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RIGHT-LEFT ORIENTATION, MENTAL ROTATION, AND PERSPECTIVE-TAKING: WREN CAN CHILDREN IMAGINE WHA T PEOPLE SEE FROM THEIR OWN VIEWPOINT? [1]

ROBERT RIGAL

Département de Kinanthropologie

Université du Québec à Montréal

Summary.-Right-left orientation, mental rotation, and perspective-taking were examined in a group of 406 subjects ranging from 5 to 11 yr. of age with equal numbers of children in each age group. Immediate recognition was not a difficult task as even young children succeeded adequately on the three tasks involving different images. Right-left identification, where right and left terms are used, was harder even for the oldest subjects when associated with mental rotation. When children had to identify which image a person would see from another viewpoint, they succeeded when the person was looking away in the same direction as they were looking. When the person was facing the children (in the opposite direction or "forward"), three different behaviours emerged which indicated absence or presence of mental rotation in perspective-taking. Young subjects chose images as if the figures in the image were seeing from the subject's viewpoint; this percentage diminished slowly across increased ages. As subjects' ages increased, more chose the correct image. Even at 11 years of age, however, only half of the subjects chose correctly. Finally, an equal percentage of subjects among the different age groups understood that the person was seeing a different orientation of the persons but did not associate this with the correct right-left position *or* the persons on the image. This transition most probably reflects the slow evolution of cognitive processes which determine the way the child will use references to internal or external frameworks. It illustrates as well the passage from egocentrism to geocentrism with the ability to consider viewpoints other than one's own.

Among the different aspects of spatial organisation, two have been particularly studied, most often independently: right-left orientation and perspective-taking (Piaget, 1924; Piaget & Inhelder, 1948; Benton, 1959; Laurendeau & Pinard, 1968; Newcombe, 1989).

Objects do not have a right or a left side unless we assign them one after a front-back or up-down orientation has already been given. Right-left orientation includes various components such as discrimination which is the ability to differentiate images with chirality or handedness, i.e., images which are a reflection of each other (like the two hands) and are not superimposable, recognition, the ability to tell if an image is identical or different from a previously seen one, and identification, the ability to use right and left terms correctly. The use and determination of people's positions with reference to right and left words evolves as age increases, and steps in verbal use

[1]Send enquiries to Robert Riga!, Département de Kinanthropologie, Université du Québec à Montréal, CP 8888 succursale Centre Ville, Montréal, Québec, Canada H3C 3P8.

of right and left terms are well known (Piaget, 1924; Benton, 1959; Laurendeau & Pinard, 1968; Rigal, 1994). As a reminder, most children first apply the terms correctly on their own bodies (this is my left band) about seven years of age and on another person facing them (this is Jour right leg) about eight years of age. When the words right and left are related to verbal commands with spatial orientation or position ("stand up to the right of the boy" or "on this image, is the little girl to the right or to the left of her mother?"), children must understand that the labels are not absolute but are relative to the reference person and his orientation in space. Before eight years of age, they first use egocentric references, translating their own orientation onto another person in the milieu looking in the same direction or in the opposite direction (looking toward the subject). This does not mean that children believe that the world appears similar to everybody: it might rather be that they have difficulty imagining or describing what people see from a different view point. After eight years of age, children begin to understand that they cannot directly transfer their own orientation onto people facing them: what is on their own right is to the left of the person looking forward. For tasks on which geometrical figures (such as triangles) are used instead of persons to test right-left orientation, there is a natural tendency to use personal, egocentric references. When another person or images of people are used, such a confusion is not possible: if an answer is wrong, it is because the child transfers his own orientation on to the person and uses his own perspective without realizing that other people may have different right and left orientations. Perspectives do not always correspond directly, and in some cases mental rotation is required to attribute right and left correctly.

Perspective-taking refers to imagining what is seen from a position other than that of the subject. In experiments related to perspective-taking, it bas been shown that, until eight years of age, most children do not report correctly the view which corresponds to the observer's (Piaget &: Inhelder, 1948; Laurendeau & Pinard, 1968; Cox, 1991). One explanation of this phenomenon was that the characteristic egocentrism of children prevents their imagining that things may not look the same from another person's view-point. As cognitive ability develops, children realize that different observers see different views of the same display of objects in relation to their own position. Is this ability related to mental rotation? The answer is not at all clear (Takano, 1989). In most mental rotation tasks, subjects must mentally turn an object around to tell if it is similar or different from a reference abject. Since the retinal projection of an object changes with its rotation along one or the other of its three axes, how is an object seen from different viewpoints recognized? Two kinds of representations can be applied to the task: an observer-centered one and an object-centered one (Marr, 1982). In an observer-centered representation, orientation is based on the perspective of the subject. All

orientations originate from what the subject sees from where he is or from where he bas been at one moment or the other. The ability to recognize an object requires that a subject bas the opportunity of seeing that object from all possible points of view or has mentally reoriented the object. Recognition in this case is orientation-bound (letters "p" and "d," for example) (Takano, 1989). In the object-centered representation, the subject uses the three orientation axes of the object as the reference system for the mental rotation leading to recognition. For each object, there would be specific elements which render the object recognizable, whatever the point of view. Thus, in this case, object recognition is orientation-free (letter "T," for example) (Takano, 1989). On all these tasks, the time necessary to answer the question is important and measured (Shepard & Cooper, 1982; Rock, Wheeler, & Tudor, 1989; Tarr & Pinker, 1989; Cohen & Kubovy, 1993; Roberts & Aman, 1993). It is argued that the larger the discrepancy between the reference object and its rotated or different version, the longer it will take to decide whether the objects are the same. This is because the subject does successive rotations and comparisons of the reference shape and its rotated image, which gives rise to a linear relation between reaction rime and the rotation angle value (Shepard & Cooper, 1982).

In perspective-taking, when asked "what the observer sees from where he is," children might use three strategies to find the answer. They may imagine their own displacement to the observer's place, physically place themselves in the observer's position, or imagine the displacement of the array until it is oriented as seen from the observer's view point (Huttenlocher & Presson, 1979). Mental rotation is not involved in all three situations but is required when the amount of rotation is larger than 90.. Roberts and Aman (1993) conducted a study in which subjects (six and eight years of age) had to imagine whether a triangle had to be turned right or left to be opposite a point. As long as the triangle's orientation was close to the subject's sagittal plane, subjects did not have any difficulty answering the questions correctly. Required rotations of 90. to 180. produced most wrong answers for the 6-year-olds but correct answers for the majority of 8-year-olds. The youngest subjects used their own orientation, saying "left" when the answer was "right," while the oldest used mental rotation. The conclusion was that children first name right-left spatial relations from an egocentric frame of reference, then imagine a rotation of their own bodies or of the array to match the orientation of the other person. In right-left orientation and mental rotation, information is orientation-bound and cannot be orientation-free. For each decision, the subject bas to determine his own orientation or that of another person before being able to identify right or left. Piaget and Inhelder (1948) were the first to explain children's progressive ability to consider viewpoints other than their own as a consequence of the passage from egocentrism to sociocentrism developing the Three Mountains Test for that purpose. This development occurs around eight years of age, when

children reach Piaget's Operational Stage. It is not egocentrism *per se* which is the explanation of young children's difficulty with right-left identification (Newcombe, 1989), for egocentrism describes the way children reason during their first years of life. One might argue that two ways to treat spatial information at primary and secondary levels may be linked to egocentrism-socio- centrism (Presson, 1987). The primary level is associated with immediate or direct spatial perception of where the subject is and what is around him, i.e., it is observer-centered. The secondary level is related to spatial representation or structuring, i.e., interpreting maps or imagining another person's viewpoint. A complete spatial representation thug includes various hierarchical aspects, some closely linked to perception, others associated with interpretation of that information.

In the present study, right-left orientation, mental rotation, and perspective-taking were investigated using questions about images of persons with their own spatial orientation instead of object images to which children had to transfer their own right-left orientation. Children had to imagine how an array of persons would look from a point of view other than their own as well as find images matching verbal descriptions involving right and left terms. Since in one of these tests the imaginary view point was opposite (1800 rotation) the position of the subject, right-left orientation skills in perspective-taking could be examined. Length of time necessary to answer the questions was not recorded since the research question was how and when children could answer correctly.

Most mental rotation tasks involving form recognition use two- or three-dimensional objects with or without chirality or handedness. Form recognition was not involved in this study because tasks were not based on rotation of objects along one or more of their orientation axes and subjects were not asked to compare objects. Rather, they had to indicate which image, among different ones, was the one described verbally or was similar to what was seen from another point of view. The children's ability to imagine what an observer might see from his viewpoint, symmetrical to the subject's, was examined.

In right-left orientation and mental rotation, the way questions are ask- ed or situations presented can influence the accuracy of the answers (Pres- son, 1987). In this study, the tasks included appearance questions where the child bas to choose the correct image from an array of different images. Other tasks included item questions in which the subject answers verbally a question related to the position or orientation of a person in an image.

The aims of the present study, based on previous researches, were to detect the specific ages reflecting the evolution of the children' s ability to imagine what other persons see from a different viewpoint and to evaluate right-left orientation and mental rotation interactions. Children answering correctly on the perspective-taking test should achieve higher scores on the right-left orientation test.

METHOD

Subjects

For six age groups from 5 to 11 years, 58 children (29 boys and 29 girls, for a total of 406 subjects) were randomly selected from schools with equivalent socioeconomic classes and were individually tested. Tests were presented in the same order for all subjects.

Tests

Right-left orientation.-Subjects had first to recognize a particular picture shown to them and left in front of them, e.g., an image in which a little boy points to his left ear with his right band (Fig. 1, Image 1), from amongst other identical or

"Among these different images, find the ones":

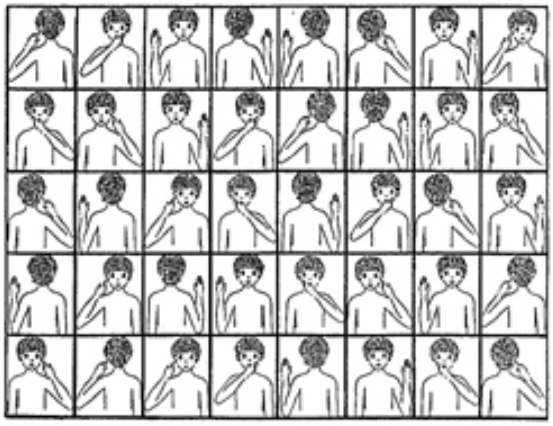


Image 1 (Recognition Test) -"similar to this one":

Image 2 (Identification Test) "where the littie boy points to his left ear with his right hand"

FIG. 1. Images used for right-left recognition and identification test

symmetrical or different pictures (recognition task). Then they had to identify an image matching a verbal description, e.g., "the images in which the little boy points to his left ear with his right hand" (Fig. 1, Image 2) (identification task). They were told to try to identify the correct images as quickly as possible. The rime necessary for completion of the tasks, the number of correct choices, and mirror errors were recorded. In another task, subjects had to identify the right and the left eye of the experimenter facing them.

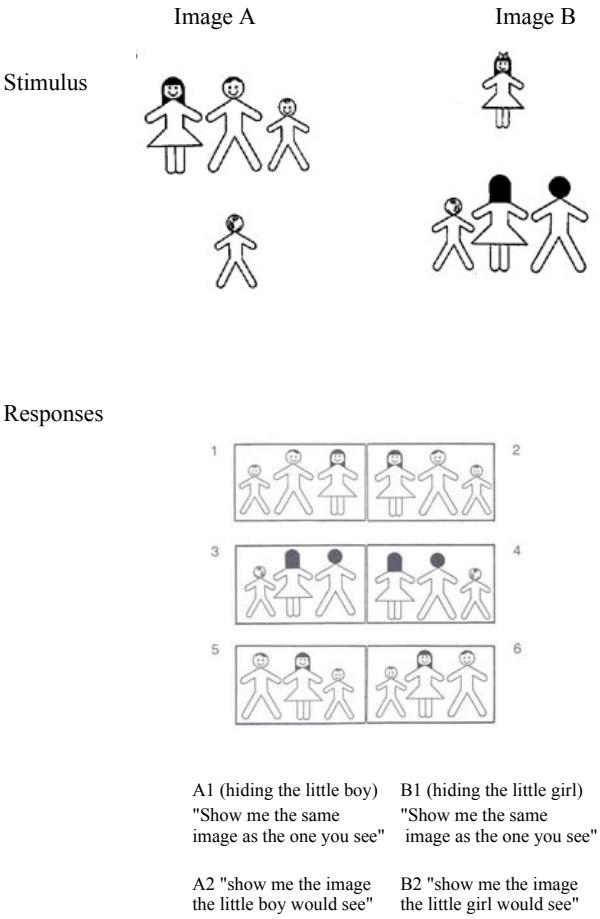
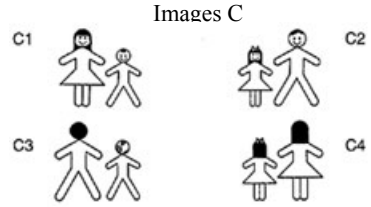


FIG. 2. Images used for the perspective-taking test

Perspective-taking.-Subjects were asked to recognize an image representing the positions of three people in a picture from the subject's own perspective (Fig. 2, A1 or B1). They were also asked to identify the image corresponding to the viewpoint of another person in the picture facing away or toward (Fig. 2, A2 or B2, respectively). The image chosen among six was recorded.

Right-left orientation and mental rotation.-Subjects had to answer to item questions relative to the position of one person in relation to another person, both of them looking toward the subject (Fig. 3, C1 or C2) or away (Fig. 3, C3 or C4).



C1 "Is the little boy to the right or to the left of his mother?"

C2 "Is the little girl to the right or to the left of her father?"

C3 "Is the little boy to the right or to the left of his lather?"

C4 "Is the little girl to the right or to the left of her mother?"

FIG.3. Images used for the mental rotation test

Statistical Analyses

To evaluate the evolution of right-left orientation knowledge from one year to the next, two-way analyses of variance were computed for each right- left orientation test with age and sex as between-subject variables. Significance level was set at $p \leq .01$; when this level was reached, means were compared using the Scheffé test. For perspective-taking and mental rotation tests" χ^2 values were calculated to compare the proportions of correct responses for each image among the age groups.

RESULTS

For the recognition task, the two-way analysis of variance with age and sex as factors yielded only a significant age effect ($F_{6,392} = 8.80$, $P < .01$), the 5 yr.-old group having a

significantly lower mean number of correct responses compared to the other groups. From six years and older, children discrirninate and recognize mirror images well. For the identification task, there was also a significant age effect ($F_{6,392} = 10.50$, $P < .01$), the groups 5 to 8 years of age having lower mean numbers of correct answers compared to the 9- to 11-yr.-old groups. Recognition was easier than identification, the mean number of correct answers for Image 1 being significantly higher than that for Image 2 *($F_{1,399}=265.90, p<01$).*

Fig. 4 shows that from five years of age, almost all children easily recognized the images similar to Al and BI (Fig. 2). For perspective-taking now (Images Al and B2), there was a significant age effect for the image chosen between the six possible answers. For Image A2, after eight years of age most children identified what the other people saw (Image A2-2) correctly, since this is a direct translation of what they themselves see *(χ_{36}^2* = 83.3, $P < .01$). For Image B2, the situation is more complex: the calculated χ_{36}^2 =

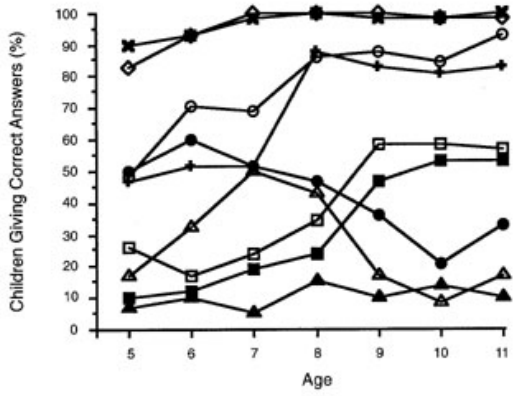


FIG. 4. Right-left orientation and perspective-taking by age group *(ns=58).* For recognition, images l (**o**), and identification, images 2 (), percentages of subjects with 75% of correct answers are reported. 2-mirror (Δ) indicates percentages of subjects choosing the mirror images of image 2, i.e., the boy showing his right ear with his left arm. For image Al (◊), [the correct answer is 2, as well as for image A2 (+). For image B1 (X), the correct answer is 3, and 5 for image B2 (_); answer 3 for image B2 (_) corresponds to "the little girl sees the same thing as I do." Answer 6 to question B2 (_) indicates that the subject has understood that the little girl sees the faces, but the child did not rotate the places of the three persons on the image.

103.1, *($p < .01$)* indicated a significant age effect in the distribution of responses. Until eight years of age, almost half of the children chose the image corresponding to their own viewpoint. Between 5 and 8 years of age, the percentage of subjects who identified the correct image increased from 1O to 20%. This percentage reached 50% at nine years of age and then levelled off until eleven years of age; at this age 30% of the children still chose wrongly image B2-3. While 88% of 8-yr.-

olds answered Image A2 correctly, only 25 % of them properly identified the image the little girl sees (Image B2). Most of the other children said the little girl sees what I see. Even at 11years of age, there were no more than 54 % accurate answers for Image B2. At all ages, between 5 and 10% of the subjects chose B2-6, the image in which faces were seen but with the position still perceived from the child's viewpoint.

As far as right-left orientation and mental rotation relations are concerned, children who answered correctly Item B2, were significantly better at identifying the images corresponding to a verbal description as in Image 2 ($F_{1,4O4}$=44.1, $p<$ .01). When children are able to adopt someone else's viewpoint, they can apply

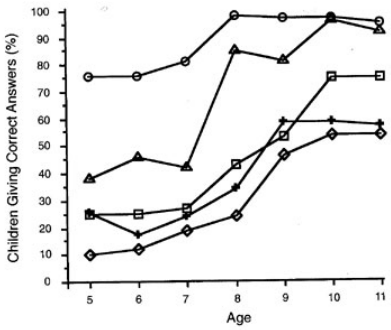


FIG. 5. Right-left position and mental rotation: Right-left position for images C3 and C4 in which people are looking away (**o**), Right-left position for images CI and C2 in which people are looking toward the subject (), Right-left identification on facing experimenter(Δ), Correct answer in 180°. rotation perspective taking of persons facing away (◊) (image B2-5), and 75% of correct answers for image identification using right and left words (+) (image 2)

the correct right and left orientation onto objects or persons seen from that viewpoint.

Finding the position of one person in relation to another person was easier for images facing away from the subject (Fig. 5, C3 and C4) than for images facing toward the subject (Fig. 5, CI and C2). At five years of age, more than 70% of children responded correctly to C3 and C4, and this percentage reached 95% for 8-year-olds. For images facing toward the subject, (' from 5 to 7 years of age only 25 % of children gave correct answers; the percentage rose to 53% for 9-yr.-olds and 75% for 10- to 11-yr.-olds (Fig. 5). Children who succeeded with Image B2 succeeded better also in Images CI and C2 than those who failed the same test

($F_{1.404}$=35.5, *p*<.*O1),* differences between means not being significant for all other images combinations (Al, A2, BI with either C3 or C4).

DISCUSSION

In this study, children had to recognize or to identify images using or Dot right and left terms and to imagine what. other persons would see from a viewpoint other than their own. Some of the tasks involved right-left recognition or identification, others mental rotation and perspective-taking. Are the results on these different tasks interwoven or independent?

Children apply right and left terms correctly for naming their own body parts from 7 years of age. At the same age, most of them correctly use the same words to give the relative position of a person in relation to another one as long as the persons on the image look away, in the same direction as the subjects (0^o rotation as for Images Al, C3 and C4) but do not succeed for facing images or real persons. This is consistent with previous results (particularly Presson, 1980; Roberts & Aman, 1993) wherein young subjects used a direct translation of their own orientation in spatial organisation. Most of 8-yr.-olds are able to designate which are the right and left body parts of another person looking at them, which is a real transition from 7- yr.-olds. But, at the same age, the majority of children do not find the image seen from a 180^o rotated viewpoint (B2) (see too Presson, 1980) nor accurately use right and left terms to point out the position of one person to another on images where people are facing forwards (CI and C2), or find images verbally described using right and left terms (Image 2). This shows clearly that there is a sharp decalage at that age between primary spatial frameworks and secondary ones involving mental representation and rotation. These are not only linked to external attractors such as objects present in the room but they reflect a cognitive block slowly evolving. It remains clear, however, that complexity varies, particularly when situations include secondary or spatial representation such as perspective-taking or right-left orientation on others. It is also clear that children show a spontaneous tendency to apply directly their own right-left orientation to other people. When older, they analyse their primary perceptions and realize that, if spatiallocalisation is absolute (things are where they are), spatial orientation is relative to the viewer's position. This is why transposition is easy as long as the main axis of an array is consistent with the individual orientation, from 0^o to $\pm$ 90^o (Presson, 1980). With only a few degrees of head rotation, the subject can easily "see" the new orientation of the display. On the other hand, when there is a 180^o rotation, mental rotation is solicited and the younger the subjects, the more frequent are the egocentric errors. A specific experiment could be done to test the importance of the array orientation on recognition and mental rotation.

At 10 years of age there is still a great difficulty in naming the position of persons facing toward the subject, as well as in identifying images, verbally described with right and left words, of facing forwards persons or imagine somebody else viewpoint in perspective taking. Imagining a 180^o rotation

perspective is still very difficult even for 11-yr.-olds (see Presson, 1980; Cox and Willets, 1982) although a decrease of egocentric responses is obvious , but still affecting between 20 to 30% of subjects. Since some of these tasks involve appearance questions (how an array looks from a viewpoint) and other item questions (is person A to the right or to the left of person B), with similar errors and evolution for both, one cannot conclude that one task is harder than the other due to the type of question. Errors are related to egocentrism, the impossibility of mentally rotating in perspective-taking tasks. In ecological space, one might evoke the importance of external frameworks or references as factors attracting children' s attention and generating confusion. The direct perceptual good figure or Prägnanz prevents a three-step information treatment : turn 180^{o} to get another perspective, deduce the new position using right and left nonverbal orientation, choose the proper image against the tendency of coming back to the actual vantage point. In right-left orientation and mental rotation, cognitive development is the significant factor. Children have to understand the consequences of another person's orientation to what is seen. This evolution in mental representation is not age-dependent but is dependent on cognitive development, since evolution is slow and does not take place suddenly from one year to the next. Development is described in leaving an egocentric perspective or reference framework, and using "alteregocentric" references by imaging now what people would see from the position in which they are located.

Apart from cognitive reasons or egocentrism, everyday's experience might also act upon the children' s thinking ability. They are more commonly faced with situations where they have to consider other's people right and left orientation than with situations wherein they have to imagine what other persons see from a different point of view. As a result, progresses happen sooner for right-left identification than for perspective-taking.

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