesion of the pre-frontal or posterior cortices to a series of conflicting and combined tasks. Although the results give additional evidence of the prominent role of the frontal lobes in Executive Functioning, it also shows evidence that Executive Functions depends of multiple, separate, and modular control processes because of the fact that certain patients with frontal lobe injury performed well on tests designed to assess Executive Functioning while others did not.

Delis [17] defines Executive Functions as the ability to manage and regulate one's behavior in order to achieve a desired goal. This author also denotes that neither a single ability nor definition captures the conceptual scope of executive functions, in reality, executive functioning is the sum of a collection of higher level cognitive skills that enable the individual to adapt and thrive in a social environment.

Similar to Delis, Miller and Cohen [18] suggest that Executive Control involve the cognitive abilities needed to perform goal oriented tasks.

Lezak [19] describes Executive Functioning as collection of interrelated cognitive and behavioral skills that are responsible for goal-directed activity, includes intellect, thought, self-control, and social interaction.

As we can see, although there is some controversy on the nature of Executive Functioning and the great number of definitions of Executive Functioning, there is the general consensus that it involves the cognitive processes that manage goal directed behavior.

3.2 Executive Functions and Software Interaction Design

There isn't much research done about the effect of Executive Functions on how it affects software or device usage.

In Mizobuchi et al. [20] a study was made to measure multitasking performance across several device interfaces and the relationship between task performance and three Executive Functioning processes (shifting, inhibition and updating). The experiments yielded that higher levels of the Executive Function improved multitasking performance, however when touch input with visual and audio output was used, the impact of cognitive demand was reduced.

In Reddy et al. [21] a study was made in order to determine some of the effects of cognitive ageing and prior experience with technology on user interfaces intuitively. The study included 37 participants, between the ages of 18 to 83. All participants were assessed for their cognitive abilities and experience with technology. The results showed a strong negative correlation between Sustained Attention (part of Working Memory), the time to complete the task and the number of errors made by the users.

4 Autism Spectrum Disorder

According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) [22] and the International Classification of Diseases and Related Health Problems (ICD-10) [23], autism affect two core areas of neurodevelopment:

- Impairment in reciprocal social interaction and communication.
- Restricted repetitive and stereotyped patterns of behavior, interest and activities.

Because of the nature of Autism, being considered a spectrum, each person with Autism is unique, since the level of severity of the afflictions in the core areas vary from person to person, even worse, usually other cognitive abilities show signs of impairment also [24]. With proper therapy and early detection, the prognosis of an autistic person can be improved in most if not all of the symptoms of autism he may have [24].

With new technologies accessible to the general public, new options for therapy emerge, serving as tools for the betterment of their quality of life, including for persons with Autism. One example is the use of tablets and smartphones. Persons with Autism, especially children, seem to have a knack for computers and other devices, making tablets the device of choice for most autistic children.

4.1 Executive Dysfunction Theory

There are several theories on what causes the symptoms of Autism that try to explain the traits that characterize Autism and what originates them. One of the theories, which has grown in prevalence in the past couple of years, relates to Executive Functions.

A growing body of work [25, 26] suggests that many, if not all, of the symptoms of Autism originate with problems in the Executive Functions, such as working memory, planning, cognitive flexibility, generativity, self-monitoring and inhibition. Some of the difficulties of a person with Autism with Executive Functioning are as follows [25, 26]:

- *Working Memory*. A temporary system where we can store and manipulate information in the short term memory. Persons with deficit in working memory have difficulty following more than one instruction. There are signs that information is absorbed but the ability to manipulate said information may be impaired.
- *Cognitive Flexibility*. Ability to shift to a different thought or action in response to a situation change. One of the symptoms of Autism is the stereotypical and repetitive behavior showing significant difficulty to adapt or respond to unexpected events such as conversations and the environment.
- *Planning*. The operation to plan a sequence of actions for a certain goal where this sequence is monitored, evaluated and updated. Tied to cognitive flexibility, persons with Autism show difficulty in organizing a sequence of tasks and completing them within the allotted time, such as homework, household chores and planned events.
- *Generativity*. Ability to generate novel ideas or behaviors. Persons with Autism have been shown to have difficulty generating new knowledge based on information presented.
- *Self-monitoring*. Ability to monitor one's own thoughts and actions. Necessary for other Executive Functions such as planning and organizing ideas.
- *Inhibition*. Ability to suppress irrelevant or interfering information or impulses. Persons with Autism have a hard time controlling impulses and emotions that interfere with current actions or tasks.

4.2 Technology Applied to Autism Spectrum Disorder Therapy

With new consumer electronics, comes new opportunities for applications for the therapy of the symptoms of Autism, such as Augmentative and Alternative Communication (AAC) [27] and Computer Assisted Instruction (CAI) software [28]. However designing this specialized software brings certain challenges. The nature of Autism, being a spectrum, makes the interaction design a very difficult task since each autistic user is unique with great variance in their characteristics, making the software more usable for some more than others. In order for the software to be an effective tool, it must be specially designed for that particular autistic user [28].

Putnam et al. [8] suggests that the main point in the development of technology based solutions for autistic users was understanding them. Some of the questions that motivated the research were:

1. What types of software and technology have users already tried?
2. What has been their experience with those products?
3. What do users report as desirous in software and technology?
4. What are end-user's attitudes and behavior toward technology?
5. What other common proclivities, interests, behaviors and talents might also help future design efforts?

As can be seen the main challenges for the development of proper special needs software and technology for autistic users has been analyzing and understanding how their particular characteristics will affect the interaction and use of the software or device, even more so since it is considered a spectrum there are no base level of characteristics to consider, each child can have the same basic traits, but the varying degree of affliction on each trait makes each person with autism unique.

5 Related Works

One of the core parts of the architecture of an Adaptive Interface is the User Model. In order to develop an adaptive system we must first determine what will be the user characteristics that will compose the user model. With this model, the user interface can be adapted based on the values of the characteristics that are being considered of the user.

Most software applications that use user models often just consider some aspects of the user that they deem relevant to the application, there is no generic solution to be used, although there is research towards achieving that goal [4, 5].

Some works center on what user characteristics must be considered for interactive systems, such as Zhang et al. [1] where it is proposed a methodology to integrate Human Computer Interaction practices in the software development life cycle, Zudilova-Seinstra [31] which notes what human factors must be taken into consideration based on the Wagner's Ergonomical Model [32] when designing software using the Yule's coefficient of colligation [33] and Biswas et al. [34] proposed a user model to be used in the design of personalized interfaces for motor impaired users taking into consideration certain related characteristics (Table 1).

Table 1. User characteristics considered in different models

Author	User characteristics
Zhang et al. [1]	Demographic (Age, gender, education, occupation, cultural background, special needs, computer training and knowledge, experience with similar systems/products), Traits and intelligence (Cognitive styles, affective traits, skill sets), Job or task related factors (Job characteristics, knowledge of application domain, rate of computer use)
Biswas et al. [34]	Experience (With the software and similar software), Age (Actual age), Occulomotor characteristics (Vision), Gender, Language level (Language medium, interaction language), Education Level, Personality (Motivation)
Zudilova-Seinstra [31]	Gender, Age, Learning abilities, Verbal and non-verbal IQ's, Locus of control, Attention focus, Cognitive strategy

Kaklanis et al. [5] present one of the most recent advances towards a standardization of a user model to be used across different platforms for simulation and adaptation purposes. The VUMS (Virtual User Modelling and Simulation Standardization) cluster of projects that works toward the development of an interoperable user model as a generic solution for the modelling for able-bodied users and users with disabilities. Currently the model includes a myriad of user attributes but for the moment no actual adaptation rules based on the attributes.

Because Adaptive Interfaces can adapt to the user characteristics, they can be used in software systems designed for special needs users, but for some reason there is not much. An example is the AVANTI project [9], in which the user interface provides views of adaptive multimedia web documents, adapting itself in a dynamic way to the characteristics and preferences of the users as they interact with the system by considering users with light or severe motor disabilities and blindness. Also research is being made toward improving accessibility for all users, especially older users, using adaptive and adaptable interfaces and multi-modal interaction, although it is still considered that there is much work to be done before a definitive methodology for the development of said systems and for the different measures to improve accessibility to be adopted [29, 30].

As we can see, there has been work on work on improving usability by integrating HCI and usability engineering practices in the software development life cycle and consideration of user characteristics. There is significant advancement towards a standardized user model but there is still much work to be done before we can have a generic solution with a standard rule set for each user characteristic.

6 Problem Definition

As we proposed in previous work [4] in order to improve usability in interactive systems it is necessary to relate software functionalities with user characteristics.

In order to establish this relation, we formulated the following statement: A software S is a set of functionalities operated by the user. This is expressed as follows:

$$S = \{F_1, \ldots, F_n\} = F \tag{1}$$

The functionality F_i involves a set of actions to be executed by the user. This is expressed as follows:

$$Fi = \{A_1, \ldots, A_n\} = A \tag{2}$$

Each action A_i can be of the type: input, indication, interpretation, etc. From the perspective of the user, an input and indication action can involve using fingers, voice, etc. in order to insert or indicate data. An interpretation action can involves processes such as perception, attention, and information processing. A perception action involves employing the senses, such as eyesight and hearing. An information processing action involves employing working memory and cognitive processor. Taking into account these assumptions, an action A_i can be expressed as follows:

$$A_i = \{t, \{C\}\} \tag{3}$$

Where t is the type of action, and C is a set of user attributes employed to interact with the software application. In this case C represents the Executive Functions (Ef) needed to interact with the software. Based on this, the functionality F_i is expressed as follows:

$$F_i = \left\{\{t, \{Ef\}\}_1, \ldots, \{t, \{Ef\}\}_n\right\} \tag{4}$$

The problem with usability arises when your user base has a very varied set of characteristics, in this case Executive Functions levels, affecting usability, adoption and user satisfaction across the board. In the case of persons with Autism, this problem is of special consideration because of the very nature of the disorder, requiring specially adapted software for each user [28].

7 Towards an Interaction Model for Users with Autism: A Proposal in Progress

In this paper we present a proposal of a potential user model based on some Executive Functions, as continuation of progress of previous work [35], that we consider necessary for the proper interaction and user of software applications. The Executive Functions we are considering are as follows:

1. *Working Memory*. Our ability to store information in the short term memory and manipulate said information.
2. *Planning*. Ability to plan a sequence of actions which involves other cognitive functions and Executive Functions, such as self-monitor, evaluation and update.

3. *Cognitive Flexibility*. Ability to shift one attention to a different thought or event in response to stimuli.
4. *Inhibition*. Suppression of conflicting impulses or external elements.

As Executive Dysfunction is shown to happen to people with other disabilities apart from Autism, it is possible that modelling Executive Dysfunction can be a generic model for any number of users.

In order to measure the Executive Functions of the model we will be using the NEPSY II battery of neuropsychological tests [36] for planning, inhibition, and cognitive flexibility. In the case of working memory we can measure it with the Wechsler Intelligence Scale for Children (WISC) [37].

In order to establish an interaction model we must first determine the impact of the different levels of the measurements of the Executive Functions and determine optimal usability patterns and interaction styles. In order to determine this, we are currently designing a variety of usability testing of software applications in tablets with different combinations of usability patterns and interaction styles for different tasks, in order to detect the best way for the user to accomplish the type of tasks being presented with his particular Executive Function levels (Fig. 1).

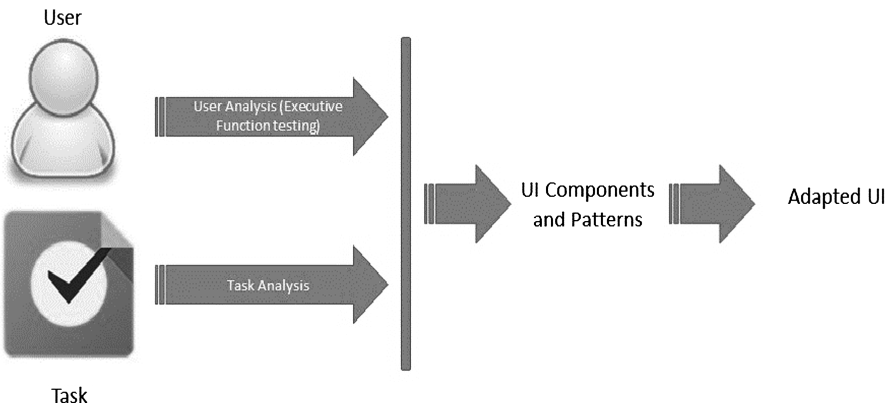

Fig. 1. Adapted UI process

8 Conclusions and Future Work

In this paper we presented a doctoral thesis proposal for a user model based on Executive Functions for adaptation purposes of the interface. A case study was proposed for Autistic users, since with their particular characteristics, provide an excellent chance to test the interaction model. Currently we are in the process of designing usability tests on software applications, where the user tries to complete a series of tasks in a different manner each time, with different usability patterns and interaction styles. Once an interaction style is determined we will test it in a broader audience by developing an AAC application with adaptive interface and determine the impact on usability and user satisfaction.

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