

Received: 2008.10.25
Accepted: 2009.03.27

A – Study Design
B – Data Collection
C – Statistical Analysis
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E – Manuscript Preparation
F – Literature Search
G – Funds Collection

AN EVALUATION OF VISUAL SPATIAL ORIENTATION IN PRESCHOOL CHILDREN

Ewa Czaplewska^{1(A,B,C,D,E,F)},
Katarzyna Bogdanowicz^{2(A,D,E,F)},
Katarzyna Kaczorowska-Bray^{1(A,B,D,E,F)}

¹ Department of Speech Therapy, University of Gdansk, Gdansk, Poland

² Psychological and Pedagogical Counseling Center No. 2, Gdansk, Poland

Background

Current research on spatial orientation indicates that, so far, we do not fully understand how spatial orientation develops in ontogenesis. Similarly, one encounters difficulties when searching for norms concerning orientation, e.g. the body scheme in adults. Another unsettled issue is the claim that a given child has disturbed spatial orientation. Certainly it is impossible to diagnose a disorder when there is no norm established. The aim of our research was to explore the level of spatial orientation skills in kindergarten children.

Material/ Methods:

1055 children were assessed: 523 girls and 523 boys from various regions of Poland. We applied an experimental method based on diagnostic experiments used to assess children's competence in spatial orientation.

Results:

We observed a certain order of spatial orientation competences: knowledge of body scheme; directions in space from one's body; projecting one's own body scheme onto another person and establishing directions in space from the body, while simultaneously speaking about the action being taken; and finally spatial orientation on paper. Simultaneously, the research shows that a majority of 6- and 7-year-olds manage the first two skills well, while orientation on a flat piece of paper is a demanding task even for 7-year-olds.

Conclusions:

The exercises in notebooks or books so often used by therapists should definitely be preceded by exercises in natural conditions, i.e. in three-dimensional reality. Should we ignore these indications, based on the ontogenetic development, we cannot expect a child to improve her functioning.

key words: *decentration, spatial perception, visuo-spatial deficit*

INTRODUCTION

The notion of space may be discussed from different – though not mutually exclusive – points of view, the majority of which combine psychological, sociological, architectural or philosophical concepts. Notions of spatial orientation accompany us almost from the very beginning of life. As soon as a few weeks after birth, the infant looks directly towards the approaching mother, and searches for the source of a sound. An 8-month-old baby searches for hidden objects and throws toys out of the pram, enjoying the sound they make. A 2-year-old consciously uses concrete spatial terms, such as adverbs (*here, there*) and prepositions (*on, towards, in*). A 3-year-old knows the terms *in front of, near, under*. School-age children can learn to tell left from right. In later years, they can use a map, and describe a route they have taken.

As an adult, we very often apply spatial notions in more abstract or metaphorical senses, concerning mostly interpersonal relations: we say that somebody could “go far in her career,” or that she is “reaching new lows”; somebody else did not hear the question because they were “mentally miles away,” while another person was “right on top of things”; politicians and governments veer “right” or “left”. One starts “at the bottom” of a firm’s hierarchy, but is “on the way up.” It is obvious that in order to use these terms in their abstract sense it is essential to master them in their concrete sense. The latter skill is connected with a certain type of spatial orientation, related to the real arrangement in which the particular elements of space (both humans and objects) are mutually located.

J. Kuczyńska-Kwapisz (1994: 21) defines spatial orientation as “an individual’s competence in discovering their environment, and the temporal and spatial relations occurring within it. Of fundamental importance are cognitive processes, the store of knowledge, the knowledge of one’s own body, spatial imagination, knowledge about the environment, operating distance and time relations, etc. the motor aspect is also not without significance as a prerequisite for shaping concepts into practical action.”

It is the right cerebral hemisphere that is mostly responsible for spatial functioning. This hemisphere primarily “specializes” in such functions as spatial localization of a stimulus, determination of gradient, or the assessment of so-called spatial frequencies, which is the number of elements constituting a particular part of an image (Budohoska & Grabowska 1994, Pachalska 2007). Nevertheless, as Pachalska points out (2007), while working with aphasic patients one may notice that damage to the left hemisphere is not without consequences for the ability to navigate. Kolb and Whishaw (2003) claim that there are qualitative differences between orientation disturbances connected with damage to the right and left hemispheres. According to Bottini and Paulesu (2003), there is no separate “center” in the cerebral cortex responsible for orientation. However, the visual cortex plays a considerable role here, for obvious reasons.

The maturing child is gradually acquiring spatial skills and knowledge. The infant does not possess a concept of either the structure or the permanence of space (Kielar-Turska 1989, Piaget & Inhelder 1989). First of all, space is something of a practical character, and cognition is initially connected with acting. The infant is not able to distinguish herself from the environment. Moreover, her sensations do not seem subjectively to be located in a concrete space. The infant does not experience her own body as being her own, or that the mother's breast is something distinct from her own mouth (Brown 2005).

A person is born with developed sense organs, which are ready to function immediately after birth. The newborn's sensitivity to gustatory stimuli is a substantial one from the start. Furthermore, smell is well developed, and tactile sensitivity is large. Hearing is at first impaired by amniotic fluid, which often remains in the middle ear for several days after birth. It is usually somewhere between the 3rd and 7th day of life that the infant starts to react to noises. At 2 months, not only do infants react to auditory stimuli, but they are also able to distinguish sounds.

The core of the development of the structure of space is the child's motor activity (Piaget & Inhelder 1989). A second issue of crucial importance is visual perception. Thanks to eyeball movements, one can direct the eye to a certain point, manipulate an image, fix the gaze in a certain position, and ensure the constancy of a visual percept. Slowly, one's own body becomes something separate from the world, and space becomes that which lies within the reach of the child's arms. The dissociation of perception and action happens when a child begins to perceive objects that are beyond arm's reach (Pachalska 2007).

Once independently mobile, the child discovers different elements of space as constituting relatively constant reference points. Space becomes independent of action. This is simultaneously the beginning of the process of differentiating "self" from "other." As Kościelska (1995) claims, the formation of a proper structure of the self is of paramount importance for intellectual functioning. This is the milestone identified by Piaget and Inhelder (1989): namely, liberation from egocentrism towards centration. All experiences encountered by the child along the way contribute to the formation of the sense of being a separate entity, a self, one of many in a world that contains other selves, without which it would be impossible to develop knowledge about oneself.

A child of kindergarten age is able to move around in space, but cannot either describe it verbally, or draw it. She studies spatial relations mostly through constructive play, when she learns to set blocks *on*, *next to*, *under*, or *inside* other blocks or groups of blocks. Moreover, she discovers the meaning of such words as *close* and *far*, and, while at play, practices also the vocabulary of spatial relations. At this age, the child is also familiar with non-symmetrical directions: *up* – *down* and *front* – *back*. However, it is still difficult for him or her to determine the symmetrical directions of *left* and *right*.

Since his or her notion of right and left have not yet been differentiated, the child relates it to herself, not to objects (Kielar-Turska 1989).

According to E. Gruszczyk-Kolczyńska (1992), the order of acquiring knowledge about particular directions is connected with human anatomy. The vertical direction is common for all people, regardless of the place occupied in space at a given moment, since it is defined by the gravitational field, which everyone experiences in generally the same way. Thanks to this, it is easiest for us to specify the location of objects using such concepts as *up*, *down*, *over*, *under*, *higher*, *lower*. Another direction that can be determined relatively easily is defined by the anterior and posterior aspects of the body. With face, eyes, mouth, and nose located on the anterior surface of the body, the human being naturally acquires the skill to distinguish the location of objects or the presence of people or objects (*behind*, *in front of*) or the movement *forward* and *backward*. Since the human body is bilaterally symmetrical, however, it is substantially more difficult to differentiate between the right and left side, and to specify a direction *to the right* and *to the left*. There is also ambiguity in naming direction (*my right* is *your left*) or in what direction the object is moving (*right* or *left*). What is right or left depends on the situation of the person assessing location or direction.

For a child of kindergarten age space is still egocentric, due to the fact that it is the child herself that constantly remains the central point of reference. She manifests interest in distinctive places and is able to recognize them. A child associates persons with particular places and is surprised to see them somewhere else. Obviously, the process of emerging from childhood egocentrism constitutes the beginning of the skill of projecting the scheme of one's own body onto another, and of learning to determine directions and the location of objects in relation to another person (cf. Gruszczyk-Kolczyńska 1997), which lasts many years.

Piaget and others have shown on many occasions that sensorimotor integration sometimes precedes conceptual reasoning by many years. It is not surprising, though, that children of kindergarten age, or early school age, can follow a known route on their own, while simultaneously they are not able to explain how they did so. There is every likelihood that the precise skill of describing the route one has traveled is connected with the formation of a cognitive map, which is a general mental model of the environment, designed on the basis of certain constant aspects present in it (cf. Cornell, Heth & Broda 1989). According to Piaget (2005), the appearance of the reasoning stage called "invention," through deduction or other mental combinations in the development of a child's intelligence, is made possible by a heightened awareness of spatial relations, a precondition for making rational predictions. Thus the basis for the development of human intelligence is space and its examination, as well as spatial relations learned by experience. Accordingly, knowledge of the stages of the formation of different competences related to spatial orientation is a matter of vital theoretical and practical importance.

Tuan (1987) claims that it is enough to be fully competent in the spatial skills, which are not the same as spatial knowledge, in order to perform ordinary, everyday activities. Educators, psychologists, teachers, and generally people working in educational fields are perfectly aware that, nowadays, the educated person needs spatial knowledge substantially surpassing common skills in this area. This is probably best reflected in the fact that almost all educational programs around the world advocate shaping spatial orientation.

It seems to be surprising, though, that so many children have major problems with spatial orientation, especially on paper, despite several years of training in this domain. First-year pupils do not understand orders connected with space. Pupils in later years cannot manage the coordinate system in mathematics classes (Oszwa 2005) or do not understand the cross section of a leaf during science classes. Many older pupils have problems with geography and geometry, which one obviously cannot master without a refined comprehension of spatial relations. Thus the question arises whether the range of schooling offered presently by kindergartens and schools actually corresponds to the real meaning of the notion of *spatial orientation*. Gruszczyk-Kolczyńska (1997) argues that the notion of spatial orientation is generally treated too narrowly. This is due to the fact that teachers are rarely aware of how a child discovers space in her natural development, although it is widely known how crucial timing is when academic demands must be coordinated with intellectual development.

A thorough analysis of the current state of knowledge concerning the development of spatial orientation indicates that, so far, there have been no unambiguous data collected that would indicate the real course of development of spatial orientation in ontogenesis. Moreover, we do not know whether there are factors that may disturb or improve this development. It also remains unclear what it really means to say that a child has “disturbed spatial orientation.” Certainly it is impossible to diagnose a disorder when there is no norm established.

Most of the data available in the literature concern disturbances of the orientation of one’s own body in adults after brain damage. As Pachalska (2008) points out, many, if not the majority of these studies have involved aphasic patients. There are also reports on spatial disturbances in schizophrenia (cf. Brugger, Surbeck & Loester 2007). Semenza (2003) notes that autotopagnosia (from Greek *auto* „own” + *topos* „place, location” + *agnosia* „lack of knowledge”) never occurs in isolation, but only in connection with difficulties in recognizing parts of other people’s bodies as well. Pachalska (2007) claims there is no evidence for orientation disturbances as such in a pure, isolated form. Therefore they do not constitute a separate problem, either theoretically or clinically. Since disturbances of body scheme do not appear in isolation, it is the scheme of the body that constitutes the basis for orienting oneself in space. Pachalska emphasizes that normative data concerning, for instance, orientation in the body scheme are scarce in the neuropsychology

logical literature. In addition, there are no standardized tests to assess visual disorientation. Most often, qualitative diagnosis is used (cf. Manning 2003). The diagnosis of topographical disorientation, in turn, is based mostly on clinical interview.

Neuropsychologists (cf. Pachalska 2008) usually divide pathologies of spatial orientation into disturbances of:

1. body scheme;
2. visuo-spatial orientation;
3. topographical orientation;
4. temporal orientation.

Psychologists who specialize in specific learning difficulties in children often do not specify exactly what functions are affected by disturbances of this kind. In the literature we find such expressions as visuo-spatial deficits (Oszwa 2005) or disturbances of visuo-spatial functions (Bogdanowicz et al. 2007). Such disturbances are very common in dyslexic children (Bakker 1990; Bogdanowicz 2001) and in other children with problems in reading and mathematics (Oszwa 2006). Lately, there has been information in the literature on dyslexia concerning a semantic deficit in the processing and organizing of linguistic information related to spatial-temporal relations (Bogdanowicz 2003, Krasowicz-Kupis 2008).

MATERIAL AND METHODS

The aim of our research was to assess the level of competence in spatial orientation among children between 3 and 8 years old. We tested 1055 children: 523 girls and 523 boys from a variety of regions of Poland. There were 179 children in the age group from 3;0 to 3;11 years, 270 children – from 4;0 to 4;11 years, 144 children were placed in the age group from 5;0 to 5;11 years, 215 children – from 6;0 to 6;11 years, while in the age group 6;0–6;11 years 215 children were diagnosed. Each child was assessed individually in a separate room.

In order to assess spatial orientation, we applied portions of an experimental method consisting in diagnostic experiments to assess children's competence in spatial orientation, developed by Gruszczyk-Kolczyńska and Czaplewska (1996).

From the original battery we selected four tests:

1. I – Body;
2. Searching for toys;
3. Greek patterns;
4. Box.

These trials are designed to assess the following competences:

- knowledge of the scheme of one's own body and establishing directions in space from one's body;

- the ability to project mentally one's own body scheme onto another person and decipher directions in space from her, while simultaneously communicating verbally with that person;
- orientation skills on paper;
- familiarity with prepositional expressions of a spatial character.

Each series begins with a learning phase, intended to enhance communication between researcher and child (the child knows what is expected of her) and equalize the children's experiences. Initial testing suggests that the learning phase helps children to display their actual competencies. However, when a child does not have such competencies, she will not benefit from the learning phase. During the second, research phase, the child manipulates familiar toys and objects, usually those used at home, kindergarten or school. The researcher uses an especially selected set of objects, which includes a beanbag, a teddy bear, a doll, a car, a piece of paper, and a pencil. All questions and prompts are the same, regardless of the child's age. During the first test, the child is asked to place the beanbag as instructed verbally by the researcher: *in front of you, behind you, on your left*, etc. During the second test, after an initial learning phase, the child instructs an adult on how to find a particular toy. The adult asks the child questions: *which way should I go: right, left, forward or backward?* The child chooses the correct answer. In the third test, the task is for a child to draw a line on a piece of paper, following an adult's instruction: *from the top of the page down, from the left to the right side of the sheet*, etc.

RESULTS

The *I – body* test consists of six tasks. The two first assess the degree of the awareness of the scheme of one's own body. The following four check the skill of establishing directions in space from oneself. A learning phase preceded the trials. During this phase, a hairband was put on the child's left hand, so that she could use it as a clue. The aim of this task was not, then, to check whether or not the child was able to recognize correctly the sides of her own body, but rather, whether or not she was able to establish directions in space starting from the axis of her own body. The child could score 1 point for each task performed correctly. Thus the maximum score was 6 points. Thanks to this scoring system, the average result in the whole subtest for each age group was calculated, with $a=84$ (see Figure 1).

The analysis of the results suggests that the awareness of the scheme of one's own body is a competence that develops with age. What is more, there are statistically significant differences between 3-, 4- and 5-year-olds ($p=0.05$). The differences between 6- and 5-year-olds and between 7- and 6-year-olds failed to reach significance. In fact, both 6- and 7-year-olds scored close to maximum (5.4 and 5.5 points). For the majority of these children, the task turned out to be easy; no additional explanations were necessary.

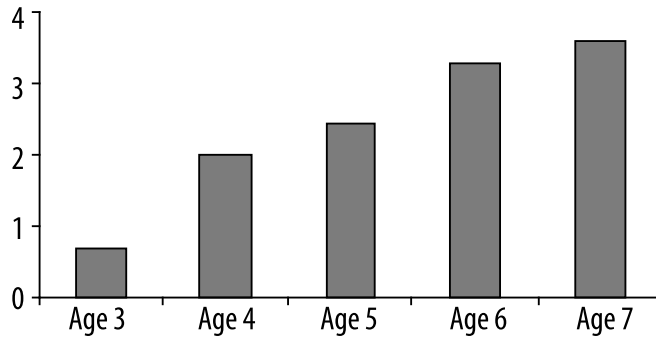


Fig. 1. Trial 1 – body. Average result for the entire subtest for each age group, $\alpha=84$.

The next task, *Searching for toys*, version B, assessed the skill of mapping the scheme of one's own body on other people, i.e. the ability to look at space from another person's point of view, while simultaneously sending verbal communications concerning space. This skill is connected with the development of both decentration and operational reasoning in children. Piaget (Piaget & Inhelder 1989) called this first step to cross the limitations of one's own "I" a "milestone" in mental development. It is simultaneously the basis of communication about space with other people. It is only when the child becomes able to look at space through the eyes of another person that she can talk with this same person sensibly and comprehensibly about the near environment.

The child could score 1 point for each trial performed correctly, for a possible maximum score of 4 points. The results achieved in this task are presented in Figure 2.

Sheffe's significance test at $p = 0.05$ ($\alpha=0.88$) indicates that all differences between age groups, with the exception of the difference between 7- and 6-year-olds, are statistically significant. In the 6- and 7-year-old groups, the average scores oscillate around the maximum (3.3 and 3.6 respectively). Thus this task was not much more difficult than the previous one, at least for 6- and 7-year-old children. For the youngest ones, however, it turned out to be absolutely impossible to perform.

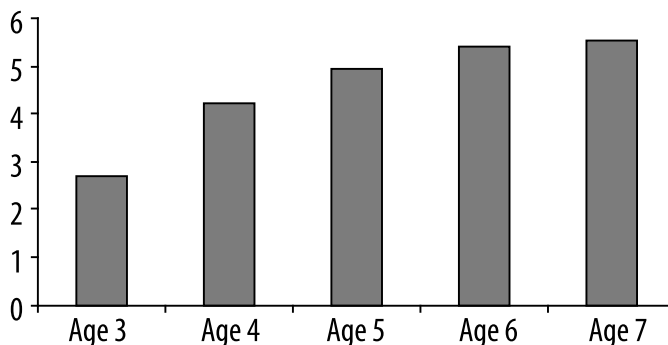


Fig. 2. "Searching for toys" subtest, mean scores (total for each age group)

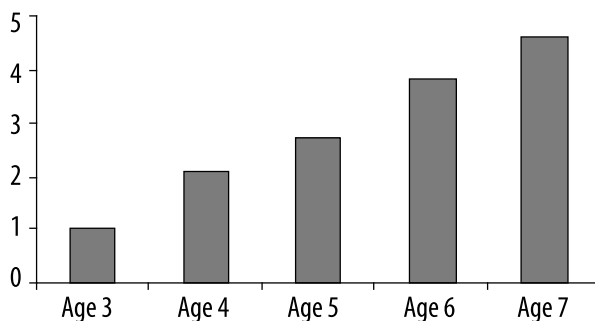


Fig. 3. Greek patterns subtest, mean scores (total for each age group)

The last task, *Greek patterns*, assessed the skill of establishing directions on a piece of paper. This skill, despite being widely regarded as something children should master quickly in school, is among the last such skills to develop in spatial orientation. This is due to the fact that the ability to project the scheme of one's own body onto other objects entails the highest level of desubjectivisation and a high degree of operational reasoning. Moreover, it is usually connected with an object – a piece of paper – that is totally differently located in space than one's own body.

A child could score 1 point for each task performed correctly. Thus the maximum possible score was 7 points. The average scores reflecting the number of tasks performed correctly in certain age groups at $\alpha=0.83$ are shown in Figure 3.

The statistical significance of the differences between the various age groups, as calculated with Sheffe's test, indicates that the differences between all age groups were significant (at $p=0.05$). It should not be overlooked, however, that even in the oldest group the average score was 4.7, far below the possible maximum result.

DISCUSSION

The results presented above are consistent with the previously presented model of the development of spatial orientation in children (Czaplewska, 2002), in the following order:

- the knowledge of one's own body scheme;
- establishing directions in space from one's body;
- the projection of the body scheme onto another person;
- establishing directions in space from another person's point of view, while simultaneously informing them verbally about the action being taken;
- spatial orientation skills on paper.

Simultaneously, our results show that a majority of 6- and 7-year-old children manage the first two skills well. According to our research, the skill of projecting the body scheme onto another person appears almost immediately after

mastering the scheme of one's own body and establishing directions in space from the subjective point of reference. Therefore it is undoubtedly this very competence that constitutes the foundation for the further development of spatial orientation. In addition, this happens in a short time. It should also be mentioned that orientation on paper is very difficult, practically not a fully achievable skill even for 7-year-old children.

The results presented in our paper demonstrate that the development of spatial orientation is also strongly connected with intellectual development, or, to be more precise, with the development of operational reasoning. Clearly, a higher stage of spatial orientation is achieved only by those children who are capable of projecting the body scheme onto other persons or objects. Furthermore, the projection of the body scheme onto a sheet of paper, which obviously does not maintain the same arrangement in space as a human body does, requires even higher intellectual capacities. Clearly, the fundamental function of operational reasoning should be used here – reversibility. Initially, the child transfers the arrangement of his or her own body onto this sheet, while at the same time being aware that the sheet when placed in a horizontal position may be reversed back to a vertical position. The fact that changes concerning one's own person in space are more easily perceivable for children than spatial orientation on paper results from the way decentration proceeds: not all at once, but step by step.

CONCLUSIONS

The presented data may explain, at least partially, why it so difficult to “facilitate” spatial orientation, especially in children who clearly manifest deficits with regard to this aspect of intellectual development. Too little time is devoted to developing the social and intellectual aspects of spatial orientation. While shaping skills connected with the development of spatial orientation, the child should be trained in spatial orientation in connection with decentration – how to project the body scheme onto other people and how to talk with them about it – only after having mastered the scheme of one's own body and establishing directions from the subjective point of reference. It is only after the child has mastered this art that she will be able to draw “a kitten in front of a fence,” or “a ball sitting on a wardrobe.” For those children who fall behind their peers in development, we may determine the current level of their development of spatial orientation, then establish where the deficits occur, which will make it possible to determine the most appropriate educational program, or, in the case of children outside the usual developmental norms – a stimulation program. The results presented here may also carry implications for neuropsychological studies. It seems possible that the diagnosis of patients with neurological impairments should take into consideration the fact that drawing on a sheet of paper is much more difficult than, for example, manipulating real objects. Limiting diagnosis only to the analy-

sis of patients' drawings on a flat, two-dimensional sheet of paper may provide the diagnostician with incomplete information.

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Address for Correspondence:

Dr. Ewa Czaplewska, Department of Speech Therapy, University of Gdansk,
ul. Wita Stwosza 58, 80-952 Gdańsk, Poland. e-mail: logec@univ.gda.pl