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Exploring figure background perception of young children

Filipa Balinha and Ema Mamede

CIEC – University of Minho

E-mail: filipa.balinha@gmail.com; emamede@ie.uminho.pt

Abstract. This paper aims to explore figure background perception of young children (3 to 5 years-old, N=15) from kindergarten in Braga, Portugal. For that, it tries to address two questions: How do children perform when solving problems of figure background perception? How do children justify their answers? Qualitative methods were used to describe children's reactions when interviewed individually solving problems of: position of shape, similarities and differences, finding shape, and shape overlay. Children were challenged to solve 4 problems of position of shape, 1 problem of similarities and differences, 4 problems of finding shape, and 3 problems of shape overlay. All the problems were presented to the children through the use of stories, and manipulative materials related to the context of the story problem were available for children. Results suggests that children can succeed in all these type of problems. Nevertheless, the problems of similarities and differences were the easiest ones for young children; the shape overlay problems seems to be the most difficult problems. However, globally one may say that even 3-years-old children used successful strategies in solving the figure background perception problems. These results suggest that figure background perception problems can be explored in kindergarten, with young children, using simple problems that enhance their spatial awareness as a way to stimulate visualization skills.

Resumé. Cet article a pour objectif d'explorer la perception de fond des personnages de jeunes enfants (âgés de 3 à 5 ans, N = 15 ans) de la maternelle à Braga, au Portugal. Pour cela, il tente de répondre à deux questions: comment les enfants se débrouillent-ils pour résoudre les problèmes de perception de l'arrière-plan des figures? Comment les enfants justifient-ils leurs réponses? Des méthodes qualitatives ont été utilisées pour décrire les réactions des enfants interrogés individuellement en résolvant des problèmes de: position de la forme, similitudes et différences, recherche de la forme et superposition de formes. Les enfants ont été mis au défi de résoudre 4 problèmes de position de forme, 1 problème de similitudes et de différences, 4 problèmes de recherche de forme et 3 problèmes de superposition de forme. Tous les problèmes ont été présentés aux enfants au moyen d'histoires, et des documents de manipulation liés au contexte du problème de musique étaient à la disposition des enfants. Les résultats suggèrent que les enfants peuvent réussir dans tous ces types de problèmes. Néanmoins, les problèmes de similitudes et de différences étaient les plus faciles pour les jeunes enfants; les problèmes de recouvrement de forme semblent être les problèmes les plus difficiles. Cependant, globalement, on peut dire que même les enfants de 3 ans ont utilisé des stratégies efficaces pour résoudre les problèmes de perception de l'arrière-plan. Ces résultats suggèrent que les problèmes de perception de l'arrière-plan des figures peuvent être explorés à la maternelle, avec de jeunes enfants, en utilisant des problèmes simples qui améliorent leur conscience spatiale pour stimuler les compétences de visualisation.

1. Spatial visualization in kindergarten education

Children's first experiences are geometric and spatial, trying to understand the world around them, distinguishing one object from another and discovering the degree of proximity of an object (Abrantes et al., 1999). When children move from one place to another, for instance, they have to use their spatial and geometric ideas as they have to decide to go ahead, go forward, turn left or right. This relation with geometry extends throughout life in many other domains of their daily routines.

According to Jones (2002) and the National Council of Teachers of Mathematics (NCTM) (2000), the study of geometry contributes to help children develop visualization skills, critical thinking, intuition, perspective, problem solving, conjecture, deductive reasoning, logical argumentation and proof. 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 (Frey et al, 2013; Gomes, 2007).

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 (Frey et al., 2013; 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 and Battista, 1992, Clements and Sarama, 2007). Children with greater spatial sense are better at mathematics (Clements and Sarama, 2007) because many mathematical concepts comprise a visual dimension (Clements and Battista, 1992, Clements and Sarama, 2007). Moreover, connections and coherence among mathematical ideas are enriched when educators can apply number concepts and processes to spatial structures (Baroody et al., 2019, Clements and Sarama, 2007).

The 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 2 or 3 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 and Gordo, 1993). Spatial visualization problems should provide the development of children's spatial reasoning.

In literature, the spatial sense is named as spatial visualization (National Council of Teachers of Mathematics, 2000, Silva et al., 2016, Matos and Gordo, 1993) or visual perception (Frostig et al., 2002, Frostig et al., 1994, Frostig, 2017). 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, National Council of Teachers of Mathematics, 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 relates to 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, Sarama and Clements, 2009, Clements and Battista, 1992, Ponte et al., 2007, Clements and Sarama, 2011).

Del Grande (1990), based on the works of Brennan, Jackson and Reeve (1972), first distinguished nine capabilities of spatial visualization: visual copying; hand-eye coordination; left-right coordination; visual discrimination; visual retention; visual rhythm; visual closure, figure-ground relationships; language and perception. After that, also in relation to the previous work of Hoffer (1977) and Frostig (1964), Del Grande (1990) argues that "have been selected as having relevance to the study of mathematics and geometry in particular.", and distinguished seven capacities, which 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 (2002, 1994). 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 (2002, 1994) 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 et al., 2002, Frostig et al., 1994, Frostig, 2017).

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; 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. The other capacity is the perception of 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 et al., 2002, Frostig et al., 1994). This ability develops after the perception of the position in space and is the consequence of it.

This paper focuses on the figure background perception, the ability to identify a specific component in a situation that involves a complex background, where portions of that component are distorted and intersected. The figure background perception ability is also defined by the distinction between foreground and the bottom of that plane and it is essential to select a center of interest from a set of stimuli - auditory, tactile or visual (Del Grande, 1990, Matos and Gordo, 1993). These stimuli form a figure in our perceptual field, that is, the part that forms the center of attention, and it that one perceives more clearly the things to which one pays most attention. It may happen that the center of interest changes and that which was a figure becomes deep. For example, when a child is playing with a ball his/her figure is the ball, set against a background that the child does not pay much attention to (flower beds, advertisements around him). If one is interested in another object, such as a bucket, the ball becomes part of the background and the figure would be the bucket. A child with poor figure background ability turns out to be inattentive and disorganized, as his/her attention jumps from one stimulus to another. The children then have difficulty finding a particular piece of text, omit sections, and cannot solve known issues if they appear on a very small page as they are unable to select the important details. Exercises that explore the background figure help to develop the ability to focus attention on the appropriate stimuli, essential in any action directed toward an end and for any school learning. This ability helps the child to see the written or printed figures clearly and in the proper order, without being distracted by the stimuli surrounding them. Activities to develop this ability include: identifying a figure from a set of overlapping figures, completing figures, and assembling a figure from its parts in tangram-type activities (Del Grande, 1990). Matos and Gordo (1993) suggest activities that require the observation of hidden figures, completing figures so that they resemble others, and looking for figures immersed in others - Tangram and paving.

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

This study tries to explore young children's figure background perception. For that, two questions were addressed: How do children perform when solving problems of figure background perception? How do children justify their answers?

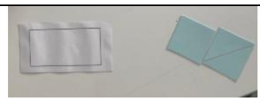
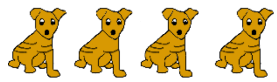
2. Methods

Qualitative methods using an interpretative approach (Fortin et al., 2009, Bogdan and Biklen, 2010) were adopted to understand children's figure background perception. 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.

Children were interviewed individually when solving figure background perception problems in order to analyse their performance and understand their reasoning. Each interview comprised 12 problems of figure background perception. These tasks included 4 problems of position of shape, 1 of similarities and differences, 4 of finding shape and 3 of shape overlay. Table 1 presents some examples of the problems presented to the children.

Table 1. Examples of the problems of figure background perception presented to the children.

	Problem	Material
Position of shape	Can you build these figures with these pieces?	
Similarities and differences	Marks with X the image that is different from all the others. Why is it different?	
Finding shape	Look at the images. Mark with a cross the images that are equal to the shapes above.	
Shape overlay	Can you find animals in the picture below? Which animals do you see?	

In each problem, the interviewer presented the problem to the child orally. For some problems, manipulative materials related to the context of the problem were available for children. 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.

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. Twelve problems of figure background perception were presented to the children, comprising position of shape, similarities and differences, finding shape, and shape overlay. Figure 1 shows the total of correct responses of children, according to age.

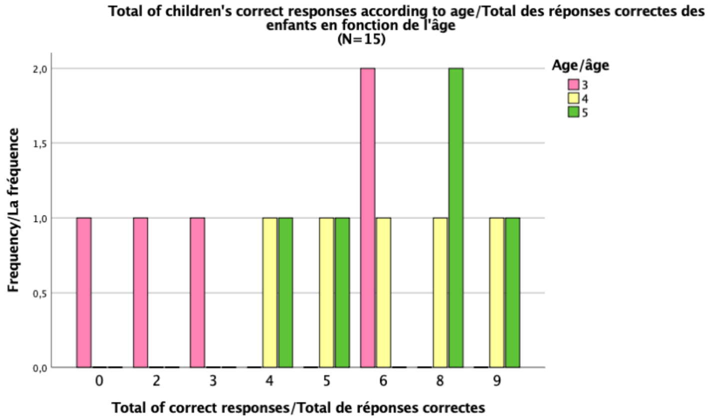


Figure 2. Total of correct responses according to age (N=15).

Only one child could not solve any of the problems. The others could succeed in at least one of the given problems, and most of the children succeeded in at least 50% of the presented problems. Figure 1 presents the total of children's correct responses according to the age level. Two children could succeed in nine of twelve given problems; one 3-years-old child could solve correctly 67% of the presented problems, and another 50% of the total of problems. Table 2 gives the mean (S.D.) of the correct responses, according to the age, for the 12 problems.

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

Age	Mean (S.D.)
3-years-old	3,4 (2,6)
4-years-old	6,4 (2,1)
5-years-old	6,8 (2,2)

These results suggest that children's performance seems to be 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 problems and this is a remarkable result.

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

An analysis on children's performance allows to identify some of their strategies, when solving the problems. This analysis will be presented here according to the type of problem (position of shape, similarities and differences, finding shape, and shape overlay).

3.1. Position of shape

Table 3 presents the percentage of the type of strategy observed when solving problems of position of shape, according to age. Children's performance when solving the position of shape problems could be distinguished into three categories: shape in correct position when children put all shapes in the correct position; some correct shape when children put some shapes in correct position, but others in wrong position; and shapes in wrong position when children does not put any shape correctly.

Table 3. *Percentages of type of strategies used by children on position of shape problems, by age (N=15).*

Position of shape (%)			
Type of strategy	3 years-old	4 years-old	5 years-old
Shapes in correct position	30	60	60
Some correct shapes	30	10	30
Shapes in wrong position	40	30	10

Figure 3 shows three examples of children's resolutions with shapes in correct position.

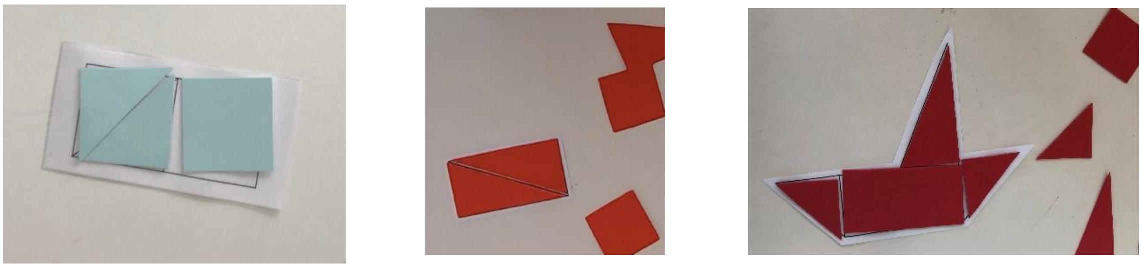


Figure 3. Examples of correct responses in problems of position of shape (N=15).

Young children of 3-years-old were able to succeed in these problems, presenting 30% of correct resolutions, and other 30% could present some pieces of the final shape in the correct position; only 40% of the 3-years-old children presented all the pieces in the wrong positions (see Table 3). Figure 4 gives some examples of wrong answers presented by children, in spite of using some of the pieces correctly.

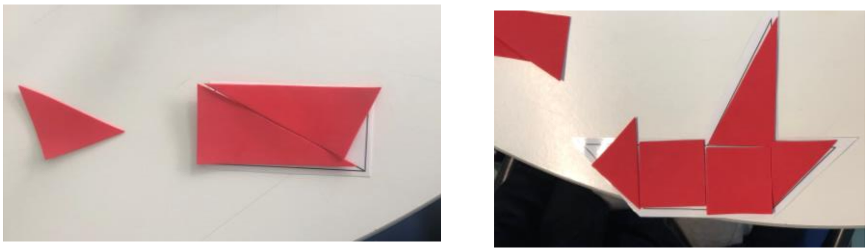


Figure 4. Examples of some wrong resolutions in problems of position of shape.

3.2. Similarities and differences

Table 4 presents the percentage of the type of strategy observed when solving problems of similarities and differences, according to age. Children's performance when solving the similarities and differences problems can be distinguished into two categories: tick the different dog when child identify and sign the dog which different; and identifies the wrong dog when child doesn't sign any dog and say that all dogs are similar or when child sign the wrong dog.

Table 4. *Percentages of type of strategies used by children on similarities and differences problems, by age (N=15).*

Similarities and differences (%)			
Answer	3 years-old	4 years-old	5 years-old
Tick the different dog	40	100	100
Identifies the wrong dog	60	0	0

Figure 5 shows the answer of a 3-years-old child, who was asked to tick the different dog.

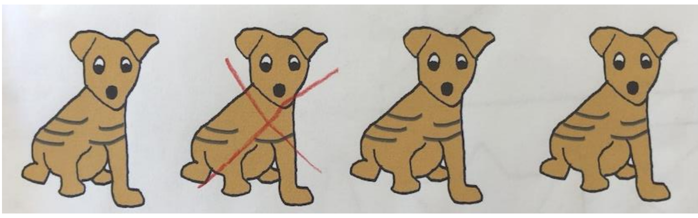


Figure 5. Example of a correct responses given by a 3-years-old child.

Results suggests that this type of problem was not difficult at all for the older children, but for the youngest the recognition of similarities and differences may need to be improved. More research is needed to have an insight on children's reasoning to understand which processes occur that allow children to easily grasp these similarities and differences at 4-years-old, but not at 3-years-old. Nevertheless, among those who presented a correct response, it was possible to find justifications of a 3-years-old arguing that "this dog has 2 scratches here and 1 here and the other dogs have more", revealing a total understanding of their answer.

3.3. Finding shape

Table 5 presents the percentage of the type of strategy observed when solving problems of finding shape, according to age. Children's performance when solving the finding shape problems can be distinguished into three categories: all shapes, when the child signs all hidden figures; some shapes, when a child signs some hidden figures but does not sign others; and incorrect shapes, when children sign shapes that does not hidden (see Table 4).

Table 5. *Percentages of type of strategies used by children when finding shape problems, by age (N=15).*

Finding shape (%)			
Type of strategy	3 years-old	4 years-old	5 years-old
All shapes	30	70	75
Some shapes	35	5	15
Incorrect shapes	35	25	10

Figure 6 shows 3- and 4-years-old children answers to problems of finding shape.

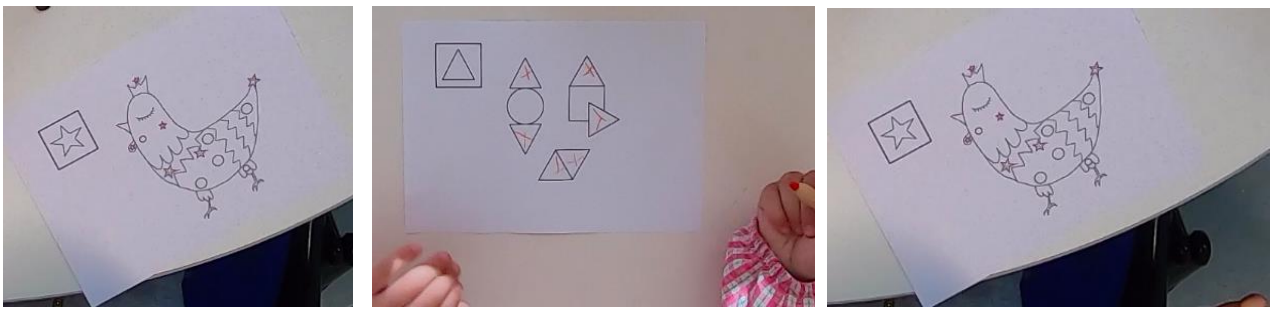


Figure 6. Examples of correct responses given by 3- and 4-years-old children (finding shape problems).

Results suggests that this type of problem was not very difficult for the older children, but for the youngest the recognition of a shape among others seems to be difficult. More research is needed to have an insight on children's reasoning to understand the processes that occur that allow children to find shapes in different positions, at 3- and 4-years-old (see Table 5). Some children even justified that "this figure is the same. I don't know the name of this figure” revealing their recognition of shape. Some children could only recognise some of the shapes, those inside the circle. Figure 7 shows an example of 3-years-old child that does not sign only one figure.

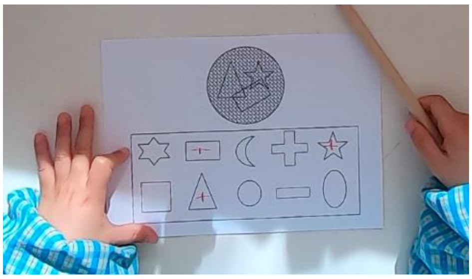


Figure 7. Examples of almost correct response given by 3-years-old child (finding shape problems).

3.4. Shape overlay

Table 6 presents the percentage of the type of strategy observed when solving problems of shape overlay, according to age. Children’s performance when solving the shape overlay problems can be distinguished into three categories: build near the card, when a child builds a construction near the card, correctly; does not overlap images; build on card but wrong, comprises the situations in which the child puts the pieces on the given card overlaying, but on the wrong position; and build near the card but wrong, comprising the cases in which a child makes a construction different from the one required in the card.

Table 6. *Percentages of type of strategies used by children on shape overlay problems, by age (N=15).*

Shape overlay (%)			
Type of strategy	3 years-old	4 years-old	5 years-old
Build near the card	0	10	20
Does not overlap images	30	30	50
Build on card but wrong	40	50	20
Build near the card but wrong	30	10	10

Figure 8 shows examples of children of 4- and 5 years-old building near the card.

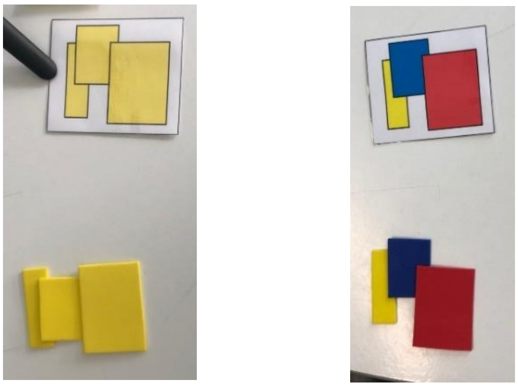


Figure 8. Examples of correct responses in problems of shape overlay (N=15).

The problems of shape overlay were the most difficult ones presented to the children of this exploratory study. These requires the attention to too much information, which makes them more difficult than the previous ones. Even when material was available to solve the problem, the levels of success were extremely low. Possibly, this was due to the fact that children could not succeed in the problem by building on the card, as this was a 3D problem. Figure 9 shows some of the 3-years-old resolutions that were close to success, failing partially on overlaying, building wrongly on the card.

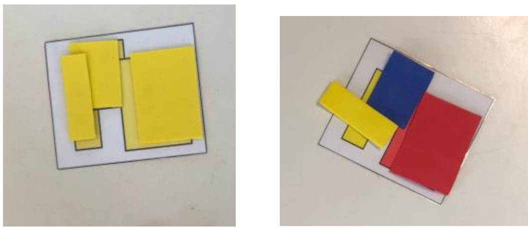


Figure 9. Examples of almost correct responses in problems of shape overlay.

In another problem, the children had to identify the animals in a picture and most of them succeeded. Figure 10 shows an example of such a problem, in which the children should identify the four animals. Most of the children identified correctly all the animals: a dog, a cat, a bird and a chicken.

Figure 10. Example of another problem of shape overlay.

4. Final remarks

These results suggest that the figure background perception problems can make sense even for the 3-years-old children. The problems about shape overlay seemed to be the most difficult ones presented to this group of children. The similarities and differences problems seemed to be the easiest ones. As expected, in all problems presented to the children, the levels of success increased among the older ones. But these findings suggest that there are many problems of figure background perception that can be explored with young children of 3-years-old, in a funny way, in order to challenge their spatial thinking.

Regarding the children's justifications, this study suggests that to solve figure background perception problems can be an opportunity for young children to improve their communication skills, when asked to explain their answers. Most of them were unable to present an explanation but they were able to use the material to show how they solve the problem.

Some of these problems were quite difficult as children had to manager colour and position in some cases, in other cases shape and position. Nevertheless, all the children tried to solve the problems with enthusiasm. In many cases, they succeeded and presented justifications that clarifies that their resolutions were made with understanding.

When solving problems of position of shape, of similarities and differences and of finding shapes, young children of 3-year-olds could succeed, in spite of not presenting many justifications for their resolutions. On shape overlay problems, only a few 4- and 5-year-olds children could succeed, making these the most difficult problems presented to the children.

The findings of these exploratory study do not allow generalizations, but give some sense of what young children from 3-years-old are able to do regarding the figure background perception. More research is required regarding these issues in order to have an insight of young children's ability to solve figure background problems. These findings also allow to think about the type of problems that can be explored with young children in kindergarten, as a way to prompt their visualization skills, in a funny way.

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