# E-BTT in primary school-aged children: preliminary results

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**Abstract**
Visuospatial orientation of attention is the cognitive process that allows to orient and focus on stimuli presented in the visual field. A cognitive-attentional bias towards one side of the visual field, often the left side, derives from cerebral, evolutionary, and cultural factors. Such a leftward bias is often referred to as "pseudoneglect". School-aged children gradually shift spatial attention to the left, with differences related to manual dominance or to possible neurodevelopmental disorders. The new Enhanced-Baking Tray Task (E-BTT) is an ecological task that enriches the spatial exploration evaluation procedure by adding a digital/hardware platform to automate the data collection.
For the first time we administered the E-BTT to school-aged children with the aim to explore children's initial orientation of spatial attention and to compare their performances to those of a sample of young adults who showed a leftward preference. Results showed that children, as adults, shifted their attention leftward in the E-BTT task, however not prominently as adults. Our results show that performances on E-BTT support what has been reported in the literature on leftward spatial bias shown in other tasks: that it emerges during development in relation to biological, cultural and biomechanical factors.

**Keywords 1**
Leftward spatial bias, Pseudoneglect, Baking Tray Task, Development

## 1. Introduction

Spatial cognition concerns the perception, awareness, and processing of spatial information, as well as the ability to use that information for the representation and resolution of visuospatial problems [1], therefore it plays a central role in human evolution, adaptation, and daily functioning. Visuospatial orientation of attention is the cognitive process that allows to orient and focus on stimuli presented in the visual field.

## 1.1. Left-ward visuospatial attention

Healthy individuals do not pay equal attention to the left and right side of space, showing the pseudoneglect phenomenon, a cognitive-attentional bias towards one side of the visual field, often the left one [2]. This phenomenon reflects the influence of hemispheric functional specialization in visuospatial attention and, more specifically, the dominance of the right hemisphere in spatial information processing [3]. The orientation of attention towards a specific visuospatial field, is evident in many daily life tasks and situations. When people respond to Likert scales, for example, pseudoneglect can cause a left bias to balance the left and right sides of the scale [4].

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In the scientific literature, various explanations for pseudoneglect have been proposed, which are not mutually exclusive: the inter-individual differences, in terms of consistency and direction of the pseudoneglect, could be explained as a function of cerebral asymmetries [5], of evolutionary mechanisms [6], of cultural differences deriving from reading experience and exposure to visuomotor explorations according to preferential reading or writing direction [7].

Visuospatial attention during line bisection or cancellation tasks apparently shifts leftward over the course of primary school years, in left-to-right reading cultures, as children learn to read. In general, the literature provides evidence for an overall spatial attention shift to the left even in school-aged children [8] [9]. Manual dominance can influence performance [8] [10], as can neurodevelopmental disorders such as Attention-deficit/hyperactivity disorder (ADHD) and Developmental Dyslexia [11]. Handedness differences in pseudoneglect decrease during development, perhaps as a consequence of the development of the corpus callosum up to the mid-20s. Children with ADHD bisect horizontal lines more rightward than control children. Children with Developmental Dyslexia display mild inattention in the left visual field and excessive distraction in the right visual field [11]. Investigating orientation and spatial directionality patterns during development could improve understanding of the functioning of cognitive processes and specific brain structures related to these behaviours.

Pseudoneglect manifests in classical experimental contexts during bisection of horizontal lines, as a small deviation to the left of the real midpoint [2] or as a bias to initiate a visual search from a left-sided element [12] [13] [14]. Considering the multicomponent nature of this visuospatial attention bias, other researchers have used different types of stimuli to investigate the phenomenon in developmental age, considering the origin, but also the directionality: cancellation of target stimuli among irrelevant distractors [15] [16], drawing or reproduction of objects [17], drawing of circles and filling of points [18]. In summary, these studies report a strong left-to-right direction preference for right-handed children which increases with age, while left-handed children show less lateralization; however, lateralization of left-handed children is still a poorly understood phenomenon.

In a visual search task, spatial attention orientation to the visual environment, can influence the organization of search behavior. An efficient visual search implies, first of all, determining a position of the space from which to start the search. Starting the visual search or the cancellation of stimuli at or near the edge of the considered space increases the probability of a more organized search, compared to starting in the center of the space [16]. Furthermore, an organized search reduces the likelihood of intersections in the path and facilitates orthogonal or radial searches. Age-related or individual-related changes in spatial orientation may play a role in spatial organization performance differences between children and adults

Many stimuli and tools used by the aforementioned and other scientific studies have not been digitized and do not permit an objective and sensitive data collection and analysis. Moreover, they evaluate a limited number of indexes regarding directionality and visual search or design strategies. Rinaldi and colleagues [15], instead, exploited a digitized cancellation test and collected chronometric and spatial parameters (measured in x and y coordinates) ranging from the starting point (first mark) of the visual search to the scanning strategy adopted (directional shifts and smooth index).

Below we will introduce an assessment tool of visuospatial behaviors and processes that combines the ecological aspect of everyday tasks with a digital and automatic system for collecting spatial data.

## 1.2. E-BTT

The E-Tan platform, designed to connect tangible environments to digital data collection, has been used to enhance the Baking Tray Task (E-BTT), an ecological visuospatial task that requires test takers to uniformly place 16 objects on a rectangular tray (see [19] [20] [21] [22] for details), originally developed to assess unilateral spatial neglect (USN).

The E-Tan platform supports tangible interfaces and is able to digitally trace performances thanks to tags and a camera placed perpendicular to the tray. It thus allows the examiner to instantly obtain data on: total time spent on the task; the time each object is positioned; spatial coordinates (x and y) of single objects positioned; objects placement order. The information collected through the new E-BTT enriches the classic evaluation procedure; E-BTT new features allow not only to investigate spatial orientation and lateralization [23] but also spatial exploration and organization patterns in clinical or healthy subjects [24], such as the strategies used to plan and organize elements in the peripersonal space.

In a recent study we have investigated the lateral dimension of spatial behaviour, particularly left-right spatial asymmetry or pseudoneglect in samples of young adults [23], mainly analyzing the starting point of the disks disposition and the general center of the arrangement of all 16 disks. The results have shown a statistically significant preference to place the first disk in the left quadrants (mostly in the upper-left one) and a slight imbalance toward the left of all disks arrangement, thus demonstrating a leftward bias consistent with pseudoneglect.

This work, for the first time, focuses on the expression of visuospatial bias of school-aged children in E-BTT performance.

## 1.3. Aims

The aims of the present study were 1) to explore children's spatial performance and 2) compare their patterns of performance with those of a sample of young adults [23] who showed signs of leftward spatial bias.

To this end, prior to administering E-BTT to children, we collected preliminary data in order to adapt the test instructions. Subsequently, we administered the E-BTT task to typically developing school-age children.

Based on previous literature on visuospatial attention bias, we expected children to often start spatial organization on the left-side of the space. This initial bias should increase with age; however, it should not be as consistent a phenomenon as in adults. Furthermore, if spatial orientation effects reflect changes related to learning to read, children should also demonstrate a propensity for initially orienting spatial attention to the upper-left quadrant of the space, consistent with the typical starting location for reading, rather than simply orienting more leftward. Another possibility is that, due to the size and location of the frame, especially younger children could be more likely to prefer the lower portion of the test space than adults.

# 2. Materials and methods

## 2.1. Participants

A small sample of school-age children was recruited from a primary school of the Campania region, in Southern Italy, for the first study on task instruction. Ten children aged 6 to 10 years, with normal or corrected vision, were involved following inclusion criteria: (1) typical cognitive development, expressed by a score above the 15th percentile for the Raven Colored Progressive Matrices test (CPM - Italian standardization) [25]; (2) no clinical diagnosis of neurological, neuropsychiatric, or neurodevelopmental disorders as reported by the parents.

Afterwards, a second convenience sample of children was recruited from 16 classes of 2 primary schools of the Campania region, for a total of 157 children from grade 1 to 5. For the recruitment of the participants, contact was made in advance with the managers of the schools and subsequently interviews were held to define the objectives and methods of the research, first with the manager himself and then with the teachers.

Participants were included in the study following inclusion criteria: (1) typical cognitive development, expressed by a score above the 15th percentile for the Raven CPM test; (2) no clinical diagnosis of neurological, neuropsychiatric, or neurodevelopmental disorders as reported by the parents. One hundred and forty-eight children (72 females and 76 males aged 6 to 11 years) met the inclusion criteria (see Table 1). All participants spoke Italian as their mother tongue, had normal or corrected vision, were both right-handed (N = 127) and left-handed (N = 21) according to the "Edinburgh Inventory Questionnaire" (EI) [26].

**Table 1**
Sample details

| Grade | Age range | Females | Males | Total |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| 1 | 6,3;7,2 | 9 | 14 | 22 |
| 2 | 7;8,2 | 14 | 13 | 25 |
| 3 | 8;9,1 | 8 | 14 | 20 |
| 4 | 9,2;10,4 | 20 | 19 | 39 |
| 5 | 10,1;11,2 | 21 | 16 | 37 |
| | | 72 | 76 | 148 |

The study was conducted in accordance with the Declaration of Helsinki and approved by the Local Ethics Committee - Department of Humanities University of Naples Federico II [protocol number: 12/2020]. Written informed consent was obtained from all participants' parents prior to the test.

## 2.2. Procedure

Both the instruction study and the task administration took place in a room of each primary school attended by the children. The rooms were bright and quiet, and there was a table suitable for the children, on which the material for the administration of the E-BTT was placed. Throughout the procedure, only one child at time and an experimenter were present in the room. The children were seated on a chair placed in front of the table on which the frame was. The material on the table was arranged as shown in Figure 1.

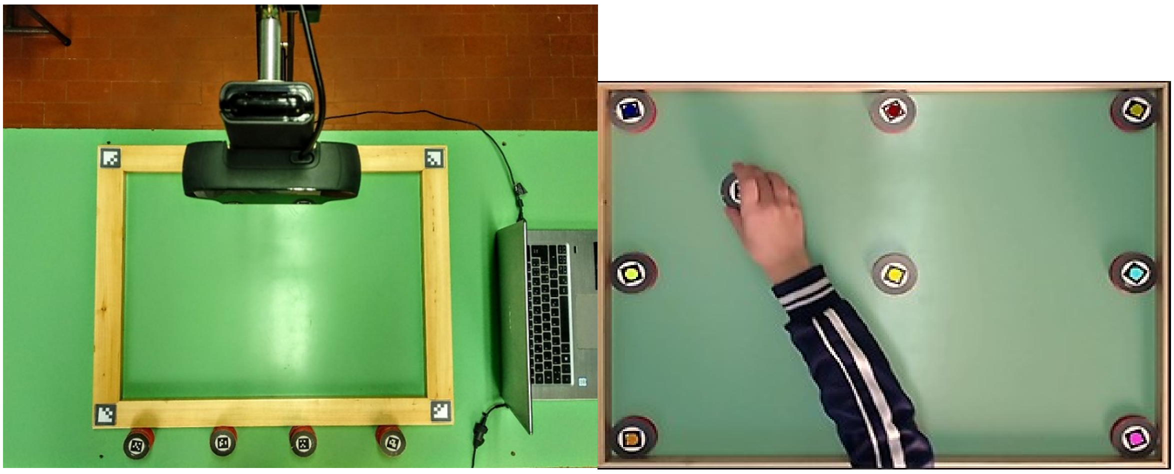

**Figure 1**: E-BTT tool setting

### 2.2.1. E-BTT instruction

In the pilot study, children were given 3 different instructions in random order, including the original instruction and other 2 modified ones. The original instruction was: "Please, arrange all the disks, one at a time with one hand, on the surface inside the wood frame as evenly as possible, as if they were biscuits to be placed on a baking tray. Once placed, the disks cannot be moved”. Two modified and simpler instructions have been proposed since children may have difficulty in understanding the expression "as evenly as possible"; thus, another instruction was: “Please, arrange all the disks, one at a time with one hand, on the surface inside the wood frame so that they are placed on as much space as possible, as if they were biscuits to be placed on a baking tray. Once placed, the disks cannot be moved”; and the other was: “Please, arrange all the disks, one at a time with one hand, on the surface inside the wood frame so that they are as far away from each other as possible, as if they were biscuits to be placed on a baking tray. Once placed, the disks cannot be moved”.

The first two instructions did not produce satisfactory configurations: children often anchored the disks to the frame, either sideways or on the top and bottom, placing them as a row one behind the other. The instruction that turned out to be more suitable, that is the one that, for most children, brought out a final configuration of evenly spaced cubes, was the third one, which was then further modified as follows: “Here are some disks in front of you: please, on my count, arrange all the disks on the surface inside the wood frame as far away from each other as possible. Pretend these are cookies to be placed on a baking tray, one at a time with one hand. Once placed, the disks cannot be moved. By repeating, arrange all the disks as far away from each other as possible."

The addition of "on my count" is motivated by the fact that very often children acted impulsively and very quickly began to place the disks without waiting for the instruction to finish. The expression "arrange them as far away from each other as possible", although different from the original E-BTT instruction, is the easiest way for most children, especially in the younger age groups, to understand that the objective is an even distribution of objects on a space; the expression equally implies an objective to be represented mentally and to be achieved, therefore a visuospatial planning and organization, albeit a very simple one. An element that is made explicit with this instruction is that of estimating the distances between one object and another. The instruction is then repeated at the end to ensure that it is understood and memorized as best as possible by the children.

### 2.2.2. E-BTT administration

The experimental sessions started immediately after the conclusion of the instruction study. The E-BTT was part of a visuospatial skills assessment battery administered in two different sessions. In the first session Raven Colored Progressive Matrices and E-BTT were administered. After performing Raven’s CPM, the children were instructed with the E-BTT task and asked to do it first with their dominant hand and then with the other.

Before giving the E-BTT adapted instruction, the procedure also required the children to perform a short pre-test: particularly, they were asked to 1) place a disk inside the frame 2) place another one near the first one and 3) place a third one away from the first. This pre-test was conducted to make sure the children understood the spatial concepts of the proximity or distance of objects from other objects.

## 2.3. Measures and data analysis

The E-TAN software platform records the spatial coordinates (x and y) of each single disk placed on the tray, the order of placement and the duration of the performance. The data output consists of an Excel file with the coordinates in pixels (then normalized in centimeters). The center of the tray has been set to coordinates 0,0. A negative x indicates a point to the left of the center and a positive x indicates a point to the right, as well as a negative y indicates a point below the center and a positive y indicates a point above.

To evaluate the initial spatial orientation, that is, where one begins to arrange objects in the peripersonal space, the coordinates of the first disk positioned on the surface has been used; moreover, the average horizontal or vertical position of all placed objects (average of the X and Y of the 16 disks) has been also considered as a measure of the center of the disposition. The center of the frame has been marked with (0, 0), we also divided the surface into 4 equal quadrants (top-left, bottom-left, top-right, bottom-right), to evaluate the quadrant of initial orientation, that is the frequency that the 4 quadrants were used to arrange the first object.

E-BTT performance was first analyzed by means of the measures described. Data computation was performed using SPSS [27] and R [28] software.

## 3. Results

To conduct the following preliminary analyses, 5 children had to be excluded due to E-TAN software issues. Left-handed participants were also excluded. Therefore, the analyses were carried out on a final sample of 122 children (63 males).

## 3.1. Spatial orientation

To evaluate the children's initial spatial orientation in the E-BTT task, we first divided the space into four equal quadrants and analyzed the distribution of the first disk (unlike adults, see [23]). Frequency analysis demonstrated that 37.70% (n = 46/122) of participants began arranging the first disk in the bottom-left quadrant of the space. The next most frequent quadrant was the top-left one (27.05%; n = 33/122). The bottom-right quadrant was chosen with a frequency of 25/122 (20.49%) and the top-right quadrant with a frequency of 18/122 (14.75%). The analysis carried out of Pearson's chi square among the four positioning alternatives led to the following results: $\chi 2$ = 14,197, df= 3, $\chi 2$ / dof = 4,732, p = .003. Hence, the result demonstrates a preference to position the first disk in the bottom-left quadrant and a lower frequency for that in the upper right portion of the space.

Regarding the comparison between children and a sample of 122 young adults [19] with respect to the quadrant of the first disk positioned, a statistically significant difference emerges ($\chi 2$ = 25,805, df= 3, p< .001). These data show that children tend to place the first disk more at the bottom and that, even if prevalent, the shift to the left is not as prominent as that of adults, since children still tend to shift to the right too.

We then conducted a univariate ANOVA, setting as independent variables the x coordinates of the first positioned disk and the x coordinates average, which revealed a difference for first disk x coordinate (Figure 2a) between adults (M = -16,013, SE = 1,826) and children (M = -6,813, SE = 1,826): F(1.242) = 12,694, p <0.001, $\eta 2$=0.050, with a low- to mid- effect size value, as for first disk y coordinates average (Figure 2b): F(1.242) = 12,905, p <0.001, $\eta 2$=0.051 (adults M = 4,129, SE = 1,479; children M = -3,385, SE = 1,479).

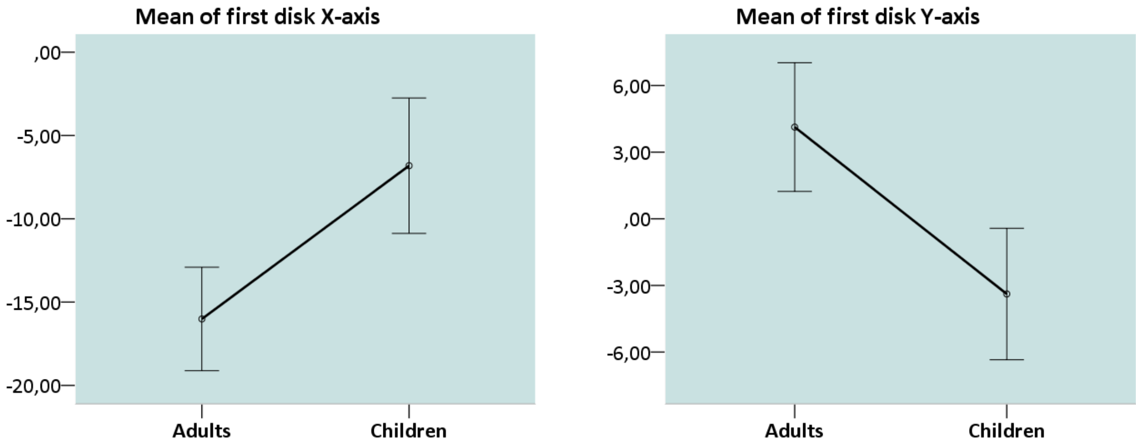


**Figure 2**: On the left (a) mean of first disks x-coordinate (cm) of adults vs children; on the right (b) mean of first disks y-coordinate (cm) of adults vs children.

Moreover, the average horizontal position of all the positioned objects turns out to be different between the two groups (F(1.242) = 9,116, p <0.05, $\eta 2$=0.036) despite a low effect size value, with the adults (M = -1,363, SE = 0,264) moved slightly more to the left than the children (M = -0,234, SE = 0,264). On the other hand, the average vertical position of all placed objects did not differ between the two groups (F(1.242) = ,147, p = 0,702, $\eta 2$=0.001).

Therefore, consistently with the results of the quadrants analysis, the X-axis coordinates average of children is shifted towards the left of the space, but much closer to the center as opposed to that of adults which is clearly more leftwards.

## 3.2. Preliminary cluster analysis

Our following purpose was to analyze the children initial attention orientation more precisely, and to highlight possible groupings among the subjects; thus, the participants were clustered according to the X and Y coordinates of the first disk, which were then compared with the adults' sample clustering, also based on the first disks' X and Y coordinates. Particularly, what we wanted to verify was the presence of groups of children whose first disk was not extremely lateralized to the left or to the right and if so, identify the representative spatial localizations of those groups.

A cluster analysis was conducted by using the K-means algorithm, that requires the number of clusters to be specified. To estimate the optimal number of clusters in our data such we used the Silhouette Coefficient and performed a silhouette analysis between 2 to 5 numbers of clusters both for children and adult dataset. The best silhouette score for the children dataset resulted for a number of clusters equal to 5 (si = 0.8); the best silhouette score for the adult's dataset resulted for a number of clusters equal to 4 (si = 0.86).

Cluster analysis on children dataset identified the following 5 distinct cluster groups (please, check Figure 3): of the 122 participants, 31,97% (cluster 5, n = 39) were classified as positioning the first disk in the bottom-left portion of the space; 22,13% (cluster 2, n = 27) as positioning the first disk at the center of the space, mainly in the center of the Y-axis, but also above and below the 0 point; 18,03% (cluster 1, n = 22) as positioning the first disk in the bottom-right portion of the space; 17,21% (cluster 3, n = 21) as positioning the first disk in the top-right portion of the space; 12,30% (cluster 4, n = 13) as positioning the first disk in the top-left portion of the space. Cluster 2 reveals a group of children directing the first object in the central area of the space.

K-means cluster analysis on adults dataset identified 4 distinct cluster groups (please, check Figure 4): of the 122 participants, 59,02% (cluster 1, n = 72) were classified as positioning the first disk in the top-left portion of the space; 25,41% (cluster 4, n = 31) as positioning the first disk in the bottom-left portion of the space; 10,66% (cluster 2, n = 13) as positioning the first disk in the bottom-right portion of the space; 4,92% (cluster 3, n = 6) as positioning the first disk in the extreme top-right portion. No cluster revealed any group of adults who placed the first object in the central area of the space.

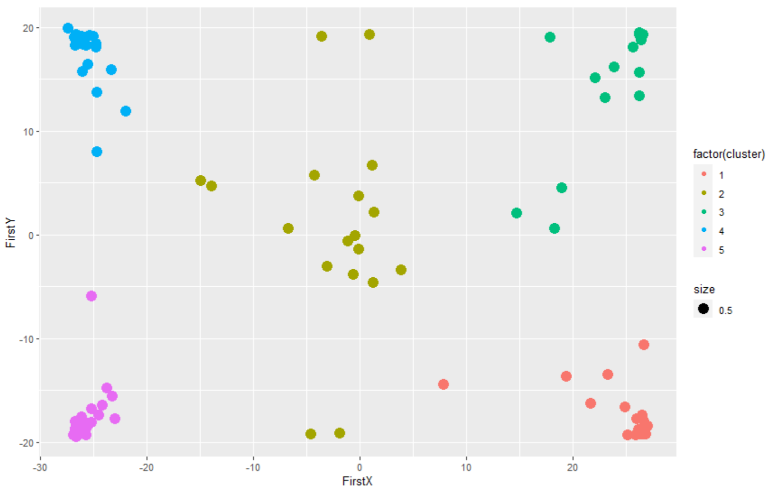


**Figure 3**: Children’s K-means Cluster Analysis results

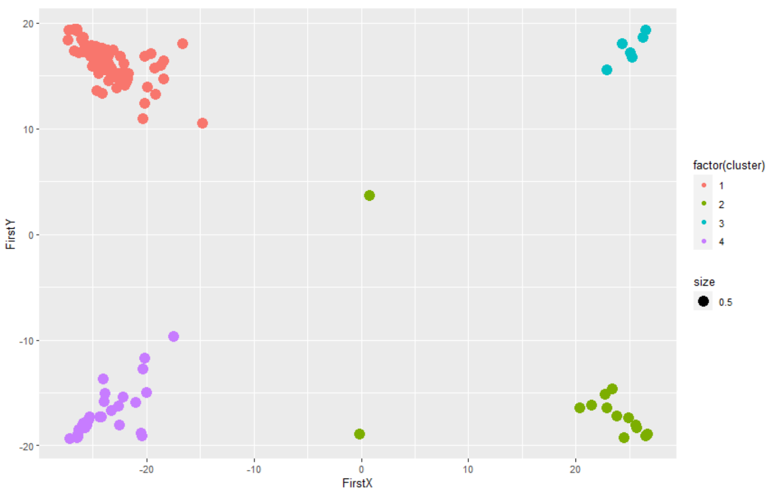

**Figure 4**: Adults' K-means Cluster Analysis results

## 4. Discussions and conclusions

As expected, the majority of children started spatial organization on the left-side of the space, particularly the bottom-left portion of space; however, the comparison between adults and children data revealed a significant difference, since children's leftward shift was less pronounced than that of adults. Children also started disks disposition on the right-side of the space and didn't demonstrate any propensity to initially orient spatial attention to the upper-left quadrant of the space (the starting location for reading) as much as adults, rather than simply orienting more leftward. This finding could be explained by the size of the frame; especially younger children could find it difficult to fully explore the frame with their arms.

Moreover, we conducted a cluster analysis to understand if, in addition to positioning first disks in specific quadrants, participants first disks were extremely lateralized to the left or to the right and, if not, identify the representative spatial localizations of those groups. The results showed that there is a group of children that is more oriented to the center of the space, positioning the first disks centrally, at the bottom or at the top of the Y-axis. This tendency toward the center was not present in the adult's sample.

Again, we expected children to be less shifted towards the left side of the space than adults, on one hand because left-sided bias gradually increases during primary school years in Western cultures. On the other hand, it is possible that children's tendency to start the task centrally reflects a preference for using specific spatial reference points of an empty space (such as corners or central points), which could sustain the orientation on the peripersonal space, as well as it happens in the landmark-based extrapersonal spatial orientation [29]. It seems that children focused on those points rather than the directional path of disposition and the final configuration of disks. However, these hypotheses will be subsequently analysed, e.g. investigating the disposition pattern followed by the children, in order to understand the disposition strategy implemented and how it develops based on the starting point.

Our results show that performances on E-BTT (so far only in terms of the positions of the first placed object) support what has been reported in the literature on pseudoneglect regarding other tasks: that it emerges during development in relation to biological, cultural and biomechanical factors. Children, as adults, show a leftward orientation shift in the E-BTT task however not marked as that of adults: children orient the first object disposition to the left side of the space but also to the right, and especially to the center.

The reported results are preliminary; we plan to implement the following analyses in the future. First, the orientation of the spatial attention in the E-BTT task will be compared with that shown in other tasks of the spatial battery, to explore if the pseudoneglect phenomenon manifests itself differently in different tasks, as demonstrated in the literature for adults [30], even in childhood. We also collected data on left-handed participants; we shall assess whether left-handers show different spatial bias, as reported in the literature [8] [10].

In the near future we also plan to assess whether the starting point of the object's organization influences the subsequent arrangement pattern and compare the organization of spatial arrangement between children and adults. We shall also use the E-BTT to assess whether starting at the extreme side of a space in a visual search task provides a foundation for more organized search than starting in the middle of the page, perhaps because it decreases the likelihood of path intersections [16].

The E-BTT task was originally developed to assess and quantify asymmetries in spatial cognition resulting from unilateral spatial neglect (USN) following brain injury. Studies have been carried out with adult patients, however the literature on children who have suffered a perinatal brain injury is scarce. Some reviews on the topic [31] [32] point out that it may be necessary to use different types of assessment tools to test children with perinatal brain damage in order to develop a complete profile of specific attentional and perceptual deficits. In this way, therapies could be tailored to target specific deficits. In addition, specific considerations may be envisaged in school settings to better accommodate these children. To adequately assess cognitive functioning in this population, the authors recommend a combination of measures, including the use of pencil and paper neuropsychological tests, which remain fundamental as well as tasks sensitive to deficits in daily functioning. The E-BTT could represent a useful ecological tool to assess USN in developmental age.

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