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MINIREVIEWS

Neurodevelopmental disorders: An innovative perspective *via* the response to intervention model

Celestino Rodríguez, Debora Areces, Trinidad García, Marisol Cueli, Paloma Gonzalez-Castro

ORCID number: Celestino Rodríguez 0000-0003-4137-4503; Debora Areces 0000-0002-9262-0623; Trinidad García 0000-0001-6012-7159; Marisol Cueli 0000-0002-4662-0534; Paloma Gonzalez-Castro 0000-0001-6685-2933.

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Celestino Rodríguez, Debora Areces, Trinidad García, Marisol Cueli, Paloma Gonzalez-Castro, Department of Psychology, University of Oviedo, Oviedo 33003, Asturias, Spain

Corresponding author: Celestino Rodríguez, PhD, Associate Professor, Department of Psychology, University of Oviedo, Room 225, Fac Psicol, Oviedo 33003, Asturias, Spain. rodriguezcelestino@uniovi.es

Abstract

Neurodevelopmental disorders are a group of conditions classified together by the most recent edition of the Diagnostic and Statistical Manual of Mental Disorders which include intellectual disability, communication disorders, autism spectrum disorder, attention-deficit/hyperactivity disorder, specific learning disorder (SLD), and motor disorders. SLD is present in many students, who exhibit significant difficulties in the acquisition of reading, written expression, and mathematics, mostly due to problems with executive functions (EF). The present study is a review of the current situation of neurodevelopmental disorders and SLD focusing on the benefits of the response to intervention model (RtI), which allows the combination of evaluation and intervention processes. It also addresses the key role of EF. The importance of adapting RtI to new possibilities such as the use of virtual reality is discussed and a theoretical framework for carrying that out is provided.

Key Words: Neurodevelopmental disorders; Specific learning disorder; Response to intervention model; Virtual reality

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Core Tip: The present study aims to look deeply into detection of and intervention for students with neurodevelopmental disorders. It includes a description of the current situation of neurodevelopmental disorders focusing on specific learning disorder and executive functions as key aspects in students with problems in reading, writing, and mathematics. The study also presents the evaluation and intervention of neurodevelopmental disorders using an approach *via* the Response to Intervention model and provides a novel avenue for implementation related to the use of virtual reality.

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INTRODUCTION

In recent years, one of the most pressing concerns at both national and international level has been achieving more effective education of students with neurodevelopmental disorders. This is evident in educational legislation and current social policies and has led education professionals to develop multiple activities in order to enhance student performance. This has meant dealing with diversity along with growing interest in the field of neurodevelopmental disorders and the students who suffer from them in one way or another[1]. Aware of this reality, the research field has produced a huge number of initiatives to help easily identify students who may be at risk of suffering from problems with their learning or their future behaviour at the earliest possible ages. At the same time, these initiatives have attempted to provide teachers with guidance and strategies so that they can provide timely instruction in pursuit of improved student academic progress and satisfactory school adjustment[2].

In this context, the present study aims to make a detailed examination of the detection of and intervention for students with neurodevelopmental disorders *via* a response to intervention model (RtI) framework. First, we describe the situation of neurodevelopmental disorders, focusing on specific learning disorders (SLD). Subsequently, we introduce the RtI model and provide an innovative approach for implementing it.

NEURODEVELOPMENTAL DISORDERS

Neurodevelopmental disorders are a group of conditions classified together by the latest edition of the Diagnostic and Statistical Manual of Mental Disorders[3] due to their common onset during childhood, high comorbidity rate of 20%-80%, and essential overlap of contributing factors across specific diagnoses[4]. This category includes intellectual disability, communication disorders, autism spectrum disorder, attention-deficit/hyperactivity disorder, SLD, and motor disorders.

SLD is a general concern in modern societies, where reading, writing, and mathematics are necessary skills for daily life[5]. However, students with SLD exhibit significant difficulties in the acquisition and use of these key skills (reading, written expression, and mathematics) despite having intact senses, normal intelligence, proper motivation, and adequate sociocultural opportunities.

Children and adolescents with SLD make up the largest group of students with educational needs in most countries[6]. According to the American Psychiatry Association[3] the prevalence of SLD in children across different languages and cultures is 5%-15% with rates of between 4 and 9% for reading deficits, and between 3 and 7% for deficits in mathematics. Bearing in mind the percentages of children exhibiting SLD, it represents one of the biggest focuses of interest in the educational community.

In recent years, research has begun to examine the common relationships and deficits in SLD (reading, writing, and mathematics) in order to better understand how they overlap rather than focusing on a single deficit, and also because findings suggest that children with a deficit in learning frequently exhibit deficits in other domains[7]. In addition, some genetic studies such as Kovas *et al*[8] have produced evidence that difficulties in reading, writing, and mathematics share genetic variations. More specifically, Kovas *et al*[8] found a genetic correlation of .67 between mathematics and reading difficulties which suggests a strong genetic overlap between them. In a meta-analytical review, Daucourt *et al*[9] indicated higher magnitude phenotypic and etiological overlaps between reading and mathematics difficulties. The consideration of common genetic risk factors linking SLD falls under the generalist genes hypothesis, which posits that the same genes underlie all cognitive abilities and disabilities both within and between academic domains[10].

Along these lines, the aetiology of SLD has been studied from general and specific domains. For example, at the specific level, low reading and writing skills have been shown to be related to problems in representation of sounds or phonological understanding, or decoding, whereas low numerical skills have been associated with a deficit in processing quantities or in the mapping of numerical symbols with mental representations of magnitude[11,12]. However, at the general level, researchers have looked at the role of attention, speed of processing, working memory, and executive functions (EF) in general.

The term EF refers to a mix of cognitive and behavioural processes such as planning, problem solving, sequencing, attention, inhibition, cognitive flexibility, and working memory, among others[13]. All of these processes allow good behavioural and emotional regulation, and have been shown to play an important role in learning in different areas such as reading, writing, and mathematics from very early ages.

While there are many different models which have attempted to give an account of the organization or structure of EF, one of the most influential models nowadays is from Miyake *et al*[14]. This model groups the different EF into 3 fundamental components: inhibitory control (also known as impulse control), cognitive flexibility (a range of attentional focus or "set shifting"), and working memory (or the ability to maintain information in mind while using it). According to this model, the different executive components would develop linked to the maturity of the individual. Miyake *et al*[14] indicated that although it is difficult to differentiate between EF at early ages, they seem to emerge separately in preschool ages (from 3-4 years old), and follow different development paths. At these ages, the children are gaining growing levels of voluntary control over attention, while at the same time being capable of keeping and representing certain information in mind, inhibiting certain responses using mental rules, and of responding and changing their focus of attention flexibly[15,16].

This developmental aspect has led to the study of EF as abilities related to school learning, generally in areas of reading, writing and mathematics[17]. Other longitudinal studies have shown the predictive value of EF measured in infancy on academic success in later educational stages[18-21]. The study by Morgan *et al*[19] with a sample of 18080 pre-school children showed how deficits in working memory and cognitive flexibility in pre-school ages posed a risk for the appearance of reading problems and difficulties with mathematics in the first year of elementary education. Similarly Clark *et al*[18] examined a group of 3-4 years old children and found a significant relationship between working memory and inhibitory control at these ages and performance in mathematics at 5 years old. As for reading, Birgisdóttir *et al*[22] found a relationship between various EF measures taken in preschool and reading understanding in first grade. These studies agree on the importance of EF as essential variables in learning, as well as the need to provide validated evaluation measures and intervention programs allowing work with students from early ages. In this context, the RtI model is one of the approaches which has begun to successfully spread in schools, specifically in early years schooling[23,24].

RTI: A POWERFUL NEW MODEL

The RtI model combines educational evaluation and intervention processes for all students within a classroom action system with 3 levels: *Level 1*- all students receive high quality, evidence-based instruction from teachers starting from an initial evaluation; *level 2*- those students who do not respond adequately in level 1 are given more explicit instruction with more frequent follow up; and *level 3*- which is a supplement to levels 1 and 2 applied to those students who need more intensive and explicit teaching to meet their learning needs[25]. Throughout the three levels, students are evaluated in order to determine their progress and needs. Because of this, RtI is recognised as an extremely valuable model, allowing evaluation and intervention to be carried out with reference to a normative group, and given the starting point, evaluating improvement against the students' own performance[26]. **Figure 1** shows an example for a design following the RtI model considering the evaluation and intervention points and levels.

Considering the potential of the RtI model, it also represents a substantive change in the conceptualisation of SLD (a broader vision of how it progresses) in lockstep with social change and changes in the guidance this emerging practice refers to. The RtI model acts as both a preventive and palliative model[27], unlike the traditional (ability-achievement discrepancy) model in which it often takes years before children with SLD are treated[28]. The RtI model offers a solution to the main problem of

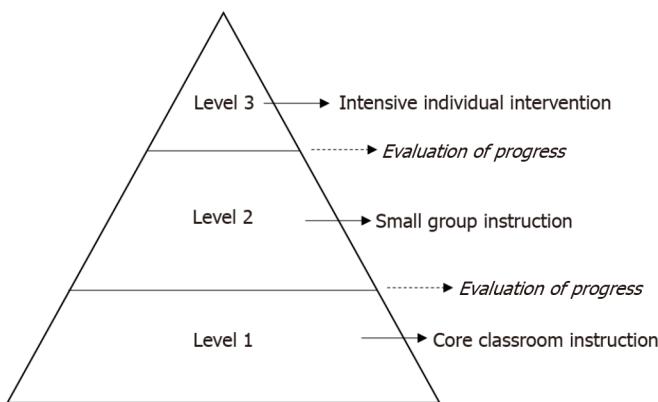


Figure 1 Example of a design based on the response to intervention model considering evaluation points and intervention levels.

previous approaches, as children are detected early and receive appropriate intervention, leading to better prognoses than those whose problems are detected later [1,29]. For instance, in Spain, like in many other countries, an approach based on the ability-achievement discrepancy model is still used to detect students with SLD. These students are usually evaluated and diagnosed from the second year of primary school onwards, when they are already exhibiting significant delays in learning and it is often too late[30]. RtI has the potential to solve numerous problems compared to the ability-achievement discrepancy model (e.g., it provides poorly performing students with individualized instruction, it allows differentiation of students who have true disabilities from students who perform poorly due to lack of proper education)[31].

There is strong empirical evidence of the benefits of using the RtI model in classes in improvement in learning results for all students. Some of those studies focused on achievement in basic academic skills such as writing[32,33], reading[34-36], and mathematics[37]. For example, de León *et al*[38] observed the benefits of implementing the RtI model for intervention with students at risk of failing math. In addition, Jiménez *et al*[39] analysed the efficacy of an intervention for reading and math within the context of the RtI model. Their results showed that at-risk children in the intervention condition appeared to benefit more than at-risk children in the control condition (who did not receive intervention following the RtI model).

Other studies have focused on promoting RtI to help highly capable students to work to the best of their potential in the classroom[40], as well as students with emotional, social and behavioural needs[41]. In all of those cases, RtI was highly successful as it overlays an approach which includes combined educational evaluation and intervention. The evaluation process covers both initial and final student evaluation, along with all the intermediate progress measures in the skills being worked on. In this way, evaluation and intervention form part of the same continuum in the classrooms. It is only in those cases where the student does not improve, after participating in high quality interventions, that a student proceeds to a more exhaustive evaluation and diagnosis by specialists[42].

In early ages the model allows differentiation between students whose performance is below expectations because of a problem in instruction and those students who really have a neurodevelopmental disorder such as SLD, thus reducing the number of false positives. RtI is considered to be an effective means of determining whether students have received adequate instruction and thereby if their academic skills have improved without needing to be seen by special education services. Furthermore, RtI helps to differentiate as early as possible those students who have not improved despite specific instruction who might not be identified by other models that are less sensitive to intervention, in other words, false negatives[27].

In short, RtI is a promising model allowing the evaluation and identification of individuals with neurodevelopmental disorders such as SLD[43] and intervention according to their levels of need in an inclusive manner.

Considering the benefits of the model, the next question is how to implement the RtI model in relation to EF.

EF AND RTI MODEL

While the RtI paradigm is fundamentally based on the most common causes of difficulties, such as poor phonological awareness or basic mathematical skills, the literature about SLD indicates a wide variety of components that contribute to its appearance and progression, from genetic to cognitive and environmental factors. The literature also shows that focusing on a single component can be a significant restriction to the effective identification and treatment of neurodevelopmental disorders[44]. For this reason many authors have advocated a combined approach which includes evaluation and intervention addressing the cognitive processing areas or EF that may underlie the learning processes in the different areas of reading, writing, and mathematics[45]. Howard *et al*[45] argued that there is sufficient research on the relationship between EF and academic skills and that the evaluation of EF would provide information that would be useful for the design of individualised instruction which is the trademark of special education.

From this combined perspective, Hale and Fiorello[46] proposed what they called the Cognitive Hypothesis Testing Model, which is based on 4 main premises: (1) Academic performance depends on a large number of complex neuropsychological and cognitive processes; (2) Children normally have unique cognitive and learning profiles, based on different strengths and weaknesses; (3) These learning profiles should be evaluated *via* direct evaluation of the associated cognitive processes as well as *via* the analysis of the response to ecologically valid treatments; and (4) Academic difficulties should be remediated or counterbalanced according to the underlying cognitive strengths and weaknesses. The authors recommended that SLD should be approached from a broad evaluation-intervention perspective, based on problem-solving, and forming part of a continual process which includes RtI and a comprehensive evaluation of cognitive processes.

Despite advances at the theoretical level in this combined perspective of RtI-cognitive (executive) processes, it has not been a well-tried approach at the empirical level to date. The few studies carried out using this approach have so far given mixed results[47]. Furthermore, the design and implementation of new evaluation and treatment models for neurodevelopmental disorders must consider advances in the development of instruments, such as using virtual reality (VR).

VR, A NEW ENVIRONMENT

Using VR improves on the evaluation and intervention systems for disorders such as SLD, offering better ecological validity which leads directly to better specificity and sensitivity than current evaluation tests (thus reducing false positives). VR gives students the perception of being in a virtual environment that is similar to their everyday surroundings, and therefore the (visual, auditory and haptic) sensations and feelings produced will be similar to those in the real classroom[48]. Ultimately, VR is an innovative alternative for performing neuropsychological evaluations of various cognitive processes involved in learning[49,50]. More specifically, in terms of the usefulness of tests in VR, previous research indicates high validity in the evaluation of memory[51], attention[52-55], and other components such as planning and impulse control[56-59]. Numerous studies have demonstrated the advantages of VR for a variety of clinical conditions and groups of healthy participants[58,60-62].

Another great advantage of including VR in current evaluation and intervention systems is that it would allow the student to progress *via* a set virtual experience that adapts to the student's own pace[63]. Various authors have stated that applications using VR have produced higher levels of motivation for learning[64,65]. These findings have even been reported in infant populations (aged between 3 and 4 years old), with not only increased motivation being observed, but also the use of this technology producing better concentration on the relevant stimuli[66].

VR has also been shown to be effective as an intervention tool. Various studies have indicated the advantages of using VR in intervention and rehabilitation programs in infant populations with intellectual disability and cerebral palsy as well as in treating learning difficulties and attentional problems[67-70]. One of the advantages indicated by the users themselves is that VR allows them to train different skills and abilities in a similar way to in the classroom without worrying about what others think of their mistakes and without embarrassment[68].

In short, VR offers the possibility of objectively analysing cognitive variables that are difficult to observe directly in the school environment, and at the same time it

allows tasks to be performed (both evaluation and intervention) with better ecological validity. Researchers often state that VR is more effective than evaluating children in laboratory settings where they are assessed individually, without classmates, under the supervision of an evaluator they do not know[70,71].

To adapt evaluation and intervention tasks to VR environments, one possibility is the innovative hardware from PICO interactive headsets which includes tools that allow the users to move, walk, crouch and do all manner of movements, without degrading the interaction with the virtual environment as there is no physical connection with any other device. With this hardware, a 3D context is created in which the participant is immersed in a natural, dynamic computer-generated environment which allows the creation of similar situations to those that happen in everyday life. In these environments, the type, amount and complexity of the presented stimuli are easily controlled, allowing the design of useful settings to gather objective indicators related to the participants' execution. To achieve this objective, the designers use various technologies such as head mounted displays, tracking systems, headphones, movement sensors, and joysticks. The possibility of controlling all of these stimuli through a multi-sensorial experience, similar to real-life surroundings, increases ecological validity while at the same time maintaining methodological standards *via* the standardisation of the tests[50]. It also has an effect on participants' motivation by giving them a more active, and interactive, role in the evaluation setting[59].

In summary, the features of this kind of hardware together with the advantages of the classic, current evaluation test, would achieve greater reliability and validity in the detection and intervention of neurodevelopmental disorders. Examples of this include the adaptation of classic tests, such as VR-Stroom[72], V-ToL (Virtual Tower of London) and V-Wcst (Virtual Wisconsin Card Sorting Test)[73], along with the creation of new contexts such as the Virtual-Store (V-Store)[73], the Virtual Action Plan-Supermarket (VAP-S)[74], the Virtual Supermarket (VMall)[57], and the well-known Virtual Classroom from Rizzo *et al*[55] and Armstrong *et al*[56].

Along with the complexity of evaluating within the RtI model, the evaluation of EF in the preschool stage is still difficult, especially considering the scarcity of EF assessment tools based on VR for this stage. One possibility for EF assessment in early years may be the adaptation of traditional measures. Examples include the Sorting Task and Animal Shifting (flexibility); the Animal Stroop, The Day and Night task, the Simon Task, and Local Global (inhibition); and Keep Track and Odd One Out (working memory)[16]. At the same time, in order to achieve more effective evaluation and intervention for SLD, VR tests must be adaptive in line with hypermedia systems.

THE NEXT STEP

The origins of educational hypermedia systems are linked to the appearance of the first intelligent tutors[75]. These tutors were student oriented and were based on the combination of study materials and the results of questionnaires, establishing an adaptive sequence for the course. As technology evolved, systems began to be developed known as Adaptive Educational Hypermedia Systems. The main objective of these systems is to adapt themselves to students based on certain characteristics such as what the student knows about the topic and the students' learning styles or learning difficulties[76]. One of the things adaptive hypermedia systems bring to e-learning is the application of an adaptation model called the user model, which is the lens through which the e-learning system organises the visualisation of content, the order of presentation, the level of difficulty, and the type of feedback, based on various parameters (number of correct answers, errors, score, etc.)[77]. However the potential of the model applied to neurodevelopmental disorders is still to be developed, from some promising initial results[78,79]. For example, Cueli *et al*[80] observed that students who worked with a hypermedia system in mathematics achieved better results in their knowledge of self-regulatory strategies. In addition, Taub and Azevedo [81] found that the use of hypermedia systems was more beneficial in the case of students with low prior knowledge.

Considering the potential of the RtI model for evaluation and intervention in EF and the benefits of VR and adaptive hypermedia systems, the future of evaluation and intervention in neurodevelopmental disorders should combine all of these main aspects. The challenge is to combine all of these new approaches (RtI, VR, and adaptive educational hypermedia systems) in order to improve EF in SLD students and incorporate this combination in schools. This will mean a new role for teachers who will have to support the process and the students at the evaluation points and in

the intervention levels that are currently part of RtI but with the new possibilities provided by VR and adaptive educational hypermedia systems.

CONCLUSION

The potential benefit of the RtI model is that, through its dynamic evaluation-intervention-evaluation processes, it is an effective system for measuring the progress and achievement of students who are lagging behind. It is also a safe method for monitoring low achievement in all students, whether due to lack of interest or motivation, boredom, or any other factor influencing insufficient learning[40]. The continued use of RtI in the classroom also aims to help children of average ability who present emotional and behavioural problems[41]. When a child is found to be exhibiting maladaptive behaviour or negative behaviours they are also evaluated and, depending on the results, evidence-based educational practices are added to reduce these behaviours and to promote positive attitudes towards the child's social and academic life.

The scientific evidence indicates that students' social and emotional competencies also play a key role in producing appropriate development and successful learning[78, 79,81]. Nevertheless, when children begin to exhibit difficulties in language and other academic areas, they run a high risk of their socio-emotional abilities deteriorating [24]. For example, children with SLD who are not dealt with early often begin to develop less involvement in school activities, by not paying sufficient attention to instructions and by interacting less with their classmates, which can lead to delays in learning and achievement and increased likelihood of developing behavioural problems. Because of that, RtI has become a model of pedagogical action that is able to meet these students' needs so that they can achieve expected academic and socio-emotional results in preschool, avoiding school failures and behavioural problems at the beginning of primary education.

In this way, RtI is an ideal opportunity for inclusively improving education for all students, both with and without neurodevelopmental disorders, through the use of innovative approaches as VR and adaptive and motivating strategies.

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