# Empowering Accessibility: Intellectual Disability Therapy and Behavior Analysis Through the Use of Extended Reality and Biomarkers

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## ABSTRACT

Recent technological advancements have sparked interest and exploration of eXtended Reality (XR) potential benefits in psychology and healthcare. Another promising technology are wearable devices, non invasive instruments capable of recording biosignals that can be correlated to emotions, cognitive states, and behavior. Despite the advancements and the interest, there is a notable lack of studies focusing on inclusive XR, with most applications targeting neurotypical individuals. This PhD research aims to leverage XR and integrate it with objective biosensor measures to develop effective therapy paradigms aimed at people with intellectual disabilities. Additionally, it seeks to explore human interactions within XR environments to gain valuable insights into the behaviors, emotions, and experiences of underrepresented categories. Through a multidisciplinary approach, this research seeks to enhance understanding and application of XR technologies, promoting inclusivity and effectiveness in therapeutic settings.

## CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; **Heuristic evaluations**.

## KEYWORDS

Extended Reality, Physiological measures, Intellectual Disability, Therapy, Behavior analysis

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## 1 INTRODUCTION

Since its development, modern psychology has shaped and continues to shape our society offering relief and treatments to mental disorders and enabling activities to help people in vulnerable situations. While conventional methods will remain a cornerstone of psychological research and treatments, there is a growing interest towards the implementation of traditional therapy and studies in eXtended Reality (XR) [13, 14]. XR is an umbrella term used to include all the immersive technologies that alter our experience of reality either by creating a completely virtual one (VR), by enhancing the physical reality (AR) or by blending the virtual and physical reality (MR). The rapid evolution of technology in recent years has allowed the widespread commercial distribution of XR devices, enabling numerous application in countless domains [2].

Another transformative technology deeply tied to healthcare and psychology are biosensors and biosignal analysis. The development of new devices, paired with the advancements in the study of physiological measures, has driven innovation in medical treatments and diagnostics, enhancing their effectiveness and contributing to increased knowledge. While psychology does not typically rely on the use of biosensor, more and more studies are investigating the links and correlations between biosignals and emotions, cognitive states, behavior and interactions, using this insights to deepen our knowledge [6, 7, 16].

Despite the advancements and the growing interest, there is a significant lack of studies in the realm of inclusive XR. In fact, most of the applications and research studies available target neurotypical non-disabled white males [17]. This gap is reflected both in the research regarding the applications of XR and regarding experiences and interactions in XR [2, 3, 7].

This PhD will leverage the benefits and opportunities offered by immersive scenarios, integrating them with the objective and reliable measures obtained through biosensors. By combining these technologies, this research aims to develop effective therapy paradigms targeted to people with intellectual disability. Simultaneously, the data obtained will enable the study of human interactions within XR, providing valuable insights on the behaviors, emotions and experiences of underrepresented categories. This work is part of the Incluverso5G project, carried out through a partnership between Universidad Politécnica de Madrid, Nokia XR Lab and Fundación Juan XXIII, which aims to apply and develop inclusive immersive technologies to people with intellectual disability and other vulnerable psychosocial situations.

## 2 CONTEXT

Current technological advancements allowed the development of more precise and smaller instruments, enabling the widespread distribution of smart wearable devices. These devices typically measure signals such as Heart Rate (HR), Electrodermal Activity (EDA), Skin Temperature (ST), Electromyogram (EMG), movements and more. While wearable devices usually provide lower quality measures compared to the typical medical-grade equipment, thanks to recent signal processing and machine learning developments, they allow countless use cases that would otherwise be impossible to achieve [9, 15]. Wearable devices can be used during daily activities allowing a thorough monitoring of well being, typical uses cases are disease diagnostics, aid in rehabilitation, stress and emotion detection [4]. Pairing stress and emotions with others signals such as movements and eye tracking allows to study how users react to environments and events, thus giving insights on experiences, behaviors and interactions patterns. The use of non invasive devices is particularly important when dealing with individuals with intellectual disabilities as it lowers the risk of aversion.

The healthcare sector is also witnessing significant interest in the potential of immersive experiences. The degree of realism and immersivity in XR has been growing steadily in the last years, posing the basis for countless of new applications. Specifically, due to its inherent immersive nature, it allows the development of efficient, cost effective and functional psychological treatment therapies. While the opportunities that these technologies open are broad, the vast majority of studies on XR are not taking into account inclusivity, focusing predominantly on able-bodied, neurotypical, young white males [17]. Such an approach underscores the necessity for more inclusive research to include a wider range of populations, particularly those facing psychosocial vulnerabilities. The few studies targeting the people with intellectual disability have shown promising results, however they often lacked a standardized well thought design, thus more research is needed to asses the real effectiveness of such treatments [11].

Researchers are now combining XR with biosignals to maximize the benefits of both technologies [1–3], however, most studies focusing on non-neurotypical individuals target those with autism [7], with few studies directed towards individuals with intellectual disabilities [10].

Lastly, traditional methods to evaluate experiences, quality, presence, sickness and more, require the use of extensive and complex questionnaires [12]. This methods are often cumbersome for the neurotypical community, this burden can only be amplified for people with intellectual disabilities.

In light of this situation, there are evident gaps in the XR research. As a general statement, there is a need for more inclusive research that addresses the needs and preferences of underrepresented categories, notably individuals with physical or mental disabilities who are rarely targeted in current studies. Regarding people with intellectual disability, there is a need to study behavior, interactions and experiences as a mean to understand thoroughly their vision of the world, which would help to design a more inclusive virtual and real world. To aid this investigations there is a need for inclusive questionnaire that are easy to understand by a vast population. Moreover there is a need for well-designed therapy studies investigating the effectiveness of XR as a mean of therapy compared to traditional methods.

## 3 OBJECTIVES AND RESEARCH QUESTIONS

This doctoral research aims to fill some of the gaps in the current state of the XR research. Specifically it will focus on therapy and inclusion of individuals with intellectual disability through the use of XR and biosignals.

In the broad scope of the Incluverso5G project, the objectives of this research are:

(1) Develop and test psychological therapies in XR.
(2) Study the use of biosignals as means to evaluate progress and mental states during therapy.
(3) Investigate behavior and interactions in XR looking for insights on typical patterns and experiences of people with intellectual disability.

Given these objectives this PhD will answer the following Research Questions:

- **RQ1:** How does XR therapy compare to the traditional one for individuals with intellectual disabilities?
- **RQ2:** Can biomarkers be used as metrics of progress and/or learning in therapy?
- **RQ3:** Are there any interesting representative and interaction patterns?

## 4 METHODOLOGY, CURRENT AND FUTURE WORK

The project will feature the development of a behavioral and a cognitive therapy treatment, moreover, a significant focus will be dedicated to adapting questionnaires to ensure their accessibility to a broader community. Existing standardized questionnaires, such as the ones present in [12], will be used as a foundation to create simplified versions that better fit the needs and capabilities of people with intellectual disabilities. Following feedback and results the questionnaires will be tailored over time.

To address potential barriers related to technology familiarity, the therapy process includes training sessions designed to help subjects become accustomed to the XR environments and learn how to interact effectively. For instance, in the behavioral therapy, one session is dedicated to explaining and testing the questionnaire voting procedure.

A team of psychologists will partake in all the phases of the project to ensure the well being of patients and a correct implementation of the therapies.

Participation in this research requires written consent from the subjects' guardians. Additionally, subjects' willingness to participate is carefully considered. Subjects may withdraw from the study at any time without any consequences. This project has received approval from the Ethical Committee of Fundación Juan XXIII and complies with the General Data Protection Regulation (GDPR).

### 4.1 Behavioral therapy

The objective is to implement traditional Systematic Desensitization (SD) in immersive scenarios, in order to cut costs and aid patients in the learning process. SD is a behavioral therapy used to address

phobias and anxiety disorders [18]. Traditionally, SD requires mental visualization of anxiety inducing situations while performing relaxation techniques which elicit an anxiety incompatible response. When following a structured approach with a gradual increase in anxiety triggers, this technique effectively reduces anxiety and fear responses. When targeting people with intellectual disabilities, SD often requires in vivo exposure [8]. XR offers a viable alternative to this approach by providing realistic immersive experiences.

Psychologists from the occupational center of the Fundación Juan XXII found a common fear inducing situation in ascending or descending stairs. Addressing this specific need, a SD therapy will be applied to treat bathmophobia, the fear of stairs. The therapy will consist of weekly 30 minutes immersive experience sessions. Progress will vary for each patient, and there is no fixed timeline, however, it is anticipated that therapy will conclude after 6 months. Throughout the sessions, a therapist will be present to monitor and assist patients as necessary, and to prompt changes in scenarios and audio tracks.

The first step of the treatment is a preliminary assessment to determine each patients hierarchy of fears by showing real photos of stairs. The second steps requires teaching breathing exercises as a form of relaxation, audio guides and relaxing 360° videos will aid the subjects in the process. Finally, patients will be slowly introduced and exposed to fear inducing scenarios, if required, the therapist will switch to the relaxing scenarios and audio tracks to aid patients in managing their anxiety. Following the hierarchy of fears, the final step will be repeated while increasing the anxiety stimulus. Through repetition patients are expected to show reduced anxiety levels and improved emotion management when exposed to fear inducing triggers.

To increase the sense of presence a segmentation algorithm will be used in order for the subjects to see their body in the virtual world [5]. During the whole process patients will wear the Empatica E4, a medical grade smartwatch to measure some physiological measures such as EDA, HR and ST. During the sessions patients will be asked to fill some questionnaires regarding their experiences and state of mind.

At the end of the therapy period, subjects' progress will be evaluated through a post-therapy assessment. The collected data will be analyzed looking for insights on anxiety levels, stress, mental states and progress during the therapy. The extracted insights will be correlated with the therapists decisions, and could ultimately lead to a semi-automatic therapy process that aids the therapist in the decision making process. Machine learning techniques will be explored as a means to analyze data and establish correlations with therapist decisions.

A first version of the application has been developed and its currently being used in the initial phase of the therapy, where patients are being taught relaxation techniques and are answering the first questionnaires. Fig. 1 shows the application developed to control and monitor the therapy sessions. The top panel features session info and basic controls to start and stop the therapy. The session control panel includes elements to cue audio tracks and change of scenarios. The right side panel is meant to provide additional insights on the subjects' experience and shows their viewport and biosignals in real time.

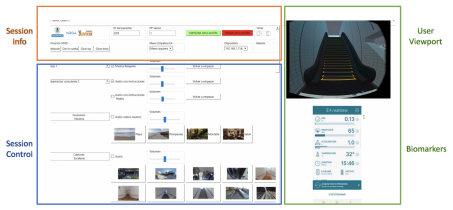


**Figure 1: Picture of the therapist monitor.**

## 4.2 Cognitive therapy

The Fundación Juan XXIII currently holds cognitive therapy sessions aimed at the integration of individuals with intellectual disabilities in the workforce. Frequently the therapy involves the use of 2D serious games. The main objective is to implement the serious games in XR, as this is expected to provide a more effective learning platform for skills that can directly apply to the job.

Subjects will be divided into two groups: one will follow the experimental XR therapy procedure, and a control group will follow the current standard therapy provided at Fundación Juan XXIII, which involves the use of 2D serious games. Within each group, all participants will follow the same process. All subjects will undergo pre- and post-assessments of their cognitive skills to evaluate any improvements. This comparative analysis will help validate the effectiveness of the proposed XR therapy method against traditional therapeutic approaches. Therapy sessions will be weekly and will amount to a total of 12 hours of gameplay per participant.

As the therapy design is still being discussed and modified, this paragraph presents the current tentative therapy procedure. Each therapy sessions will last 20 to 30 minutes, every subject's progress will be saved so that the next session will start from the last checkpoint. Participants will experience a game composed of various work-like scenarios. At the start of each session participants will have a couple of minutes to get used to the XR environment. Subjects will then start with the actual game, each scenario will have various tasks to be completed. The game will be divided into levels, each with a given amount of time to complete a number of tasks. Levels get harder by having more difficult tasks and by limiting the maximum time available. To unlock access to the next level, participants will have to first succeed in all of the scenarios of a level. If a participant fails 3 times in a row the game will push him back to the previous level. A therapist will attend each session, providing guidance when needed.

Considering the subjects' work preferences, the preliminary set of scenarios includes a restaurant, a supermarket, a clothing store and a home. As requested by the team of psychologists the therapy will aim to train skills such as inhibition, sustained attention, selective attention and alternating attention. Skill will be trained through tasks that require to move and interact with the environment.

All of these choices were discussed with the psychologists team, following their directions on how to develop an effective therapy program.

As Head Mounted Display we plan to use the HTC Elite XR Pro with the eye tracking add on. Besides eye tracking and head movements, various physiological measures such as EDA, ST, HR and EMG will be measured using the Empatica E4 and the Cometa

Picoblue sensors. In addition to using biosensors, the therapy includes real-time subjective feedback from participants through questionnaires, ensuring a comprehensive understanding of their experiences.

Therapy effectiveness will be evaluated by the psychologists at the end of the treatment.

Finally, the collected data will be analyzed to evaluate the mental state, anxiety and emotions of patients during therapy. As for the behavioral therapy, this data will be correlated with progress during the game. Machine learning techniques will be investigated both for the data analysis and to correlate biomarkers with progress, aiming to automate the therapy process. User behavior models and machine learning will be used to study behaviors and experiences in virtual scenarios, extracting patterns in saliency and movements.

## 5 MAIN CONTRIBUTIONS TO IMX

Interactions and experiences within immersive scenarios are complex, and multifaceted, requiring an interdisciplinary approach to study them. With the numerous research opportunities offered by these technologies there is a risk of overlooking underrepresented groups. This research offers to study how to create a more inclusive real and virtual world, by means of immersive experiences. The study will focus on pairing biosignals and XR to study behaviors, interactions and experiences of people with intellectual disabilities in order to gain insights on their view of the real world and virtual world. Finally, designing and assessing technology aimed at individuals with intellectual disabilities provides robust insights that can be generalized to the general population.

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