Journal of Educational and Developmental Psychology; Vol. 5, No. 2; 2015
ISSN 1927-0526 E-ISSN 1927-0534
Published by Canadian Center of Science and Education

How Flexible Is the Visuospatial Reference System in Children Aged 4 to 12?

Julie Heiz[1] & Koviljka Barisnikov[1]

[1] Child Clinical Neuropsychology Unit, Department of Psychology, University of Geneva, Genève, Switzerland

Correspondence: Julie Heiz, Child Clinical Neuropsychology Unit, Department of Psychology, University of Geneva, 40 bvd du Pont d'Arve, 1211 Genève 4, Switzerland. Tel: 41-223-79-9891. E-mail: julie.heiz@unige.ch

Received: August 11, 2015 Accepted: September 8, 2015 Online Published: September 28, 2015

doi:10.5539/jedp.v5n2p51 URL: http://dx.doi.org/ jedp.v5n2p51

Abstract

The ability to correctly process spatial information largely depends on the capacity to either use a viewpoint according to a visual scene or a Frame Of Reference (FOR) and to flexibly shift between them. Literature indicates 2 types of FOR mainly used to represent the location of an object. The egocentric FOR uses the location of an object relative to oneself and develops earlier than the allocentric FOR, which uses the location of an object relative to other external objects. This study examined the spontaneous use of different FOR as well as their use following explicit task instructions. One hundred and thirty-five children (aged 4-12) were assessed with an adapted version of Taylor and Rapp's (2004) spatial reference task. In the spontaneous instructions condition, most of the children aged 7 and above used an allocentric FOR. While in the allocentric instructions condition, children aged 4, 5 and 6 gave significantly more allocentric responses. In the egocentric instructions condition, all participants showed more egocentric responses, independently of their age group. The present study is the first to demonstrate that simple instructions enable children to use allocentric and egocentric FOR earlier, more effectively and more flexibly than do their spontaneous use. These findings also demonstrate that specific instructions could help children use a viewpoint in accordance to a situation. This could help improve academic performances and overcome the difficulties of some young children in developing the use of an allocentric FOR.

Keywords: allocentric, egocentric, flexibility, frames of reference, spatial cognition

1. Introduction

Visuopatial skills are multiple and fundamental to our understanding of the environment. More particularly, they play an important role in learning practical and academic skills. According to Johannsen and De Ruiter (2013), the ability to process visuospatial information is necessary to daily communication and activities with other people. For example, it is common to specify the location of an object in comparison to another object, to cardinal points, to oneself, to others, or to be able to understand a specific instruction (e.g., "The apple is on the chair"; "Put your bag on the left of the table"). To assimilate these spatial descriptions, individuals must give meaning to the space around them (Burigo & Sacchi, 2013). To do so, they chose a perspective that allows the creation of a Frame Of Reference (FOR) that corresponds to an origin, a coordinate system, and a point of view (Taylor & Tversky, 1996).

Spatial FOR can be determined through the perspective of a speaker, a listener, or an object (Carlson-Radvansky & Radvansky, 1996). Unless they all occupy the same spatial location and position, each FOR can lead to a different interpretation (Taylor & Rapp, 2004). Furthermore, each FOR depends on whether the relationship between 2 objects is interpreted relative to a viewpoint defined by the viewer, or relative to the elements of the visual scene altogether (Carlson-Radvansky & Radvansky, 1996; Taylor, Faust, Sitnikova, Naylor, & Holcomb, 2001).

Several authors distinguish between 3 FOR. However, different terminology has been assigned to these frames depending on their use in studies on cognitive development or language (Dasen, Mishra, Niraula, & Wassmann, 2006).

Piaget and Inhelder (1947) were the first to distinguish between 3 types of FOR to describe spatial situations.

Firstly, the Euclidean FOR, which focuses on the environmental sphere, uses a system external to the observer (e.g., north, south, etc.) and is also known as the absolute FOR (Levinson, 1996). Secondly, the topological FOR, which is relative to the observer, focuses on the perspective of the viewer, uses projective terms (e.g., left, right, back, front, below, above) and is also known as the intrinsic FOR (Levinson, 1996; Taylor & Tversky, 1996), the relative FOR (Levinson, 1996) or the egocentric FOR (Shelton & Mcnamara, 1997). Thirdly, the projective FOR, also known as the deictic (Taylor & Tversky, 1996), allocentric or exocentric FOR (Nardini, Burgess, Breckenridge, & Atkinson, 2006), uses the reference point of another person or another object's coordinate system (e.g., on the left of the object or the person). This last FOR describes a binary relationship and uses the same projective terms as a relative frame (Taylor & Rapp, 2004).

Nevertheless, the majority of studies on developmental and neurocognitive aspects of spatial information processing, in relation to the ability to take a specific viewpoint, agree on 2 main types of FOR (e.g., Galati et al., 2000; Howard & Templeton, 1966; Levinson, 1996; Lourenco & Frick, 2013; Newcombe, Huttenlocher, Drummey, & Wiley, 1998). Therefore, in the context of the present study, the Euclidean FOR will not be discussed, as it is not part of the subject of this research. However, we will focus on the egocentric and allocentric FOR, as we are interested in the developmental course of these 2 specific abilities.

The egocentric FOR serves as a primary reference and is used naturally and automatically (Shelton & Mcnamara, 1997). This FOR allows one to locate an object relative to oneself; therefore, by referring to the observer himself, for example "the apple in front of me" (Galati et al., 2000). According to Klatzky (1998), the allocentric FOR allows the location of external objects, benchmarks or cues in relation to their different component parts as well as to other objects in their environment, for example, "the apple is on the table" (Nardini et al., 2006; Shelton & Mcnamara, 1997). This allocentric FOR develops with age (for a review see Lourenco & Frick, 2013) and developmental studies have reported that the egocentric FOR is typically used by children as young as 3 years old (Taylor & Tversky, 1996). In contrast, the allocentric FOR is suggested to emerge later in childhood. Piaget's studies indicate that this FOR only develops from the age of 7 or 8 (Piaget & Inhelder, 1947). However, Nardini et al. (2006) or Newcombe and Huttenlocher (2003) suggest that this development takes place at the age of 5. Rochat (1995) and Ribordy, Jabès, Banta Lavenex and Lavenex (2013) claim it emerges at age 3, and as early as 16 months according to Huttenlocher, Newcombe and Sandberg (1994). The discrepancy regarding the emergence of the ability to use an allocentric FOR could be attributed to methodological issues, related to the use of different tasks. The experimental designs of the abovementioned studies varied in terms of the factors that can influence the choice of a particular FOR. For example, the number of objects, the nature of the spatial dimensions (e.g., back/front; right/left), the type of instructions and the response modalities (oral or manual) (Coie, Costanzo, & Farnill, 1973, cited by Verjat, 1994). Despite numerous developmental studies, it remains difficult to conclude at which age children spontaneously and naturally shift from the sole use of an egocentric FOR to the simultaneous use of an egocentric and an allocentric FOR. The majority of studies in adults show that adults with a typical development preferentially use an allocentric FOR if no specific instructions have been given, but can flexibly use an egocentric FOR if they are instructed to (Taylor & Rapp, 2004).

However, a study conducted by Waismer and Jacobs (2013) is, to our knowledge, the only one that has explored the ability to switch from one FOR to another in young children aged 3 and 4. The children in their study had to find a toy in one of 4 possible hiding places (plastic boxes associated with 4 different figurines). The task necessitated short memory abilities, and the combination of 2 FORs in spatially conflicting situations. The results showed that from the age of 4 children begin to demonstrate flexibility in their use of FOR in different spatial configurations. This informative study was only performed with young children and did not provide information regarding the developmental trajectory of the capacity to explicitly choose a particular FOR. In their important work entitled "Where is the Donut?", Taylor and Rapp (2004) examined whether adults use an allocentric or egocentric FOR in conflicting visuospatial situations and if they demonstrate flexibility in the use of them. To do this, they asked participants to verbally declare the position of a donut with respect to the position of the reference object's intrinsic sides (e.g., an airplane or a chair, although they have intrinsic sides, will look different from different perspectives). Results showed that adults naturally tend toward an allocentric FOR but are flexible enough to use an egocentric FOR if instructions require them to.

As seen above, most authors have observed 2 main types of FOR that develop with age. The use of an egocentric FOR emerges earlier, but research on the development of the ability to use an allocentric FOR remains inconsistent. The ability to coordinate different points of view or to link different benchmarks requires decentration efforts that allow an individual to see the world in relation to others and not only to the self (Henriques, Klier, Smith, Lowy, & Crawford, 1998). Therefore, the ability to use an allocentric FOR and to flexibly choose a type of FOR according to a spatial situation, is important to every daily life, to the development of complex visuo-spatial skills, and to academic achievement. Furthermore, no study has systematically examined flexibility in the ability to switch between egocentric and allocentric reference systems during childhood.

The present study aimed to assess developmental trends in the use of 2 FOR in response to 3 types of specific instructions, as well as flexibility in the use of one of the 2 reference systems in response to these specific instructions. As we have seen in the above literature review, most authors are not in agreement regarding the age at which children begin to use an allocentric FOR. For this reason, we have decided to investigate the age at which children tend to naturally shift from the use of an egocentric FOR to an allocentric one. Furthermore, this study investigated if the type of instructions provided influences the flexibility of the use of a FOR. Particularly, we wished to see if children's natural use of an egocentric FOR is influenced by specific instructions, which may or may not force them to subsequently use an allocentric FOR. To do so, we adapted the spatial reference task "Where is the donut?" (Taylor & Rapp, 2004) by suppressing the memory component as well as the verbal response modality.

2. Materials and Methods

2.1 Participants

One hundred and thirty five children were included in this study, all of which were recruited from regular elementary schools in Geneva. The children were aged between 4 and 12 years (mean age = 8;6 ; SD = 2;5) and consisted of 50% girls and 50% boys with 15 children in each of the following age groups: 4-year-olds (mean age = 4;7, range = 4;3-4;11); 5-year-olds (mean age = 5;5, range = 5;0-5;10); 6-year-olds (mean age = 6;6, range = 6;0-6;11); 7-year-olds (mean age = 7;8, range = 7;3-7;11); 8-year-olds (mean age = 8;5, range = 8;1-8;11); 9-year-olds (mean age = 9;6, range = 9;0-9;11); 10-year-olds (mean age = 10;5, range = 10;1-10;11); 11-year-olds (mean age = 11;7, range = 11;1-11;11); and 12-year-olds (mean age = 12;4, range = 12;0-12;11). All children performed the Colored Progressive Matrices (Raven, Raven, Court, & Raven, 2003) and had a percentile score corresponding to the norms for their chronological age, over the fifth percentile. The ethics committee of the Department of Psychology at the University of Geneva approved the study.

2.2 Materials

The material consisted of a computerized spatial reference task adapted from Taylor and Rapp's study (2004). This visual paradigm is specifically designed to probe or assess the use of egocentric and allocentric FOR. It contains 108 trials, each one consisting of a simultaneously appearing stimulus-picture and 4 response-pictures.

The stimulus-picture illustrated 2 objects: a reference object and a "located object" whose location had to be stated on the computer. The reference object, with intrinsic sides, was one of 8 everyday objects: a chair, a bicycle, a frying pan, a pitcher, a violin, a toy, a bottle or a hairbrush. This object was presented in 3 different possible orientations: left, right or back (Note 1) (See Figure 1 for an example).

Figure 1. Example of the 3 different directions in which the canonical object is facing for the stimulus-picture: left, right and back

The located object, without intrinsic sides, was a soccer ball, as this object looks the same from different representations (2D or 3D). This object could be placed in one of two locations, either on the left or on the right side of the reference object. Thus, there were 6 different configurations and each was tested 6 times, for example, the reference object was oriented right with the soccer ball on the right.

In the 4 response-pictures, the reference object was always presented with the same orientation and seen from above. The soccer ball could be placed in 4 different locations, either on the left (ImL), right (ImR), front (ImF) or back (ImB) of the object. A large fixation cross separated each trial. Figure 2 shows the example of a trial.

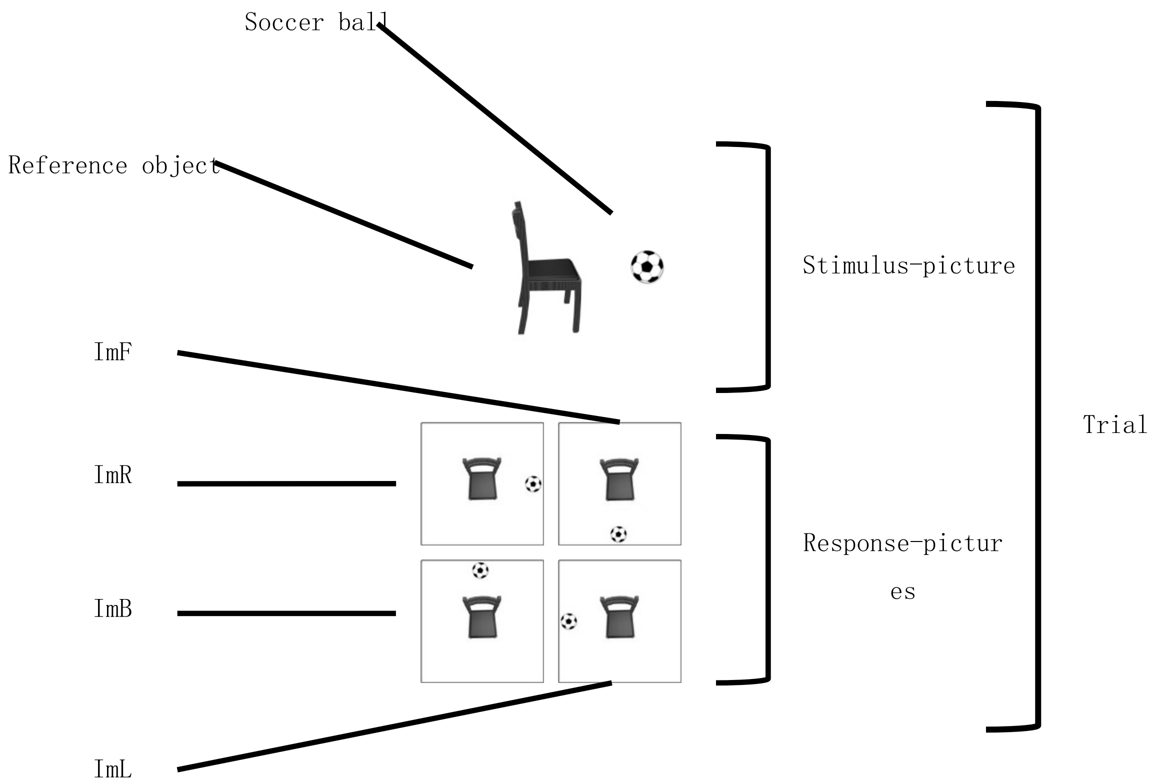

Figure 2. In this example of a trial, ImR is the egocentric response-picture and the ImF is the allocentric response-picture. ImB and ImL are incorrect responses. All elements were displayed at the same time

2.3 Procedure

The task was presented on a Windows touch screen computer (19 inch color monitor) running Eprime2.0® Software. Participants were told that they would see the stimulus-pictures with 2 objects (a reference object and the soccer ball) and 4 response-pictures. They were asked to choose the correct response-picture in accordance with the instructions given, to touch the response-picture on the touch screen, and to respond as quickly as possible.

Each participant was presented the task 3 times with all 3 different instructions manipulating the FOR that they were asked to use: spontaneous, allocentric or egocentric instructions. Each task presentation began with a training phase (consisting of 5 trials) to verify whether the participants understood the instructions. All participants began with the spontaneous instructions. Following this, half the participants continued with the allocentric instructions followed by the egocentric ones, whilst the other half continued with the egocentric instructions followed by the allocentric ones. In order to avoid the effects of fatigue, there was a pause of at least 20 minutes between the different types of instructions. The 3 types of instructions given to each participant were the following:

- In the spontaneous instructions condition, participants were asked the following: "select among the 4 small pictures the one that matches the big one, the one with the soccer ball in the right place". Here, the participants individually chose their preferential FOR. This was intended to illustrate whether participants tend to spontaneously use an allocentric or egocentric FOR. If participants did not choose the allocentric or the egocentric response type, their response was considered "incorrect". The percentages of allocentric, egocentric and incorrect responses were calculated, which allowed us to determine if participants preferentially used an allocentric, egocentric or incorrect FOR.

- In the allocentric instructions condition, participants were asked the following: “select among the 4 small pictures the one that matches the big one, the one with the soccer ball in the right place in relation to the object”. The responses given by participants in the allocentric instructions condition were then analyzed. The percentages of allocentric, egocentric and incorrect (not egocentric and not allocentric) responses were calculated, which allowed us to determine if participants preferentially used an allocentric, egocentric or incorrect FOR. This was intended to demonstrate if participants were able to change their FOR flexibly according to the instructions given and if they were able to use the allocentric FOR.
- In the egocentric instructions condition, participants were asked the following: “select among the 4 small pictures the one that matches the big one, the one with the soccer ball in the right place in relation to yourself”. The responses given by the participants in the egocentric instructions condition were then analyzed. The percentages of allocentric, egocentric and incorrect (not egocentric and not allocentric) responses were calculated, which allowed us to determine if participants preferentially use an allocentric, egocentric or incorrect FOR. This was done in order to see if they were able to use the egocentric FOR according to the instructions.

2.4 Statistical Analyses

This present study examined the use of egocentric or allocentric FOR following spontaneous instructions and following specific instructions.

Firstly, we aimed at determining whether age is related to changes in the type of FOR used. To do so, a Chi-Square (χ^2) test was performed with SPSS software by comparing the proportion of children, per age group, who gave egocentric vs allocentric vs incorrect responses in the spontaneous instructions condition, as a function of an age group (there were 9 age groups: 4 vs 5 vs 6 vs 7 vs 8 vs 9 vs 10 vs 11 vs 12 years old). A logistic regression analysis was also performed with SPSS software. This was done to determine the impact of age on the use of, or lack thereof, an allocentric FOR in the allocentric instructions condition. This was also done with the egocentric FOR in the egocentric instructions condition.

Secondly, we aimed at determining the extent to which children were able to change their FOR as a function of the received instructions, relative to the spontaneous instructions condition. To do so, repeated analysis of variance (ANOVA) were performed with the SPSS software. A 9 between-subjects (age groups: 4 vs 5 vs 6 vs 7 vs 8 vs 9 vs 10 vs 11 vs 12 years old) x 2 within-subjects (instructions: spontaneous vs allocentric/spontaneous vs egocentric) design was used by calculating, per age group:

- the percentages of the allocentric responses in the spontaneous and allocentric instructions conditions.
- the percentages of the egocentric responses in the spontaneous and egocentric instructions conditions.

3. Results

3.1 Spontaneous Instructions Condition

In the spontaneous instructions condition, a contingency table analysis (table 9 x 3) showed that most children aged 4 (10/15 children) chose an incorrect response (See Table 1). Among children aged 5 and 6, an equal number of children gave egocentric responses (6/15) or allocentric responses (6/15). Finally, at age 7, most children gave an allocentric response (≥ 12/15 children).

Table 1. Response frequencies in the spontaneous instructions condition as a function of age group and response type

	Responses			
Age	Allocentric	Egocentric	Incorrect	Total
4	3	2	10	15
5	6	6	3	15
6	6	6	3	15
7	12	3	0	15
8	11	3	1	15
9	13	2	0	15
10	11	4	0	15

11	12	3	0	15
12	13	2	0	15
Total	87	31	17	135

A χ^2 test of independence showed a significant association between the 2 variables "age" and "type of response" ($\chi^2_{(16)} = 63.04$, $p < 0.001$). Cramer's V was 0.48, showing that nearly 23% of the variation in one variable can be explained by the variation in the other variable, demonstrating support for a strong link between the variables "age" and "type of response".

3.2 Allocentric Instructions Condition

In the allocentric instructions condition, a contingency table analysis (table 9 x 3) showed that the majority of children provided allocentric responses, and this for all age groups (See Table 2).

Table 2. Response frequencies in the allocentric instructions condition as a function of age group and response type

Age	Responses			Total
	Allocentric	Egocentric	Incorrect	
4	10	3	2	15
5	8	4	3	15
6	10	2	3	15
7	12	3	0	15
8	12	3	0	15
9	13	1	1	15
10	12	3	0	15
11	12	3	0	15
12	13	2	0	15
Total	102	24	9	135

A χ^2 test of independence revealed no significant association between the variables "age" and "type of response" ($\chi^2_{(16)} = 18.19$, $p = .31$).

A logistic regression analysis was conducted to predict the "type of response" (allocentric or non allocentric) in the allocentric instructions condition. The variable "age" was used as the predictor. Results of the test of the full model were statistically significant, indicating that as a set the predictor reliably distinguished between the "types of responses" ($\chi^2_{(1)} = 5.146$, $p = .023$). Nagelkerke's R^2 of .056 indicated a relationship between the prediction and grouping. Overall, the success of the prediction was at 75.6%. The Wald criterion demonstrated that "age" made a significant contribution to the prediction ($p = .027$). The EXP(B) value indicated that when "age" is raised by one unit, the odds ratio is 1.2 times as large.

The ANOVA for the variables "age" and "instruction type" (spontaneous versus allocentric) on the percentage of allocentric responses revealed a main effect of the instructions condition ($F_{(1, 126)} = 293.12$; MSE = 16.31, $p < .001$, $\eta^2 = .699$).

In general, children gave more allocentric responses in the allocentric instructions condition (M = 62.79%, SD = 14.28) compared to the spontaneous instructions condition (M = 54.37%, SD = 18.51) (See Figure 3).

A significant interaction was also observed between the instructions and the age of the children ($F_{(8, 126)} = 10.571$; $p < .001$, $\eta^2 = .402$). Tukey Post-Hoc tests ($p < .005$) confirmed a difference for age groups ≤ 7 years versus age groups ≥ 8 years.

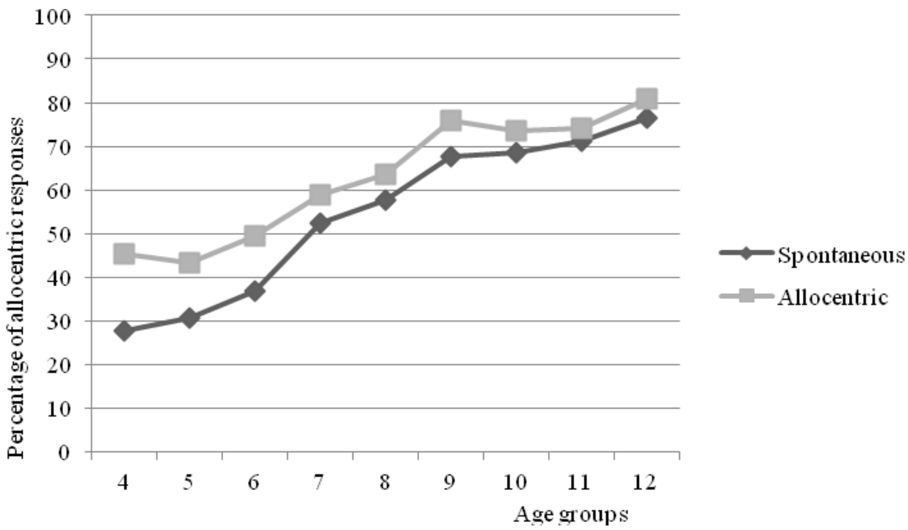

Figure 3. Percentages of allocentric responses in the spontaneous instructions condition and the allocentric instructions condition

3.3 Egocentric Instructions Condition

In the egocentric instructions condition, a contingency table analysis (table 9 x 3) showed that the majority of children aged 4 (11/15) provided allocentric responses (See Table 3). Among the 5-year-old children, 7 provided allocentric responses and 7 provided egocentric responses. Finally, between 7 and 12 years old, children provided more egocentric responses (≥ 10/15).

Table 3. Response frequencies in the egocentric instructions condition as a function of age group and response type

	Responses			
Age	Allocentric	Egocentric	Incorrect	Total
4	11	4	0	15
5	7	7	1	15
6	5	10	0	15
7	1	12	2	15
8	3	12	0	15
9	1	13	1	15
10	3	12	0	15
11	3	12	0	15
12	2	13	0	15
Total	36	95	4	135

A χ^2 test of independence revealed a significant association between the variables "age" and "type of response"

($\chi^2_{(16)}$ = 37.72, p = 0.002). Cramer's V was 0.37, showing that nearly 13% of the variation in one variable can be explained by the variation in the other variable, demonstrating support for a strong link between the variables "age" and "type of response".

A logistic regression analysis was conducted to predict the "type of response" (egocentric or not egocentric) in the egocentric instructions condition. The variable "age" was used as the predictor. Results of the test of the full model were statistically significant, indicating that as a set the predictor reliably distinguished between the "types of responses" ($\chi^2_{(1)}$ = 17.578, p < .001). Nagelkerke's R^2 of .174 indicated a relationship between the prediction and grouping. The overall success of the prediction was 75.6%. The Wald criterion demonstrated that "age" made a significant contribution to the prediction (p < .001). The EXP(B) value indicated that when "age" is raised by one unit, the odds ratio is 1.4 times as large.

The ANOVA for the variables "age" and "instruction type" (spontaneous versus egocentric) on the percentage of egocentric responses revealed a main effect of the instructions condition ($F_{(1, 126)}$ = 42.616; MSE = 1895.45, p < .001, η^2 = .253).

In general, children gave more egocentric responses in the egocentric instructions condition (M = 69.96%, SD = 15.23) compared to the spontaneous instructions condition (M = 35.37%, SD = 8.88) (See Fig. 4).

No interaction was observed between the instructions and the age of the children ($F_{(8, 126)}$ = 1.85; p = .074, η^2 = .105).

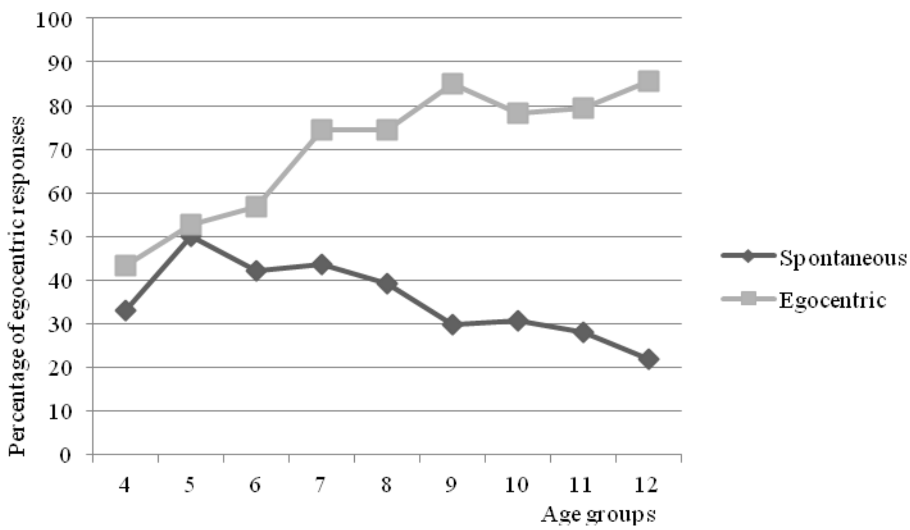

Figure 4. Percentages of egocentric responses in the spontaneous instructions condition and the egocentric instructions condition

4. Discussion

The present study aimed to assess developmental trends in the use of egocentric and allocentric FOR among children aged 4 to 12 years old. More specifically, it aimed to assess these trends in either spontaneous conditions or conditions where children were explicitly instructed to use a specific type of FOR.

Firstly, our results showed that only from the age of 7 and above do children spontaneously used an allocentric FOR, whilst children aged 5 and 6 years old do not show a preference toward a particular FOR. The youngest group of children, aged 4, provided a high number of incorrect responses. These results indicate that at the age of 7, children naturally shift toward the use of an allocentric FOR and preferentially use it from that age on. Secondly, results showed that specific instructions help children to make a more effective FOR choice, in accordance with instructions. From 5 years old, allocentric instructions help children to use an allocentric FOR and egocentric instructions help children to use an egocentric FOR. Thus, explicit instructions could support flexibility in the choice to use one or the other reference system, which demonstrates for the first time the existence of flexibility in the use of 2 types of FOR in school-age children.

In the spontaneous instructions condition, the results of this study are in accordance with Piaget's early work in which he suggested that an allocentric FOR is used only from the age of 7 or 8 (Bullens, Iglói, Berthoz, Postma, & Rondi-Reig, 2010; Piaget & Inhelder, 1947). The results of the children aged 5 and 6 years old show that they gave an equal amount of egocentric responses and allocentric responses, which suggests that they perceive the spatial scenes as conflicting. More specifically, they seem to realize that 2 types of FOR could be correct depending on the point of view. These results are also in accordance with Nardini et al.'s (2006) study, which reports a shift from the use of an egocentric to an allocentric FOR at the age of 5. Other authors claim that this shift occurs as early as the age of 3 (Rochat, 1995) or 4 years old (Waismeyer & Jacobs, 2013). However, we believe that these discrepancies stem from methodological differences. Contrary to studies conducted by Piaget and colleagues, studies reporting earlier egocentric-to-allocentric shifts used visual cues (e.g., color, array, ceramic figures) or auditory cues, and varied the memory load (e.g., scenario perceptually available or not). All of these factors could help children to use objects and spatial scenes as references rather than to use their own body. In Nardini et al.'s task (2006), the children were asked to find a toy hidden under a cup, among others on a board; in Waismeyer and Jacobs's task (2013), young children were asked to find an object in one of 4 possible hiding places. These 2 studies manipulated such above-mentioned factors and were interesting in terms of types of strategies used by children for spatial orientation and for remembering a particular object's position, rather than for the developmental trend in the use of egocentric and allocentric reference systems. Therefore, it is difficult to compare our results with these studies because they did not examine the spontaneous change in the 2 types of FOR uses. In contrast, our experimental task was designed to allow the spontaneous choice to use an egocentric or allocentric FOR without an additional memory load and external cues.

Therefore, our results are in line with studies that provide evidence that the ability to use an allocentic FOR develops later in a child's life (e.g., Bullens et al., 2010; Iglói, Zaoui, Berthoz, & Rondi-Reig, 2009; Piaget & Inhelder, 1947; Poirel et al., 2011). More precise knowledge about the developmental trend of such ability could help to adjust demands and needs according to age. It could also contribute to a better understanding of performances in the spatial tasks of preschool age and young school age children (e.g., spatial orientation and pattern construction). However, these results changed once participants were instructed to use one or the other FOR. As we have seen with our results, children demonstrate the ability to use an egocentric/allocentric FOR following specific instructions. Thus, the allocentric condition particularly helped young children to descend from their own point of view and use a FOR utilizing external objects. These results corroborate other studies that suggest that children shift from the use of an egocentric to an allocentric FOR at the age of 5 (Nardini et al., 2006) or at age 4 (Waismeyer & Jacobs, 2013). Therefore, we could assume that the period between ages 5 and 6 is important to the emergence of the ability to use an external object as a spatial reference. Our results also demonstrate that the ability to use an allocentric FOR emerges earlier than its spontaneous use and that simple instructions could support the flexible choice to use one or the other reference system in young children. As seen above, coordinating different points of view or linking different cues requires more complex abilities that allow individuals to decenter from themselves. Consequently, they are able to see their environment in relation to others and the external world, which is essential to everyday functioning and learning (Henriques et al., 1998). Thus, our findings suggest that specific instructions could be used to improve children's ability to process spatial information sooner and more accurately, which in turn could be used as a learning support. Additionally, the dynamic relationship between the development of these abilities and individual experience were also highlighted. According to Poirel et al. (2011), improvement in children's use of an allocentric FOR around the age of 8 is representative of a shift in visuospatial perception, which stems from visual experience and school curriculums. For example, learning more advanced level geometry and spatial concepts encourages such a shift. It is possible that such practices could lead to a shift in visuospatial thinking, which would teach children to evolve from the use of their own point of view to the use of an external object.

Nevertheless, our study demonstrates that specific instructions could help school-age children to use either one of the FOR earlier than their spontaneous use. Surprisingly, egocentric instructions seem more difficult for young children. However, the use of different FOR, in simple 2 objects scenarios and the ability to process several spatial relations are necessary (Carlson, West, Taylor, & Herndon, 2002; Logan & Sadler, 1996). Thus, difficulties evidenced in the youngest group could reflect their struggle to coordinate different pieces of information in conflicting spatial situations. In the egocentric condition, the child had to find the location of the soccer ball in comparison to him or herself (e.g., left from their body) and to ignore the canonical object. The allocentric condition appeared to be less cognitively demanding for young children aged 4. We could hypothesize that they only had to focus on the canonical object to determine the location and to match it with the response picture (identical to the stimuli picture). In order to facilitate this novel perspective taking strategy, future studies should examine the impact of different types of stimuli on the choice of a FOR, such as animated stimuli-pictures, a human figure or animals. Such studies could help us to see if these stimuli are more adapted in terms of support to improve the flexible use of egocentric and allocentric FOR in young children. The relationship between this flexibility, visuo-spatial abilities (e.g., spatial orientation) and visuo-spatial skills (e.g., copy of geometric figures) should also be examined.

5. Conclusion

In conclusion, the present study showed that only from the age of 7 and above do children spontaneously use an allocentric FOR. However, children aged 4, 5 and 6 were able to use this type of FOR when they were specifically instructed to do so. In contrast to previous studies, our results demonstrate that the shift between the uses of an egocentric to an allocentric FOR does not occur at a specific age. Rather, there is a transition process that occurs between the ages of 5 and 6. In addition, this study is the first to demonstrate that simple instructions could help children use egocentric and allocentric FOR earlier, more easily, more effectively, and more flexibly in comparison to their spontaneous use. These results are of importance as the ability to correctly process spatial information depends largely on the capacity to use a FOR or a viewpoint according to the visual scene. Furthermore, its flexible use plays an important role in the development of several visuospatial skills. Thus, a specific instruction could help children to use a viewpoint according to the situation and subsequently help to improve their academic performances. Moreover, our modified experimental tasks provide the advantage of being accessible to very young children as they are administrated easily and rapidly and are sensitive to the typical development of a wide range of ages (4 to 12 years old). Children with visuospatial developmental disorders could also benefit from our assessment tools for the early detection of specific spatial deficits. Finally, our two-object experimental design, with simple instructions, could improve flexibility in the choice of a reference system in young children and could be used in re-education strategies for visuospatial disorders.

Acknowledgements

We would like to thank Professor Steve Majerus for his help with the conception of this article and his constructive critiques. We would also like to thank Dr. Cécile Ballaz for her suggestions regarding the construction of the task as well as the interns of the Child Clinical Neuropsychology Unit (Department of Psychology, University of Geneva, Switzerland) for their assistance in the data collection.

References

Bullens, J., Iglói, K., Berthoz, A., Postma, A., & Rondi-Reig, L. (2010). Developmental time course of the acquisition of sequential egocentric and allocentric navigation strategies. *Journal of Experimental Child Psychology*, *107*(3), 337-350. http://dx.doi.org/10.1016/j.jecp.2010.05.010

Burigo, M., & Sacchi, S. (2013). Object orientation affects spatial language comprehension. *Cognitive Science*, *37*(8), 1471-1492. http://dx.doi.org/10.1111/cogs.12041

Carlson, L. A., West, R., Taylor, H. A., & Herndon, R. W. (2002). Neural correlates of spatial term use. *Journal of Experimental Psychology. Human Perception and Performance*, *28*(6), 1391-1408. http://dx.doi.org/10.1037/0096-1523.28.6.1391

Carlson-Radvansky, L. A., & Radvansky, G. A. (1996). The Influence of Functional Relations on Spatial Term Selection. *Psychological Science*, *7*(1), 56-60. http://dx.doi.org/10.1111/j.1467-9280.1996.tb00667.x

Dasen, P., Mishra, R., Niraula, S., & Wassmann, J. (2006). Développement du langage et de la cognition spatiale géocentrique. *Enfance*, *58*(2), 146-158. http://dx.doi.org/10.3917/enf.582.0146

Galati, G., Lobel, E., Vallar, G., Berthoz, A., Pizzamiglio, L., & Le Bihan, D. (2000). The neural basis of egocentric and allocentric coding of space in humans: a functional magnetic resonance study. *Experimental Brain Research*, *133*(2), 156-164. http://dx.doi.org/10.1007/s002210000375

Henriques, D. Y. P., Klier, E. M., Smith, M. A., Lowy, D., & Crawford, J. D. (1998). Gaze-Centered Remapping of Remembered Visual Space in an Open-Loop Pointing Task. *The Journal of Neuroscience*, *18*(4), 1583-1594. Retrieved from http://www.jneurosci.org/content/18/4/1583.abstract

Howard, I. P., & Templeton, W. B. (1966). *Human spatial orientation*. New York, NJ: Wiley.

Huttenlocher, J., Newcombe, N., & Sandberg, E. H. (1994). The coding of spatial location in young children. *Cognitive Psychology*, *27*(2), 115-147. http://dx.doi.org/10.1006/cogp.1994.1014

Iglói, K., Zaoui, M., Berthoz, A., & Rondi-Reig, L. (2009). Sequential egocentric strategy is acquired as early as allocentric strategy: Parallel acquisition of these two navigation strategies. *Hippocampus*, *19*(12), 1199-1211. http://dx.doi.org/10.1002/hipo.20595

Johannsen, K., & De Ruiter, J. P. (2013). The role of scene type and priming in the processing and selection of a spatial frame of reference. *Frontiers in Psychology*, *4*, 182. http://dx.doi.org/10.3389/fpsyg.2013.00182

Klatzky, R. L. (1998). Allocentric and Egocentric Spatial Representations: Definitions, Distinctions, and Interconnections. In C. Freksa, C. Habel, & K. F. Wender (Eds.), *Spatial Cognition* (pp. 1-17). Berlin, Germany: Springer Berlin Heidelberg. http://dx.doi.org/10.1007/3-540-69342-4_1

Levinson, S. C. (1996). Language and Space. *Annual Review of Anthropology*, *25*(1), 353-382. http://dx.doi.org/10.1146/annurev.anthro.25.1.353

Logan, G. D., & Sadler, D. D. (1996). A computational analysis of the apprehension of spatial relations. In P. Bloom, M. A. Peterson, L. Nadel, & M. F. Garrett (Eds.), *Language and space* (pp. 493-529). Cambridge, MA: The MIT Press.

Lourenco, S. F., & Frick, A. (2013). Remembering Where: The Origins and Early Development of Spatial Memory. In P. J. Bauer, & R. Fivush (Eds.), *The Wiley Handbook on the Development of Children's Memory* (pp. 361-393). Chichester, UK: John Wiley & Sons Ltd. http://dx.doi.org/10.1002/9781118597705.ch16

Nardini, M., Burgess, N., Breckenridge, K., & Atkinson, J. (2006). Differential developmental trajectories for egocentric, environmental and intrinsic frames of reference in spatial memory. *Cognition*, *101*(1), 153-172. http://dx.doi.org/10.1016/j.cognition.2005.09.005

Newcombe, N., Huttenlocher, J., Drummey, A. B., & Wiley, J. G. (1998). The development of spatial location coding: Place learning and dead reckoning in the second and third years. *Cognitive Development*, *13*(2), 185-200. http://dx.doi.org/10.1016/S0885-2014(98)90038-7

Piaget, J., & Inhelder, B. (1947). *La conception de l'espace chez l'enfant*. Paris, France: Presses Universitaires de France.

Poirel, N., Vidal, M., Pineau, A., Lanoë, C., Leroux, G., Lubin, A., & Houdé, O. (2011). Evidence of different developmental trajectories for length estimation according to egocentric and allocentric viewpoints in children and adults. *Experimental Psychology*, *58*(2), 142-146. http://dx.doi.org/10.1027/1618-3169/a000079

Raven, J. C., Raven, J., Court, J. H., & Raven, J. (2003). *Manual for Raven's Progressive Matrices and Vocabulary Scales*. *Section 1: General Overview*. San Antonio, TX: Harcourt Assessment

Ribordy, F., Jabès, A., Banta Lavenex, P., & Lavenex, P. (2013). Development of allocentric spatial memory abilities in children from 18 months to 5 years of age. *Cognitive Psychology*, *66*(1), 1-29. http://dx.doi.org/10.1016/j.cogpsych.2012.08.001

Rochat, P. (1995). Perceived reachability for self and for others by 3- to 5-year-old children and adults. *Journal of Experimental Child Psychology*, *59*(2), 317-333. http://dx.doi.org/10.1006/jecp.1995.1014

Shelton, A. L., & Mcnamara, T. P. (1997). Multiple views of spatial memory. *Psychonomic Bulletin & Review*, *4*(1), 102-106. http://dx.doi.org/10.3758/BF03210780

Taylor, H. A., Faust, R. R., Sitnikova, T., Naylor, S. J., & Holcomb, P. J. (2001). Is the donut in front of the car? An electrophysiological study examining spatial reference frame processing. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale*, *55*(2), 175-184. http://dx.doi.org/10.1037/h0087364

Taylor, H. A., & Rapp, D. (2004). Where is the donut? Factors influencing spatial reference frame use. *Cognitive Processing*, *5*(3), 175-188. http://dx.doi.org/10.1007/s10339-004-0022-2

Taylor, H. A., & Tversky, B. (1996). Perspective in Spatial Descriptions. *Journal of Memory and Language*, *35*(3), 371-391. http://dx.doi.org/10.1006/jmla.1996.0021

Verjat, I. (1994). Confrontation de deux approches de la localisation spatiale. *L'année psychologique*, *94*(3), 403-423. http://dx.doi.org/10.3406/psy.1994.28774