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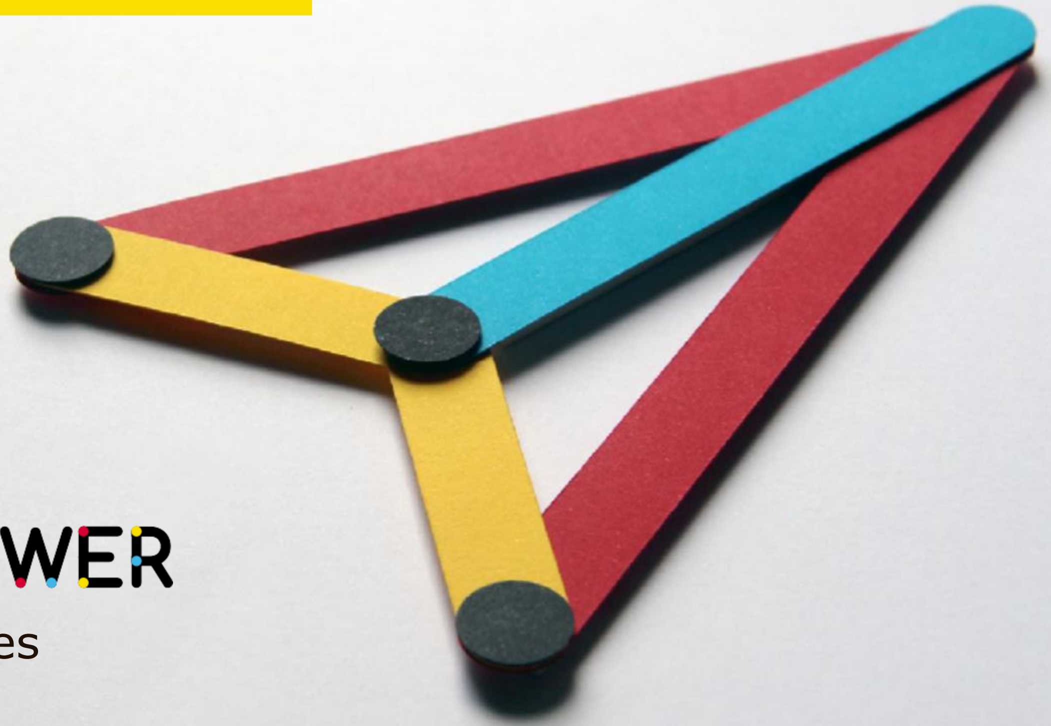

EMPOWER

deliverables

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This deliverable includes the Protocol on how to develop educational technological platforms This protocol will present in detail all the necessary steps of the conceptual development of the psychological and educational contents of the platform. It is part of WP2.

Description

WP.2

Work Package. 3

Lead Beneficiary – (RU)

Conceptual development Protocol of EMPOWER Platform and Games

Executive Summary

This deliverable includes the Protocol on how to develop educational technological platforms. This protocol will present in detail all the necessary steps of the conceptual development of the psychological and educational contents of the platform.

Date	Version	Description	Authors
10.01.2024	1.0	First Draft of the conceptual development protocol	Sara Lopes, Diana Stilwell, Aristides Ferreira, Paula Ferreira, Cristina Cotescu, Carmen David, Adrian Rosan, Lucia Vera, Ana Margarida Veiga Simão, Diogo Domingues
23.01.2024	2.0	Second Draft: inclusion of the data from the pilot studies and revision of the information included	Cristina Cotescu, Carmen David, Adrian Rosan, Aristides Ferreira, Sara Lopes, Diana Stilwell, Paula Ferreira, Lucia Vera, Ana Margarida Veiga Simão
29.01.2024	3.0	Final version	Sara Lopes, Diana Stilwell, Aristides Ferreira, Paula Ferreira, Cristina Cotescu, Carmen David, Adrian Rosan, Lucia Vera, Ana Margarida Veiga Simão

Table of Content

#1. Introduction

In this protocol, we present EMPOWER, a digital platform with serious games specifically designed to assess and train executive functions and emotional regulation. The platform is conceived for children aged between 6 and 12 years old with neurodevelopmental disorders (NDDs), who often present difficulties in these particular cognitive domains.

EMPOWER is a novel platform based on new paradigms from psychology that suggest that executive functions and emotional regulation are two key sets of skills to target in the educational intervention for students with NDDs. The core output of EMPOWER is thus an educational platform, co-created by all the stakeholders involved, that facilitates the improvement of these key skills in children with NDDs.

The platform is being tested and validated in school settings with all stakeholders, according to the strict standards of a randomized clinical trial. In addition to technological advances, the lessons learned from the development and deployment of this platform will provide valuable insights into the needs and possibilities for training teachers in the use of new technologies, as well as input into future policies governing technology in education, including, in particular, refined ethical frameworks.

In creating and developing this serious-game-based platform, our main objective is to empower teachers to better support children in schools regarding their emotional and behavioral difficulties and ultimately improve their quality of life. The platform will include a range of games and activities for children with NDDs that will serve the purpose of assessing and training a variety of important skills for their success in school and in life. We believe that including both an evaluation phase and an intervention phase, constitutes a novel process through which the EMPOWER platform can be validated. The assessment component provides an initial description of the child's executive functions and emotional regulation profile, as well as information on the specific areas to be strengthened. The intervention component functions as a means to strengthen the less developed skills. Moreover, the platform is equipped with a data collection system and internal report generator which allows to track the student’s progress and set objectives. This project also includes training sessions for teachers to ensure the accurate implementation of the games in the platform. To this end, there was ongoing support and collaboration among partners to ensure the project's success.

The platform design will be built upon different sources of available data, including scientific evidence, experts/professional opinions, online reviews, and evidence from the actual use of available technologies (Zervogianni et. al., 2020). This framework will provide information regarding the reliability, engagement, and effectiveness of the digital platform, and also regarding its ethical acceptability or trustworthiness. We expect to provide scientific evidence of the platform's impact, namely, quantitative and qualitative information regarding the platform's reliability, engagement, and effectiveness.

THEORETICAL FOUNDATION

In this deliverable, we will focus on the concept of NDDs as it is described in the latest version of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5, and DSM-5-TR) (APA, 2013). According to DSM-5, NDDs are developmental deficits that affect personal, social, academic, or occupational functioning. Attention deficit/hyperactivity disorder (ADHD), particular learning disorders, impairments affecting speech, language, and communication, autism spectrum disorder (ASD), and specific and moderate learning challenges are the most frequent NDDs. NDDs typically co-occur with each other (APA, 2013). If not diagnosed and treated earlier, children with NDDs can experience negative consequences on their academic performance and social skills (Barkey, 1997).

As an upcoming research and practice field, the use of computer-based interventions has addressed many barriers in treatment, in terms of accessibility, pace, setting, cost, access to appropriately trained therapists, and the potential to increase motivation and adherence (e.g., Khan et al., 2019; Ahn & Hwang, 2017). The use of gamified computer-based tasks to train and improve executive and emotional skills has become a hot field for research and development. Most of the published interventions show promising evidence of the effectiveness of computer-based interventions (e.g., Khan et al., 2019; Ahn & Hwang, 2017), and evidence of the ability to improve the cognitive ability of children suffering from neurodevelopmental disorders (NDDs) (Ren et al., 2023), highlighting the relevance of serious games in creating opportunities for children to practice competencies that are crucial for their development.

A recent systematic review established that technologies (such as serious games) can provide the delivery of automated and self-directed interventions, the delivery of therapies over distance, the reduction of patient pressure from face-to-face consultations, and the improvement of clinical effectiveness and personalization of treatment approaches (Valentine et al., 2020). Moreover, these technologies to evaluate and train cognitive function in children with NDDs must be empirically evaluated, in particular for executive functions and emotional self-regulation.

Nonetheless, more research and empirical evidence are needed to understand the full impact serious games can have on children with neurodevelopmental disorders in terms of emotion recognition, anxiety reduction, stress regulation, and rehabilitation (Miyake et al, 2000). Clinical evidence is needed to understand the impact of serious games on the needs of children with neurodevelopmental disorders. This platform exemplifies current possibilities for such games with functional prototypes supporting education.

In a recent meta-analysis, Ren and colleagues (2023) found that a combination of training content in digital games and some specific game features were associated with enhanced core cognitive abilities of children with several types of NDDs. Moreover, Kollins and colleagues (2021) also observed in a sample of 206 children with ADHD that playing a digital game specifically developed for training some executive functions for 4 weeks, was effective in improving ADHD-related difficulties, even in the children that were undergoing treatment with medication.

We have found that there are hardly any serious games specifically designed for the assessment and training of certain executive functions and emotion regulation skills, as is for example the case of inhibitory control in children with NDDs. For instance, in the work of Ramos and Garcia (2019) the authors performed a quasi-experimental study to evaluate the performance of children with NDDs in proposed playful activities connected to inhibitory control. However, the researchers used a database of cognitive games that already exist, with little empirical proof that these games truly evaluate inhibitory control.

The currently available data on serious games designed to evaluate and train executive functions and emotion regulation is scarce (Ren et al., 2023), particularly when employing these digital activities as reliable tests and intervention tools, leading to the relevance of this platform as a means to improve the state of the art is this field as well as increasing the number of resources available to support children with NDDs overcome their difficulties.

COLLABORATIVE GAME DEVELOPMENT

To develop each game we used a common framework to support us in coordinating a multidisciplinary team through a shared regulation of task execution. We followed a strict social-cognitive perspective (Bandura, 2006; Zimmerman, 2013) on the process of game development, to articulate the assets of the team in a structured manner in terms of varying competencies and to overcome possible scientific language barriers from the different areas. We believe that this interdisciplinary collaboration is a key factor in developing serious games, as the different experts from various areas (clinical, research, technical, and game design) can provide different and relevant contributions to the platform construction. This co-design approach facilitated the conceptual development of the resources by having the common framework in a common template for all games, where we also presented example images of what the games should look like to aid the design aspect of the games and the gamification of the tasks

To make this collaborative work possible and feasible, we created a common framework for game development for all the games in the Empower platform, which are: (1) the game's name, (2) the objectives of each game, (3) the area/s of intervention covered in each game, (4) a complete description of the functionality of each game, (5) the type of stimuli to be included in each game, (6) a description of modes of playing, (7) a detailed list of levels of difficulty, (8) a list of variables to be measured during the game, and (9) the data to be recorded about the game and the user's performance

A SERIOUS GAME PLATFORM FOR CHILDREN WITH NDDS

As we have discussed above, we believe digital serious games can be useful pedagogical tools to improve learning in children, including by promoting development of cognitive skills, learning by discovery, and having a motivational effect in children with NDDs (Ramos & Garcia, 2019). Developing and training executive functions is crucial for children with NDDs. However, few digital solutions on the market can work with these children in a personalized approach.

In addition to the innovations necessary for the development of the platform itself, the evidence-based model for digital technology used to develop the EMPOWER platform will be able to inform those developing digital tools for the educational setting about what the important steps and critical types of evidence are. The platform design is built upon different sources of the available evidence and this framework will provide information regarding the platform's reliability, engagement, and effectiveness, and also regarding its ethical acceptability or trustworthiness.

#2. Platform and Game Design

We used the Intervention Mapping protocol developed by Bartholomew et al. (2016) to design the platform and all its serious games. The Intervention Mapping protocol (IMP) provides support in systematic intervention designs based on evidence and behavior change theories, helping build a framework for each step of game development, including planning, implementation, and evaluation. The process of developing the EMPOWER platform according to IMP is outlined in Fig. 1 and described in more detail below.

Figure 1: Intervention Mapping Protocol

Step (Evaluation)	IMP Objectives and tasks	Results	Timeline
Step 1 Needs assessment	Assessing needs and planning intervention	Literature Review Focus group interviews (n= 19)	↓
Step 2 Outcomes and Objectives	Establishing target cognitive and emotional components and most appropriate devices	Project report	↓
Step 3 Platform Design	Development of psychological content App Analysis and Design App Development	Report with detailed content Full system design document Wearables and Eye-tracking module Database with composite scores	↓
Step 4 Platform Development	Testing the preliminary version of the platform (pilot studies) Algorithm integration with games	Report on sensory interpretation of algorithms, integration, and suitability. Evidence-based model for digital education.	**M7-24**
Step 5 Implementation Plan	Defining requirements for user's profile Validation and usability of the platform Algorithmic refinement	Strategy for implementation	**M21-31**
Step 6 Evaluation Plan	Testing the effectiveness of the platform	Final release report documenting the final version of the sensory algorithms and effectiveness of the platform	**M24-32**

NEEDS ASSESSMENT AND RESULTS FROM FOCUS GROUP INTERVIEWS

The first step was to conduct a needs assessment on interventions with digital platforms for children with NDDs from stakeholders, which informed the design and development of the EMPOWER game platform. We also gathered information about behavior assessment requirements in school contexts to have ecological validity, collected suggestions from stakeholders, and revised previous literature, leading us to the development of the psychological content according to the needs of children with NDDs. Based on these, we decided to include nine different digital assessment-intervention games on our platform, to cover nine key developmental and educational areas of intervention, that have been conceptualized and are currently in their development phase: (1) working memory, (2) inhibitory control, (3) attention shifting, (4) cognitive flexibility, (5) delay of gratification, (6) emotion naming, (7) emotion intensity level rating, (8) emotion understanding, and (9) emotion regulation strategies.

Focus group interviews were carried out to gather information on the needs and adequacy of tasks for game development, gaining deeper insights into the perspectives of concerning the utility and requirements of resources to help neurodiverse children develop their executive functions and emotional skills, as well as to identify the main game features recommended for incorporation in the games' construction phase.

A total of 32 experts (29 female and 3 male) agreed to participate in the focus group interviews, 19 Portuguese nationals and 13 Romanian nationals. The majority of the participants were teachers (14), and the others were trained psychologists (10), psycho-pedagogues (5) or had other types of training (3). Participation was confidential and voluntary, all focus group interviews audio was recorded with participants' permission, and data was anonymized at that stage. Written consent to participate was given by participants. The approximate duration of the interviews was 60 minutes. All focus group interviews were conducted online via Zoom platform and participants were interviewed in their mother tongue, either Portuguese or Romanian.

The focus group interviews were analyzed using the thematic analysis methodology (Braun & Clarke, 2006), applied to the transcripts of the focus group interviews, enabling us to closely examine the data and identify common themes and patterns of meaning that might be of interest in answering our research questions.

Results from the focus group interviews highlighted the features of the games being constructed through our project and the utility they pose for their practice and children's development. The experts provided many different features they believed would be useful to make the EMPOWER games more accessible and engaging for children with NDDs. They mentioned adding video (3-3), images (7-13), and sound (5-11) needed to make the games more intuitive, with a multi-sensory approach. Adding the possibility of making recordings (1-2) was also mentioned as a feature that would promote the interaction of the children with the game. Additionally, the experts also suggested the games should not be too long or complex (6-12) due to the children's specific abilities.

To make the games effective, many experts mentioned it would be interesting if the games could be calibrated and customized depending on a child's specific needs (8-18), with levels of difficulty (7-25) and the possibility to make changes to scenarios taking into account the children's specific interest (9-18), some even suggesting that some games should have some simulation components (5-8) to promote player/game interaction. Finally, the participants strongly emphasized that the games should give the children and the teacher/practitioner the possibility of seeing the child's progress and receiving feedback upon completing game tasks (8-28), and to add rewards dependent on the children's success in the games (8-25).

During the focus group interviews, the participants also gave their opinion regarding the use of online serious games in their practice with children with NDDs, highlighting how these tools are useful, but also how they should be used with caution.

One mentioned *not using* online resources at all ("I do not use digital games.(1-1)"), others mentioned that due to lack of resources they found these games to be *hard to implement* and build ("We need a computer at school to be able to use online resources. (3-7)"), many said there should be *precautions* taken when using them with NDD children (9-26), and a lot mentioned they find these resources *very useful* (10-53).

Regarding the cautions, interviewees highlighted that practitioners should take into account that using online resources might be *addictive* to some children (3-3), pose as a *trigger* and provoke some level of emotional dysregulation (2-4), might *lack contextual cues* compared to the real day-to-day living (2-2), and might become *repetitive* and lack in spontaneity and novelness

(1-1). In line with these concerns, interviewees frequently stated that they feel computerized serious games should be implemented with care, taking into consideration and mindful of the required *balance* with other activities and how they are introduced to the children (4-6), being aware of the appropriate *screen time* for each child (4-5), and be implemented with the *supervision and support* of parents, teachers or therapists (4-5).

EMPOWER GAME PLATFORM

Games are being developed with Unity cross-platform game engine (by Unity Technologies), with incorporated physiological data capture devices to record real-time sensitive data of users' attention (using eye-tracker) and users' arousal (using biosensors that will measure variables such as heart rate or movement).

A set of Artificial Intelligence (AI) algorithms is also currently under concurrent development, to allow real-time processing of eye-tracking, wearables, and students' performance data to continuously inform teachers of the user's performance and to allow games' self-adaptation to improve student wellbeing and performance. Further details can be found in the deliverables of the platform development work package (WP3) including D3.1 to D3.5.

MACHINE LEARNING ALGORITHMS

As we have mentioned above, the assessment and adaptation mechanisms for the EMPOWER platform will be supported by AI technology, in particular Machine Learning (ML) algorithms, as well as pattern analytic models. ML algorithms build models from historical data, for example, scores and sensory data of students collected in previous sessions, which can be used for making predictions for future situations.

In the EMPOWER platform, we will use the ML algorithms as a new approach to understanding children's strengths and weaknesses in terms of executive functions and emotion regulation strategies as predictors for their mental health representing a different perspective in terms of intervention and teaching strategies. The output of the AI algorithms will feed directly to

Game Adaptation Mechanisms [E] and Feedback Generator [F] modules. Further details can be found in the deliverables from WP4.

THE USE OF BIOSIGNALS IN SERIOUS GAMES

Assessment of cognitive and emotional factors holds a crucial role in the teaching-learning process, serving as a potent tool to boost children's achievement and enable personalized interventions. Its adoption has the potential to yield higher-quality assessments, providing greater utility for teachers and more directly benefiting students' learning (Koomen & Zoenetti, 2018).

Recently, there has been a growing interest in combining digital games with wearable technology (Meijer et al., 2018), such as smartwatches. These devices can easily send data to an external database or network, making serious games more engaging. Furthermore, wearables can measure physical improvements throughout the game, providing the monitoring of the individual progress (Meijer et al., 2018). By including wearables, we aim to use the collected data as complementary information in evaluating NDD children and predicting potential NDD-specific behavior. There is some evidence in the literature that eye gaze and HR rate can be variables of interest in adapting an educational activity.

Eye-tracking technologies are commonly used to examine social attention and social motivation in ASD, but their sensitivity varies. Eye-tracking provides insight into the attentional relationships of performance. The ecological significance of social stimuli is an important consideration for measuring social attention and motivation in ASD. The main focus here will be on the analysis of basic, static, and dynamic complex emotions based on eye movement parameters such as the time one looks at an object, total fixation duration, fixation duration, fixation number, first fixation, saccades, and smooth pursuit. Researchers have found that eye movement predicts working memory performance during the encoding and recall phases (Hodgson, T., 2019). Moreover, when working memory deficits are present, refixations or longer fixation duration are put to use. Using a continuous performance test (CPT), to measure sustained attention, Lev et al. (2020) found that ADHD patients spent more time gazing at irrelevant regions, either on the screen or outside of it. Another study performed by Vakil et al. (2016) demonstrates that adult individuals with ADHD also have a particular pattern of eye gaze (such as total fixation duration, and transitions between target and distractor stimuli) when performing the Stroop task.

Overall, research suggests that eye tracking in combination with the actions in the game may enhance the classification accuracy of standard tasks, but further research is necessary to validate the findings for children with NDD.

Heart Rate (HR) is defined as the number of contractions of the heart per minute, and heart rate variability (HRV) which refers to the variations between consecutive heartbeats is widely used to investigate the impact of emotion. HRV is widely used to gather implicit measurements of arousal, although a study conducted by Choi and colleagues (2017) underlines the HRV-based classification of emotion should only be used when a high level of emotion is induced. In the EMPOWER platform, measures of HR are important across all possible scenarios as it could be a measure of stress, in particular during an Emotion Regulation Task, during which children will be exposed to a high-level frustration task.

On the EMPOWER platform, the physiological response of the children is recorded using Samsung Galaxy 5 PRO smartwatches. Our main aim was to make use of “off-the-shelf” devices that can be easily procured by future stakeholders. This may ensure that the platform can be easily adapted and integrated into existing educational settings, with minimum financial and technical configuration effort.

As the recording needed to be continuous and non-intrusive, performed while the participants are interacting with the games and implementing different tasks, we have focused on the information that can be obtained without any user interaction (apart from wearing the watch on the wrist): heart rate, the time interval between two consecutive heartbeats and hand movement. The first two pieces of information are collected through photoplethysmography, an optical technique used to detect volumetric changes in blood in peripheral circulation. Based on the time interval between two consecutive heartbeats we also compute HRV (Heart Rate Variability) which assesses the variation in time intervals between successive heartbeats and is a good indicator of different emotional states. The hand movement is recorded through the conjunction of two separate sensors: an accelerometer and an oscilloscope. This information can also provide some insights on the confidence of a child's actions when interacting with the game task, while also adding valuable data on the agitation level of the child.

THE SERIOUS GAMES' CONCEPTUAL FRAMEWORK

The EMPOWER game platform has an ECOFARM concept as the common thread of the game. The different games are represented by icons that illustrate diverse activities within the theme of building an eco-farm, such as self-sufficiency, recycling management, fauna, and flora diversification. We firmly believe that enhancing social and economic resilience and sustainability requires a deeper understanding of their impacts on daily life. By incorporating these themes into the design of the EMPOWER platform, our goal is not only to raise awareness but also to inspire meaningful change. Comprising nine single-player serious games, each with a sustainable theme, the platform addresses multiple objectives for players, including the reduction of food waste and engagement in recycling tasks.

For the psychological construct behind the cognitive components of each game, the EMPOWER game platform uses the executive functions model by Miyake and colleagues (2000), one of the most cited models of executive functions. It proposes that self-regulatory and goal-directed behavior is influenced by three core executive functions: shifting attention in response to environmental change, monitoring and updating the content of working memory, and inhibition of impulses and inappropriate responses (i.e., shifting, updating, inhibition).

In this model, working memory/ updating is one of three core components of EFs. Working memory updating has been defined as the ability to dynamically modify the content of memory according to task requests. Working memory capacity and training in children with developmental disorders has received little attention from the research community, as opposed to children with typical development (Alloway et al., 2006). Moreover, from the existing previous work, working memory has been associated differently with various neurodevelopmental disorders. For the EMPOWER game platform, we chose to use the Corsi block computerized task (Macizo, Soriano & Paredes, 2016) for working memory.

Inhibitory control is operationalized as the ability to suppress stimuli that may interfere with a response (Cragg, 2016). The fundamental idea is creating agreement (via congruent stimuli [C]) or conflict (via incongruent stimuli [IC]) between values of the target feature (recycling bin color) and the distractor feature (recycling bin color/types of trash) when responding to the target feature. The standardized task that was chosen was the Stroop task setup (Parris et al., 2022).

Cognitive flexibility /shifting control refers to the ability to adaptively switch between different cognitive tasks or mental sets, adapting thoughts and behavior according to changing task demands (FitzGibbon et al., 2014). The standardized task is based on the Wisconsin Card Sorting Task (Heaton et al. 1993), which is an instrument commonly regarded as ‘‘the gold standard executive function task’’ (Ozonoff et al. 2005, p. 532). It promises to be a highly sensitive indicator of executive functions, especially such as mental flexibility, planning, and set maintenance.

Next, a sustained attention game was developed with the background psychological theory of authors Posner and Petersen (1990) - attentional system networks. The standardized task is based on the Computerized Continuous Performance Task (CCPT; by Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956). This task is designed to improve the function of sustained attention by training the cognitive system to activate and maintain attention at an optimal level for prolonged periods while simultaneously inhibiting the response system. The task involves a long series of stimuli presented (mostly) sequentially with the participant instructed to respond as fast as possible only when a pre-specified target (e.g., brown mushroom) is presented while withholding responses to other stimuli (e.g., flowers, small branches, butterflies (targets) appearing on the screen).

Finally, delayed gratification is the extent to which one can resist the temptation of an immediate reward and wait for a larger reward later. It is a self-regulatory skill (Duckworth et al., 2013) that predicts positive outcomes. The psychological theory behind the delay of gratification game was Mischel and Ebbesen's (1970) - Attention to delay of gratification. The standardized task that was chosen was the marshmallow test (Watts et al., 2018), linked with the identification of behavior children exhibit during the delay of gratification task (Lundquist et al., 2019). For example, children can stay still or fidgeting can remain silent or talk (Lundquist et al., 2019). Fidgeting has been defined as moving any body part for more than one second and includes moving of the head, swinging feet under the table, and playing with hands (Lundquist et al., 2019).

For the games aimed at the emotional components, emotion naming/recognition is defined as the ability to identify emotions in oneself and others (Baron-Cohen et al., 1985, 1986). Emotion recognition is an essential part of social development and is considered to be a basic ability that underlies more complex emotional understanding and social skills (Jones et al., 2011).

A group of components entitled “external” is considered in this task according to Pons and Harris (2005). This is the easiest level of emotional understanding according to the authors. It focuses on external aspects of emotions, including the recognition of facial expressions (Recognition), understanding of the impact of situational causes on emotions (Cause), and understanding of the impact of associated external events or reminders on emotions (Reminder). The game proposes to assess and train children’s ability to recognize basic and discrete emotions, as well as the situational causes and reminders associated with those emotions. The psychological theory behind this construct is Baron-Cohen et al. (1985, 1986) and Ekman & Friesen (1971) – Emotion Theory. The standardized Task chosen was the Test of Emotion Comprehension (TEC) (Pons, Harris, & Rosnay, 2004).

Concerning emotion intensity, the intensity of an emotion may be defined as the magnitude or strength of the experienced or expressed emotion (Frijda et al., 1992, Sonnemans & Frijda, 1994). Accordingly, differences in emotion intensity may occur due to different cognitive appraisals. Emotional intensity may be determined by concerns, appraisals, regulation, and individual differences (Sonnemans & Frijda, 1995). Moreover, steepness at onset, skewness, and number of peaks may be considered characteristic features (Ramsey & Silverman, 2005). The standardized task used for this game was the Emotions Thermometer (Burg, 2005).

Table 1 summarizes the different skills, psychological backgrounds, standardized tasks and games' main objectives, for each of the 9 games in the EMPOWER platform.

Table 1. Skills, definitions, and game development.

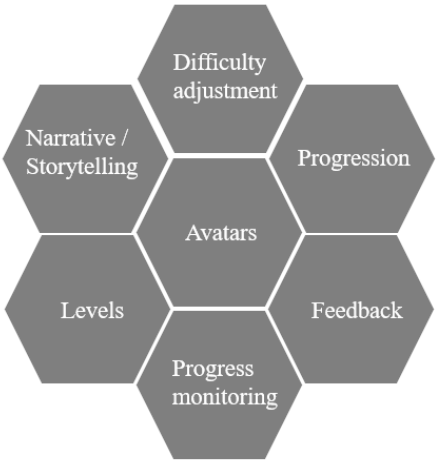
Skill	Definition	Game name	Theoretical background for game development	Game summary
Working Memory Miyake et al. (2000)	The ability to dynamically modify the content of memory according to task requests.	**WorM**	Corsi block computerized task (Macizo, Soriano & Paredes, 2016)	The task of the child is to pick up the yellow peppers as they ripe while considering the order.
Inhibitory Control Miyake et al. (2000)	The ability to suppress a well-learned prepotent response to perform a subdominant response.	**RE Stroop**	Stroop task set-up (Parris et al., 2022)	The child has to clean up the garden and recycle the trash that he/she picks up from the ground.
Sustained Attention Posner & Petersen (1990)	The ability to sustain attention on a task in the presence of internal and external distractors.	**Mushroom Hunters**	Computerized Continuous Performance Task (CCPT; based on Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956)	The child has to respond to the appearance of mushrooms (target) while maintaining focus and inhibiting responses to other appearing objects.
Cognitive Flexibility Miyake et al. (2000)	The ability to adaptively switch between different cognitive tasks or mental sets, adapting thoughts and behavior according to changing task demands.	**ReFlex**	Wisconsin Card Sorting Task (Heaton et al., 1993)	The child has to match an item on the table with the item in the crate by selecting one using a specific sorting rule.

Delay of Gratification Mischel & Ebbesen (1970)	The ability to control one's own behavior and emotions to resist temptation and not act impulsively.	**BEeHOLD**	The marshmallow test (Watts et al., 2018)	The child has to wait for the beekeeper to press the button/honey pot, to receive the greater reward.
Emotion Naming Baron-Cohen et al. (1985, 1986), Ekman & Friesen (1971)	The ability to identify emotions in oneself and others.	**EMOeggi**	Test of Emotion Comprehension (TEC) (Pons, Harris, & Rosnay, 2004)	The child has to observe customers going to the market and face different situations eliciting emotion at each market stall.
Emotion Intensity Frijda et al. (1992) -	The magnitude or strength of the experienced or expressed emotion.	**IntensEMO**	Emotions Thermometer (Burg, 2005)	The child has to help the farmer feed hens to collect their eggs, with the least waste possible.
Emotion Understanding Hadwin, Howlin, & Baron-Cohen (2015)	Understanding emotional expressions, internal feelings, and the antecedents and consequences of emotions in one's self and others.	**EMOwizz**	Test of Emotion Comprehension (TEC) (Pons, Harris, & Rosnay, 2004)	The child has to help the farmer manage the farm and visit different emotion-eliciting events.
Emotion Regulation Gross (1998)	The processes by which individuals manage their emotional experiences.	**EMOve**	Tower construction task (Anger-eliciting task) (Rohlf and Krahne, 2015)	The child has to help the farmer and choose the adaptive emotion regulation strategy depending on the situation.

THE PLATFORM'S DESIGN AND CONCEPTUAL DEVELOPMENT

For the gamification of the tasks to be included in the EMPOWER platform, several actions were performed. First, we included specific game objectives and transformed the gamified tasks into games with a clear purpose for players during gameplay. Specific features such as the impact of the overall playing experience (such as different levels and one-player system), game performance metrics (which are available for teachers and researchers), feedback for the player, as well as rewards linked to the theme of the eco-farm's sustainability were also considered. Furthermore, we included game mechanics which enabled us to capture the player's actions and their impact on the game (such as whether the game continues or not, depending on the number of mistakes made by players). Game mechanics refer to the actions the players can accomplish in the game, along with the actions' cue (i.e., a stimuli/demonstration to motivate the player to perform the action), as well as resources or other requirements needed to perform the actions in the game (such as instructions, touch screen use, mouse use, keyboard use); and rewards for performing the action successfully. We did not include penalties for performing tasks unsuccessfully due to the characteristics of the population. Drawing from the information acquired during the needs assessment phase, we have identified seven key game elements to be featured consistently across all games on the platform, as depicted in Figure 2. Additionally, a set of special features (see Table 2) has been strategically planned and designed to enhance gameplay, streamline navigation, and increase the training aspect of each game.

Figure 2. Game elements



Game mechanics are the essential building blocks of game design, upon which other design elements are included, such as procedures, rules, and objectives. Each EMPOWER game has its own mechanics, consistent with the constructs that are being tested and trained in each game. Those games will have different difficulty levels that will allow adaptation to the student's pace and skill level at various moments.

Table 2. Special features of the platform

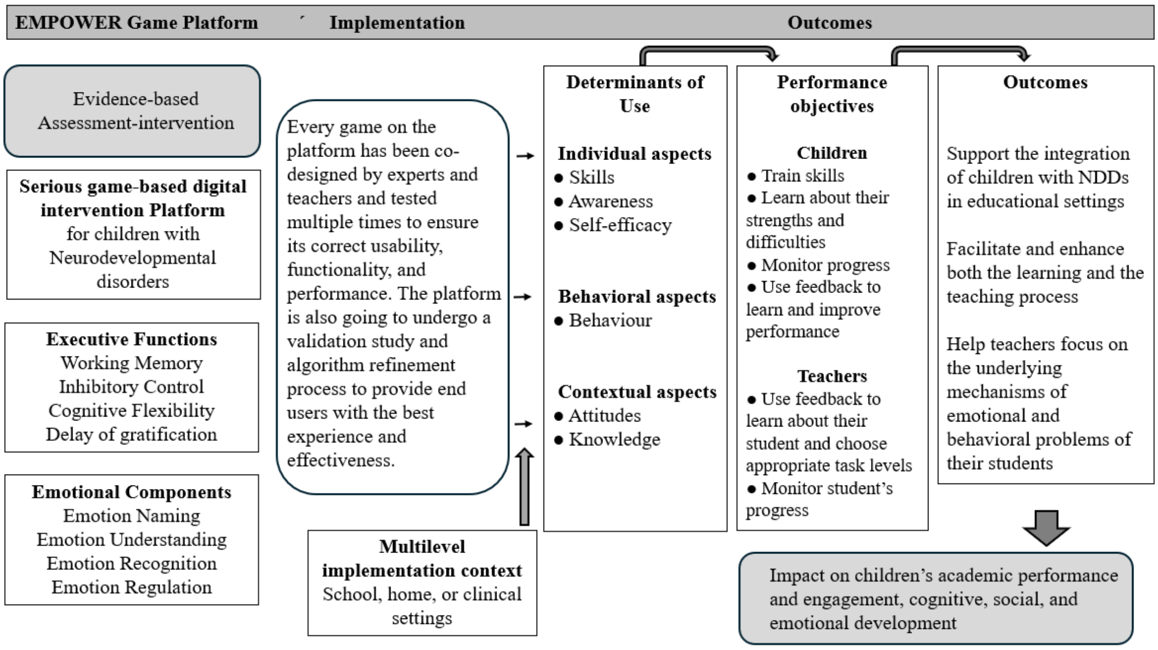
Special features	Description
Child profile	Children have a player profile within the game, which includes an avatar picture, a list of all the games/levels they completed, a progress bar for each game, and a sticker book.
Teacher's App	Teachers have access to the joint Teacher's app, where they can find student information, assessment results, and progress parameters. Teachers may also use this app to interact with the incorporated game algorithm and generate game session reports.
Sticker Book	Children will have access to the sticker book, in which the badges earned for completing levels to a specific standard will be stored. Players will be able to earn 3 badges per level (bronze, silver gold), depending on in-game performance/score (BRONZE: 0-29%, SILVER: 30%, GOLD: 60%-100%). The maximum number of badges per game in the sticker book is 10 per game (3 for each level, and an additional 10th badge awarded upon the successful completion of the three golden badges for that specific game).
Progress bar #1	This bar shows how many tasks the child still has to complete (games to play) in a game session

Progress bar #2	Within each game, each child will have a progress bar, representing the progress they have made after playing the game multiple times. The implementation of this bar will be tested in pilot study #3 and a decision will be made beforehand on whether this bar will be fixed (for all the students) or enabled or disabled depending on the student (configurable).
Stars bank	This feature will be in the main menu and it will show how many stars the child has available to use in the farm store. Players will accumulate stars after playing each game and the amount of stars gained will be dependent on performance. is.

SETTING IMPLEMENTATION OBJECTIVES

Setting implementation objectives runs throughout the whole development process, and serves the purpose of ensuring that the finished platform is feasible to use in practice, considering all aspects of how the platform and the games are going to be implemented, from deciding who the target population is, which skills to focus, what is feasible in average gameplay duration, to how to share the platform with the public. Table 3 provides an overview of the EMPOWER platform, implementation, and expected outcomes.

Table 3. An evidence-based assessment-intervention platform.



PILOT TESTING AND REFLECTION

All information from the previous steps was combined to create and design our platform. Information from Pilot test studies is being used to revise earlier decisions and test the usability, functionality, and performance of our design. Based on the feedback received in the pilot studies, the design process of the development phase will be revised and increased in complexity, as depicted in Tables 4 and 5. The platform will be tested also for the proper use of wearable devices and eye-tracker.

Table 4. Process Pilot testing and reflection

Activity	Measures	Sources	Timing	Data Analysis	Stakeholders
Adoption					
Dissemination	Survey	Schools	Prior to studies	Frequencies	Research team

		Teachers			
Agreement to participate in the studies	Signed consent form	Parents Children Teachers	Prior to studies	Frequencies	Research team
Participation in teacher training	Survey	Teacher training platform	Prior to studies	Means	Research team
Pilot Testing					
Scheduling of sessions	Interview	Teachers	During studies	NA	Development team, research team, teachers, funders, and scientific literature
Activities executed	Observation	Research team	During studies	Frequencies	
Data collected	Database	Research team	During studies	Frequencies	
Use of ET and Wearable	Database	Research team	During studies	Frequencies	
Video recordings	Observation	Research team	During studies	Frequencies	
Usability					
User evaluation	Questionnaires	Children Teachers	During and after intervention	Frequencies and comment summaries	Development team, research team, teachers, funders, and scientific literature

Table 5. Functionality and Performance Piloting

Variables	Measures	Sources	Timing	Data Analysis	Stakeholders
Academic performance	Direct measurement	Intervention group	Baseline	Pre and post-intervention *Change in scores compared*	Research team, teachers, funders, parents and children, and scientific literature
Self-regulated learning	Questionnaire Observation	Intervention group	Baseline	Pre and post-intervention *Correlational, cross-sectional design*	
Cognitive development	Questionnaire (teachers) Direct measurement	Intervention group	Baseline	Pre and post-intervention *Correlational, cross-sectional design*	
Social, and emotional development	Questionnaire (teachers) Direct measurement	Intervention group	Baseline	Pre and post-intervention *Correlational, cross-sectional design*	

RESULTS FROM PILOT STUDIES 1 AND 2

Two pilot studies were conducted to date, with the following purposes:

- Functionality- to assess whether the designed games runs according to the functional requirements.
- Usability- to assess the overall configuration, the easiness of navigation throughout the menu and the game, clarity as far as indications.

- Performance- to assess the percentage of errors, time to complete the task, minimum score and maximum score on each of the tasks, ceiling or floor effects for the difficulty of each task.

To test the effectiveness of the platform in assessing cognitive and emotional characteristics of children with NDDs in ecological settings (i.e., schools) we started conducting pilot studies with prototypes of the games to inform the future assessments we will conduct in randomized control trials. These initial trials are enabling us to investigate innovative possibilities to adapt the platform according to the children's needs and teachers' feedback, to establish key features of children with NDDs that might be important when developing the game platform. The pilots aimed to gather information regarding usability, functionality, and performance.

For the first pilots, we enrolled 23 children with neurodevelopmental disorders aged between 8 and 13 years old (M=10.78, SD=1.65, 69,6% males) from Romania and Portugal. Out of each 11 of them had moderate intellectual disorder, 2 of them with an associated diagnosis with autism spectrum disorders, 10 children with ADHD, and 2 with learning disabilities.

To test the usability we implemented instruments that assess the overall configuration, the easiness of navigation in the menu, and the clarity as far as indications, and actions, given the characteristics of children belonging to different groups inside the NDD. We used the following instruments: observation checklist, student usability questionnaire, usability questions after each game for children; usability questions at the end of the game session for children, and teacher usability questionnaire. Regarding the overall configuration of the games, 19 teachers rated the games as either "Good", 4 teachers rated it as "Excellent" and one teacher rated it as "Very poor".

The observation checklist also revealed some positive results, meaning that 91% of the children were willing to play another game and requested to play the game another time. Only 20% of the children complained that the games were too long. For the complete answers of the children please see Table 6.

Table 6. The responses provided by teachers based on the observations and questions addressed to the children involved in the pilots.

Observation checklist item	Freq.	%
O1. Navigates with ease inside the game so that he/she notices the important aspects, and does not request help to restart the game or to go back to the home menu.	20	83,3%
O2. Understands the indications without further developments or explanations.	19	79,2%
O3. The child offers the answer when he/she is supposed to, not earlier.	20	83, 3%
O4. The child presses the answer key with a delay that affects overall performance.	11	45,8%
O5. Stays involved in the game for 10 minutes/ for as long as the game lasts.	20	83, 3%
O6. Complains that it is too long.	5	20,8%
O7. Follows the indications with attention.	18	75%
O8. Finalizes the game.	14	58,3 %
O9. Gets out of task in the breaks between the tasks or until the answer screen is activated.	23	95,8%
O10. Requests for a prolongation of time.	3	12,5%
O11. Is willing to play another game.	22	91.7%

O12. Requests to be involved in playing the game one more time.	22	91,7%
O13. Understands the feedback provided.	22	91,7%
O14. Has enough time to observe the situation in the game.	21	87,5%
O15. Requests for a replay of the situation, to go back several times.	21	87,5%
O16. The child's frustration increases as he/she follows the game (touches the screen more aggressively, throws the tablet, throws things etc.).	0	0%

We also asked usability questions after gameplay. For the attention game, 19 students, 79,2% answered they had enjoyed the game a lot and one student did not enjoy the game at all. For the same game, 10 children (41%) answered that the game was easy and 11 children mentioned that the level of difficulty was so and so. 62% of the children declared that they did not need help to complete the game. For the working memory game, 17 children mentioned that they enjoyed the game a lot and only 7 answered *so and so* to the question of how much they enjoyed the game. 58% of children considered that the game had a moderate level of difficulty and 42% considered that the game was very easy. For the working memory game, 41% of the children answered that they would need more help in playing the game. For the inhibition game, 80% of the children answered that they enjoyed playing the game and 20% considered the game to be *so and so.* The inhibition game was considered to be the easiest game among the three games played (83% of the children considered it to be very easy) and only 29% of the children needed help to complete all the levels of the game.

In Table 7 you can see the answers of the children at the usability questionnaires for children. The majority of the children consider the games to be useful, and interesting and they would like to play the games more often.

Table 7. Responses provided by childrens based on the usability questionnaire.

Usability questions for children	**FREQ. OF "YES" ANSWERS**	**%**
Q1. "DID YOU DO WELL?"	24	100%
Q2. "WAS THIS GAME INTERESTING?"	23	95,8%
Q3. "WAS THIS GAME USEFUL FOR YOU?"	20	83,3%
Q4. "DO YOU FEEL GOOD ABOUT PLAYING THIS GAME?“	23	95,8%
Q5. "WOULD YOU LIKE TO PLAY THIS GAME FREQUENTLY?"	20	83,3%
Q6. "WAS IT DIFFICULT TO PLAY THIS GAME?"	5	20,8%

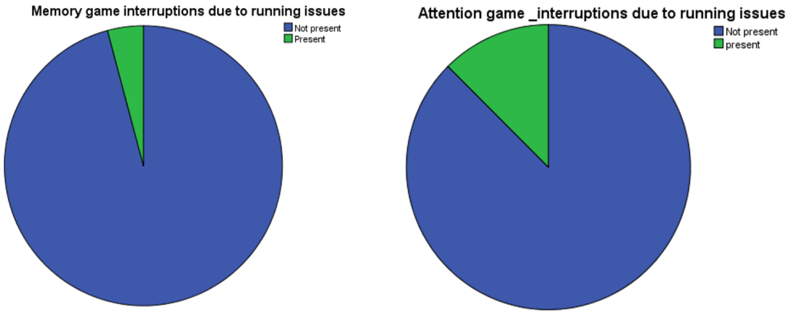
In Table 8 the questions administered to the teachers at the end of the game sessions are listed. The majority of the teachers (11 answers out of 16) considered that the games have an appropriate level of difficulty. Also, they considered the games to be intuitive for the children and easy to navigate.

Table 8. Responses provided by teachers at the end of the game sessions.

The teacher questionnaire was administered at the end of the game session	No	Yes
Q1. Does this game have an appropriate difficulty level for your students with neurodevelopmental disorders?	5	11
Q2. Do your students need help understanding the task?	4	19
Q3. Are the starting points easy enough for children to engage with the game?	-	23
Q4. Do you find the main menu intuitive, and visually informative?	2	21
Q5. Is the estimated time to complete the task adequate?	1	21
Q6. Are the instructions accessible to all your pupils?	5	18
Q7. Is the game easy to navigate?	2	20
Q8. Does the game need to be customizable?	16	7

In terms of the functionality of the games, we concluded that all three games ran according to the functional requirements. Figure 3 lists the frequency of unexpected events, such as eye-tracker or game interruptions. There was no case of interruption in the case of the inhibition game.

Figure 3. Frequency of unexpected events.



To test if the games measure what they are supposed to measure, we used a standardized instrument that measures the same constructs: *Childhood Executive Functioning Inventory (CHEXI; Thorell & Nyberg, 2008)*, which is a 24-item inventory that includes subscales for working memory, inhibition, behavioral regulation, and planning. This instrument has previously shown adequate test–retest reliability, as well as good diagnostic and cross-cultural validity (Catale et al., 2015; Thorell et al., 2010; Thorell & Nyberg, 2008). For data analysis, we used Item Response Theory/Rasch Analysis with Winstepts 3.9.

Regarding the reliability of the task of working memory, we found a good reliability indicator and a vast span of difficulty. Cronbach's alpha 0.73. Item fit: 97; Person fit: .84. The same was calculated for CHEXI and the results were similar, revealing a good reliability indicator and a vast span of difficulty.Cronbach's alpha 0.92; Item fit: 83;   Person fit: .91.

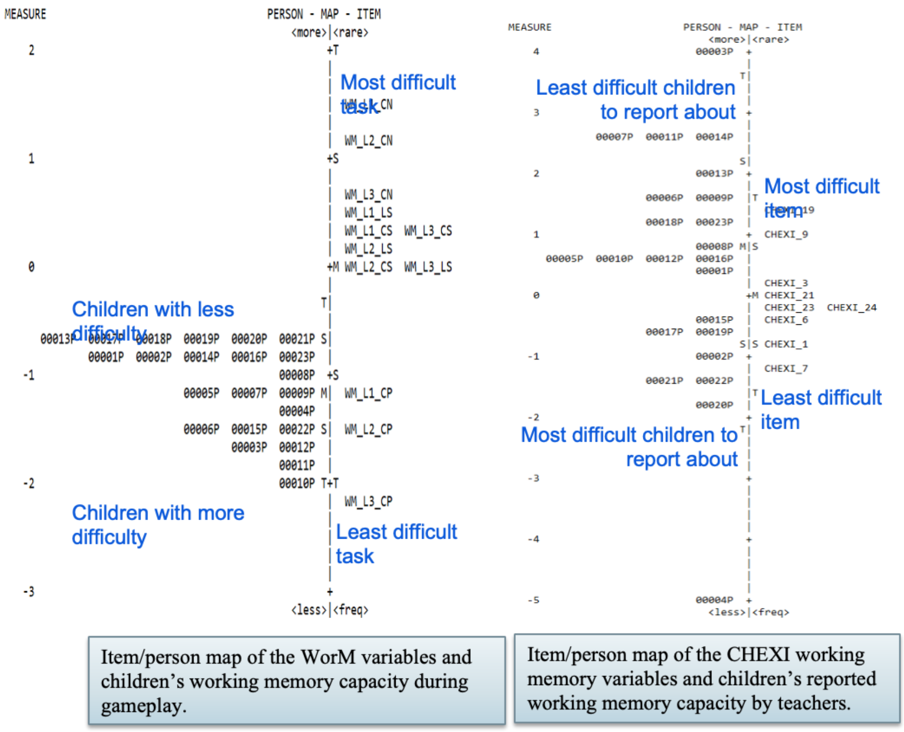


Figure 4. Item/person map of the WorM and CHEXI variables and children's working memory capacity.

#3. Conclusions

The educational platform of EMPOWER is highly innovative both in its educational objectives (Executive functions and Self-Regulation combined with augmented information about the arousal status of the student) and in the underlying technologies that enable such functionality to work efficiently.

The rising number of children with NDDs together with the life-long care and support that most people require across domains such as education, healthcare, and community services make it a major societal concern involving significant costs for children with NDDs, their families, the public health system and society (Rogge & Janssen, 2019). Although intervention and therapy appear to be the major costs, other costs also need to be considered, such as costs of lost productivity for adults with NDDs, costs of informal care, and lost productivity for family/caregivers.

We believe the EMPOWER platform will impact the quality of life of children with NDDs by creating awareness of their emotional and cognitive strengths and weaknesses, afterward through the educational platform created for children and teachers we will facilitate their access to personalized interventions and reduce their difficulties in school inclusion.

Together with children with NDDs, teachers, and parents, we aim to develop the contents of the digitally enhanced assessment and intervention platform. Together with our specialists in special education and psychology, they will establish the most suitable tasks for assessment and intervention for children with NDDs. These types of activities together with testing the effectiveness of the platform will increase the awareness of teachers toward the importance of the assessment process and cognitive and emotional strategies of children with NDDs. Furthermore, the good practice sharing and guidelines developed for the use of the platform will help us reach teachers from different schools and countries.

Through a new approach in educational and psychological assessment and intervention, from a scientific point of view, the EMPOWER platform will impact the domain of how executive function and executive functioning strategies are being assessed and trained. Teaching practices for children with NDDs can benefit from the results of our project and the results can be also extended to general practices in education for both children with special needs and typically developing children. The emphasis on emotional regulation strategies and their influence on learning outcomes and school adaptation has the potential to lead to a significant step forward in the understanding of psychopathology.

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