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Inhibitory Control of Attention, Difference *Versus* Developmental Theory: Findings in Mild Intellectual Disability and ADHD

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Abstract

We investigate the relationship between inhibition and cognition in developmental age adding values for the understanding of EFs. The aim of this study was to examine the development of EFs by comparing children of different clinical populations: children with a Mild Intellectual Disability (MID) with atypical cognitive development and children with ADHD inattentive subtype with impaired inhibition development. Results obtained suggest that only a subgroup of MID has an inhibition deficit (not overlapping with ADHD). So, the data seemed to support the hypothesis that EFs, even when impaired, could follow different pathways of development, partially independent from intelligence. Moreover, our findings seemed to fit with the hypothesis that the diagnosis of intellectual disability include different neuropsychological phenotypes.

Keywords: Mild Intellectual disability; ADHD; Inhibitory control; Attention; Development

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Introduction

Most international classification systems [1] describe Mild Intellectual Disability (MID) as a neurodevelopmental disorder involving general mental abilities with a strong impact on adaptive functions. Thus, intellectual disability must be assessed by considering adaptive behaviour and intellectual functioning.

According to ICD-10, it is possible to consider that mild intellectual disability (MID) corresponds with an approximate IQ range of 50 to 69 measured by a psychometric instrument. However, according to the DSM-5 [1], intellectual disabilities involves a score below 65-75 (i.e. 70 ± 5), but the assessment of adaptive functioning is necessary to define a MID diagnosis: at least one domain of adaptive functioning—conceptual, social or practical—must be impaired. These three different areas of competence predict an individual's ability to deal with daily life tasks. The conceptual domain includes language, knowledge, learning and memory; the social area refers to empathy, social judgment, communication skills and interpersonal relationships; and the practical domain includes self-care skills, money management, work organization and leisure.

Two different theories about cognitive development in individuals with intellectual disabilities are currently being discussed. The first theory, the developmental theory, argues that these children follow the same evolutionary path as developmentally typical children, but they proceed more slowly and reach an early stop; the second theory, the difference theory, argues that the cognitive development of people with MID shows specific deficits in cognitive functions and proceeds atypically when compared to the normative population [2]. It is not clear which of the two theories better fits with the cognitive development of individuals with intellectual disabilities, but it is reasonable to assume that children with MID can show both deficits (difference theory) and delays in cognitive development (developmental theory) [3].

Neuropsychological studies seem to show that people with MID have difficulty with inhibition, working memory and cognitive flexibility [4,5], integration of new information, social information processing [6] and theory of mind [7,8].

Therefore, executive functions seem to be particularly involved in this disease. In the literature, executive functions are often described as a family of top-down mental processes needed when it is necessary to concentrate and pay attention, when going on automatic or relying on instinct would be ill-advised, insufficient or impossible [9-11].

Despite an increase in studies investigating this area, a shared

definition of executive functions has yet to be established, and the cognitive functions belonging to these control processes have yet to be identified. Nevertheless, there is general agreement in the literature about three basic core EFs: inhibition, working memory and cognitive flexibility [12,13].

Inhibitory control involves the ability to control one's attention, behaviour, thoughts and/or emotions to override a strong internal predisposition or external lure to do instead what is more appropriate or needed [14].

Inhibition is divided into three areas, depending on the type of control skills: attentive, behavioural and cognitive inhibition. Inhibitory control of attention (interference control at the perception level) enables us to selectively attend, focusing on what we choose and suppressing attention to other stimuli [14]. So, investigating the development of this specific process could be very important to better understand the development of executive functions in MID. Moreover, the assessment instruments created to evaluate attentive control, compared with tests for other inhibitory (behavioural and cognitive) domains, does not require complex reasoning, rules and motor skills to succeed. Thus, in this research, we choose to deeply investigate this particular skill (i.e. inhibitory control of attention) to allow us to assess it with a test fit for MID.

Certain studies investigate the possibility to sort this population into different clinical groups based on their neuropsychological profiles [3,15]. Executive functions seem to be particularly related to the development of intelligence and fluid reasoning in the typical population [16-19], so they have been extensively investigated in MID, but only a few studies have specifically investigated the development of inhibitory control in this clinical population.

Very often, the difficulty of children with MID to maintain sustained attention and inhibit distractors is considered impaired by caregivers and teachers, but this issue is often attributed to an intellectual disability; this view seems to be more consistent with developmental theory. Thus, the aim of the present study is to investigate the inhibitory control of attention in a group of students with MID. We try to better understand whether it is possible to find two subgroups in the MID population based on attentive inhibitory development (i.e. one group with attentive inhibitory impairment and another group without this issue). We think that a deep study of this topic could be useful to discriminate if this particular cognitive domain fits better with the difference or the developmental theory. Moreover, finding specific attention deficits in a subgroup of individuals with MID could have advantageous implications in the assessment and treatment of these children.

Participants

We assess 10 children with mild intellectual disability (MID) and five children with attention deficit and hyperactivity disorder inattentive subtype (ADHD-I). The little sample size is due to the establishment of restrictive inclusion and exclusion criteria in order to reduce the possibility of covariates' interference. Therefore, the present study should be considered a preliminary research on the application of CPT-II in mild intellectual disability.

The MID group has a cognitive developmental age below their chronological age (i.e. min: 4.11, max: 7; mean: 6.22; SD: 0.86). The psychometric test WISC-IV [20] is used to assess intellective quotient (IQ; min: 52, max: 69, mean: 64.8, SD: 5.85). The Children Global Assessment Scale C-GAS [21] is used to evaluate the adaptive behavior in addition to Vineland Adaptive Behavior Scales [22]. The IQ scores are in accordance with cognitively delayed-mild children sample and the comparison with normal sample, as expected, point out difficulties to achieve age appropriate standard in adaptive behavior (Age equivalent scores - norm sample: min: 4.06, max: 8.06, mean: 6.54, SD: 1.58).

Inclusion criteria for MID are: IQ between 50 and 69, C-GAS below 60, cognitive developmental age between 4.6 and 7 years of age [23].

All the subjects of the ADHD-I group performed a multidisciplinary diagnostic evaluation with neuropsychological tests and clinical interviews, collecting behavioral data from multiple sources according to the national and international guidelines for the diagnosis of ADHD [24,25]. Inclusion criteria for ADHD-I, according to DSM-5 are: IQ above 85, C-GAS above 70, clinical interview K-SADS-PL [26] positive for Attention Deficit and Hyperactivity Disorder (Inattentive subtype).

The inclusion criteria for both groups are: italian monolingual mother-tongue, chronological age between 7 and 11 years of age.

The exclusion criteria for both groups are: cerebral palsy, severe language and psychopathological disorders, sequential or simultaneous bilingualism.

All participants' caregivers signed informed consent prior to the present study.

Materials and Procedure

The executive functions' assessment is made by Conners' Continuous Performance Test-II (CPT-II) [27], and the behaviour evaluation is made via parents' report: Child Behavior Checklist for Age 6–18 (CBCL 6-18) [28].

Conners' Continuous Performance Test-II (CPT-II) is a computerized assessment tool that aims to evaluate sustained attention, or vigilance [27]. The task consists of pressing the space bar every time a letter appears on the PC screen, except for 'X'. The letters, which are shown one at a time, remain on the screen for 250 minutes. The interval between two stimuli (ISI) lasts 1, 2 or 4 seconds, depending on the subblock presented. Every subblock consists of 20 trials, and the order of the subblock is randomized. The time needed to administer the test is 14 minutes, and it can be used with children as young as 6 years of age (the test does not have any reading requirement).

The measures of the CPT-II are converted into T-scores and percentiles; in the present study, we choose to base the measures on conversion to T-scores. High scores (i.e. 60 or above) for all measures indicate a potential clinical problem.

The measures calculated by CPT-II software are shown in **Table 1**.

The validity of the CPT-II administration depends on several factors,

in particular, a high percentage of omission or perseveration errors (e.g. T-score>100) indicate an invalid protocol. All of the protocols administrated to the experimental group are valid.

Conners et al. [27] consider a clinical assessment with a confidence index above 50% or two or more T-scores above 60. In this research, we used the second method (i.e. two or more T-scores >60) to identify clinical patterns since previous studies demonstrated that using only the confidence index was not suitable for identifying clinical respondents when the test is administered to children with neurodevelopmental diseases [29]. Therefore, we divided the children with MID into two subgroups based on their profiles obtained from the CPT-II (i.e. clinical vs. non- clinical patterns). Then, the same tests (WISC-IV, CPT-II & CBCL) were administered to an ADHD-I group of children equalized by chronological age with an MID group.

Results

Data were analyzed with non-parametric statistics (Mann-Whitney U-test) because of the sample's size (MID+ N=5; MID N=5; ADHD-I N=5). The differences between the MID and MID+ groups **(Figure 1)** are quite significant in the following measures: omission (U=1; z= -2.30; p=0. 012). hit RT (Std Error) (U=2.5; z= -2.09; p=0.018) and suggest for the measure variability (U=4; z= -1.67; p=0.047) an interesting trend, despite not statistically significant. Instead, the comparison between MID and MID+ on the measure hit RT (U=0.5; z= -2.40; p=0.008) obtain good statistically significant results.

Overall the MID group had better performances (vs. MID+), which fits with the performances of a typical population paired by chronological age.

Moreover, MID and MID+ are quite different even in several psychopathological clusters of CBCL 6-18 **(Figure 2)**: thought problem (U=2; z=2.09; p=0.018); attention problem (U=4; z= -1.67; p=0.047) and ADHD (DSM-IV oriented) (U=4; z= -1.67; p=0.047). The ADHD-I group also had a lower score than the MID on the CPT-II **(Figure 1)**: omission (U=0; z= -2.51; p=0.006); hit RT (U=2; z= -2.19; p=0.014); hit RT (Std Error) (U=0; z= -2.51; p=0.006); variability (U=0; z= -2.51; p=0.006) and in CBCL 6-18 **(Figure 2)**: attention problem (U=4.5; z= -1.57; p=0.058); ADHD (DSM-IV oriented) (U=3.5; z= -1.78; p=0.037). However, there are no differences between the groups (ADHD-I vs. MID) on the thought problem scale (CBCL 6-18), and the only indicator in which the ADHD-I group obtained better scores was on social problem (U=3.5; z= -1.78; p=0. 037).

Table 1 Measures calculated by CPT-II software [27].

Validity of the Administration	
Response style (Beta Statistic)	Evaluation of the speed/accuracy trade-off Higher values of beta (T score >60) reflect individuals who want to make sure they are correct when they give a response. Lower values of beta (T score <40) reflect individuals who want to make sure they respond to most all targets (less concerned about mistakenly responding to a non-target).
Omissions and Perseverations	High percentage of omissions of perseverations errors may indicate an invalid protocol (e.g. T- score >100). (e.g. premature cessation of the test, misunderstanding or random responding.
Examine Measures	
Omissions	Number of targets to which the individual did not respond. Omission errors can be caused by a subject responding slowly to a target, and the slow response can produce a subsequent commission error after the omission error [27].
Commissions	Number of times the individual responded to a non-target ('X'). Slow RTs + elevated number of omission and commission errors = inattention. Fast RTs + elevated number of commission = impulsivity.
Hit Reaction Time (Hit RT)	Mean response time (in milliseconds) for all target responses over all six time blocks. High T- scores reflect slow response times. (RT averaging over 900 ms are considered sluggish responses.)
Hit Reaction Time Standard Error (Hit RT Std Error)	The consistency of response times is expressed in terms of standard error for response to target. High T-scores are often related to inattentiveness.
Variability of Standard Error (Variability)	Standard deviation of the 18 standard error values calculated for each subblock
Attentiveness (d')	Measure of how well the individual discriminates between target and non-target.
Perseverations	Response that occurs less than 100 ms following a stimulus. Large number of perseverations = 1, impulsivity (anticipatory responding) or 2, severe impairment (random responding) or 3, inattentiveness (very slow responses to the preceding stimuli).
Hit Reaction Time Block Change (Hit RT Block Change)	Vigilance measure: the slope of change in reaction times over the six time blocks. A high T- score indicates a loss of vigilance.
Hit Standard Error Block Change (Hit SE Block Change)	Vigilance measure: the slope of change in reaction times standard error over the six time blocks. A high T-score indicates that RTs became less consistent as the test progressed (possible loss of vigilance). A small SE indicates the respondent is adjusting his or her tempo to the task.
Hit Reaction Time ISI Change (Hit RT ISI Change)	Adjusting to presentation speed. Slope of change in RTs over the three inter-stimulus intervals (ISIS: 1, 2 and 3 seconds). A high T-score indicates a slowing RT as time increased. A low T-score indicates faster RT as the time increased.
Hit Standard Error ISI Change (Hit SE ISI Change)	Adjusting to presentation speed. Slope of change in RTs SE over the three inter-stimulus intervals (ISIS: 1, 2 and 3 seconds). A high T-score indicates means RTs became more erratic as time increased.

Therefore, the scores at the CPT-II test are different between the groups (ADHD-I vs. MID) for most of the indicators (i.e. 10/12), pointing out that the MID group demonstrated significant better performances than the ADHD-I group. Despite the subject of MID+ sample do not meet diagnostic criteria for ADHD, (i.e. as described before for ADHD-I group), the comparison between

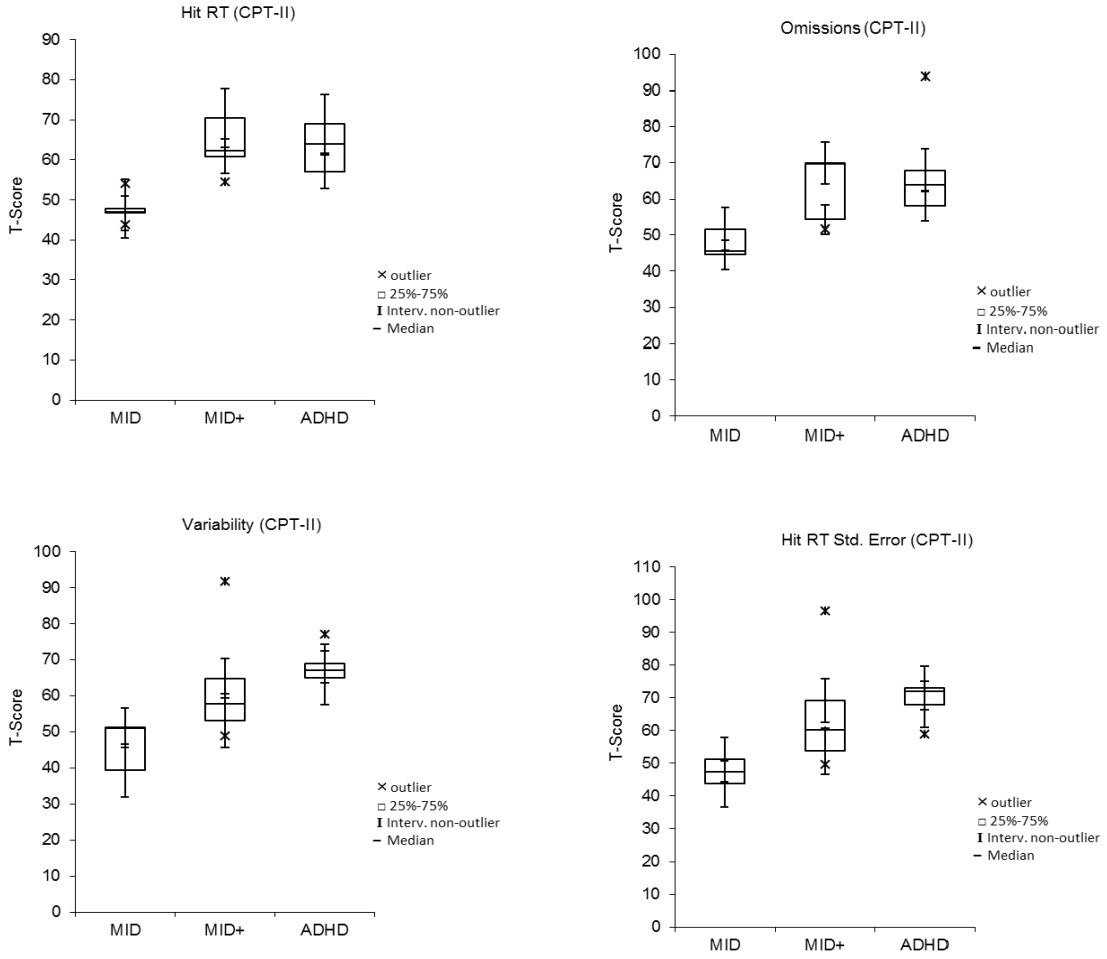

Figure 1 Data distribution of CPT-II significant measures. Comparison between the groups MID *vs.* MID+ and MID *vs*. ADHD are reported.

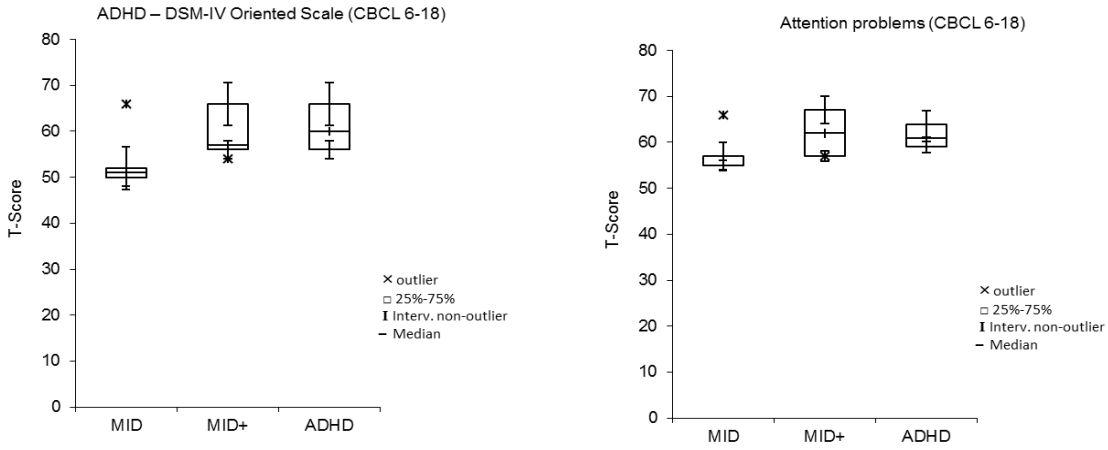

Figure 2 Data distribution of CBCL 6-18 significant measures. Comparison between the groups MID *vs*. MID+ and MID *vs*. ADHD are reported.

Table 2 Performance (T-score) of the three groups (MID, MID+, ADHD-I) at CPT-II and CBCL 6-18. Scores above 60 indicate significant problems.

		MID		MID+		ADHD-I	
		Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)
Conners Continuous Performance Test II	Omission	42-52	47,1 (4,3)	52-72	63,5 (9,8)	54-94	67,6 (15,7)
	Commisions	46-61	54,6 (5,5)	24-55	42,5 (14,3)	43-60	51,2 (6,3)
	Hit RT	44-54	47,9 (3,8)	54-74	64,4 (7,8)	48-72	62,0 (9,7)
	Hit RT (Std Error)	43-52	47,5 (4,2)	50-97	65,8 (18,7)	59-77	69,8 (6,8)
	Variability	38-56	47,1 (7,9)	49-92	63,3 (17,0)	64-77	68,4 (5,2)
	(d')	46-59	52,3 (5,2)	26-63	44,8 (15,2)	46-63	56,6 (6,4)
	beta	41-50	46,4 (3,8)	36-63	52,2 (10,1)	50-66	57,0 (6,1)
	Perseverations	43-51	47,6 (3,1)	47-53	49,7 (3,0)	51-71	61,4 (8,4)
	Hit RT Block Change	35-54	45,0 (6,8)	37-62	50,5 (10,3)	53-78	63,8 (9,3)
	Hit SE Block Change	29-52	38,7 (10,5)	39-59	49,7 (8,4)	48-66	56,6 (6,8)
	Hit RT ISI Change	38-53	45,9 (6,7)	37-56	45,8 (8,6)	48-87	70,0 (19,7)
	Hit SE ISI Change	36-59	46,9 (8,2)	39-63	51,4 (10,0)	58-70	64,8 (5,4
Child Behaviour Checklist 6-18	anxoius/depressed	50-82	63,4 (12,0)	50-65	55,2 (6,6)	50-67	60,0 (6,3)
	withdrawn/ depressed	50-85	60,2 (15,0)	50-93	62,2 (18,5)	50-58	53,2 (4,4)
	somatic complaints	50-86	60,0 (14,9)	50-61	53,6 (5,1)	50-53	50,6 (1,3)
	social problems	57-80	66,2 (9,5)	52-62	57,6 (4,7)	50-62	55,4 (5,0)
	Thought problems	51-73	60,4 (8,1)	50-54	51,2 (1,6)	50-67	56,0 (7,6)
	attention problems	53-66	57,2 (5,1)	57-68	62,2 (5,3)	57-69	62,0 (4,7)
	rule-breaking behavior	50-64	53,2 (6,1)	50-55	52,2 (2,2)	50-60	53,0 (4,1)
	agressive behavior	50-68	57,8 (8,1)	50-58	52,4 (3,3)	50-64	54,2 (5,8)
	af f ective problems	52-76	58,4 (10,4)	52-77	60,2 (9,8)	52-60	54,4 (3,6)
	anxiety problems	50-73	64,4(8,6)	51-65	56,2 (6,1)	51-70	60,8 (8,2)
	somatic problems	50-87	59,6 (16,0)	50-65	54,2 (6,6)	50-57	51,4 (3,1)
	ADHD-DOS	50-66	53,8 (6,9)	54-66	59,8 (5,8)	53-75	62,0 (8,7)
	DOP-DOS	50-62	56,0 (5,2)	50-56	53,6 (2,5)	50-58	54,4 (3,8)
	DC-DOS	50-60	52,0 (4,5)	50-60	53,2 (4,1)	50-63	53,8 (5,4)

MID+ and ADHD-I shows no differences in CBCL reports, suggesting similar behavioral phenotype. In particular, high values were scored by both groups for the following scales: attention problem, ADHD (DSM-IV oriented) and for the clusters anxious/depressed, withdrawn/depressed, affective problem (DSM-IV oriented) and anxiety problem (DSM-IV oriented).

Instead, the attentive performances at CPT-II do not seem to be completely equal between the two groups (MID+ vs. ADHD-I): perseveration (U=2; z=2.09; p=0.18); hit RT block change (U=3.5; z=1.78; p=0.037); hit RT ISI change (U=4; z=1.67; p=0.047); hit SE ISI change (U=3; z=1.88; p=0.030). These differences suggest a different qualitative attentive impairment between MID+ and ADHD-I, but it is possible that it was not pointed out in the caregiver reports.

Table 2 shows the performances of the three groups: MID (i.e. mild intellectual disability without attention impairment), MID+ (i.e. mild intellectual disability plus attention impairment), ADHD-I (i.e. normal cognitive development with ADHD inattentive type).

Furthermore, **Figures 1 and 2** show the distributions of CPT-II and CBCL 6-18 significant measures.

Conclusion

This study aimed to understand the relationship between EFs and intelligence by adopting a developmental perspective. We tried to better understand the development of executive functions in children with a mild intellectual disability (MID). In fact, the comparison between children with MID and children with ADHD-I matched for chronological age has been necessary to explore a wide-open question: Is the development of executive functions in MID individuals comparable to cognitive development or can it present specific impairments? To deep this issue we have chosen an easy-to understand-task without complex motor output and only one rule to keep in mind to solve the task. Based on the results obtained from the CPT-II (i.e. attentive neuropsychological test) and the CBCL 6-18, the MID sample was divided in two different subgroups, with or without inhibitory control of attention disease. Both experimental groups (i.e. MID/ MID+) point out similar output concerning response style (beta; both of them try to do not make omission mistakes), ability to distinguish the target from the non-target (d') and normal skills in adjusting their reaction time to the task (block change and ISI change).

However, the performance of the MID+ obtain lower T scores than the MID group in omissions, hit RT, hit RT Std Err and variability. Since the MID+ group seems to exhibit slower reaction times, it is possible to hypothesize that this is the reason for the increased number of omission errors in this group; furthermore, the MID+ group gave more impulsive mistaken answers when inter-stimuli intervals were shorter. In addition, performances of the ADHD-I group were lower than performances of the MID group in all the CPT-II measures and in the scales attentive problems and "ADHD DSM-IV oriented part of caregiver questionnaires (CBCL 6-18). The analyzed data seemed to support the hypothesis that children with an intellectual disability can have attentive skills equal to their chronological age (MID), or they can have a specific impairment (MID+). Hence, this competence (i.e. inhibitory control of attention) [30] seems to be, at least partially, independent from cognitive development.

The comparison between MID+ and ADHD-I shows important differences even between these two groups. On the CPT-II, the ADHD-I group had lower scores particularly in perseverations, hit RT block change, hit RT ISI change and hit SE ISI change measures. Conners [27] hypothesized that a high number of perseveration errors could be due to impulsivity (i.e. anticipatory responding), severe impairment (i.e. random responding) or inattentiveness (i.e. very slow responses to the preceding stimuli). It is possible to exclude the first hypothesis because anticipatory responding scores do not show a significant difference between the MID+ and the ADHD-I groups. The severe impairment hypothesis does not fit with the groups' performances because they have comparable scores on response style value (i.e. beta statistic: speed/accuracy trade-off) and attentiveness (i.e. d': how well they discriminate between targets and non-targets). So, the best hypothesis to explain the different performances between the MID+ and ADHD-I groups seems to be inattentiveness described as very slow responses to the preceding stimuli.

However, the MID+ group exhibited a slower, unvarying reaction times, whereas the ADHD- I group had increased inattentiveness during the task, especially when the rapidity of inter- stimuli presentation was modified.

Therefore, it seems that inattentiveness in MID+ individuals is stable, whereas ADHD-I individuals are prone to progressive attentive-weariness and show difficulty in maintaining vigilance. Moreover, the comparison between ADHD-I and MID+ seem to suggest that attentional problems could have different features in various clinical populations.

Despite the present study represent a preliminary research, with a small sample size that could affect data reliability, it provides encouraging results supporting the hypothesis that children with MID could have specific deficits in cognitive functioning (i.e. difference theory) [31]. Moreover, the visual processing speed could be impaired in a subgroup of MID. Finally, this research seems to point out that is possible to differentiate MID subgroups based on visual selective attention [32-34].

It is necessary to deal with a problem often overlooked in clinical practice: This study seems to demonstrate that intellectual disability is a diagnosis that could include different neuropsychological phenotypes depending on different etiopathogenetic factors that are often unknown [35,36].

Thus, a future challenge is to enhance the size of the experimental groups, not only to increase the representativeness of the sample and data reliability but also to provide other evidence of different developmental profiles of executive functions in individuals with MID. This research line would define clusters with different neuropsychological development in this clinical population and thus increase our knowledge about the development of neuropsychological functions in MID. The hypothesis that a specific attention problem could exist in children with mild intellectual disability requires new and expanded rehabilitative training.

Declarations of Interest

No potential conflict of interest was reported by the authors.

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