

ORIGINAL ARTICLE

# Psychometric properties of the Movement Assessment Battery for Children (MABC-2): an analysis based on the Item Response Theory

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## Abstract

**Introduction:** the American Psychiatric Association reveals that 6% of school-age children have developmental coordination disorder.

**Objective:** this study aimed at assessing the suitability of the tasks proposed by the MABC-2 motor assessment instrument based on the psychometric properties of such an instrument and the analysis of the Item Response Theory.

**Methods:** 582 children ranging in age from 3 to 5 years old of both sexes participated in the study. The motor tasks suitability for children was verified by using the Gradual Response Model, and applying the Maximum Likelihood Estimation method.

**Results:** the motor task ‘bicycle trail’ showed a lower discriminatory power and was removed from the analysis. Considering the ‘Aiming & Catching’ dimension, ‘Threading Beads’ was the motor task with the highest degree of difficulty. Regarding balance, the ‘One Leg Balance’ task was classified as having a high degree of difficulty; on the other hand, the motor tasks ‘Jumping on mats’ and ‘Catching Beanbag’ required below average motor performance levels, that is, they are tasks with low discrimination capacity. The results showed that the low discriminative capacity of some MABC-2 items regarding this study sample makes it difficult to correctly classify the child’s general motor performance level.

**Conclusion:** the findings show that there is a need to review the suitability of the MABC-2 motor tasks in order to equate the difficulty and discriminatory capacity of the tasks so that standardization more appropriate to the reality of children from different populations is established.

**Keywords:** psychometric properties, motor tasks, motor performance.

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## Authors summary

### Why was this study done?

The motor performance assessment and classification of the Brazilian children has been carried out based on standardized scores from social contexts of other countries. This fact might generate a literary nonsense, since it runs the risk of inappropriately judging the motor performance of children and, consequently, evidencing a possible delay in motor development. If the maturational paradigm were the reference for studies on this theme, there would be no need for contextual adjustments. However, given the current theoretical foundation, which is predominantly based on contextualist paradigms, studies are needed to adapt the theoretical models for the demands of each context.

### What did the researchers do and find?

This study aimed at investigating the suitability of the set of motor tasks included in the Movement Assessment Battery for Children (MABC-2) for Brazilian children by determining the degree of difficulty and discrimination capacity of each task, using the Item Response Theory (IRT) as a statistical tool. The findings suggest that either the adjustment of the MABC-2 instrument or the revision of the standardization of the items is necessary to improve the construct validity of this motor assessment instrument. Specifically, the removal of the motor task 'bicycle trail' is suggested due to cultural factors and/or lack of specific stimulus for this task.

### What do these findings mean?

1) the need to improve the construct validity of the MABC-2 motor assessment instrument for Brazilian children; 2) the removal of the motor task 'bicycle trail' from the set of motor tasks in the test; and 3) adjustment of the score standardization for each child when assessed individually, or the sample used in the case of research. These findings make it possible to better classify children, as well as to avoid the possible false positive diagnoses of Developmental Coordination Disorder (DCD).

## INTRODUCTION

Currently in Brazil, 92.4% of the children ranging in age from 3 to 5 years old attend a kindergarten center<sup>1</sup>. The American Psychiatric Association (APA)<sup>2</sup> reveals that 6% of school-age children have Developmental Coordination Disorder (DCD), and 15% are at risk of developing such disorder. Thus, there are more than 1 million children in Brazil who are vulnerable to some disorder during their motor development. In this sense, diagnosing DCD is a primary task for teachers in the early school years. However, having a valid, reliable and faithful diagnostic method is necessary so as to minimize assessment errors.

Since DCD is not a directly measurable phenomenon, it is diagnosed based on the children's motor performance, besides some other different skills. Therefore, a battery of tests that is adequate to the reality of these children is necessary. Some authors<sup>3-5</sup> suggest that the instrument referred to as Movement Assessment Battery for Children – Second Edition (MABC-2) is a comprehensive measure of motor skills, besides being the most appropriate one to identify children with DCD. Following this line, studies based on both, the reality of Brazil<sup>6-8</sup> and other countries<sup>9-13</sup> have been using the MABC-2 in order to identify children with DCD.

Considering the motor experiences and cultural differences that exist among children from different parts of the world, it is prudent to take these aspects into account before using an instrument created and standardized for a specific population. Brown and Lalor<sup>14</sup>, after reviewing the MABC-2, argued that there are issues to be addressed in relation to culture, translation of the instrument, and the assessment of the instrument according to age group, rather than the instrument as a whole. Under this perspective, studies in Europe<sup>13,15,16</sup> and Asia<sup>17</sup>, elucidated problems related to the adequacy of motor tasks for the children evaluated, and highlighted the importance of adjusting the assessment instrument for each context.

In Brazil, the MABC-2 was evaluated in one study<sup>18</sup>, which showed good reliability and discrimination indices to identify children aged 3 to 13 years old with DCD. However, as highlighted in the study mentioned above, it

is necessary to investigate other contexts in Brazil, given the wide cultural diversity of the country. Thus, the present study aimed at assessing the degree of difficulty and discriminatory capacity of the MABC-2 motor tasks based on the psychometric properties of such an instrument and the analysis of the Item Response Theory.

## METHODS

### Population and Sample

The study population was represented by 6,278 children ranging in age from 3 to 5 years old, enrolled and attending Municipal Centers for Early Childhood Education (CMEIs). In order to guarantee sampling with an error of 5% and a 95% confidence interval, the sample should have 362 children. However, 582 children aged between 36 and 71 months (mean = 50.0, sd = 9.3) were randomly, probabilistic and unintentionally selected as shown in Table 1.

**Table 1:** Characterization of the study sample

	Boys n(%)	Girls n(%)	Total n (5%)
3 years old	149 (49.0)	131 (47.1)	280 (48.1)
4 years old	92 (30.3)	90 (32.4)	182 (31.3)
5 years old	63 (20.7)	57 (20.5)	120 (20.6)
Total	304 (52.2)	278 (47.8)	582 (100.0)

### Instrument

The Movement Assessment Battery for Children - Second Edition (MABC-2), proposed by Henderson, Sugden and Barnett<sup>19</sup> was used to verify the children's motor performance. The motor tasks were grouped according to the following categories: (1) 'Manual Dexterity', which includes the activities of 'posting coins', 'threading bead' and 'bicycle trail'; (2) 'Aiming and Catching', which involves activities of 'catching a beanbag' and 'throwing a beanbag' at a target; (3) 'Balance' with activities of 'one-leg balance', 'walking heels raised'

and ‘jumping on mats’. The Band 1 of the instrument was used in this study. Raw data were measured by using a time scale or the number of misses/hits.

**Procedure**

Data collection was approved by the Standing Committee on Ethical Research with Humans at the Brazilian university referred to as Universidade Estadual de Maringá (Protocol 35712011). After the ethical precepts and the drawing of schools in each region, the dates for data collection at the CMEIs were scheduled. The children were moved from the classroom to the assessment site, and each child was assessed individually, for approximately 20 minutes.

Considering data collection, the researchers were trained twice a week for thirty days according to the domains of the MABC-2 motor task set. Intra and Inter-rater reliability was verified for each motor task by using the Intraclass Correlation Coefficient (ICC) with a 95% confidence interval. The results showed quite significant correlations (ICC:  $0.91 \leq 0.99$ ;  $P < 0.001$ ) and significant Intra or Inter raters ( $0.75 \leq 0.90$ ;  $P < 0.001$ ).

**Data analysis**

In order to align the motor performance classification in each motor task under the logic that the higher the gross number, the lower the child’s motor performance, the motor tasks assessed by the number of hits/errors were tabulated according to the number of errors. After this procedure, the raw data were initially changed into z-scores, standardizing the metric of motor tasks. To transform these z-scores into a more convenient scale for analysis, the formula below was applied to convert the data into standard scores with a mean of 10 and a standard deviation of 3.

$$\text{New Standard Score} = (\text{Z Score}) * (\text{New SD}) + \text{New Mean}$$

This manipulation follows the same procedures performed in the original standardization of the instrument, in which the scores range from 1 to 19. From the standardization of scores, a polytomous scale with 3 points was created, and the following values were adopted: a) ‘0’ for scores from 1 to 6; b) ‘1’ for scores from 7 to 12; c) ‘2’ for scores from 13 to 19. These values were arbitrarily classified as ‘below average’, ‘on average’ and ‘above average’, respectively.

In order to identify multivariate extreme cases, the Mahalanobis distance was used, and the values higher than the significance level adopted were excluded, considering the degrees of freedom of the model (df = 9). The reliability

of the MABC-2 was verified by using Cronbach’s alpha coefficient and composite reliability.

**Item Response Theory (IRT)**

The IRT paradigm was used in order to assess the items (motor tasks) included in the MABC-2 motor assessment instrument. Each dimension of the instrument was investigated separately, so as to comply with the one-dimensionality assumption. The IRT models start from the assumption that the probability of an item (motor task) is at the same level as the latent construct (for example, manual dexterity) that can be modeled by using a mathematical function.

The item parameters include the child’s motor performance and the discrimination parameter, which determines how well the item captures the latent construct. Considering the response system adopted for this study (polytomic), an analysis was performed by using the Gradual Response Model<sup>20</sup>, with estimation applied according to the Maximum Likelihood Estimation Method. The item’s difficulty parameter ranges from -4 to 4 (standard scale), in the latent dimension metric, theta (Θ), represented on the x-axis. The value 0 (zero) indicates the average of the phenomenon represented in the latent dimension (e.g, manual dexterity ability).

Positive values indicate better motor performance, and negative values represent the child’s less motor skill. The quality of the model was verified through the infit and outfit indices. Values greater than 1.3 indicated a misfit between the model and the sample<sup>21</sup>.

The standardization created for the present study fits a 3-point Likert-type scale: 0 = below average; 1 = on average; and 2 = above average. In this sense, the Two-Parameter Logistic (2PL) model was used, obtaining 2 difficulty parameters (b) and 1 slope parameter (a) for each item. The R Studio program was used so that the analyses were carried out.

**RESULTS**

After verifying the outliers through Mahalanobis distance, 516 children were considered for the analyses. The analysis of internal consistency (Cronbach’s alpha) and composite reliability showed values of 0.44 and 0.60, respectively. It is worthy to mention that if the motor task ‘Bicycle trail’ were removed from the analysis, it would increase the value of Cronbach’s alpha to 0.62; however, the values remained below 0.7, which is recommended in the literature<sup>22</sup>.

**Table 2:** Ratio of children classified in each level of motor skill of the standardized scale.

Items	Below average	On average	Above average
Posting Coins with Dominant Hand (it1a)	0.6412	0.3039	0.0549
Posting Coins with Non-dominant Hand (it1b)	0.6294	0.3059	0.0647
Threading Beads (it2)	0.3941	0.5294	0.0765
Bicycle Trail (it3)	0.6471	0.1647	0.1882
Catching Beanbag (it4)	0.0980	0.3118	0.5902
Throwing Beanbag (it5)	0.1863	0.6235	0.1902

**Continuation - Table 2:** Ratio of children classified in each level of motor skill of the standardized scale.

Items	Below average	On average	Above average
Dominant One-leg Balance (it6a)	0.6529	0.2059	0.1412
Non-dominant One-leg Balance (it6b)	0.6804	0.2196	0.1000
Walking Heels Raised (it7)	0.1961	0.2314	0.5725
Jumping on Mats (it8)	0.0667	0.1863	0.7471

Note: it = item (related to MABC-2 motor task). a = dominant side. b = non-dominant side

Table 3 shows the results of the estimation of the parameters (difficulty and discrimination) for each item of the MABC-2. It is worth to highlight that the MABC-2 motor tasks were grouped into two dimensions, according to evidence raised in the previous study<sup>23</sup>.

**Table 3:** Estimation of the difficulty and discrimination parameters for each MABC-2 item.

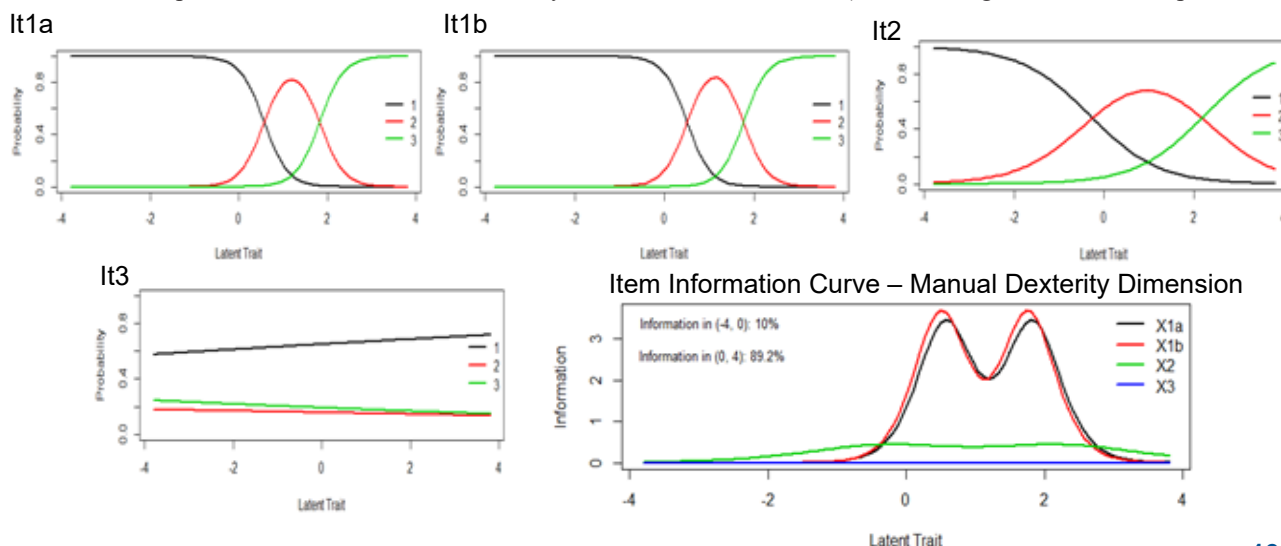
MABC-2 Dimension	Item	Parameters		
		Difficulty - Categories 0 and 1 ( $b_{i,1}$ )	Difficulty - Categories 1 and 2 ( $b_{i,2}$ )	Discrimination ( $a_i$ )
Manual Dexterity	It1a	0.56	1.82	3.69
	It1b	0.50	1.76	3.82
	It2	-0.31	2.23	1.30
	It3	-0.75	-17.44	-0.08
	It4	-2.44	-0.40	1.08
Aiming/Catching and Balance	It5	-1.93	1.91	0.87
	It6a	0.51	1.38	2.19
	It6b	0.53	1.44	3.32
	It7	-1.36	-0.29	1.38
	It8	-3.65	-1.55	0.79

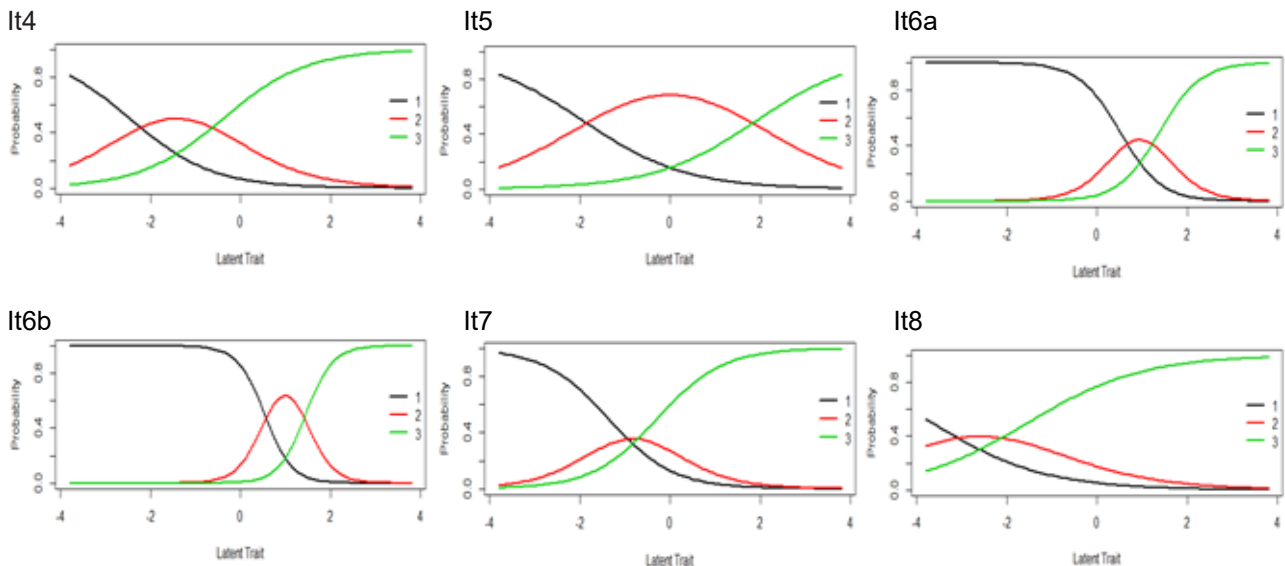
Note: a = preferred limb. b = non-preferred limb. It1 = Posting coins. It2 = Threading beads. It3 = Bicycle trail. It4 = Catching beanbag. It5 = Throwing beanbag. It6 = One-leg balance. It7 = Walking heels raised. It8 = Jumping on mats

Parameters  $b_1$  and  $b_2$  indicate the point from which there is a higher probability of the child to be classified under categories ‘on average’ and ‘above average’, respectively. Based on this premise, it is possible to see (Table 3) that a child with a motor performance level of 1.82 has a 50% chance of being classified as ‘above average’ in the task of ‘posting coins’ with the dominant hand (it1a). Similarly, regarding the same task mentioned above, a child with a motor skill level of 0.56 has a 50% chance of being classified as ‘below average’ or ‘on average’. These values indicate the thresholds between classification categories. ‘Threading Beads’ is the motor task with the highest degree of difficulty (it2), which requires higher levels of motor performance from the child than any other

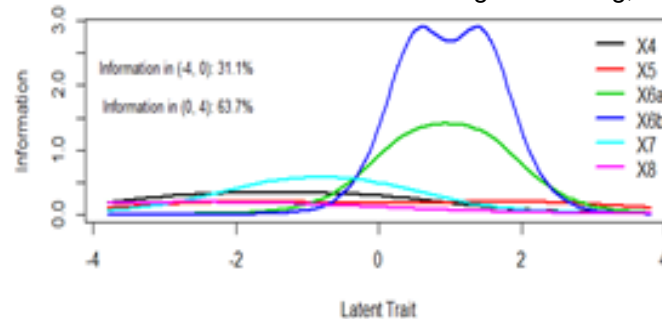
task, for a 50% probability of being classified as ‘above average’. On the other hand, ‘Jumping on Mats’ (it8) is the motor task with the lowest degree of difficulty, since even children with an ability of  $\theta = -1.55$  have a 50% probability of being classified as ‘above average’.

Table 3 shows that items it1b and it1a have, respectively, the greatest discrimination powers (3.82 and 3.69) of the motor skill referred to as ‘manual dexterity’. On the other hand, it3 has the lowest ability (-0.08) to discriminate different levels of manual skill. Figure 1 shows the Item Characteristic Curves (ICC) and Item Information Curve (IIC) of MABC-2. Furthermore, the fit indices of the Infit ( $m = 0.85$   $sd = 0.35$ ) and outfit model ( $m = 0.85$   $sd = 0.27$ ), indicate a good fit to the sample<sup>21</sup>.





Item Information Curves – Dimensions: Aiming & Catching, and Balance



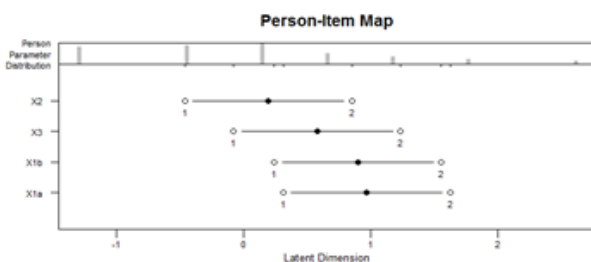
**Figure 1:** Item Characteristic Curve and Item Information Curves according to MABC-2 dimension.

**Note:** a = preferred limb. b = non-preferred limb. It1 = Posting coins. It2 = Threading beads. It3 = Bicycle trail. It4 = Catching beanbag. It5 = Throwing beanbag. It61 = One-leg balance. It72 = Walking heels raised. It8 = Jumping on mats.

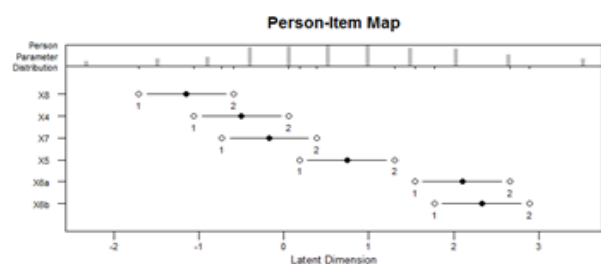
Figure 2 shows the item-map distribution of motor tasks related to the following dimensions: Manual Dexterity, Aiming & Catching, and Balance. These maps

show how children with different levels of motor ability fit into each motor task of the MABC-2 instrument.

#### Manual Dexterity Dimension Items



#### Aiming & Catching and Balance Dimension Items



### DISCUSSION

The discrimination of items (a) ranged from 3.82 to -0.08 with regard to the tasks ‘Posting Coins – Non-Dominant Hand’ and ‘Bicycle Trail’, respectively. This shows that the latter motor task has less discrimination power than recommended in the literature<sup>24</sup>, which indicates a low quality of item information, which can be seen in Figure 1. This evidence corroborates some studies<sup>13,16,25,26</sup> whose authors pointed out that the motor task ‘Bicycle Trail’ did not fit the theoretical model tested in the study samples, considering both, the exploratory and confirmatory factorial analyses.

‘Threading Beads’ (it2), ‘Throwing Beanbag’ (it5) and ‘Posting Coins’ (it1) were the most challenging motor tasks for the children. Furthermore, based on Figure 2, it is possible to synthesize some considerations about the children’s motor performance level. Children with mean motor performance ( $\theta = 0$ ) are more likely to be rated as ‘on average’ and ‘below average’, considering the Manual Dexterity motor tasks. It should be highlighted that the motor task ‘Bicycle Trail’ (it3) proved to be problematic and not suitable for the sample.

Considering Aiming & Catching, and Balance dimensions, the children who managed to be fit as ‘above

average' in the non-dominant one leg balance (it6b), can be classified in the same category in all other motor tasks due to the high degree of difficulty required by this task. In other words, the aforementioned motor task requires high motor performance. On the other hand, the motor tasks referred to as 'Jumping on Mats' (it8) and 'Catching Beanbag' (it4) require below-average motor performance levels so that the children are classified as 'above average', thus, the tasks have low discrimination capacity with regard to the children with different levels of motor performance. In addition, children with a motor performance level of  $\theta = 0$  have a 100% probability of being classified as 'above average' in the motor tasks 'Catching beanbag' (it4) and 'Jumping on mats' (it8).

It is noteworthy that the Item Characteristic Curves (Figure 1) are shifted to the right of the mean reference  $\theta = 0$ , which indicates a greater degree of difficulty than expected for the children assessed in the present study. This shows the significance of considering cultural factors adjacent to the children's motor development process. A possible explanation for the low motor performance of 3-year-old children, according to the APA<sup>2</sup>, can be found in environmental factors, such as the lack of opportunity to learn and use motor skills. For example, the study by Chow *et al.*<sup>27</sup> showed that experience with the use of chopsticks with the dominant hand since early childhood might make the performance of manual dexterity of other types easier, a common task for Japanese children. Hirata *et al.*<sup>17</sup> reported that experience with the use of public transport is likely to stimulate dynamic balance skills, such as jumping from different vehicles, for example, buses and trains. These activities are demanded from young children of that culture.

During data collection and subsequent data analysis, it was possible to notice the low motor performance of children in manual dexterity activities, especially considering the motor task 'Bicycle Trail' (it3). Bakke, Sarinho and Cattuzzo<sup>28</sup>, when analyzing the MABC-2 multidimensionality of 7-10-year-old children, pointed out problems related to the correlations of the variables, which required the exclusion of three subtests, including 'Bicycle Trail' for obtaining a more adjusted model. With similar results, Hua *et al.*<sup>25</sup> concluded that the exclusion of two items, that is, 'Bicycle Trail' and 'Walking heels raised' resulted in greater internal consistency (alpha values increased from 0.502 to 0.549 if the two items were excluded). In addition, the study by Ellinoudis *et al.*<sup>29</sup> showed that test-retest reliability values were high for all test items, except for a moderate finding for the 'Bicycle Trail' activity.

Psotta and Abdollahipour<sup>16</sup> suggested that the speed of goal-directed drawing, rather than the number of errors, might be a more sensitive measure of fine motor-visual coordination. Since the speed of drawing and writing is essential for a child's continuing education, despite the modern rise of other methods of written communication using information technology<sup>30</sup>.

Another interesting issue revealed in the results was the divergence between the tasks of 'Catching beanbag' (it4) and 'Throwing beanbag' (it5). It was evidenced that it is easier for the child to catch the object than to throw

and hit it on the target. The hypothesis was raised to explain that the difference in difficulty between the tasks relies on the fact that the child often plays throwing and catching objects with adults, who adapt the trajectories of the object to facilitate the continuity of the game. This fact was also observed during the data collection process, and empirically confirmed by the teachers. According to Ellinoudis *et al.*<sup>29</sup> the moderate, but significant value of the 'Throwing and Catching' domain found in their study might denote a problem inherited from the test to deal with the specific domain.

Finally, items with greater discrimination capacity provide more information about the child's motor performance level than items with less discrimination power. In this sense, the low discriminative capacity of some items of the MABC-2, considering the sample of the present study, makes it difficult to ensure the correct classification of the child's general motor performance level. However, it is possible to predict the probability that the child has to be classified in a certain category based on the standardized score achieved in each motor task, which refers to the advancement of the present study in the literature. These results support the use of the test to examine the effectiveness of motor intervention programs; however, they suggest that the professionals are careful in the final assessment of the child.

Regarding each dimension, the Item Information Curves (Figure 1) show the items that most contribute to better discriminate children with different motor skill levels. Most items have a low ability to discriminate the children included in the present study, which indicates the need to review the degree of difficulty of these items or even the standardization of raw scores. In addition, a standardization of raw scores mediated by a pondering based on the degree of difficulty of each item could improve the model's adjustment to the sample, which is one of the limitations of this study.

Other limitations of the study are noteworthy. Although the sample is representative for the ages in question in the city where data were collected, socioeconomic factors were not considered in the sample stratification, as performed in the original validation study. The need to standardize the raw scores might have resulted in some loss of information, although the standardization of scores was based on the proposal of the original version of the assessment instrument. This standardization was equally carried out for all motor tasks, considering that all motor tasks have the same weight/degree of significance. The results found in this study does not allow a deliberate extrapolation for other samples, thus, further studies are required to confront the results found. However, this preliminary study allows some pertinent inferences related to the quality of MABC-2, regarding the difficulty and discriminatory capacity of the motor tasks listed to explain the variance of each dimension.

Based on the degrees of difficulties evidenced in the MABC-2 motor tasks, it is possible to think of pedagogical strategies to readjust the planning of motor activities offered to 3-5-year-old children. Under this perspective, the results of the present study help to understand the difficulties faced by children in performing certain motor

tasks. In addition, it is possible, in practice, to discriminate the child's motor skill level when performing some motor tasks, without the need to apply the entire instrument, which facilitates its application and the work of Physical Education teachers regarding school context.

## CONCLUSIONS

The analyzes based on the Item Response Theory revealed that certain MABC-2 items did not work as expected in the originally proposed theoretical model. The information curve obtained by applying the Item Response Theory revealed that the MABC-2 motor tasks are better suited to children with higher motor skill levels. This issue might have negative repercussions when using the MABC-2 to diagnose children with Developmental Coordination

Disorder, which indicates that there is a need to review the adequacy of the MABC-2 motor tasks in order to equate the difficulty and discriminatory capacity of the tasks to create a more adequate standardization with regard to the reality of children from different populations.

The use of the Item Response Theory showed that considering that all motor tasks of the MABC-2 instrument have the same weight/impact in the assessment of the children's general motor performance might lead to inconsistent assessments/data, since the results revealed that each motor task has its own level of difficulty and discrimination ability.

## Conflicts of interest

nothing to declare.

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## Resumo

**Introdução:** a American Psychiatric Association revela que 6% das crianças em idade escolar apresentavam desordem coordenativa desenvolvimental.

**Objetivo:** analisar a adequabilidade das tarefas propostas no instrumento de avaliação motora MABC-2 a partir da análise da teoria de resposta ao item.

**Método:** participaram do estudo 582 crianças de 3 a 5 anos de idade, de ambos os sexos. A adequabilidade das tarefas motoras às crianças foi verificada por meio do modelo de resposta gradual, com método de estimação de máxima verossimilhança.

**Resultados:** os resultados evidenciaram a existência de apenas dois fatores, sendo que as tarefas relativas ao “Equilíbrio” e “Lançar e “Receber”, das dimensões propostas no modelo original foi agrupado em uma dimensão. Além disso, a tarefa motora “Caminho da bicicleta” não apresentou bom ajuste ao modelo, sendo eliminada das análises. Com isto, o modelo final apresentou bons índices de ajuste, e os parâmetros relacionados à tarefa indicaram a falta de equivalência de dificuldade e capacidade discriminatória entre as tarefas motoras do instrumento.

**Conclusão:** os achados indicam que existe a necessidade de rever a adequabilidade das tarefas motoras do MABC-2 no sentido de equiparar a dificuldade e a capacidade discriminatória das tarefas a fim de criar uma padronização mais adequada a realidade de crianças de diferentes populações.

**Palavras-chave:** desempenho motor, avaliação motora, psicometria.

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