Artigo Original

Zero-a-Seis

EXPLORING KINDERGARTEN CHILDREN'S PERCEPTION OF SPATIAL RELATIONS

Percepção das relações espaciais em crianças da Educação Pré-escolar

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ABSTRACT
This paper focuses on young children's perception of spatial relations. It analyses spatial relations of kindergarten children (3-5-years-old, N=15), addressing two questions: How do children perform when solving perception of spatial relationships problems? What strategies do children use when solving these problems? Qualitative methods were used to describe children's reactions when solving problems of: recognizing position from 2D to 3D, recognizing parts of the whole, recognizing the position of the objects. Results suggests that recognizing position from 2D to 3D seems to be the most difficult problems. Even 3-years-old used successful strategies in solving the perception of spatial relations problems. Thus these problems can be explored in kindergarten, as a way to stimulate visualization skills.
KEYWORDS: Kindergarten; Mathematics; Spatial relations; Geometry.

RESUMO
Este artigo explora o conhecimento de crianças pequenas sobre as relações espaciais. Analisa as relações espaciais de crianças de jardins de infância (3 aos 5 anos, N=15), procurando responder a duas questões: Como as crianças resolvem problemas de percepção das relações espaciais? Que estratégias as crianças usam ao resolver esses problemas? Foram usados métodos qualitativos para descrever as reações das crianças na resolução de problemas de: passagem de imagens em 2 para 3 dimensões, reconhecer partes de um todo e reconhecer a posição dos objetos, construção com blocos, puzzles e identificação de posição. Os resultados sugerem que os problemas de construção com blocos parecem ser os problemas mais difíceis. Até os três anos de idade usaram estratégias bem-sucedidas na solução da percepção de problemas de relações espaciais. Assim, esses problemas podem ser explorados no jardim de infância, como uma maneira de estimular as capacidades de visualização.
PALAVRAS-CHAVE: Educação pré-escolar; Matemática; Relações espaciais; Geometria.

1. INTRODUCTION

Kindergarten children possess an informal geometry that serves as the basis for learning formal geometry. Geometry in general, and spatial reasoning in particular, are fundamental components of mathematical learning from the earliest years (GOMES, 2007; JONES, 2002; NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS, 2000). Spatial thinking is a human capacity used in daily life, in problem solving, and contributes to mathematical ability (CLEMENTS; BATTISTA, 1992; CLEMENTS; SARAMA, 2007). Children with greater spatial sense are better at mathematics (CLEMENTS; SARAMA, 2007) because many mathematical concepts comprise a visual dimension (CLEMENTS; BATTISTA, 1992; CLEMENTS; SARAMA, 2007). Moreover, connections and coherence among mathematical ideas are enriched when educators can apply number concepts and processes to spatial structures (BAROODY; CLEMENTS; SARAMA, 2019; CLEMENTS; SARAMA, 2007).

The National Council of Teachers of Mathematics (NCTM, 2000) points out that kindergarten programs through Grade 2 should enable children to, among other things, use visualization, spatial reasoning, and geometric modelling to solve problems. Also the Portuguese official guidelines for pre-school education (from 3 to 6 years-old) refers that spatial visualization is a process that involves the construction and manipulation of mental images of objects in two or three dimensions, and building visual representations that are essential for life. In this document, spatial thinking integrates spatial visualization and spatial orientation (Silva, et al., 2016). Spatial visualization includes abilities related to children perceiving the surrounding world and their ability to interpret, modify and anticipate transformations of objects (MATOS; GORDO, 1993). Spatial visualization tasks should provide the development of children's spatial reasoning.

In literature, the spatial sense is named as spatial visualization (MATOS; GORDO, 1993; NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS, 2000; SILVA; MARQUES; MATA; ROSA, 2016) or visual perception (FROSTIG, 2017; FROSTIG; HORNE; MILLER, 1994; 2002). According to Matos and Gordo (1993), spatial visualization includes abilities related to children perceive the surrounding world and their ability to interpret, modify and anticipate transformations of objects. For NCTM (1989; 2000), spatial sense is an intuitive sense of environment and objects. As there is no agreement in the definition of spatial visualization, in this paper spatial visualization is understood as visual perception. This concept it is the ability to observe, manipulate, transform, comprehend and imagine movements of objects, images in two and three dimensions, with the purpose of organizing information, thinking, developing previously unknown ideas and advancing in knowledge (ARCAVI, 2003; CLEMENTS; BATTISTA, 1992; CLEMENTS; SARAMA, 2011; PONTE; SERRAZINA; GUIMARÃES; BREDA *et al.*, 2007; SARAMA; CLEMENTS, 2009).

Del Grande (1990), based on the works of Brennan, Jackson and Reeve (1972), first considered nine capabilities: visual copying; hand-eye coordination; left-right coordination; visual discrimination; visual retention; visual rhythm; visual closure, figure-ground relationships; language and perception. Afterwards, Del Grande distinguished seven capacities, also in relation to the previous work of Hoffer (1977) and Frostig (1964), arguing that "have been selected as having relevance to the study of mathematics and geometry in particular." (DEL GRANDE, 1990, p. 14). These capacities are: eye-motor coordination; figure-ground perception; perceptual constancy; position-in-space perception; perception of spatial relationships; visual discrimination; visual memory. The firsts capacities are the same of Frostig and colleagues (1994; 2002). The visual discrimination is the ability to identify similarities and differences among or between objects, independent of the position. The visual memory is the ability to remember accurately objects no longer in view and list their characteristics to other objects in view or not (DEL GRANDE, 1990).

Frostig, Horne, and Miller (1994; 2002) focused on visual perception considering it as the ability to recognize and discriminate visual stimulus and interpret them, associating them with previous experiences. The development of these abilities extends to other areas of learning (FROSTIG, 2017; FROSTIG; HORNE; MILLER, 1994; 2002).

Frostig and colleagues (1994; 2002) defined five visual perception abilities important in children's learning: visual motor coordination, figure background perception, perceptual constancy, perception of position in space and perception of spatial relationships. Visual motor coordination is the capacity to coordinate vision with the movements of the body and its parts; figure background perception is the ability to identify a specific component in a situation that involves a complex background, where portions of that component are distorted and intersected. This ability is also defined by the distinction between foreground and the bottom of that plane. Perceptual constancy, also called constancy of shape and size is the ability to identify an object with invariant properties presented in different shapes, positions, sizes, brightness, textures and colours; perception of position in space, that is the relation in the space of an object with its observer, and it carries the ability to perceive objects that are behind, ahead, above, below, or to the right and left side of oneself. This paper focuses on the perception of spatial relations or spatial relationships, the ability of an observer to perceive the position of two or more objects in relation to themselves and the relation between objects (DEL GRANDE, 1990; FROSTIG; HORNE; MILLER, 1994; 2002). This ability develops after the perception of the position in space and is the consequence of it. The authors suggest beads, balls, geometric blocks and other similar materials to develop this ability.

The ability of perception of relation of space is essential to play hide and seek, because the child has to be able to imagine the point of view of the colleague who is looking for him to hide (MATOS; GORDO, 1993). The relationship between geometric objects and perspectives and their planning is included, since in a construction with cubes, the children must perceive the position of the cubes in relation to her/himself and the relation of the cubes to each other. The authors suggest activities such as copying cube constructions, that is, an image is presented with cubes constructed and the child is asked to reproduce with cubes (DEL GRANDE, 1990; GORDO, 1993; MATOS; GORDO, 1993).

In Portugal, research studies on kindergarten children's abilities related to spatial visualization are seldom. Nevertheless, curricula for mathematics in the kindergarten underlies the exploration of tasks related to it in order to develop children's visual perception. In order to understand kindergarten children's visual perception, their ability to solve spatial visualization problems was analysed.

Ceia (1991) studies 12 children's ideas of square and rectangle, using individual interviews to 8 – 9- year-olds students. Ceia's findings revealed that children have difficulties when identifying these shapes in different positions. In particular position of the shape, children also showed some confusion with angles recognition. The children found difficult to represent the relation between squares and rectangles, depending on position.

Gordo (1993) studied third-graders' (N=44) spatial visualization abilities and their relation with mathematical concepts acquisition. Experimental and a control group were organized. The experimental group were expose to tasks to prompt their spatial visualization whereas the children of the control group did not. Pre-, Post- and delayed Post-tests were used. Results showed that children of the experimental condition improved their spatial visualization abilities, except their perception of spatial relations, in which low results were achieved. Gordo underlined that the children's spatial visualization awareness can be related to their ideas of geometrical concepts.

More recently, Alves and Gomes (2011) studied the perception of spatial relations with kindergarten children and 1st-graders (N=61), from 3-6-years-old, trying to understand children's spatial visualization abilities. The geometrical tasks tried to assess visualization ability (visual memory, perceptual constancy, background-figure perception, perception of position in space, and perception of spatial relations) and also children's knowledge of shape and geometric vocabulary. Results showed that kindergarteners have some visualization competency but requiring improvement, suggesting that appropriate tasks could be used in that sense. Alves and Gomes (2012) also studied the perception of spatial relations with 16 kindergarten children, using qualitative methods relying on interviews to pairs of children. The authors argue that children possess predominately topological relations in spatial representation, namely on proximity relations (children use the expression "near of" instead of "on left" or "or right"); and that it seems that there is a relation between the figure-background perception and the identification of the spatial relations abilities, which is very important to the development of children's geometrical representation and vocabulary.

Batista (2013) analysed children's figure-background perception and perception of position in space with 1st-graders (N=20), using qualitative methods to analyse their reaction to a battery of 13 tasks on these issues. Results showed that children developed their ability to identify figures immersed on others, and to draw figures with reflection symmetry, underlying that the resources and materials used were fundamental for these achievements.

The international literature also presents some studies on spatial thinking. Clements, Swaminathan and Sarama (1999) investigated the criteria of preschool children (N=97), to distinguish some figures from others. Individual interviews were carried out on 97 children aged 3 to 6 years, emphasizing the identification and description of the shapes and reasons for these identifications. The children would have to select the circles, among a set of figures and explain the reason why they chose that figure. The same was done for squares, triangles and rectangles. Results showed that there were children who could not reliably distinguish circles, triangles, squares and rectangles from counterexamples. For this reason, they should be classified as included in a Van Hiele pre-recognition level, and children who are learning to do this, in the transition rather than considering them at the visual level. Thus, they consider that there is a pre-recognition level before Van Hiele's Level 1 ("visual level") and that level

1 should be re-conceptualized.

Tian and Xuang (2009) used an image with several houses that appear in perspective, one behind the other, to carry out this study. Participants included children from kindergarten and children from the 1st cycle (4- to 8-years-old, N=1887). Results suggest that children's spatial reasoning ability develops earlier than their quantitative reasoning ability; that interactions between the individual and the environment are fundamental factors for children's development; that children's cognitive process is a successive integration phase.

(COHRSSEN; QUADROS-WANDER; PAGE; KLARIN, 2017) investigated 4-5-years-old children's ideas of shape and their representations of spatial thinking (N=19), when solving tasks related to geometry in the early years. The tasks involved the explorations of patterns and shapes, cross-sections of buildings and architectural drawings were used, given children the opportunity to spatial orientation and spatial visualization, to use language of shapes, direction and location or other forms of symbolic representation. Their results showed that children identified, named and explained 2D shapes (like the circle, square, hexagon and octagon) and identified and named 3D shapes (like the cube, pyramid and cylinder); they also drew their own maps and interpreted their colleagues' maps. These achievements were a strong acquisition for the early years mathematics.

The study presented here was inspired in previous research on children's spatial sense. It is an academic novelty contribution for the Portuguese research as it includes children aged 3 and 4 years, and embraces several components of geometry, specifically the perception of spatial relationships.

This study tries to understand young children's spatial relations. For that, two questions were addressed: How do children perform when solving tasks of perception of spatial relationships? What strategies do children use when solving these tasks?

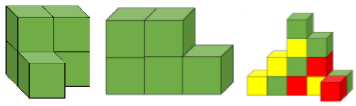
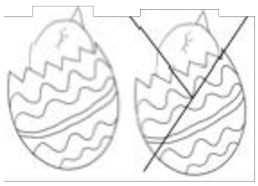
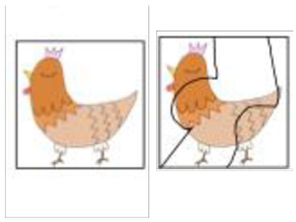
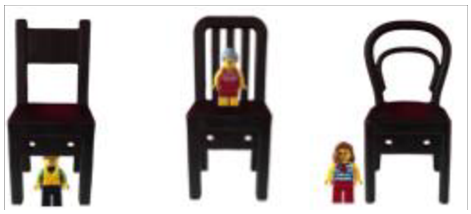
2. METHODS

Qualitative methods using an interpretative approach (BOGDAN; BIKLEN, 2010; FORTIN; COTÊ; FILION, 2009) were adopted to understand children's spatial relationships. A descriptive research was carried out, in which the data source was the natural environment, and data was collected in the form of words or images. In agreement with Bodgan and Bicklen (2010), and Denzin and colleagues (2005), in this type of research, the main interest is more in the process than in the results or products.

The participants were 15 children, from 3 to 5 years old, from state supported and private kindergartens of Braga, in Portugal. There were 5 children of each age level.

Individual interviews were carried out on the children in order to analyse their performance when solving spatial relationships problems. Each interview comprised tasks of perception of spatial relationships. These tasks included 6 problems of building blocks, 2 of puzzles, 2 of position identification. Table 1 presents some examples of these problems.

Table 1 - Examples of the problems of perception of spatial relations presented to the children.

Problem	Materials
Recognizing position from 2D to 3D - Can you do this building with these blocks?	
Recognizing parts of the all - Solve the puzzle. Did it look the same?	 
Recognizing the position of the objects - Can you put the chairs and dolls as in the picture? What is the dolls position?	

Fonte: dados da pesquisa (Balinha e Mamede, 2019).

In each problem, the interviewer presented the problem to the child orally and made the material available. After solving the problems, the children were challenged to explain their answers by the questions "Why do you think so?" or "How do you know that?". During the interview, the children were free to interrupt or quit at any time. For some problems, manipulative materials related to the context of the problem were available for children.

The interview was conducted by the researcher, one of the authors of this paper. Each interview lasted, approximately, 20 minutes.

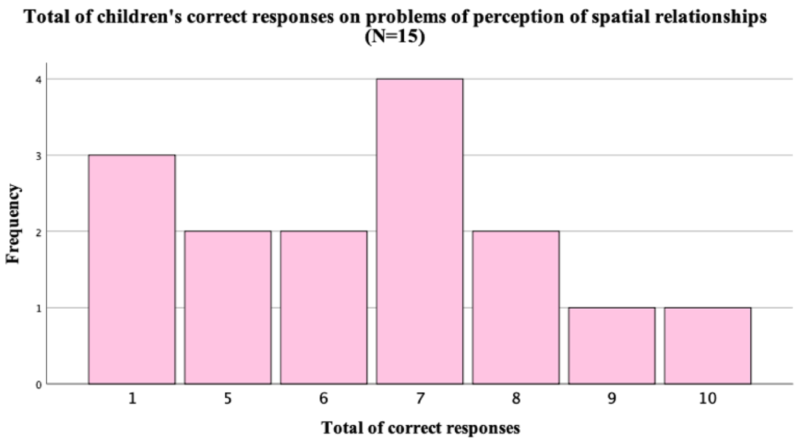
The data collection was carried out using audio and video recording, children's written resolutions, children's constructions, and researcher's field notes.

3. RESULTS

One point was awarded to each correct response given by the child when solving the problems. Ten problems of perception of spatial relationships were presented to the children, comprising recognizing position 2D do 3D, recognizing parts of a whole and recognizing the position of the objects.

The total of children's correct responses to the problems of perception of spatial relationships had a Mean of 5,9 (S.D.= 0.74). Eight of the 15 children could succeed in at least 70% of the given tasks. Figure 1 presents the total of children's correct responses on these problems.

Figure 1 - Total of children's correct responses on problems of perception of spatial relationships.



Fonte: dados da pesquisa (Balinha e Mamede, 2019).

All the children could succeed in at least one of the given problems, and most of the children succeeded in at least 50% of the presented problems. Table 2 gives the mean (S.D.) of the correct responses, according to the age, for the 10 problems.

Table 2 - Mean (S.D.) of the correct responses according to the age.

Age	Mean (S.D.)
3-years-old	3,2 (3,0)

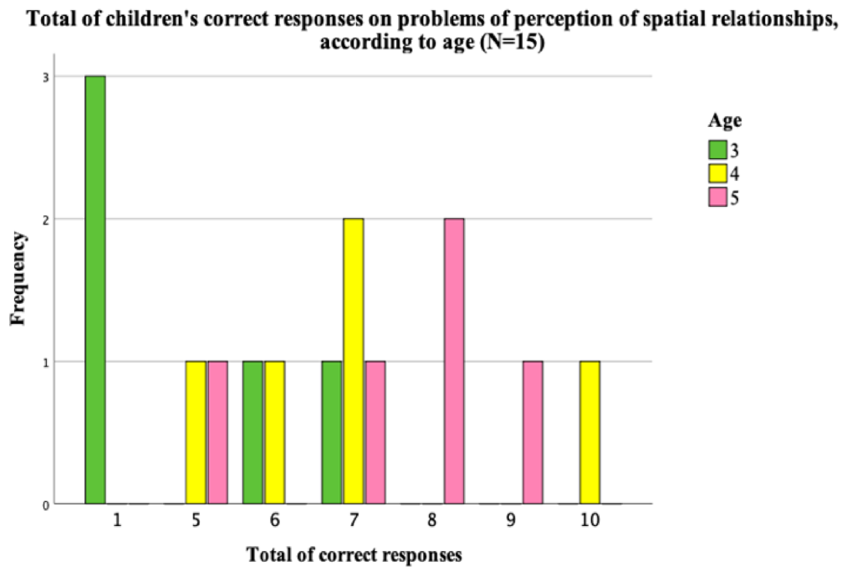
4-years-old	7,0 (1,9)
5-years-old	7,4 (1,5)

Fonte: dados da pesquisa (Balinha e Mamede, 2019).

These results suggest that perhaps the children's performance is affected by their age level. Five-year-olds children have a higher success than 3-year-olds children, which is not a surprisingly result, but 3-years-old were able to succeed in several tasks and this is a remarkable result.

Figure 2 presents the total of children's correct responses according to the age level. Only one child could succeed in all the given problems, and this child was 4-years-old; one 3-years-old child could solve correctly 70% of the presented problems, and another 60% of the total of problems.

Figure 2 - Total of children's correct responses on problems of perception of spatial relationships, according to age.



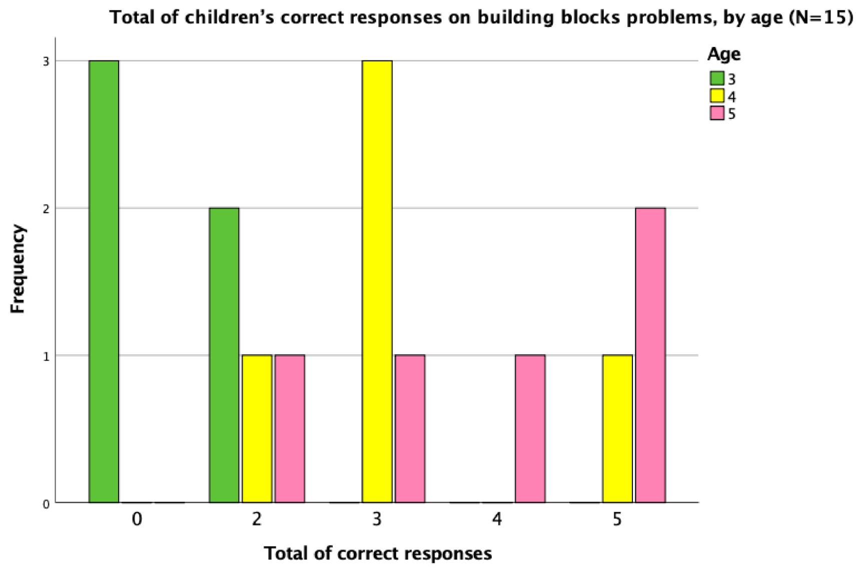
Fonte: dados da pesquisa (Balinha e Mamede, 2019).

These results suggest that the younger children, such as 3-years-old, could get some sense of the perception of spatial relations in order to succeed in these problems. Possibly this can indicate that it makes sense to include these type of tasks in the kindergarten practices, in order to stimulate and prompt children's development of spatial visualization.

An analyse on children's performance allow to identify some of their strategies, when solving the problems. These analyses will be presented here according to the type of problem (recognizing position 2D do 3D, recognizing parts of a whole and recognizing the position of the objects).

To analyse the perception of position in space, three types of problems were analysed: comprising the recognition of position from 2D to 3D, the recognition of parts of a whole, and the recognition of the position of the objects. Figure 3 presents the distribution of the number of children's correct responses when solving problems to recognizing position from 2D to 3D with building blocks, according to age. Children were challenged to solve six problems of building blocks, in which they had to recognise the position of block given in a card and represent it with real blocks.

Figure 3 - Total of children's correct responses on building blocks problems, by age.

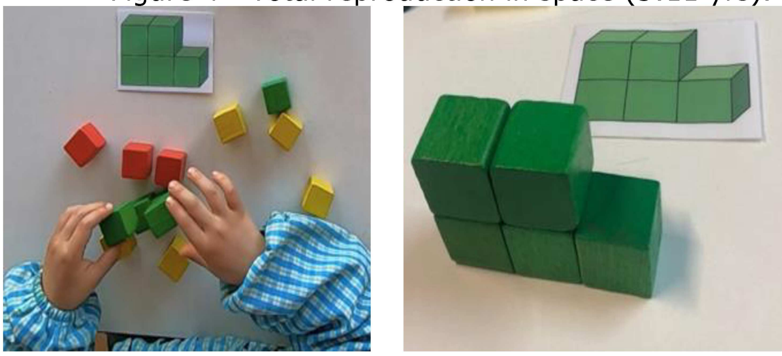


Fonte: dados da pesquisa (Balinha e Mamede, 2019).

Analysing children's performance when recognizing position from 2D to 3D, different strategies were identified. Children's strategies can be distinguished into the following categories: 1) total reproduction in space, when the child reproduces the picture in space building the correct construction; 2) build on card, when the child builds the construction on the card; 3) random blocks, when the child put the blocks in random position and choose blocks randomly; 4) wrong number of blocks when child use more or less blocks than their needed; and 5) wrong position if the children put the blocks in the wrong position, in relation to the picture.

Only the strategies of total reproduction in space and build on card could allowed children to succeed. Figure 4 shows one 3-years-old and 11 months child solving the problem correctly, using the total reproduction in space, building the blocks in the right position in space near the picture. For that, the children had to choose the correct colour blocks, and put them in the right position.

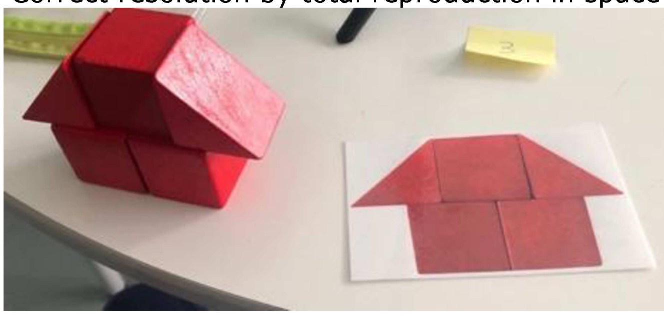
Figure 4 - Total reproduction in space (3:11 yrs).



Fonte: dados da pesquisa (Balinha e Mamede, 2019).

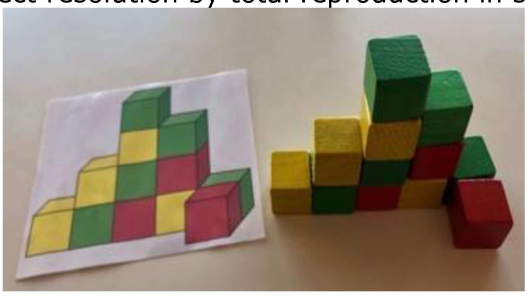
Figures 5 and 6 also show correct solution presented by two different 4-years-old children. In both problems, the children were able to build their constructions near the given picture. Some of the children were only able to succeed in these problems when building the constructions on the card of a given picture (Figure 7).

Figure 5 - Correct resolution by total reproduction in space (4:0 yrs).



Fonte: dados da pesquisa (Balinha e Mamede, 2019).

Figure 6 - Correct resolution by total reproduction in space (4:0 yrs).



Fonte: dados da pesquisa (Balinha e Mamede, 2019).

Figure 7 - Correct re … the card (5:5 yrs).

Fonte: dados da pesquisa (Balinha e Mamede, 2019).

Table 2 presents the percentage of the type of strategy observed when solving recognizing position 2D do 3D, according to age.

Table 2 - Percentage of type of strategy used, by age - Building blocks problems.

	Building blocks (%)		
Type of strategy	3-years-old	4-years-old	5-years-old
Total reproduction in space	16	64	72
Build on card	24	0	4
Random blocks	44	8	4
Wrong number of blocks	0	4	4
Wrong position	16	24	16

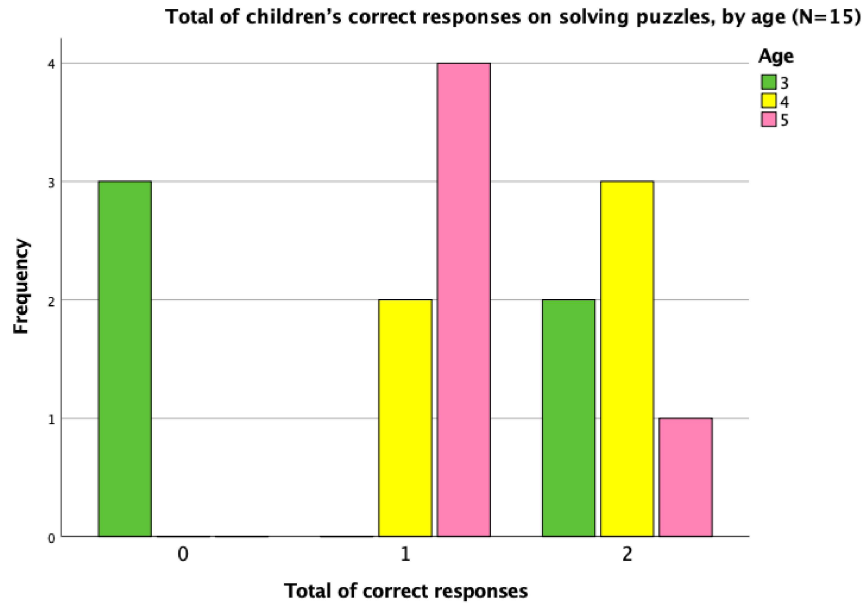
Fonte: dados da pesquisa (Balinha e Mamede, 2019).

In the building blocks problems, the 4- and 5-years-old children could succeed in most of the problems; the youngest ones found it more difficult, but even being so, 40% were able to succeed, from which 16% made a total reproduction in space and 24% made the construction on the card. All the other strategies produced incorrect responses. No child was able to solve correctly all the problems.

3.1. Recognizing parts of a whole picture

Figure 8 presents the distribution of the number of children's correct responses when recognizing parts of a whole (puzzles) according to age. Children were challenged to solve 2 puzzles.

Figure 8 - Total of children's correct responses on solving puzzles, by age.



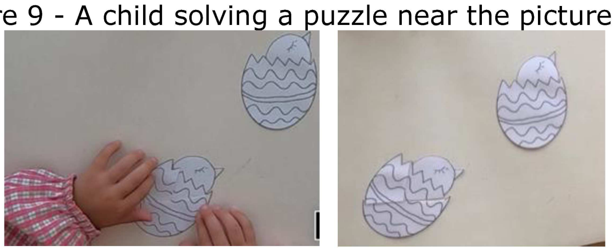
Fonte: dados da pesquisa (Balinha e Mamede, 2019).

Among the youngest ones, there were 3 children who could not solve any puzzle problem at all, but 2 could succeed in solving both puzzles. For the remaining children, these did not seem to be difficult problems.

When analysing children's performance in recognizing parts of a whole, three different strategies were identified: 1) building near the picture, when the child builds the puzzle near the picture presented; 2) build on the picture, when the child builds the puzzle on the card with the picture; and 3) wrong construction, if children does not build the puzzle correctly.

Figure 9 shows a solution to the problem presented by a 3 years and 11 months child, building it near the picture. Figure 10 gives an example of a solution presented by a child who built the puzzle on the top of the picture.

Figure 9 - A child solving a puzzle near the picture (3:11 yrs).



Fonte: dados da pesquisa (Balinha e Mamede, 2019).

Figure 10 - A child solution to a puzzle building on the picture (3:10 yrs).

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Fonte: dados da pesquisa (Balinha e Mamede, 2019).

Table 3 presents the percentage of the type of strategy observed when solving the puzzles, according to age.

Table 3 - Percentage of type of strategy used, by age – Puzzles.

Recognizing parts of a whole (%)			
Type of strategy	3-years-old	4-years-old	5-years-old
Build near the picture	20	80	60
Build on the picture	20	0	0
Wrong construction	60	20	40

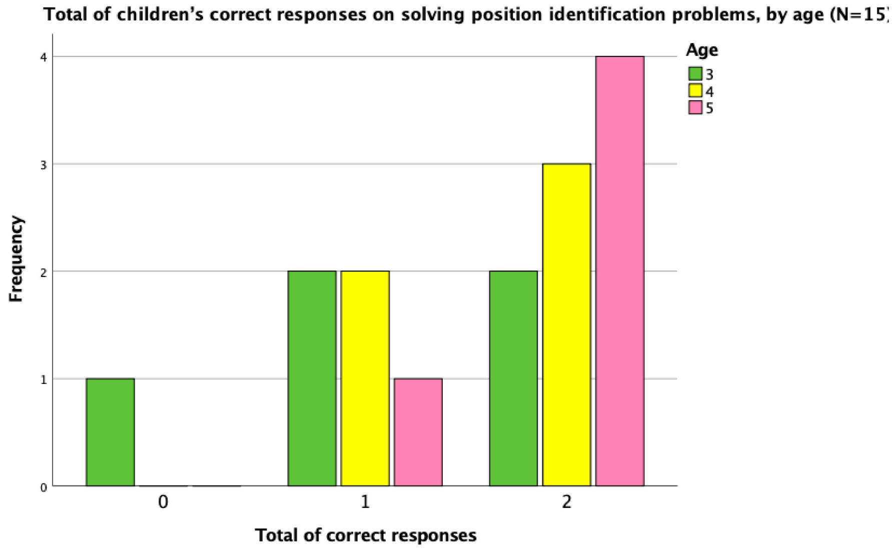
Fonte: dados da pesquisa (Balinha e Mamede, 2019).

In the problems to recognise the parts of a whole, the 4- and 5-years-old children could succeed in most of the problems; the 3-years-old found it more difficult, but even being so, 40% were able to succeed, from which 20% were able to build the puzzle near the picture and 20% succeeded on building the puzzle on the picture. Two 3-years-old children were able to solve correctly all the puzzle problems.

3.2. Recognizing the position of the objects

Figure 11 presents the distribution of the number of children's correct responses when recognizing the position of the objects problems, according to age. Children were challenged to solve 2 problems.

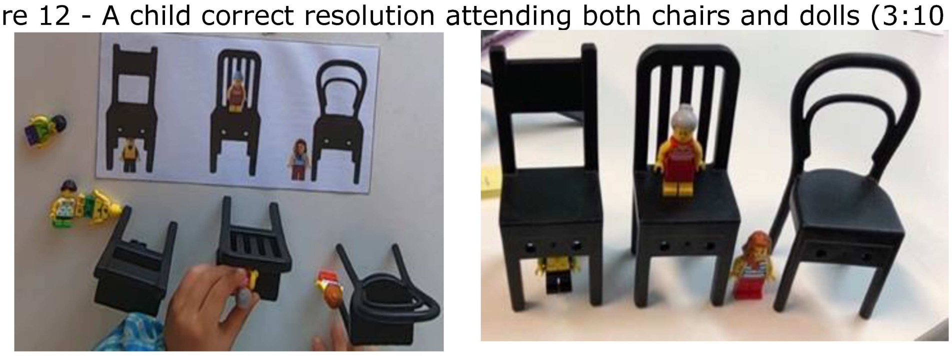
Figure 11 - Total of children's correct responses on solving position identification problems, by age.



Fonte: dados da pesquisa (Balinha e Mamede, 2019).

Children's performance when solving the position identification problems can be distinguished into three categories: 1) attending both chairs and dolls, when children put all chairs and dolls in the correct place; 2) attending only one, when children attends only to one of the elements of the problem, either the chairs or the dolls (e.g. the child puts one or two of the three dolls in the right place, with the wrong position of the chairs); and 3) incorrect, if children do not put any doll or any chair in the right place. Figure 12 presents a 3 years and 10 months child solution, putting the dolls and the chairs in the right position.

Figure 12 - A child correct resolution attending both chairs and dolls (3:10 yrs).



Fonte: dados da pesquisa (Balinha e Mamede, 2019).

Table 4 presents the percentage of the type of strategy observed when solving the position identification problems, according to age.

Table 4 - Percentage of type of strategy used, by age – Position identification.

Position identification (%)			
Type of strategy	3-years-old	4-years-old	5-years-old
Attending both chairs and dolls	40	60	80

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Attending only one	0	40	20
Incorrect	60	0	0

Fonte: dados da pesquisa (Balinha e Mamede, 2019).

Children of all ages were able to succeed in at least one of the position identification problems. However, there was a 3-years-old child that could not get any of the problems correctly solved.

4. FINAL REMARKS

These results suggest that the perception of spatial relations problems can make sense even for the 3-years-old children. The recognizing position from 2D to 3D problems seemed to be the most difficult ones presented to this group of children. The position identification problems seemed to be the easiest ones. In all problems presented to the children, the levels of success increased among the older ones. These findings are in agreement of those presented by previous research (see Gordo, 1993), that showed that it is difficult for children to represent information given in 2D to 3D. Nevertheless, more recent research (see Alves & Gomes, 2011) suggest that even 3- and 4-years-old children can succeed in these types of problems.

In relation to the strategies use by the children on building blocks problems, 3-years-old children could use successful strategies such as total reproduction in space and reproduction on the top of the picture. Some of these problems were quite difficult as children had to manager colour and position in some cases, in other cases shape and position. No problems combining shape, colour and position were presented to these children.

On recognizing parts of the whole problems, 3-years-old children used successful strategies, such as building near the card and building on the top of the picture, whereas the older children succeed mostly by building near the picture. These puzzles had 3 and 4 pieces needed to be put in the correct position. It was remarkable to find children as young as 3-years-old able to solve the puzzle near the picture. Literature has been revealing that children have difficulties when identifying shapes in different positions (see Ceia, 1991). In particular position of the shape, children of the Ceia's research also showed some confusion in recognizing parts of the whole, like in this experiment with puzzles.

When recognizing of the position of the objects, 3-year-olds children could reproduce a correct position of the objects in almost half of the tasks, and these levels of success increased among the older ones, who succeeded in most of the tasks. The children seemed to have no problem in identifying the correct position of one object, but found more difficult to master position identification when the attention to the position of two objects was required. The findings of this study are in agreement with Alves e Gomes (2011), who argue that kindergarten children have some spatial visualization competency as proximity and relative position abilities, such as being able to recognise the "near of", "in front of" and "on top of".

The findings of these exploratory study do not allow generalizations, but give a sense of what young children, since 3-years-old, are able to do regarding the perception of spatial relations. Thus, converging with Cohrssen and colleagues (2017) ideas, educators should provide differentiated, appropriate and adapted practices for children in a way that allows them to build on their informal skills in order to build mathematical ideas that are relevant for the early years geometry.

More research is required regarding these issues in order to have an insight of young children's ability to solve spatial relationship problems such as building blocks, puzzles and position identification. These findings also allow to think about the type of problems that can be explored with young children in kindergarten, as a way to challenge their visualization skills.

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NOTAS

PERCEPÇÃO DAS RELAÇÕES ESPACIAIS EM CRIANÇAS DA EDUCAÇÃO PRÉ-ESCOLAR

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