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Rositsa Iossifova [1], *Fernando Marmolejo-Ramos* [2]

Spatial and temporal deixis. The role of age and vision in the ontogeny of a child's spatial and temporal cognition

Abstract: *Background:* A revision is presented of the effects that motor, visual and language impairments have on the ontogeny of spatial and temporal cognition. *Purpose:* To explore the role of age and the state of vision in pointing related to spatial deixis (SD) and temporal deixis (TD) in 1) typically developing children (CG), 2) children with strabismus and/or amblyopia (ASG), and 3) blind children (BCG). *Method:* 96 children between 3.11 and 8.1 years participated in the study. Children were asked to point at space and time locations in relation to their bodies by using their hand or finger immediately after a verbal instruction was given. *Results:* Children from CG group aged from 3.11 to 8.1 were almost two times more likely to perform correct SDs than TDs. An increasing trend in performing more SDs than TDs such that CG group < ASG group < BG group was detected in children from these three groups in the 7 to 8 years old range. A significant association between personal deixis in lieu of TD and/or SD and children group was also found. *Conclusion:* Vision and age play an important role in the performance of SD and TD embedded in tasks requiring the use of axial structure of reference objects. It is argued that the mastering of the stage of *coordinate representations* is a crucial precondition for the evolution of concepts related to space and time.

Key words: space, time, deixis, amblyopia, strabismus, blind children, low vision, specific language impairments, motor development, SLT.

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Przestrzenne i czasowe deixis. Rola wieku i wzroku w ontogenezie przestrzennego i czasowego postrzegania u dzieci

Abstrakt: *Tło*: Zaprezentowano przegląd konsekwencji jakie upośledzenia ruchowe, wzrokowe i językowe wywierają na ontogenii poznania przestrzennego i czasowego. *Cel:* zbadanie roli wieku i jakości wzroku we wskazaniu powiązanym z przestrzennym deixis (SD) i czasowym deixis (TD) u 1) zwyczajnie rozwijających się dzieci (CG), 2) u dzieci z zezem i/lub ambliopią (ASG), oraz 3) u niewidomych dzieci (BCG). *Metoda:* 96 dzieci pomiędzy 3.11 a 8.1 rokiem życia uczestniczyło w badaniach. Dzieci zostały poproszone o wskazanie przestrzennych i czasowych lokalizacji w odniesieniu do swojego ciała za pomocą ręki lub palca bezpośrednio po otrzymaniu ustnej instrukcji. *Wyniki:* Dzieci z grupy CG w wieku od 3.11 do 8.1 miały pra-

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[1] **Rositsa Iossifova, MD in SLT and PhD** – Biomedical Sciences Department, Speech and Language Pathology Rehabilitation, New Bulgarian University, Sofia, Bulgaria.

[2] **Fernando Marmolejo-Ramos, MAppSc and PhD** – School of Education, Faculty of the Professions, University of Adelaide, Australia.

wie dwukrotnie większe szanse na poprawne wykonanie SD niż TD. Tendencja wzrostowa do wykonywania SD raczej niż TD, w układzie: grupa CG < grupa ASG < grupa BG została wykryta u dzieci z tych trzech grup pomiędzy 7 a 8 rokiem życia. Znaczny związek między osobistym deixis zastępującym TD i/lub SD a przynależnością do danej również została potwierdzona. *Konkluzja:* Wzrok i wiek odgrywają ważną rolę w SD i TD osadzonych w zadaniach wymagających wykorzystania osiowej struktury przedmiotów odniesienia. Autorzy twierdzą, że opanowanie etapu *przedstawienia współrzędnych* może być decydującym warunkiem koniecznym dla ewolucji pojęć powiązanych z przestrzenią i czasem.

Słowa kluczowe: przestrzeń, czas, deixis, ambliopia, zez, niewidome dzieci, słaby wzrok, upośledzenia językowe, rozwój ruchowy, SLT.

1. Introduction

Prevention of communicative disorders

A speech and language therapist (SLT) is qualified for the prevention, assessment, and treatment of human communication and associated disorders, regardless of their aetiology [3]. Nevertheless, one of the main stages of prevention activity is to keep abreast of scientific findings explaining the causal relationship between communicative disorders and their risk factors. In recent decades enough experience has been gained to confirm the common genetic, neuronal and cognitive bases for a great number of specific developmental impairments (Bates, Dick, 2002; Bishop, 2002, 2006; Hill, 2001; Mazeau, 2005; Ojemann, 1984).

The harmful effects of pre-, peri-and postnatal factors on child development are to be primarily observed in motor and sensory systems, and only later in the cognitive, linguistic, and behavioural sphere. The question arises whether the relationship between the possible pathogenic factors and language development is direct and whether these factors operate through more complex mediated mechanisms, for example, through the motor system and vision.

In this paper we interpret motor and vision impairments (level 1) as important factors that negatively affect body scheme awareness, and the learning of space and time (reflected in spatial and temporal cognition) [4] (level 2). In turn, both groups of factors affect language production and comprehension (e.g., babbling, word comprehension, production of words, word combination) (level 3).

From the age of 4.0 to 4.6 syntax and narrative language seem to be limited in that knowing the names of objects in the world around us is not sufficient to transmit accurate information to the addressee. Objects and

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[3] Official position of Standing Liaison Committee of Speech and Language Therapists / Logopedists in the European Union (CPLOL), available at: http://www.cplol.eu/eng/SLT.htm

[4] In this article we will refer to "space and time learning" as analogous to "spatial and temporal cognition" and will use these terms indifferently.

events (the "what" system in terms of Mishkin and Ungerleider, 1982) must be identified, selected and localised in space (the "where" system) or time (the "when" system) in order to communicate the message properly. Thus, motor and vision impairments impact body scheme awareness as well as spatial and temporal cognition. Together, these factors affect language development, which is reflected in language delay and a large range of communicative disorders.

In the next sections, motor and vision impairments are discussed in relation to language impairments. Then, research in cognitive science and neuropsychology is used to describe the ontogeny of temporal and spatial cognition. This review aims at suggesting that motor and vision impairments affect body scheme and spatial and temporal cognition and that these factors, altogether, affect language comprehension and production. An empirical study is reported in order to show that spatial and temporal cognition can be affected by motor and vision impairments.

Motor system and language; comorbidity of motor and language impairments

Iverson (2010a, p. 27) posits that motor development has a participatory role in language acquisition: "All other things being equal, and given a typically developing child in a typical environment, motor development is a key participant in the process of language acquisition". We will briefly describe the onset of language in the context of early psychomotor development from sitting posture to unsupported walking.

Sitting and babbling

The independent sitting (6th to 9th m.) liberates arms and enables the digital manipulation of objects. The grasping and the manipulation of objects (4th to 9th m.) marks the onset of vision-motor coordination. This period coincides with rhythmic arm movements, which appear 2 to 3 weeks before reduplicated babbling. Hand shaking or banging produces multimodal feedback that facilitates infants' awareness of correlations between their own movements and produced sound (Iverson 2010a; Iverson, 2010b; Iverson et al. 2007; Locke, 1997; Masataka, 2001; Thelen, 1979). Babbling delay is found in almost all cases of motor and language delays. Rondal (2009) points out that developing children typically vocalise about three seconds, then stop and wait for the adult's response, while children with Down syndrome vocalise longer (about 5 seconds), leaving the communicational partner with less time to respond.

Use of tools and first word comprehension

Indiscriminate and compulsive grasping (Atkinson, Nardini, 2008) participates in understanding the function of objects and brings the child to the target usage at the age of 8 to 10 months (e.g. a child can move a phone to his ear or bring a cup to his lips). This transition from simple manipulation to a specific use of tools marks the understanding of the meaning of words that label those objects. Bates and Dick (2002) argue that i) the intended use of objects, ii) the emergence of routine gestures (e.g., gesture *bye*), and iii) the protodeclarative pointing are the three most important prerequisites for the emergence of word comprehension. Regarding the use of objects, de Campos et al. (2009) found that prematurely born children, children with cerebral palsy, Down syndrome, intrauterine exposure to the influence of cocaine, and with agenesis of the corpus callosum have subsequent problems with reaching and grasping of objects.

Walking and production of first words

Crawling (7th to 9th m.), body verticalisation (10th to12th m.), and walking (12th to15th m.) change the quality and type of interaction of the child with the environment and objects in that the contact with distal objects becomes significantly easier. The main aspect gained during the first steps of the child are the first words. They are usually immediately preceded by a pointing gesture and by the stylized versions of actions with objects (recognitory gesture), e.g., the child can touch briefly his lips with a cup (Bates, Dick 2002; Capirci et al., 2005; Iverson, 2010a; 2010b; Nicolich, 1977). Luria (1979) labels the early words *sympractic,* i.e., directly related to action/practice and context, and Bruner (1975) argues that linguistic concepts are first realised in action.

Protodeclarative pointing and pretended play based on decontexualised recognitory gestures (e.g., using objects as something else, object substitution, transformation of objects, etc.) are found to be absent or poor in children with an intellectual deficit or with Williams syndrome, Down syndrome, speech delay, autism, early brain damages, etc. (Baron-Cohen et al., 1992; Bates, Dick, 2002).

Disorders of early psychomotor development (Haynes, Naidoo, 1991; Hill, 2001; Masataka, 2001), gait and balance (Vernazza-Martin et al., 2005), general and vision-motor coordination (Caputo et al., 2007; de Campos et al., 2009; Saavedra et al., 2009), imitation and nonverbal body kinesics (Bates, Dick, 2002; Capone, McGregor, 2004; Hill et al., 1998), praxis (oral, manual and ocular) (Alcock, 2006; Hill, 1998; Mazeau, 2005), handwriting (Albaret, 1995), and other body functions are shown to be associated with language delay and most communicative disorders such as: developmental dysarthria (Barca et al, 2010; Ouzilou, 1988), developmental dysgraphia (Marr et al., 2001; Mazeau, 2005), specific language impairments (SLI) (Bishop, 2006; Hill, 1998; Powell, Bishop, 1992; Vukovic et al., 2010), specific disorders of reading, writing and mathematics (Gompel et al., 2003; Mazeau, 2005; Monfort, Sanchez, 1996), stuttering (Edgar et al. 2008; Krahmer, Swerts, 2007; Mayberry, Jaques, 2000), autism (Archipov et al. 2010; Vernazza-Martin et al., 2005) and many genetic syndromes (Bates, Dick, 2002; Masataka, 2001; Rondal, 2009). On the other hand, the language profile of children with major developmental coordination disorders is shown to be more or less similar to that of children with SLI and certainly much lower than that of typically developing children (Archibald, Alloway, 2008; Hill, 2001; Powel, Bishop, 1992; Vukovic et al., 2010).

Vision system and language – comorbidity of vision and language impairments

While the comorbidity of language and motor disorders is pervasive in many areas, the relationship between vision functions impairments and language seems limited to problems of handwriting, reading delay or reading impairments (Marr et al., 2001; Mazeau, 2005; Reed et al., 2004; Valdois, 2008).

In fact, vision is a much more powerful factor in language acquisition. We drew especially on the work of Hyvärinen and colleagues (Hyvärinen, 1995, 2000, 2004; Hyvärinen et al., 2012) where low vision is interpreted in relation to communicative development. Hyvärinen et al. (2012) describe the vision disability due to brain damage as a collective result of 1) structural changes and diseases in and damage to the *eyes and vision pathways* that *alter the quality* of the vision information entering the brain; 2) damage to the *ocular motor functions,* and/or 3) *changes in the processing of vision information* in the brain. All three factors may simultaneously affect a child's functioning of vision.

Several areas of risk for children with low [5] vision have been identified:

Communication and interaction

Poor head control and general hypotonia, together with the problems of face recognition and the inability to follow moving objects or people, shifting gaze from one object to another, scanning to find and fix objects, impaired perception of fast movements (e.g., the eyes of interlocutors), can lead to atypical development of children's early social interactions.

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[5] Both strabismus and amblyopia may be viewed as paediatric low vision conditions which have an effect on the child functioning (Hyvärinen, 2000). Amblyopia ("lazy eye") refers to low vision in either one or both eyes, because the eye and the brain are not working together properly. Severe amblyopia may be related to poor depth perception, poor spatial acuity, low sensitivity to contrast, reduced sensitivity to motion, and problems of binocular vision such as limited stereoscopic depth perception. Strabismus ("squint") is a condition in which the eyes are not properly aligned with each other. This involves a lack of coordination between the extraocular muscles, which prevents bringing the gaze of each eye to the same point in space. Strabismus, as well as amblyopia, is related to problems of binocular vision, which may affect depth perception. According to Hyvärinen (2000) the decreased vision function in children must take into consideration its effect on communication (in both person to person communication and group communication), orientation and mobility, sustained near vision tasks like reading, looking at pictures, eye-hand co-ordination, and use of vision in daily living skills.

For instance, Duchaine and Nakayama (2005) indicated that some of their patients with prosopagnosia were diagnosed as being autistic or as having Asperger syndrome and Elsabbagh et al. (2012) found that low neural sensitivity to dynamic eye gaze is associated with later emerging autism. When these problems appear quite early in infancy, they can block eye contact and join attention mechanism and thus complicate the transition from dyadic to triadic communication. The absence of stable central fixation at 6 months is a pathological sign (Wright, 2006) as well as the lack of familiar faces recognition at 10 months (Duchaine, Nakayama, 2005);

Motor function

Later sitting, delayed walking, object manipulation impairments, and specific motor coordination disorders can occur when children are at risk of having low vision (Caputo et al., 2007; Crawford et al., 2004; Mazeau, 2005; Niechwiej-Szwedo et al., 2011; Webber et al., 2008);

Language development

Children with right hemispheric impairments (including inferotemporal and parietal regions) are usually early talkers as their language is shown to be overdeveloped as a compensatory strategy (Semenovich, 2002). And yet, vision impairments can determine language delay through the late object permanence and the late development of concepts of space and time. The difficulties in objects' perception and localisation may have consequences such as i) "micro" object dysgnosias with semantic substitutions due to a lack of fine vision differentiation of objects/pictures, ii) absence or imprecise use of vision and spatial vocabulary based on colour, shape, size, position, and quantity, and iii) absence or incorrect use of spatial and temporal prepositions and adverbs, absence or difficulty in mastering motion verbs, impairments of space-time sequences, syntax and causality, etc (see Hyvärinen, 2000; Hyvärinen et al., 2012, for further discussion; Mazeau, 2005; Monfort, Sanchez, 1996).

It has been reported that children with strabismus or amblyopia have significantly more academic and non-academic difficulties than typically developed children. These difficulties might impair handwriting, reading, mathematics and other subjects that require an understanding of abstract concepts, sports or fine motor performances (Gompel et al., 2003; Mazeau, 2005; Reed et al., 2004). A high incidence of strabismus, amblyopia, and refractive errors are found in prematurely born infants, in children with cerebral palsy, in children with mental retardation, and in children in institutions (Barca et al., 2010; Hyvarinen, 1995, 2000, 2004; Schalij-Delfos et al., 2000).

The learning of space. The ontogeny of spatial cognition

Spatial awareness arises quite early on in ontogeny. Any form of disontogeny is primarily characterised by some type of deficiency of spatial cognition. The child begins to understand locatives only after it understands its body, that is, after the transformation of body-gnostic space in vision-gnostic space (Semenovich, 2002).

Space learning starts first by getting to know the internal body space (Semenovich, 2002; Archipov et al., 2010), which can be described as a container without axial structure (Landau, Jackendoff, 1993) and zero distance or no contrast with the external world (Clark, Sengul, 1978). Later, the cutaneous mechanism helps to build the body's boundaries, and, through interactions with the environment, the body begins to be perceived as a reference object that possesses a surface (Landau, Jackendoff, 1993; Paillard, 1991; Semenovich, 2002). Next, the coordinate system(s) appear with the awareness of axial structure of objects and places (Semenovich, 2002; Landau, Jackendoff, 1993).

The evolution of space learning founded in the pathway from body to distal objects and the establishment of places and directions is well documented by various authors (e.g., Archipov et al., 2010; Barca et al., 2010; Coquet, Maetz, 1999; Landau and Jackendoff , 1993; Munnich, Landau, 2010; Paillard, 1991; Semonovich, 2002). Based on the work of Semonovich (2002), Landau and Jackendoff (1993), Archipov et al. (2010), Paillard (1991), and Clark and Sengul (1978), a developmental model of space learning can be proposed.

First stage

According to Semonovich (2002) and Archipov et al. (2010) the protopathic (sensing pain, pressure, heat, or cold in a nonspecific manner, usually without localizing the stimulus) and epicritic (accurate determination of the stimulus via cutaneous nerve fibres sensitive to fine variations of touch or temperature) sensitivity is formed during the first stage of space learning. The proprioceptive system (called "dark muscle sense" by Sechenov, 1947) plays a dominant role at this stage. Archipov et al. (2010) argue that protopathic sensitivity is basic for self-perception and that depersonalisation disorders are mostly due to this type of sensitivity disorders. Low protopathic sensitivity makes the perception of the body in space defective, thus the child needs to keep moving, exciting the surface sensitivity to locate and feel himself. This behaviour has often been diagnosed as attention deficit hyperactivity disorder (ADHD).

According to Landau and Jackendoff's (1993) model, at this stage of space perception, the body can be characterised as a container with no axial structure. As such, the internal body space can be described as the frame of reference, while the sense of (dis)comfort and the affective tone can be described as the object to be located.

Second stage

Semenovich (2002) labels this stage *somatognosis.* In this stage, the infant adds a new spatial knowledge through the contact of the whole body with the external word. According to Landau and Jackendoff's (1993) model, at this stage the body can be described as a container but also as a reference frame that possesses a surface and is bounded.

Third and fourth stage

Semenovich (2002) argues that during the third stage *metric and topological representations* are formed and that during the fourth stage *coordinate representations* occur. The third stage is characterised by limited spatial interactions with any object in a specific relationship to the body. Specifically, while proximal space becomes familiar by using touch and manipulation with hands and mouth, distal space becomes familiar thanks to visual exploration. Paillard (1991) describes in detail the plurality of sensorimotor action-spaces, or "sensorimotor dialogues", between the whole body and specific body parts as eyes, head, hands, etc.

Stage four, or the system of coordinates, develops in the course of lying, sitting, crawling, standing, etc. Thus, the postural development of the child at the intrauterine position is 0°, 45° at the time of birth, 90° at the stage of sitting and crawling, 180° from the moment of transition to upright posture, and finally 360° after mastering space to the rear (Semenovich, 2002). This postural space co-ordinate system is anchored to the invariant direction of gravity forces through the powerful mechanisms of maintaining an upright body posture (Paillard, 1991). According to Landau and Jackendoff's (1993) model, the coordinate system (the "where" system) requires an axial structure, i.e., it requires a "detailed geometry" (p. 227).

Fifth, sixth and seventh stage

These stages cover the verbalization of spatial concepts. Stage 5 represents the formation of structural and topological concepts; stage 6 represents the verbal designation of conceptual space and which allows abstract manipulation; and stage 7 is when the cognitive style of the individual begins to emerge and is shaped by the interaction between the internal and external space.

Thus, Semenovich (2002) generalises that the internalisation of space (and time) is a situation in which the child is able to understand and express its propioceptive system in a verbal way. The spatial concepts according to his model, reach the highest level of development when they become mediated not only by the right but also by the left (subdominant for space) hemisphere. Moreover, the development of spatial concepts is not only mediated by inter-hemispheric communication, but also by cortical-subcortical communication.

The verbalization of distance and directions in children goes through several stages. Landau and Jackendoff (1993) differentiate four discrete categories representing levels of distance prepositions in English: i) containment: the object is located in the region interior to the reference object (*in, inside*); ii) contact: the object is located in the region exterior to the reference object but in contact with it (*on, against*); iii) proximal: the object is located in the region proximal to the reference object (*near*); and iv) distant: location is distant from the reference object (*far, beyond*). According to the authors, the set of directions derives from the axial structure of the reference object. The three principal axes, *up/down*; *front/back* and *left/right*, can be viewed as originating from the centre of the reference object thus providing six possible directions.

Container prepositions (*in, inside*) appear quite early in ontogeny (between the ages of 2 and 4 years old) together with the positive and the negative ends of vertical axis (*up/down*), and with the demonstratives *here* and *there,* and *this* and *that* (Clark, Sengul, 1978; Johnston, Slobin, 1979; Stoyanova, 1992; Weist, 2002, 2009). Clark and Sengul (1978) report that children acquire the proximal/non-proximal contrast between *here* and *there,* and between *this* and *that,* following three main stages: they start off with no contrast, then work out a partial contrast, and finally master a full contrast equivalent to that of adults'. *Front* and *back* are shown to appear between the ages of 3 and 5 years old (Coquet, Maetz, 1999; Johnston, Slobin, 1979; Munnich, Landau, 2010; Weist, 2002).

Our previous experiments showed that 78.74% of 487 Bulgarian children between the ages of 3 and 4 years old gave accurate deictic answers to the instruction of pointing to *up*, 76.34% pointed correctly to *down*, 49.35% pointed correctly to *behind you*, and 38.26% pointed correctly to *in front of you* (Stoyanova et al., 2010). A large percentage of non-correct answers were due to substitutions of spatial deixis (SD) for personal deixis (PD). At this age children very often refer to the topology of their bodies in lieu of distal pointing gesture. These results suggest that in the process of conceptualisation of a novel space level, such as directions in empty space, children refer to a more primitive grounded level, such as the *topology* of the body by performing self-contact in lieu of distal gesture. For this reason, the topology of the body and body parts can be regarded as a possible frame of reference. In this article this type of pointing is termed *autotopological pointing* (or personal deixis) in order to describe pointing (or touching) at body parts (see also Iossifova, Marmolejo-Ramos, under review). It has been found that, until the end of their fourth year, normally developing children perform about 20% of autotopological pointing (Iossifova, 2012).

Learning of time. The ontogeny of temporal cognition

Time is interpreted as symmetrical or asymmetrical to space depending on the research paradigm or the type of task performed. For instance, the theory of magnitude (ATOM) proposed by Walsh (Bueti, Walsh, 2009; Lourenco, Longo, 2011; Lourenco, Longo, 2010, Walsh, 2003) demonstrates an early reciprocal interaction among the dimensions of space, size, time, speed, and number that has a common representational code and that is supported by shared neural mechanisms. The processing of information takes place regardless of the specific dimension, be this spatial or temporal, to ensure a quick response and adaptation to the environment and to account for the economy of the cognitive activity. Moreover, the lexical "blending" or the overgeneralisation of certain "units" by children and adults is reported to be a direct consequence of the action of the general *Magnitude* system proposed in ATOM (e.g., children often determine the larger train to be faster than the smaller one, thus referring to an irrelevant dimension).

The question that has not been elaborated upon in adequate detail in the ATOM theory is why the process of lexical "blending" is not reciprocal and rather unidirectional (e.g., when we talk about time, we borrow lexical funds primarily from the field of space, but when we talk about space, we hardly ever borrow temporal terms). The asymmetry in the conceptualization and lexicalization of space and time has also been commented on in cognitive science and linguistics (Ahrens, Chu-Ren, 2002; Boroditsky, 2000; Casasanto et al. 2010; Evans, 2004; Gentner, 2001; Gibbs, 1996; Iossifova, Marmolejo-Ramos, under review; Kranjec, 2006; Lakoff, Johnson, 1999; Moore, 2006; Özçalışkan, 2007; Pederson, 2003)**.**

According to the theory of conceptual metaphors theory (CMT) (Lakoff Johnson, 1999), space, as it is characterised by a high degree of specificity, metaphorises time, which is characterised by a high degree of abstraction, primarily by verbs of motion (time *passes, comes, rushes*). This is possible because time is represented as a material object with specific physical and spatial parameters that can potentially move in space. In terms of Lakoff and Johnson (1999), space is the "source domain" and time is the "target domain". In CMT the issue of the asymmetry between the two areas is set explicitly, thus the assumption that in the process of the conceptualization of time the child will draw on their knowledge of space is tenable.

The abstract concept of time is acquired later than the more concrete concept of space, explaining why children produce spatial terms earlier than their temporal counterparts (Casasanto et al., 2010). The rise of temporal deixis starts with the inclusion of the first *temporal-aspect* contrasts between verbs in the present tense and in aorist, and after a period of several months the future tense is introduced. By the end of the third year, most Bulgarian speaking children begin to use five of all nine verb tenses (Stoyanova, 2006) and some basic temporal adverbs, such as *now*, *then*, *yesterday*, *today*, and *tomorrow*, start to appear. However, these adverbs are initially often used with generalised semantics, e.g., *yesterday* and *tomorrow* are used to describe events in time that are different from the present. After some time, *yesterday* is used for each past moment, and *tomorrow* for any future time. After a stage of relative location and concatenation of events, children aged from 3 to 4 years old enter the stage of temporal objective location and that is significantly more accurate than the previous one. This objective localisation stage is complex and relies on adverbs and adverb phrases whose semantics includes not only a deictic component but also some cyclic units of measurement such as *one hour*, *evening*, etc.

In an extensive study on the ontogeny of cyclical time concepts, Ames (1946) found that the timing of the concepts in spontaneous speech of children does not always correspond to the age at which children understand these concepts. She found out that the adverb *today* is used spontaneously and understood at the age of 24 months; the adverb *tomorrow* is used at 30 months but understood at 36 months; and the adverb *yesterday* is used at 36 months but begins to be understood at 48 months. Thus, the temporal sequence *yesterday* – *today* – *tomorrow* is situated within the 2 to 4 years old range.

For speech therapists it is essential to know the basic stages that children go through to achieve not only the comprehension and the expression of time concepts, but also the ability to order events and cycles in a time continuum. This ability (understanding of the prepositions *before* and *after*, the successive and the simultaneous gnosis, causality, etc.) enables four-year-old children to develop syntax and narratives as well as the ability to recount stories or do sums. An original and accessible way to explore the ability to order time events is described by Ducret and Saadi (2008). In their study, three and four-year-old children were asked: 1) how old they are, 2) how old they will be at their next birthday, and 3) how old they were at the last birthday. The results showed that 94% of children gave a correct answer to the first question, 32% know how old they will be the next year, and only 18% managed to answer how old they were at their last birthday. The data thus showed that the ability to order events in this age group is minimal. The overall conclusion is that 3 to 4 years old children find it difficult to connect days of the week, months, seasons, and years, i.e., they struggle with the continuous flow of time.

According to Semenovich's model (2002) the notion of *past-present-future* emerges at the level four of space learning, i.e., at the stage of *coordinate representations*. In an earlier study (Iossifova, 2012), 80 children aged from 4 to 8 years old were asked to verbally explain and to point where *yesterday*, *tomorrow*, and *today* are located. It was found that children from 4 to 5 years old used the container way of location, i.e., they explained that *yesterday* and *tomorrow* are located "outside", but *today* is located “in the room”, “at home”, “in the kindergarten”, etc. From 5 to 6 years the partial contrast was shown to be related to “forward” for *yesterday* and *tomorrow* and “here” for *today*. At the age of 5.4 years old, 45% of the children started to use conventional temporal deixis (i.e. they start to point *in front* for *tomorrow*, and *behind* for *yesterday*) and explained their choice referring to deictic or non-deictic verbs as *come*, *pass*, etc. At the age of 6 to 8 years old, 75% of children used both correct nonverbal and verbal means for the location of cyclical time concepts.

The purpose of the study

In line with the claim that age and any kind of disontogeny can affect spatial and temporal cognition, we can concentrate the present research on two main factors, i.e., the children's age and their state of vision. The purpose of the current study is to explore the mastery of pointing in relation to spatial deixis (SD) and temporal deixis (TD) in typically developing children from 4 to 8 years old (CG), and 7 to 8 years old children with vision-motor impairments due to strabismus and/or amblyopia (ASG), and in blind children (BCG).

In typically developing children from 4 to 8 years, we expect to find different stages in the mastering of distal (empty) space including contact kinemas (autotopological deixis) in lieu of distal kinemas (pointing space directions in space). There are reasons to believe that in the process of conceptualisation of directions in the allocentric space and of temporal references children might refer to the *topology* of the body as a less abstract level of reference. It can be expected that seeing children at early school age should exhibit adult-like conventional pointing for temporal-related references that have a single codable direction (*front-back* or *left-right*).

In children with vision-motor impairments and in blind children, we expect to find differences in the accuracy of the responses in both experimental groups because of the vision status and the role that vision plays in conceptual knowledge. Vision is linked mostly with allocentric frames of reference, so it is assumed that both directional pointing (spatial cognition) and temporal pointing (temporal cognition) may be impaired in these groups of children. It is expected that children with vision-motor impairments, due to strabismus or amblyopia, should exhibit substitutions of SD for PD (or autotopologic) more often than the CG children because of the low vision which affects the conceptualization of egocentric and allocentric frames of references. As the ASG children rely on their vision, it is expected that they should follow trends similar to those of the CG children. In the BCG, a significant number of substitutions of SD and TD for PD are expected because of a lack of vision. In these children the conceptualization of spatial and temporal references relies primarily on motor and auditory modalities.

2. Method

Participants

A total of 96 children between the ages of 3.11 and 8.1 from schools in Sofia, Bulgaria, participated in the study (equal number of males and females in each age group). Table 1 reports the demographics of the sample of study.

Table 1. Demographics of the children who took part in the study

Children group (acronym)	Age range	Mean age (SD)	Sample size
Normal vision (CG)*	3.11-4.90	4.20 (.59)	16
	5,10-5.90	5.46 (.28)	16
	6.00-6.90	6.35 (.27)	16
	7.00-8.10	7.50 (.42)	16
Visual-motor impairments due to strabismus or amblyopia (ASG)	6.10-8.00	7.35 (.58)	16
Blind (BG)	7.00-8.10	7.50 (.41)	16

* The mean age (and SD) in the CG group was 5.88 (1.28).

Procedure and materials

Children were asked to point at space and time locations in relation to their bodies by using their hand or finger, immediately following a verbal instruction. That is, children had to use a non-verbal deictic gesture to materialise the verbal request given by the researcher. Children were asked to perform two types of deixis. First, children were asked to perform the spatial deixis and immediately after they were asked to perform the temporal deixis as follows: in the spatial deixis situation (SD) the instruction was: "use your hand/finger and point *in front of you*, *behind you*, and *down*", in random order. In the temporal deixis situation (TD) the instruction was: "use your hand/finger and point *yesterday*, *tomorrow*, and *today*", in random order. The rationale behind this ordering was that asking someone to gesture via temporal adverbs is not as common as a task asking to gesture via spatial adverbs. Thus, the spatial deixis task was requested first to help children become familiar with the whole experimental session.

The deictic gestures were registered according to their accuracy. Correct deictic gestures were scored as 1, whereas incorrect ones were scored as 0. Incorrect responses were those in which a verbal answer was given in lieu of the requested gesture, when children pointed to themselves in lieu of the temporal (PD_TD) or the spatial (PD_SD) deixis requested, or when temporal-related gestures had no single categorisable direction.

Design and analysis

The first analysis focused exclusively on the CG group. In that analysis, the independent variables were the four age groups (i.e., ~4, ~5, ~6, and ~7) and the two types of deixis requested to be performed. For the second analysis, the independent variables were the three groups of children (i.e., CG, ASG, and BG) at the age of 7 and the two types of deixis requested to be performed. In all analyses, the dependent measures were the number of correct temporal and spatial deictic gestures (i.e., TD and SD, respectively) and the number of PD_TD and PD_SD. Thus, the data sets consisted of the following 2-dimensional contingency tables: Analysis 1; 4 (age group $_{\text{CG group only}}$: ~4, ~5, ~6, and ~7 years old) × 2 (deixis type: SD and TD), and 4 (age group $_{\text{CG group only}}$: ~4, ~5, ~6, and ~7 years old) × 2 (personal deixis in lieu of SD and TD: PD_SD and PD_TD). Analysis 2; 3 (children group $_{\text{7-years old}}$= CG, ASG, and BG) × 2 (deixis type: SD and TD), and 3 (children group $_{\text{7-years old}}$ = CG, ASG, and BG) × 2 (personal deixis in lieu of SD and TD: PD_SD and PD_TD).

Frequency data was analysed using a chi-square test with simulated *p*-values (based on 2000 replicates). The *p*-value of the generalised Fisher's exact test (here, $p_{g\text{FET}}$) was computed whenever a contingency table had cells with values below 5 and/or equal to 0 (see West, Hankin, 2008).

Mosaic plots (Hartigan, Kleiner, 1984; see also Friendly, 1994) were used to present the results of the number of correct and erroneous deictic gestures. Standardised residuals (z_{sr}) were computed to assess the significance of results observed in specific cells (see Field, 2012, pp. 825-826). Only significant z_{sr} values at $\alpha = .05$ (i.e., $-1.96 \geq z_{sr} \geq 1.96$) were reported in the mosaic plots.

Cramér's *V* effect sizes (*V*) were computed for significant associations. This measure of association can be interpreted on a range between 0 (no association) and 1 (complete association). Also, odds ratios (*OR*) and their 95% CIs were computed for pair-wise comparisons of interest (see Bland, Altman, 2000, for the computation of *OR*s and their confidence intervals). Note that when a contingency table has values of 0 in some of the cells or row/column totals, *OR*s and their 95% CIs cannot be estimated.

3. Results

Accuracy of spatial and temporal deixis of the CG group at the age of 4, 5, 6, and 7

The chi-square test suggested that there was a significant association between the age of the children and the deixis type, $\chi^2(3) = 8.97$, $p = .03$ ($V = .18$).

As the z_{sr} values suggest, all ages in the CG group showed percentages of spatial (62.04%) and temporal (37.95%) deixis that were within the expected values for that group. Although children across all ages were almost two times more likely to perform correct SDs than TDs ($OR_{\text{SD>TD, all ages}} = 1.63$, 95% CIs = [.53, 4.97]), it was not a significant trend (i.e., the lower limit of the 95% CIs was below the value of 1). Within each age group, children performed deixis within expected frequencies, all z_{sr} = ns. Interestingly, the results showed a pattern in which, as age increased, the amount of correct SDs and TDs tended to level out. For instance, while the number of correct TDs was just around 20% at the age of 4 ($\text{SD}_{\sim 4\ yo}$ = 80%), 32.81% at the age of 5 ($\text{SD}_{\sim 5yo}$ = 67.18%), and 43.37% at the age of 6 ($\text{SD}_{\sim 6yo}$= 56.62%), at the age of 7 it was 44.82% ($\text{SD}_{\sim 7yo}$= 55.17%). In other words, the likelihood of performing more correct SDs than TDs tended to decrease and level out as age increased; $OR_{\text{SD>TD}, \sim 4\ yo} = 4$ (95% CIs = [1.31, 12.17]), $OR_{\text{SD>TD}, \sim 5\ yo} = 2$ (95% CIs = [.67, 6.23]), $OR_{\text{SD>TD}, \sim 6\ yo} = 1.3$ (95% CIs = [.42, 3.97]), and $OR_{\text{SD>TD}, \sim 7\ yo} = 1.23$ (95% CIs = [.40, 3.74]). For example, only at the age of 4 were children four times more likely to perform correct SDs than TDs, while at the other ages it could have happened just by chance (see Figure 1A).

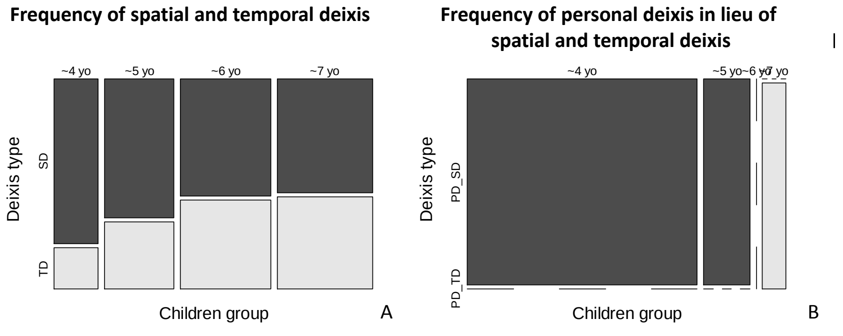

Figure 1. Mosaic plot of the frequencies of correct (A) and erroneous (B) spatial and temporal deixis in the CG children group. The z_{sr} values signal cases in which children significantly performed more or fewer deictic gestures than expected (in this particular case, no z_{sr} were plotted since all z_{sr} = ns)

The generalised Fisher's exact test showed there was no significant association between personal deixis in lieu of temporal and spatial deixis and the age of the children in the CG group, $p_{g\text{FET}} = .07$ (see Figure 1B).

Accuracy of spatial and temporal deixis of the CG, ASG, and BG groups at the age of 7

The chi-square test suggested that there was a significant association between the age of the children and the deixis type, $\chi^2(2) = 11.99$, $p < .002$ ($V = .26$).

As the z_{sr} values suggest, children in the CG and ASG groups showed percentages of spatial ($\text{SD}_{\text{CG group}} = 55.17\%$, $\text{SD}_{\text{ASG group}} = 69.04\%$) and temporal ($\text{TD}_{\text{CG group}} = 44.82\%$, $\text{TD}_{\text{ASG group}} = 30.95\%$) deixis that were within the expected values for those groups. However, in the case of the BG group, while children performed SD within expected values ($\text{SD}_{\text{BG group}} = 84.78\%$), the number of TD children performed fell significantly below expected values ($\text{TD}_{\text{BG group}} = 15.21\%$). Also, there was an increasing trend in the likelihood of performing more SDs than TDs such that CG group < ASG group < BG group, $OR_{\text{SD>TD, CG group}} = 1.23$ (95% CIs = [.40, 3.77]), $OR_{\text{SD>TD, ASG group}} = 2.23$ (95% CIs = [.72, 6.83]), and $OR_{\text{SD>TD, BG group}} = 5.57$ (95% CIs = [1.81, 17.07]). A combination of the *OR*s and the z_{sr} results suggests that, only in the case of the BG group, was the likelihood of performing more SDs than TDs significant due to the fact that children performed fewer TDs than expected (see Figure 2A).

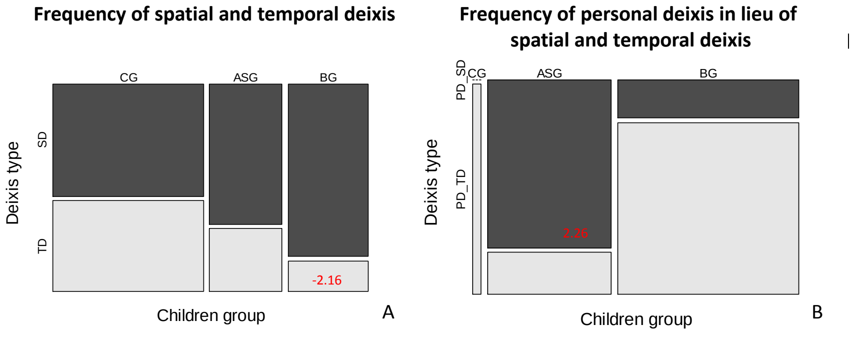

Figure 2. Mosaic plot of the frequencies of correct (A) and erroneous (B) spatial and temporal deixis in the CG, ASG, and BG children groups at 7 years old. The z_{sr} values signal cases in which children significantly performed more or fewer deictic gestures than expected

Pairwise comparisons showed that the likelihood of performing more SDs than TDs was higher in the ASG group than in the CG group ($OR_{\text{SD>TD, ASG vs CG}} = 1.81$, 95% CIs = [.59, 5.55]), higher in the BG group than in the ASG group ($OR_{\text{SD>TD, BG vs ASG}} = 2.49$, 95% CIs = [.81, 7.65]), and significantly higher in the BG group than in the CG group ($OR_{\text{SD>TD, BG vs CG}} = 4.52$, 95% CIs = [1.47, 13.87]).

Finally, Figure 2A further suggests that while children in the CG performed 49.71% SDs and TDs of the entire number of deixis collected, children in the ASG and the BG group performed only 24% and 26.28% spatial and temporal deixis, respectively. That is, children in the CG group were approximately two times more likely to perform correct SDs and TDs than children in the ASG group ($OR_{\text{SD+TD, CG vs ASG}} = 2.07$, 95% CIs = [.67, 6.34]) and children in the BG group ($OR_{\text{SD+TD, CG vs BG}} = 1.89$, 95% CIs = [.61, 5.79]). Children in the BG group were almost equally likely to perform similar number of TDs and SDs than children in the ASG group ($OR_{\text{SD+TD, BG vs ASG}} = 1.09$, 95% CIs = [.35, 3.35]).

The generalised Fisher's exact test showed a significant association between personal deixis in lieu of temporal and spatial deixis and children group, $p_{g\text{FET}} < .001$ ($V = .62$) (see Figure 2B). The z_{sr} values suggest that children in the CG and BG group performed PD_SD and PD_TD within expected values; however, although children in the ASG group performed PD_TD within expected values, these children performed significantly higher frequencies of PD_SDs than expected ($\text{PD\_SD}_{\text{ASG}} = 80\%$). The results further showed that while children in the BG group were 4.5 times more likely to perform PD_TD than PD_SD, children in the ASG exhibited an opposite pattern in which they were 4 times more likely to perform PD_SD than PD_TD. Finally, while children in the BG group were 1.46 times more likely than children in the ASG group to perform more PD_SD and PD_TD, both ASG and BG groups were 37 times more likely to perform these types of deixis than children in the CG group. That is, while 57.89% and 39.47% of the total number of PD_SD and PD_TD were performed by children in the BG and ASG groups, respectively, children in the CG group performed only 2.63% of these types of deixis.

4. Discussion

The starting point of our study was the assumption that spatial and temporal cognition are highly contingent on the state of the motor and vision systems, the age, and any kind of disontogeny. We concentrated the research on two main factors, i.e., the age (typically developing children from 4 to 8 years) and the state of vision in 7 to 8 years old children with amblyopia and/or strabismus (ASG) and congenitally blind children (BG). In typically developing children from 4 to 8 years we expected to find different manifestations of mastering of distal (empty) space including contact kinemas (autotopological deixis) in lieu of distal kinemas (pointing directions in space). The results suggested that there was a significant association between the age of the children and the deixis type. Children across all ages were almost two times more likely to perform correct SDs than TDs. These results are consistent with data reported by many researchers and that suggests that space seems to be basic and asymmetric to time. It was found that the likelihood of performing more correct SDs than TDs tended to decrease and level out as age increases. The analyses further showed that there was no significant association between personal deixis in lieu of temporal and spatial deixis and the age of the children in the CG and these children performed only 2.63% of these types of deixis. Despite the low and non-significant percentage of substitution of distal kinemas (pointing directions) by contact kinemas (pointing or touching own body parts), referring to their own body topology in younger children (from 4 to 5) is a demonstration of limited spatial contrast. The transition from the body perceived as reference frame to coordinate systems, and awareness of axial structure of the body seems not to be achieved in these children yet (Semenovich, 2002; Landau, Jackendoff, 1993).

In groups of visually impaired children, a tendency to "narrowing" the space frames was observed. More specifically, the allocentric (distal) space was shown to be substituted by bodily space. These findings suggest that vision plays an important role in the mastering of space and time contrasts in tasks requiring the use of axial structure of reference objects. In line with the models of Semenovich (2002), Landau and Jackendoff (1993) and Clark and Sengul (1978), we define the mastering of level 4 of space learning, i.e., the stage of *coordinate representations*, as a crucial precondition for the evolution of space and time contrasts. In the same vein, we interpret the substitution of non-verbal spatial or temporal deixis for autotopological (or personal) deixis as evidence of low axial coordinate representation in younger children and in children with vision impairments.

Pointing space directions such as *in front*, *behind*, *up*, *down* and cyclical time concepts such as *yesterday*, *today* or *tomorrow* can be used together with other instruments as a screening tool for determining the level of space/time contrasts or distance/directions differentiation in young children and in children with low vision. It is of interest to expand the study including other groups of impaired children such as SLI, DCD, ADHD, cerebral palsy, autism, stuttering, attachment, mental retardation, etc, and who reportedly privilege self-touching and self-directed gestures in lieu of partner-oriented communicative gestures. Another domain of interest is to investigate the links among the ability to use axial structures by gesturing (pointing) and the syntax and narratives both in young typically developing children and in children with developmental impairments. Such a study would assist in explaining the way vision, space, and time interact in the context of language comprehension and production.

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