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Multi-Sensorialità fra Neuroscienze Educative e Pratiche Didattiche

Multi-Sensory Stimulation between Neuroscience and Educational Practice

A cura di
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EDIZIONI UNIVERSITARIE ROMANE

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EDUCATIONAL NEUROSCIENCE: CLINICAL AND PEDAGOGICAL SIGNIFICANCE OF NEUROFEEDBACK TRAINING AND READING PROGRAM INTERVENTION IN STUDENTS WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER

NEUROSCIENZE EDUCATIVE: SIGNIFICATO CLINICO E PEDAGOGICO DEL NEUROFEEDBACK TRAINING E DEL PROGRAMMA ABILITATIVO DELLA LETTURA IN STUDENTI CON DISTURBO DI ATTENZIONE E IPERATTIVITA'

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Abstract

The paper investigates the role of multisensoriality between educational neuroscience and didactic practices in the processes of taking care of students with attention and hyperactivity disorders. The survey presented in this article was designed and conducted by a multidisciplinary team in order to test clinical and pedagogical potential in the integration of neurofeedback training and specific reading interventions for students with attention and hyperactivity disorders. The research shows important results obtained from the synergy of interventions that revolve around the core category of multisensory and that allow to understand fundamental operational dimensions for the Quality of Life of people with attention and hyperactivity disorders.

Il contributo indaga il ruolo della multisensorialità fra neuroscienze educative e pratiche didattiche nei processi di presa in carico di studenti con disturbi di attenzione e iperattività (ADHD). L'indagine presentata in questo articolo è stata progettata e condotta da una équipe multidisciplinare al fine di sperimentare le potenzialità cliniche e pedagogiche di interventi che prevedono l'integrazione di training di neurofeedback e di programmi di lettura per studenti con disturbi di attenzione e iperattività. La ricerca mostra importanti risultati ottenuti dalla sinergia degli interventi che ruotano proprio intorno alla *core category* della multisensorialità e che permettono di comprendere dimensioni operative fondamentali per la Qualità di Vita delle persone con ADHD.

Key words

Educational Neuroscience, neurofeedback training, reading program, ADHD
Neuroscienze educative, neurofeedback training, programma abilitativo della lettura, ADHD

1. Introduction

Basing the role of health and education professionals on scientific evidence is a bridge between good science and good clinical practice. Thus, while attending a student with problems related to attention, behavior and learning, the questions that arise from each specific issue serve as a compass to guide the search for correct answers to a problem that includes etiology, diagnosis, differential diagnosis, prognosis and intervention. Generally, the search for these correct answers commences with the systematization of information on a specific subject and the integration of this information in a critical way to support the diagnostic or therapeutic decision-making process.

Since ADHD is a neurobiological disorder that compromises cognitive mechanisms related to learning, such as sustained attention, executive functions and motor inhibition deficit (Cardo, 2011; Van de Voorde, Roeyers & Wiersema, 2010), many questions regarding identification , diagnosis, differential diagnosis and intervention arise in the day-to-day of the evaluator, therapist and teacher. These are due to the difficulty in attention and inhibitory control of irrelevant stimuli, which compromises the metacognitive and metaphonological aspects involved during the literacy process (Mulas et al., 2006, Gräf et al., 2019). Likewise, the same occurs with the perceptual-visual-motor skills necessary for learning to read and write (Vasquerio-Madrid, Estévez-Dias & Dias-Maílo, 2006, Gräf et al., 2019).

Although the literature widely refers to the changes presented by ADHD that compromise the learning of reading and writing, as previously presented, there are still few studies on the use of interventions for students with ADHD that focus on the specific area of learning.

However, in the international literature there are studies that relate the proposal of phonological intervention to neurofeedback training, the results from which have been positive for students with ADHD (Duric et al., 2012; Hillard et al., 2013), also for the outcomes on self-determination processes (Del Bianco, 2019) and on the Quality of Life (Giacon, 2015).

The practice of neurofeedback is understood as direct training of brain function that enables the brain to be stimulated and begin to function more efficiently; it is a gradual learning process in which we can observe and control the brain functioning during various cognitive-linguistic activities. Thus, brain activity can be observed via electroencephalogram (EEG), to monitor the self-regulation that allows the Central Nervous System to perform better in those tasks involving attention, reading and writing (Hamadicharef et al., 2009; Breteler; Arns; Peters & Verhoeven, 2010; Nazari; Mosanezhad; Hashemi & Jahan, 2012; Cerqueira; Arns; Buitrago; Gutiérrez & Freund, 2012).

In view of the above, the research presented in this paper is based on the hypothesis that students with ADHD undergoing phonological and reading intervention associated with neurofeedback may present greater clinical significance than students with ADHD undergoing

only phonological and reading intervention, furthermore it is possible to determine the efficacy or otherwise of using neurofeedback training.

2. Material and Methods

This research was approved by the Research Ethics Committee of the Faculty of Philosophy and Sciences – FFC/UNESP - Marília - São Paulo - Brazil, under protocol number 0770/2013.

This study aimed to verify the clinical significance of neurofeedback training, neurofeedback associated to the phonological and reading program intervention in students with attention deficit hyperactivity disorder.

2.1 Participants

Twenty elementary school students with confirmed diagnosis of ADHD, of both genders, aged between 7 and 10 years old, attending the 2nd to 5th year of elementary education at a Municipal Public School in the city of Marília-SP, participated in this study and these were divided at random into five groups each with four students (Table 1):

Group I (GI): students who underwent neurofeedback training, without auditory and visual stimulation (placebo effect).

Group II (GII): students who underwent phonological and reading intervention.

Group III (GIII): students who underwent neurofeedback training.

Group IV (GIV): students who underwent phonological intervention associated with neurofeedback training.

Group V (GV): students who did not undergo the training program.

Table 1. Distribution of the number of students per group according to gender

Group	Male	Female
GI	4	-
GII	3	1
GIII	4	-
GIV	3	1
GV	3	1

2.2 Inclusion and exclusion criteria for participants

For the selection and distribution of students into the groups of this study, it was necessary for the students to be referred with complaints regarding attention problems for an interdisciplinary assessment consisting of a neurologist, speech therapist, neuropsychologist and educator at the Laboratory for Investigation of Learning Disorders (LIDA) of the Department of Speech Therapy, Faculty of Philosophy and Sciences, São Paulo State University "Júlio de Mesquita Filho – FFC/ UNESP – Marília – SP in order to confirm the diagnosis of ADHD.

2.3 Methodological Procedures

After distributing the students into the five groups of this study, all students were submitted to application of the Collective and Individual Linguistic Cognitive Performance Protocol (Capellini; Silva & Smythe, 2012) in a pre- and post-testing situation for application of the intervention programs of this study, as described below.

In the collective version, there are the following tests:

- **Writing the alphabet in sequence**: The students were instructed to write the alphabet in sequence. The letters K, W and Y were included following orthographic reform of the Portuguese language.
- **Copy shapes**: The students were instructed to copy four different geometric shapes, which must be reproduced within a given space;
- **Mathematical calculati**on: The students were instructed to solve 20 simple arithmetic operations, comprising addition, subtraction, multiplication and division;
- **Dictation of words and pseudowords**: Students were instructed to write 30 real words and 10 pseudowords. The words were presented verbally by the examiner and the child performed the writing only after hearing the word, in relation to the pseudowords the child was guided to write as he/she understood. Each word and pseudoword was repeated no more than twice;
- **Repetition of numbers in random order**: Students were instructed to copy 10 numbers, each containing from two to six digits.

In the individual version, there are the following tests:
- **Word reading**: The students were instructed to read aloud 70 words, in which the total time needed for reading was marked, using the stopwatch, and marking the number of words read correctly in 1 (one) minute.
- **Non-word reading**: The students were instructed to read aloud 10 non-words, in which the total time needed for reading was measured with a stopwatch and marking the number of non-words read correctly.
- **Alliteration**: The students were instructed to carry out the identification of pairs of words that alliterate, they were instructed by the examiner to listen to a sequence of three words and then choose two of them that present alliteration.
- **Rhyme**: The students were instructed to carry out the identification of rhyming pairs, having been instructed to listen to a sequence of three words and then chose two of them that rhyme.
- **Repetition of words**: Composed of eight sequences of words, in which the student was instructed to reproduce the words in the same sequence in which they were spoken verbally.
- **Repetition of non-words**: Composed of seven sequences of non-words, in which the child was instructed, by the examiner, to reproduce the non-words in the same sequence in which they were spoken aloud, also by the examiner.
- **Rhythm**: Comprising 12 rhythmic sequences, in which the student reproduced the rhythmic beats as presented to him or her. The dashes correspond to the beats and each slash corresponds to the pauses.
- **Syllabic segmentation**: The students were instructed to segment 20 words, comprising 4 monosyllables, 4 disyllables, 4 trisyllables and 4 polysyllables.
- **Quick naming of figures**: Composed of a table with four different pictures that were repeated in random order, in which the student was instructed to quickly name the pictures presented, while the researcher marked the time with a stopwatch.
- **Fast digit naming**: Composed of a table with digits from one to nine, which were repeated in random order, in which the student was instructed to quickly name the digits presented, while the researcher marked the time using a stopwatch.
- **Visual memory for shapes**: Composed of five pairs of pictures with different shapes, in which the child was guided, by the examiner, to perform the visual memorization of the pictures presented. A set of five pictures remained with the examiner and another set with the child, the examiner sequenced the pictures (according to the model sheet of the Protocol), then allowed the child to observe the sequence for 1 (one) minute and after covered the sample and asked the students to organize their figures. The student was instructed to pay attention to the sequence offered and the positioning of each figure (attention to the details that make up the figures). This subtest consisted of eight sequences ranging from two to five figures.

- Discrimination of sounds: The students were instructed to discriminate between sounds, such that they were instructed by the researcher to listen to pairs of words and then decide whether the words were the same or different.
- Repetition of numbers in reverse order: Composed of ten sequences of numbers, in which the student was instructed to reproduce the sequence pronounced, also by the researcher, in the opposite order to the one presented, i.e. backwards.

After performing the pre-test, the students were submitted to the following intervention programs, according to their group:
a. Training with neurofeedback: neurofeedback training was carried out in 18 sessions, individually lasting 15 minutes. In which a game (Pacman) was presented to the student on the computer and he or she performed the activities proposed in the game. Before the start of the game, electrodes were placed on the student's scalp in the frontal, parietal and temporal regions and the signals were captured by the neurofeedback device, Neurobit Optima 4 unit, and transmitted to the researcher's computer, as described by Breteler, Arns, Peters & Verhoeven (2010).
b. Neurofeedback training associated to the phonological intervention program (Silva, Capellini, 2011).

The neurofeedback training was carried out in 18 sessions, and the training with neurofeedback was introduced in the 6th session of the phonological intervention program associated to the reading. Neurofeedback training was introduced at the end of the session where a game (Pacman) was presented to the student on a computer and he or she performed the activities proposed in the game.

The phonological and reading intervention program was carried out in 18 cumulative and individual sessions, lasting 50 minutes. This program consists of ten tasks, namely: alphabet recognition, word identification within a sentence, identification and manipulation of syllables in the word, rhyme, phonemic synthesis, phoneme identification and discrimination, phoneme segmentation, phoneme subtraction, phoneme substitution and phoneme transposition.

The reading training was carried out in 18 sessions, with the reading of children's storybooks, at each session a new book is introduced, and the level of reading complexity was only modified when the student presented 94% accuracy (one error or less in every 20 words) while reading. Thus, the change in the degree of reading from one book to another occurs after two reading sessions of books of the same level of difficulty with 94% correct answers in the reading of words, as proposed by Clay (1985). The collection of sequential reading records was performed using a protocol designed for this purpose, which consists of a record of information regarding the number of words in each story, number of words read per minute, percentage of correct answers and typology of errors. The reading material used was books from the *Estrelinha* Collection (1984) with reading difficulty levels I, II and III.

In the groups of students who underwent phonological intervention associated to neurofeedback, to neurofeedback training or to the placebo effect, we used a neurofeedback Neurobit Optima 4 unit, with electrodes placed on the scalp of the students in the frontal, parietal and temporal regions for the signals to be captured by the device and transmitted to the researcher's computer.

The placebo effect was conducted in the same way as neurofeedback training, with the difference that in this training there were no auditory and visual stimuli.

2.4. Analysis of Results

Statistical analysis was performed using the JT Method (Jacobson & Truax, 1991) which is based on two central concepts: clinical significance and the Reliable Change Index (RCI).

The JT Method is a single case method, used in order to verify possible differences in clinical significance between the five groups in this study.

3. Results, Discussion and Conclusion

In Table 1, it was possible to observe that student 1 presented positive reliable change (RC+) in non-word repetition, rhythm and visual memory, while student 4 presented RC+ in reading and word repetition. This showed that two students from GI presented improvement in skills involving analysis and auditory and visual perception even when submitted to placebo. This finding reveals that there was a response to the use of neurofeedback even without stimulus, which demonstrates that such an instrument may not be indicated as an intervention procedure. Hence, further studies are required involving placebo in a larger population sample to verify the relevance of using this training procedure in students with ADHD.

Table 1. Positive Reliable Change in the performance of students in GI for tests of the Assessment Protocol of Cognitive-Linguistic Skills in pre- and post-testing situation

Students	WLA	CS	MC	D	RRN	R	RNW	A	R	WR	NWR	RT	S	QNF	FDN	VM	SD	RNR
1	-	-	-	-	-	-	-	-	-		RC+	RC+	-	-	-	RC+	-	
2	-	-	-	-	-	-	-	-	-		-	-	-	-	-		-	
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4		-	-	-	-	RC+	-	-	-	RC+	-	-	-	-	-	-	-	

Key: RC+= Positive Reliable Change; WA= Writing Letters of the Alphabet; CS= Copy Shapes; MC= Mathematical Calculation; D= Dictation; RRN= Repetition of Random Numbers; R= Reading; RNW= Reading Non-Words; A= Alliteration; R= Rhyme; WR= Word Repetition; NWR= Non-Word Repetition; RT= Rhythm; S= Syllabic Segmentation; QNF= Quick Naming of Figures; FDN= Fast Digit Naming; VM= Visual Memory; SD= Sound Discrimination; RNR= Repetition of Numbers in Reverse order

In Table 2, it was possible to observe RC+ in students 1, 2 and 4. Student 1 presented RC+ in word repetition and visual memory; student 2 presented RC+ in writing under dictation, reading, alliteration and visual memory and student 4 presented RC+ in writing alphabet letters, repetition of non-words and visual memory.

These results showed that three of the four GII students responded to the phonological intervention associated with reading, indicating that this intervention program modifies the behavior of cognitive-linguistic skills necessary for reading, such as phonological working memory, knowledge of alphabets, visual memory for word recognition; skills that are necessary for decoding and word recognition during reading.

Table 2. Positive Reliable Change in the performance of students in GII for tests of the Assessment Protocol of Cognitive-Linguistic Skills in pre- and post-testing situation

Students	WLA	CS	MC	D	RRN	R	RNW	A	R	WR	NWR	RT	S	QNF	FDN	VM	SD	RNR
1	-	-	-	-	-	-	-	-	-	**RC+**	-	-	-	-	-	**RC+**	-	-
2	-	-	-	**RC+**	-	**RC+**	-	**RC+**	-	-	-	-	-	-	-	**RC+**	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	**RC+**	-	-	-	-	-	-	-	-	-	**RC+**	-	-	-	-	**RC+**	-	-

Key: RC+= Positive Reliable Change; WA= Writing Letters of the Alphabet; CS= Copy Shapes; MC= Mathematical Calculation; D= Dictation; RRN= Repetition of Random Numbers; R= Reading; RNW= Reading Non-Words; A= Alliteration; R= Rhyme; WR= Word Repetition; NWR= Non-Word Repetition; RT= Rhythm; S= Syllabic Segmentation; QNF= Quick Naming of Figures; FDN= Fast Digit Naming; VM= Visual Memory; SD= Sound Discrimination; RNR= Repetition of Numbers in Reverse order

In Table 3, it was possible to observe RC+ in student 1 for word repetition, non-word repetition, visual memory and repetition of numbers in reverse order, student 2 presented RC+ word repetition, visual memory and repetition of numbers in reverse order and student 4 presented RC+ in writing the letters of the alphabet and repetition of numbers in reverse order.

These findings showed that three of the four GIII students responded to training with neurofeedback, indicating that this type of intervention can help in the development of cognitive-linguistic skills.

Table 3. Positive Reliable Change in the performance of students in GIII for tests of the Assessment Protocol of Cognitive-Linguistic Skills in pre- and post-testing situation

Students	WLA	CS	MC	D	RRN	R	RNW	A	R	WR	NWR	RT	S	QNF	FDN	VM	SD	RNR
1	-	-	-	-	-	-	-	-	-	**RC+**	**RC+**	-	-	-	-	**RC+**	-	**RC+**
2	-	-	-	-	-	-	-	-	-	**RC+**	-	-	-	-	-	**RC+**	-	**RC+**
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	**RC+**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**RC+**

Key: RC+= Positive Reliable Change; WA= Writing Letters of the Alphabet; CS= Copy Shapes; MC= Mathematical Calculation; D= Dictation; RRN= Repetition of Random Numbers; R= Reading; RNW= Reading Non-Words; A= Alliteration; R= Rhyme; WR= Word Repetition; NWR= Non-Word Repetition; RT= Rhythm; S= Syllabic Segmentation; QNF= Quick Naming of Figures; FDN= Fast Digit Naming; VM= Visual Memory; SD= Sound Discrimination; RNR= Repetition of Numbers in Reverse order

In Table 4, it was possible to observe a RC+ in all students from GIV. Student 1 presented RC+ for mathematical calculation, repetition of numbers and visual memory; student 2 presented RC+ for repetition of words and non-words and visual memory; student 3 presented RC+ for writing under dictation, repetition of words and non-words and visual memory, and student 4 presented RC+ for repetition of words.

The GIV findings revealed that all students responded to the intervention when with phonological and reading intervention was associated to neurofeedback training, showing that

there was an improvement in the skills necessary for decoding words during the reading process.

Table 4. Positive Reliable Change in the performance of students in GIV for tests of the Assessment Protocol of Cognitive-Linguistic Skills in pre- and post-testing situation

Students	WLA	CS	MC	D	RRN	R	RNW	A	R	WR	NWR	RT	S	QNF	FDN	VM	SD	RNR
1	-	-	**RC+**	-	**RC+**	-	-	-	-	-	-	-	-	-	-	**MNP**	-	-
2	-	-	-	-	-	-	-	-	-	**RC+**	**RC+**	-	-	-	-	**RC+**	-	-
3	-	-	-	**MNC**	-	-	-	-	-	**RC+**	**RC+**	-	-	-	-	**RC+**	-	-
4	-	-	-	-	-	-	-	-	-	**RC+**	-	-	-	-	-	-	-	

Key: RC+= Positive Reliable Change; WA= Writing Letters of the Alphabet; CS= Copy Shapes; MC= Mathematical Calculation; D= Dictation; RRN= Repetition of Random Numbers; R= Reading; RNW= Reading Non-Words; A= Alliteration; R= Rhyme; WR= Word Repetition; NWR= Non-Word Repetition; RT= Rhythm; S= Syllabic Segmentation; QNF= Quick Naming of Figures; FDN= Fast Digit Naming; VM= Visual Memory; SD= Sound Discrimination; RNR= Repetition of Numbers in Reverse order

In Table 5, it was possible to verify positive reliable change (RC+) in student 2 for word repetition and student 4 presented RC+ for syllabic segmentation, indicating that the activities in the classroom favored the development of syllabic analysis and phonological working memory in two students from GI, which was the control group of this study.

Table 5. Positive Reliable Change in the performance of students in GV for tests of the Assessment Protocol of Cognitive-Linguistic Skills in pre- and post-testing situation

Students	WLA	CS	MC	D	RRN	R	RNW	A	R	WR	NWR	RT	S	QNF	FDN	VM	SD	RNR
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	**RC+**	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-	**RC+**	-	-	-	-	

Key: RC+= Positive Reliable Change; WA= Writing Letters of the Alphabet; CS= Copy Shapes; MC= Mathematical Calculation; D= Dictation; RRN= Repetition of Random Numbers; R= Reading; RNW= Reading Non-Words; A= Alliteration; R= Rhyme; WR= Word Repetition; NWR= Non-Word Repetition; RT= Rhythm; S= Syllabic Segmentation; QNF= Quick Naming of Figures; FDN= Fast Digit Naming; VM= Visual Memory; SD= Sound Discrimination; RNR= Repetition of Numbers in Reverse order

The results of this study revealed that, with the exception of the GIV students, all other groups, including GI submitted to the placebo effect, performed better in a post-testing situation when compared to pre-testing in skills involving phonological working memory, such as repetition of non-words, knowledge of alphabet letters and visual memory, which are necessary for word recognition.

In the literature, we found studies that reported that while reading, students with ADHD have difficulties related to decoding, such as reading errors due to flaws in grapheme-phoneme correspondence, flaws in sequencing of graphemes in reading, as well as errors due to omission and substitution of graphemes and /or words. These difficulties are due to problems with

attention and the use of working memory to manage the information necessary for the phonological processing of items and essential for the formation of correct orthographic representations of words (Barkley et al, 2014; Miranda & Soriano, 2011; Brock & Knapp, 1996)

Therefore, all the programs used in this study, including the placebo effect, enabled students with ADHD to improve decoding and reading fluency and, consequently, improved word recognition.

Phonological working memory plays a crucial role in many forms of complex cognition such as learning, reasoning and language comprehension. Therefore, as students with ADHD have a deficit in these skills, they tend to perform poorly in tests that involve phonological working memory, such as the non-word repetition test (Granzotti; Furlan; Domenis & Fukuda, 2013).

Changes in the perception and organization of acoustic stimuli according to DuPaul (2011) can be attributed not to a primary deficit, but to the hypothesis that children with ADHD present these changes as a phenomenon secondary to inattention. Therefore, the deficit in the sequential and temporal organization of phonemes and the difficulty to retain in memory words with longer segments can be explained by the deficit in phonological working memory (Miranda & Soriano, 2011; Cunha, Silva, Lourencetti & Padula, 2013).

Therefore, the data described in this study cannot be considered conclusive, since the use of neurofeedback was not a differential for the improvement of cognitive-linguistic skills in students with ADHD, since the group of students with ADHD submitted to the placebo effect also presented a response to the intervention, according Enriquez-Geppert et al., (2019).

However, among the groups with the highest number of cognitive-linguistic skills with RC+, we highlight GIV, where we observed an improvement of all students with ADHD who underwent phonological and reading intervention associated with neurofeedback training, possibly indicating that the association between these intervention programs can generate better neurocognitive gains for the development of skills necessary for the development of reading.

Future research should be conducted in an attempt to understand whether the clinical significance of the intervention programs applied in this study is maintained and, therefore, to assess the implication of the placebo effect in the findings of the intervention with Neurofeedback.

Therefore, the hypothesis of this research was not confirmed due to the interference of the placebo effect in the analysis of the clinical significance of our results. It is only possible to consider that when Neurofeedback was associated with the phonological and reading remediation program, the occurrence of the clinical significance number was higher when compared to the other interventions.

The results of this study allowed us to conclude that with the exception of the students in GIV, all other groups, including GI submitted to the placebo effect, performed better in a post-testing situation when compared to pre-testing in those skills that involve phonological working memory, such as the repetition of non-words, in addition to knowledge of alphabet letters, visual memory, and skills necessary for word recognition while reading.

However, the data from this study cannot be considered conclusive, since the use of neurofeedback was not a variable with clinical significance between the groups, given that students with ADHD undergoing the placebo effect also presented a reliable positive change for improvement in cognitive-linguistic skills. As we have shown in previous studies (Giaconi, Capellini, 2015; Giaconi, Del Bianco, 2019), these results are significant for understanding and planning new educational paths for inclusion.

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