Neurohab: a platform for virtual training of daily living skills in autism spectrum disorder

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Abstract

Autism spectrum disorder (ASD) is a neurodevelopmental disorder that besides the core symptoms of impairment in communication, social interaction and repetitive behaviour, seriously compromises adaptive functioning limiting social inclusion. A number of studies also support executive dysfunction in ASD, although its specificity remains controversial. Furthermore, recent studies point to the relevance of ecologically valid executive tasks that match patient’s daily lives and therefore address the correlation with social cognition and learning of adaptive behaviour. These disabilities are usually addressed in rehabilitation therapies, usually performed in a scheme of one therapist for individual, having high costs for the individuals and patient associations in human resources. This usually results in lesser hours of intervention, leading to lesser impact of the behaviour training. To avoid this impact, some technological responses have been arising in the literature to perform training of individuals with ASD, although lacking scientific validity. In this work, we propose a platform for training daily activities in controlled environments, which allow caregivers and therapists to follow the patients’ performances and improvements along the time. This platform contains several serious games, which target specific adaptive and executive dysfunctions. Games can be added to the platform and become automatically available for the users.

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1. Introduction

Autism spectrum disorder (ASD) is a severe, early-onset and life-long neurodevelopmental disorder with a high prevalence worldwide and also in Portugal, and a distribution of four males (M) to one female (F) [1-3]. ASD is characterized by deficits in social interaction and communication as well as by the presence of a repetitive pattern of behaviour and interests [4]. These core symptoms compromise functioning across multiple domains, including cognitive functioning and adaptive behaviour (AB), affecting multiple areas of a person's life [4-6].

AB refers to the capacity to accomplish conceptual, social and practical demands on a daily basis [7]. To be successful in those demands and therefore support personal, domestic and social self-sufficiency, individuals have to perform daily activities that require adaptive skills [8-9]. Deficits in this area are a primary barrier to a wide range of tasks that go from basic personal and domestic autonomy (such as hygiene, dressing, making meals) to self-sufficiency (such as having a competitive employment or managing your money) [12]. Difficulties in AB appear early in life [5-6] and, without appropriate and effective intervention, persist throughout life [13].

Humans are deeply social creatures living in highly collective environments, which mean that adaptive behaviours require social imitation learning. Social cognition usually refers to the fundamental abilities to perceive, categorize, remember, analyse, reason with, and behave toward other individuals [14]. Executive functions (EF) are necessary for goal-directed and adaptive behaviour and include the ability to initiate and finish actions, to monitor and change behaviour as needed, and to plan future behaviour when faced with novel tasks and situations [15]. EF allows us to anticipate outcomes and adapt to changing situations. The ability to form concepts and think abstractly is also considered a component of EF.

These life-long disabilities are one of the most important in the prognosis of the people with ASD and consequently have social and economic repercussion with large cost to the society [16].

ASD has a significant economic and social impact due to its high prevalence, absence of specific therapeutic intervention, comorbidity, outcome and impact on families. Discarding medical costs, intensive behavioural interventions for children with ASD are estimated to cost between $40,000 and $60,000 per year for each child, in the United States of America [17]. This economic burden is very difficult to support for both parents and governments. The main problem is related to the fact that therapy must be intensive, which required specialized human resources allocated for long time with children, which is very expensive. In order to lower these costs and increase the access of families to economically viable therapy solutions, technology has been targeted as a potential help. Inside the technology field, virtual reality (VR) has gained a particular focus. VR addresses the possibility of creating computer simulations of real environments, providing safer learning experiences for individuals with ASD [18]. Its use in autism therapy is argued by the characteristics of VR allowing the control of the stimuli provided to users, reducing the complexity of the real world, along with the safety, control, repetition and some preference found in ASD people for computer interactions [19-20]. Furthermore, the realism of virtual environments increases the probability of transferring learning skills to the real life [19, 21-22]. There are also some works proposing guidelines for the development of such applications, addressing most issues autism patients have with interactive learning software [23].

In this direction, we present in this paper the development of the Neurohab platform. It is an integrated solution of serious games for individuals with ASD, which allows users and caregivers to train in virtual environments daily activities, in order to improve their autonomy. Here we describe the requirements identified together with patients associations and clinical staff, as well as the way they were addressed and incorporated in the current solution.

The paper is structured in four sections. After this introduction, the methods’ section presents how we established the requirements of the system, the results’ section describes the solution developed and then we discuss the results in the final section.
2. Methods

For the development of the platform, requirements were defined together with two local autism patients’ associations – Associação Portuguesa para as Perturbações do Desenvolvimento e Autismo (APPDA) of Coimbra and Viseu – and clinical staff from the Unidade de Neurodesenvolvimento e Autismo, Centro de Desenvolvimento da Criança, Pediatric Hospital, Centro Hospitalar e Universitário de Coimbra. Such interactions yielded, in a first phase, the main characteristics of the platform.

- Aim: It should enable participants to train daily living activities in virtual environments.
- Interoperability: Solutions for different types of platforms.
- Self-incremental: It should be possible to incrementally add new training tasks to the platform.
- Reporting: Caregivers should be able to remotely follow the progress of the patients.
- Enabled for Immersion: When immersion technology is available, the platform should be able to use it.

Requirements focused on two distinct user types: the patient and the caregiver. For the patient, basic needs were identified regarding not only the basic features for the platform and its interface, but also for the main serious games to be included on the system. For the caregiver, there were identified the type of follow up needed to monitor the progress of the users.

On a second phase, the principal areas of interest for the daily routines to rehabilitate were identified, in order to direct the development of the serious games to include in the platform. Those areas are:

- Hygiene: teeth brushing, hand washing after using the toilet, choose clothes adapted to the weather, etc.
- Privacy: inter-personal distance regulation, keeping secret codes private, etc.
- Employment: train different professions, job interviews, etc.
- Social: adapt dialogs to the relationship with the other person, questions you should not ask, questions you should not answer, etc.
- House keeping: cooking, cleaning, place groceries, wash dishes, etc.
- Outdoors: deal with loud noises, exposure to animals, crossing the street safely, etc.
- Money: identify the money, use the debit card, attach costs to products value, etc.

Using those requirements, we built the platform we present in the next section.

3. Results

Following the requirements identified with the clinical partners, we developed the architecture defined in Figure 1. It incorporates a backbone of serious games, interfaced with different devices with different levels of immersion. For the caregivers, a web interface allows access to the monitoring of the patients information and their progress and usage of the platform along the time.
Therefore, Neurohab is a software platform that provides access to a growing catalog of rehabilitation games on multiple platforms with focus on ubiquitous access and real-time feedback. The software has several features which allow caregivers and therapists to closely follow the patients’ performance along their usage timeline.

Ubiquitous access is achieved by having the same software run on multiple platforms like the desktop computer, the smartphone and the increasingly popular tablet. This allows for subjects to perform their training more frequently as they don't require any specific device or location. Using a centralized server, the user can automatically synchronize their progress across all devices so they can continue as they left it. This synchronization is optional, as the software does not require the server to run locally on any device, although required for the therapeutic follow up.

The serious games provided in the platform can be parameterized. Subjects are able to directly (through the settings configuration) or indirectly (throughout progress) affect how the games are played. From changing the controls, the ability to enable the use of specialized hardware for virtual reality scenarios, for instance, as well as several aspects affecting the difficulty of the game. There is a special emphasis on adaptive learning. Therapists can take advantage of this feature to enforce a more personalized learning, tailored to the user’s needs.

The ability to run games in a cross-platform environment with shared state comes from the Neurohab architecture as shown in Figure 1. Running on the personal computers there is a standalone application that runs an embedded webserver that serves a simple UI navigation website, where users can automatically maintain an updated catalog of games and their progress data. Having the UI built on HTML5 and JavaScript, standard languages for web applications, makes it easy to share the same code between the standalone (running a machine executable) and the tablet use case (where patients access a public address serving the same UI website). When games are started from the standalone version, communication between games only happens locally. Optionally the user can have the standalone application automatically synchronizing their progress data with the Neurohab main server, allowing for other platforms to retrieve this progress and monitoring by the caregivers. In limited devices such as tablets and

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Fig. 1. Architecture of the application.
smartphones, access to games are restricted to web games as the user are given access to the application through their web-browsers.

Using the Neurohab’s website both caregivers and therapists can watch closely how their assigned subjects are improving on the available games. For instance, on a conversations game, where subjects roam a virtual world engaging in conversations with digital avatars, caregivers are able to see how many conversations the subject performed, for how long, and how much confidence he gained with that individual avatar from the conversations made. These data are only available in the cases where the subject enables synchronization with the server (see Figure 2).

![Neurohab interface](image)

**Fig. 2.** Web interface for caregivers monitor users’ progress.

There is an emphasis on data privacy in the system, resulting in a number of security features regarding the access to subjects data, both personal information and progress record. Access to a subjects’ data can only be permitted after a therapists and/or caregiver been given a secret token generated by the subject himself. This access can be revoked by the subject at any time.

The serious games are being developed as a continuous process, since the application provides the option of adding new games gradually. The games under development focus mainly daily routines targeting specific adaptive and executive dysfunctions. These games try to achieve a highly interactive and active learning experience for the user by leveraging the use of 3D virtual worlds and digital avatars to mimic subjects’ real-world settings and offer ecologically valid tasks. Instructions are made available both on-screen and using text-to-speech.
Fig. 3. NeuroHab platform for ASD users. On the left (a) is the main interface for selecting a serious game to practice. On the right (b) it is shown the application running on a tablet device.

4. Discussion

Neurohab is both aimed at ASD patients who want to develop target specific adaptive and executive dysfunctions and therapists who want to follow on these developments and complement their rehabilitation programs with complementary autonomous training. Running the platform in several devices and integrating the data from wherever the participant is playing, it enhances the possibilities of usage and may adapt so each patient uses their preferred devices.

Furthermore, more immersive solutions can be provided by the autistic patients associations as a service, adding to their current rehabilitation offers. We believe this platform has the potential to be a complement to current therapies, reducing the costs of interventions and enhancing the follow-up of patients.

Next steps involve the validation of the serious games and the continuous improvement and development of new games to add to the catalog.

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