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Spatial language in blind children: expressing location and motion without vision

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Abstract: This study compares the performance of blind and sighted children (6-11 years old) in the production and comprehension of spatial prepositions and motion verbs in French language. In both populations, performance was better in comprehension than in production and with prepositions than with verbs. Performance was better in the sighted than in the blind, although with prepositions this difference mostly concerned young children and gradually disappeared thereafter. With verbs, population differences decreased only at 11 years and never disappeared entirely. In both populations, but especially among blind children, performance was better with prepositions marking containment or implying a vertical plane than with those implying a sagittal plane, particularly with non-oriented entities. Performance was also best when verbs implied a vertical plane (ascend, descend). The discussion explores implications of these results in light of blind children's performance.

Key words: blindness, child development, spatial language, spatial prepositions, motion verbs.

Résumé : Cette étude compare les performances d'enfants aveugles et voyants (6-11 ans) dans la production et la compréhension de prépositions spatiales et de verbes de mouvement en langue française. Dans les deux populations, les performances étaient meilleures en compréhension qu'en production. Les performances étaient meilleures chez les voyants que chez les aveugles. Pour les prépositions cette différence concernait surtout les jeunes enfants et disparaissait progressivement par la suite. Pour les verbes, les différences de population n'ont diminué qu'à l'âge de 11 ans et n'ont jamais complètement disparu. Dans les deux populations, mais surtout chez les enfants aveugles, les performances étaient meilleures avec les prépositions marquant le confinement ou impliquant un plan vertical qu'avec celles impliquant un plan sagittal. Les performances étaient également meilleures lorsque les verbes impliquaient un plan vertical (monter, descendre). La discussion explore les implications de ces résultats à la lumière des performances des enfants aveugles.

Mots-clés : cécité, développement de l'enfant, langage spatial, prépositions spatiales, verbes de mouvement

Introduction

Space is a fundamental domain of cognition that is vital for survival in many species. Learning to represent space verbally and non-verbally allows us to find one's way or to give instructions for how to get from one place to another. From a developmental point of view, this domain has given rise to some theoretical debates such as the extent to which knowledge about space is biologically pre-programmed vs. gradually constructed by children through cognitive processes that include language learning. One aspect of this question revolves around the relative weight of language vs. visual perception as two factors potentially influencing the way in which children and adults construct different types of spatial representations (e.g. descriptions of itineraries, of spatial relations, of motion events).

Very few studies have looked at the impact of a disability on the acquisition of spatial prepositions in French. The few studies identified focus on children with mental disabilities (Comblain et al., 1993; Piérart, 1998). Among visually impaired children, the studies identified are old, relates to non-French-speaking linguistic contexts and only concern the pre-school period. This article presents the results of a study comparing the performance of blind and sighted children in tasks involving the production and comprehension of spatial language (spatial prepositions, verbs of movement) during the school period.

Spatial representations and language in blind children

Because our representation of space depends heavily on vision, questions arise as to how blind children learn to conceptualize their environment, e.g. through modality-specific or modality-independent representations (see a review in Bedny & Saxe, 2012).

Blindness effect on spatial representations

It is in the spatial domain that blindness, particularly before one year, has the most impact, resulting in important developmental delays (Bigelow, 1991; Bigelow, 1996; Morrongiello et al., 1995; Ungar et al., 1997; Lewis & Collis, 1997; Brambring, 2006). Blind children have difficulties in understanding space in the preschool years, especially with respect to putting objects in spatial relation to one another (Fraiberg & Adelson, 1973; Fraiberg, 1977).

Several studies show a deficit in spatial representations, as well as better results when blindness has occurred late rather than early (Warren, 1994; Thinus-Blanc & Gaunet, 1997). Children with early blindness encounter difficulties in constructing cognitive maps and in understanding the consequences of movements (their own or of other entities), although some show exceptional performance (Landau & Gleitman, 1985; Landau & Gleitman, 1997). Particularly, blindness interferes with the development of spatial knowledge directions, especially in distance judgments (Bigelow, 1991). For example, the development of spatial knowledge of the home environment in school-age shows that blind children were delayed in judging straight-line distances between familiar locations (Bigelow, 1996).

Experiments investigating mental rotation show difficulty in blind children for rotating to oblique (rotation 45 through to 315″). Blind children also had more difficulty with far than near orthogonal test positions (Millar, 1976).

Finally, to compensate for the lack of visual information, blind children explore objects through touch. Tactile or haptic perception generates an egocentric experience of space and a kinesthetic encoding of exploratory movements. This type of encoding of space, which is egocentric and therefore not allocentric as vision may allow, also persists into adulthood (O'Connor & Hermelin, 1978; Lederman & Klatzky, 1987). People who are blind from birth use egocentric coding strategies because the amount of distal information provided by the environment is limited (Millar, 1988). And this particularity is found in the understanding of spatial relationships.

Spatial language acquisition in blind children

Blind children's understanding of spatial relationships involves the ability to understand the relationship between spatial terms referring to parts of objects. In this regard, the correct use of spatial terms such as 'top' and 'bottom' depends on understanding the spatial relationships between parts of an object (Landau, 1991). Sighted adults know that when an object is upright, its top and bottom are at opposite ends of the object's main vertical axis. Adults also know that these regions are defined by the object's reference system. For an upside-down object, the top is the lowest in the environmental datum and the bottom is the highest. Even for an unknown object, once adults know where the top of an object is, they can deduce the location of the bottom, and even the side, front and back. Such inferences about the meaning of terms in the spatial parts depend on understanding the spatial relationships between the labeled object parts independently of the particularities of the object's shape, and on the ability to mentally manipulate this group of terms according to the current orientation of the object.

Despite difficulties understanding spatial relationships and some deficits in spatial representations among blind children, little evidence is available regarding spatial language acquisition in blind children (Bigelow & Bryan, 1982; Mills, 1983; Landau & Gleitman, 1985; Mulford, 1988; Landau, 1991; Baker, 2010).

Landau (1991) investigated the blind child's understanding of five English spatial terms: 'top', 'bottom', 'front', 'back' and 'side'. She remarked that at 3 years old, the percentage of error produced by a blind child observed for this study was very close to those made by sighted children. However, differences were observed for the front and rear terms which were generally more difficult for the blind child to learn. According to the author, these results would be evidence that visual experience is not necessary for the early natural emergence of the capacity to represent and transform spatial descriptions of objects.

However, several studies in English are less categorical (Mills, 1983; Landau & Gleitman, 1985; Mulford, 1988; Baker, 2010). Indeed, even if blind children follow the same developmental patterns as sighted children when they acquire spatial prepositions, delays are observed, particular with changes in reference frames (egocentric/allocentric). Blind children do initially understand spatial terms egocentrically. Indeed, it is easier for them to demonstrate a spatial relationship between their own body and an object than it is to correctly demonstrate a spatial relationship between two independent objects (Bigelow & Bryan, 1982)

Regarding the production of spatial terms, Mulford (1988) has shown in blind children a delay in the acquisition of deictic spatial devices ('this one', 'that one', 'here', and 'there') which continues until the age of six years. These spatial devices were rare and never accompanied by gestures clarifying the referents. Finally, 'this' and 'here' are used earlier than 'that one' and 'there'. It is likely that blind children use "this" and "here" more frequently because their interaction with the world is primarily based on tactile and auditory perceptions within close proximity. The terms "that one" and "there", which depend on visual references for distant objects and places, are less useful and therefore less used by blind children (Mulford, 1988; Pérez-Pereira & Conti-Ramsden, 2013) .This result corroborates studies on language acquisition that show delays and particular patterns (Andersen et al., 1984; Landau & Gleitman, 1985; Dunlea, 1989; McConachie, 1990; McConachie & Moore, 1994; Lewi-Dumont, 1997; Pérez-Pereira & Conti-Ramsden 2013; Galiano & Portalier, 2011; Galiano et al., 2014). However, another study in Spanish by Pérez-Pereira (1999) does not show any difference between blind and sighted children in the acquisition of spatial adverbials ('here', 'there') demonstrative pronouns ('this one' and 'that one'). On the other hand, this study confirms the precocity in the acquisition of proximal adverbs ('here', 'there') compared to those of distance ('over there'). This result is interesting because it indicates that blindness therefore impacts the way they use language in relation to their experience of the physical environment. Indeed, children who are blind, because they do not have access to the distant environment, tend to use language in an ego-centered way, meaning it is closely tied to their direct experience. Which explains why 'here', 'there' are acquired before 'over there'.

Regarding the understanding of English spatial prepositions, Bigelow and Bryan (1982) studied blind children's three spatial prepositions between the ages of two and four years: 'in', 'on', 'under' in two tasks. In the first one, children had to place themselves in relation to objects (e.g., tables, a box) and in the second one they had to put toys ‘in’, ‘on’, and ‘under’ these same objects. The results show that blind children were able to perform correctly in the first task: ‘in’ and ‘on’ at 33 months, ‘under’ at 38 months. In the second task the correct answers have been observed respectively: ‘in’ and ‘on’ at 34 months, and ‘under’ at 45 months. Sighted children generally begin to produce and comprehend simple spatial prepositions (e.g., in, on, and under) around 2 years of age (Brown, 1973; Clark, 2004). The authors explain the delay with the preposition ‘under’ in this task by invoking the fact that blind children comprehend spatial prepositions at first in an egocentric mode. This can be explained because blind children have no experience seeing objects in relation to another object. Similar results were observed in the group of sighted children although sighted children were younger (1;6 and 3 years). However, this study confirms the early acquisition of proximal adverbs in comparison to distal ones. It has also been shown that these children’s responses are governed by their previous experience with objects and that visual perception influences the acquisition of certain spatial terms (everything ‘above’ is often visually perceptible while everything ‘below’ is not) (Clark, 1973).

Thus, this acquisition depends on the one hand, on cognitive factors, linked to spatial representation and the understanding of spatial relationships and, on the other hand, on environmental factors. About it, some observations also suggest that adult scaffolding helps blind children master locative prepositions (Peters, 1994). Indeed, due to lack of access to visual means of communication (eye contact, shared gaze), blind children are particularly dependent on language production in social interaction. At first, they tend to rely heavily on partially analyzed segments of speech they hear. As their language becomes more productive, they discover how the language system works when they use it. It has been observed, for example, that mothers of blind children use more directives and tend to repeat the language productions of the children (Pérez-Pereira, & Conti-Ramsden, 2001).

These studies also show delays occurring during the preschool period. Data from studies using a longitudinal methodology show that language delays tend to disappear over time (see for example Mulford 1988; McConachie & Moore, 1994; Galiano et al., 2014). This progression could be explained by the presence of residual vision (McConachie & Moore, 1994), and also other factors such as early intervention, cognitive stimulation and social support. No study has to date examined whether the delays in spatial language acquisition observed in blind children at pre-school age persist into school age. Likewise, no research has looked at verbs of movement in blind children. In summary, although studies show specific aspects in the understanding of spatial relationships for blind children, little is known about the impact of blindness on spatial language acquisition.

Aims and hypotheses

This study compares spatial language development in same-aged blind vs. sighted children (6 to 11 years) in tasks involving the production and comprehension of two types of linguistic expressions that are fundamental for spatial cognition: spatial prepositions (static space : In, On, Under, Above, In front of, Behind) and motion verbs (dynamic space : Ascend, Descend, Enter, Exit, Jump-Over). The following hypotheses were tested.

Most spatial prepositions are acquired during the preschool period. However, some studies indicate that blind children experience delays in this acquisition during the preschool period (Bigelow & Bryan, 1982; Mulford, 1988). These delays fade during the school period and the differences between sighted and blind children diminish. First, we expect to find there should be a gap between sighted and blind children at the end of the pre-school period. On the other hand, gaps between blind and sighted children should close during school age. Second, in both populations, it was also expected that production should be more difficult than comprehension. Third, however, some differences were also expected for markers requiring complex processing (Bigelow & Bryan, 1982), i.e. to place objects in spatial relation to each other, particularly in children who have no access to vision. Thus, such differences should be observed for spatial relation markers (vertical, sagittal, indicating containment and boundary crossing) (see e.g. Hickmann & Hendriks, 2006), as tactile experience of these relations is less efficient than vision. In fact, haptic perception appears to be less global and more analytical (e.g. sequential processing of tactile information) than visual perception (Bara et al., 2004).

Ultimately, the results should have implications for a better understanding of the relative weight of vision and language in the development of spatial cognition.

Method

Participants

As summarized in Table 1, two populations of children participated in the study: 61 sighted children (33 girls and 28 boys) and 18 blind children (10 girls and 8 boys). Blind children had no previous experience with vision (congenital blindness) or had totally lost vision before the age of 12 months (early blindness). Sighted children had no known visual problems. No child in either population had any known neurological problem, disability, language or other impairment, and they were all monolingual French speakers from middle-class families. The samples contained a balanced number of each gender at all ages. Handedness was noted as additional background information. Blind children were recruited in special centers for visual impairment in France. The sighted children were selected from a regular primary school and had normal or corrected to normal vision.

This research respects ethical principles for research involving human subjects (World Medical Association Declaration of Helsinki). Permission to test children in the study was granted by the parents and by the Commission Nationale de l'Informatique et des Libertés (CNIL n°1442230) which is responsible for ethical issues.

Table 1. Participants divided into three age groups (6, 8 and 11 years) and school level with Mean age and Age range.

Age groups	School level*	Mean age	Age range	N sighted	N blind
6 years	Preschool 3rd year	5;9	5;02 - 6;07	23	6
8 years	Primary 2nd year	8;0	7;03 - 9;03	19	6
11 years	Primary 5th year	10;8	9;07 - 12;03	19	6

*School level corresponds to the following classes in the French educational system: Preschool 3rd year: *Ecole Maternelle Grande Section;* Primary 1: *Cours Préparatoire* (CP); Primary2 *Cours Elémentaire 1* (CE1); Primary 5: *Cours Moyen 2* (CM2).

Each population comprised three age groups: children who were in their third year of preschool (group 6 years), in their second year of primary school (group 8 years), and in their fifth year of primary school (group 11 years). In total, there were 19 to 23 children per age for the sighted population and six children per age for the blind population.

Procedure

Experimenter and child sat at the same side of a table. Children were seen individually in a quiet room, sitting next to the experimenter. Prior being presented with test items, they were first familiarized with the environment and encouraged to explore the device as well as all relevant objects which they were asked to name (or for which they were given a name if necessary). Once all objects had been clearly recognized and named, the production and comprehension tasks began.

Stimulus materials

Children were shown a doll house (Fig. 1) (visual exploration for sighted children and tactile for blind children) containing two floors linked by an inside stairway. The house comprised a living room and a dining room on the ground floor, as well as two bedrooms on the top floor, one for children and one for parents. In addition to the house, the stimuli comprised various items including human figures and objects: children (boy, girl) and adults (man, woman) as well as various entities (e.g. a teddy bear, pieces of furniture, a doll's tea set, a vase). The stimuli comprised two sets of items, one focusing on spatial prepositions and the other on motion verbs.

Figure 1. Dollhouse used in the experiment (left: house closed; right: house open).

Image Description: A first photograph shows a closed Playmobil dollhouse with drawings of the parts of the house (window, French window); a second photograph shows the open doll's house with miniature objects (people, table, chairs, rocking chair, teddy bear, stroller, beds, doll's tea set, a vase) and parts of the house (living room, parents' room, children's room, kitchen, staircase, gate).

Test items

Children were tested on spatial prepositions and motion verbs. Items testing knowledge of prepositions concerned the spatial relations are summarized in Table 2. This set included two different versions of "in front" and "behind" depending on whether the located entity was intrinsically oriented (e.g. a toy bear) or not (e.g. a uniform empty vase).

To test the production of prepositions, the experimenter placed one entity, always the same teddy bear ("*Nounours*", French children's most common name for a teddy bear) in a particular spatial relation to another entity. As illustrated in (a), children were then asked to describe its location. To test the comprehension of prepositions, children had to place the object in some location according to a verbal instruction in the form of an imperative sentence that contained the relevant preposition, as illustrated in (b).

(a) Production of spatial prepositions (9 items)
Où est Nounours?
('Where is Teddy bear?')

(b) Comprehension of prepositions (9 items)

Mets Nounours sur la table.

('Put Teddy bear on the table')

Table 2. Item types (spatial relations: In, On, Under, Above, In front of, Behind) and examples

Preposition	**Examples in French**	**Examples in English**
In	*Dans le berceau*	in the crib
On, under	*Sur la table*, *sous le lit*	on the table, under the bed
Above, under	*Au-dessus du salon,* *En-dessous de la chambre d'enfants*	above the living room under children's room
In front of, behind ± intrinsic orientation	*Devant / derrière la chaise* (ground entity oriented) *Devant / derrière le vase* (ground entity not oriented)	in front of / behind the chair in front of / behind the vase

Table 3 presents the markers of spatial relations. The markers are classified as follows:

1) spatial prepositions: vertical plane (*sur* 'on', *au-dessus* 'above', *sous* 'under simple', *en-dessous* 'under complex'), sagittal plane (*devant* 'in front of' oriented and not oriented, *derrière* 'behind' oriented and not oriented), and indicating containment (*dans* 'in').
2) motion verbs: vertical motion (*monter* 'ascend', *descendre* 'descend') and boundary crossing (*entrer* 'enter', *sortir* 'exit', *sauter par-dessus* 'jump over'). The item *sauter par-dessus* ('jump over') intrinsically involves a categorical change of location (e.g., from one side of the fence to the other side) but unlike other boundary crossings expressed in the verb (e.g., entrer/sortir 'to enter/exit'), location change in this case requires an additional motion verb

Note that some French prepositions can be formally "simple" or "complex" (e.g. *sous* vs *en-dessous de*) both of which can be translated as *under* (see Hickmann & Hendriks, 2006).

To test the production of motion verbs, the experimenter asked children to answer a question which was preceded by a couple of context sentences which presented a problem to be solved by one of the characters (boy, girl, man, woman, Teddy bear). For each item, a question then asked children to provide a solution using a motion verb. Context sentences all contained between 15 and 21 words and they were all composed of three to four propositions ending with the conjunctions *et* ('and') or *alors* ('so'), pronounced with a rising intonation and followed by a question and then by an imperative "What must s/he do afterwards, tell me'. Example (c) illustrates a production item about upward motion (to go from the living room on the ground floor to the bedroom on the top floor in the doll house).

(c) Production of motion verbs (5 items)
Context sentence: *Le papa est dans le salon et il veut aller se coucher. Il y a un escalier et...*
('The daddy is in the living-room and he wants to go to bed. There are stairs and...')
Question: *Qu'est-ce qu'il doit faire ? Explique-moi.*
('What must he do? Tell me)

To test the comprehension of motion verbs, children were asked to act out, using toys, sentences describing motion events, as illustrated in (d). Context sentences contained four to nine words and two to three propositions.

(d) Comprehension of motion verbs (5 items)
Le papa monte l'escalier. Montre-moi.
('The daddy ascends the stairs. Show me')

Table 3. Items testing (Up, Into, Out of, Above) the production and comprehension of motion verbs (Ascend, Descend, Enter, Exit, Jump-Over)*

Relation	Verb	Examples in production and comprehension tasks
UP	*Monter (ascend)*	**Prod**: *Le papa est dans le salon et il veut aller se coucher. Il y a un escalier et...*'The daddy is in the living room and he wants to go to bed. There are stairs and...
		Comp: *Le papa monte l'escalier. Montre-moi.* 'The daddy goes up [ascends] the stairs. Show me.'
	Descendre (descend)	**Prod**: *La petite fille est en haut et elle veut aller manger. Il y a un escalier et...*'the little girl is up there and she wants to eat. There are stairs and...'

		Comp: La maman descend l'escalier. Montre-moi. 'The mommy goes.down [descends] the stairs. Show me.'
INTO	*Entrer (enter)*	**Prod:** *Le papa arrive du travail en voiture. Il y a un portail, il l'ouvre et …* 'The daddy arrives from work in his car. There is a gate, he opens it and…' **Comp:** *Le papa ouvre le portail et puis il entre. Montre-moi.* 'The daddy opens the gate and he enters. Show me.'
OUT OF	*Sortir (exit)*	**Prod:** *La maman est dans le jardin et elle veut aller faire des courses. Il y a un portail, elle l'ouvre et …* 'The mommy is in the garden and she wants to go shopping. There is a gate, she opens it and…' **Comp:** *La maman sort. Montre-moi.* 'The mommy goes out [exits]. Show me'
ABOVE	*Sauter (jump-over)*	**Prod:** *Le nounours veut aller se promener, mais il ne peut pas ouvrir le portail et…* 'The Teddy bear wants to go for a walk but he cannot open the gate and…' **Comp:** *La petite fille saute par-dessus la barrière. Montre-moi.* 'The little girl jumps over the fence. Show me.'

Coding

The coding was done with the software CLAN (Computerized Language Analyses) program on transcripts that are in CHAT format (MacWhinney, 2000). CLAN determines the total number of prepositions and verbs in the selected sample. Responses to all items in both tasks (production, comprehension) fell into the following four categories:

1) Correct responses:
   - Correct use of preposition or verb in the production task.
   - Correct action in response to the stimulus sentence in the comprehension task.

2) Incorrect responses:
   - Incorrect spatial preposition or motion verb in the production task, e.g. *Il monte* ('He ascends') rather than *Il descend* ('He descends').
   - Incorrect action in the comprehension task (e.g. moving the boy down the stairs rather than up).

3) Vague responses:

- In production, vague responses involved the use of deictic devices in the preposition task (e.g. *ici, là* 'here, there') and of neutral verbs in the motion task (mostly *aller* 'to go') rather than more specific prepositions (*au-dessus* 'above') or verbs (e.g. *monter* 'to ascend' expressing Path).
- In comprehension, vague responses involved actions that were unclear as to what the child meant with respect to spatial relations between objects (e.g. placing an object next to the table rather than on it) or displacements (moving a character randomly without any indication of Path or Manner).

4) Non-codable responses:

- Irrelevant, inaudible, no response and/or "I don't know"

Results

For our quantitative analyses, two logistic mixed-models were fitted, utilizing the binary categorical answer (correct/incorrect) for spatial prepositions (analysis 1) and the same type of answer for motion verbs (analysis 2) as dependent variable. All analyses included Population (sighted, blind), Age (6, 8 and 11 years), gender (male, female) and Task (production, comprehension) as fixed effects, as well as interactions between Population, Age and Task. For all models fitted, random intercepts for participants, Population, Age and Task were included. Results showed neither effect of gender value =0.007, $t(1412)=0.253$, $p=0.800$, nor any interaction between this factor and other factors, so Gender is ignored in subsequent analyses (Gender* Group, $F(1,1412)=0.980$, $p=0.322$; Gender*Task, $F(1,1412)=0.040$, $p=0.842$; Gender*Age, $F(2,1412)=1.963$, $p=0.141$).

We will restrict ourselves to descriptive analyses to examine the more specific hypotheses concerning the categories for both prepositions and verbs.

Spatial prepositions

Table 4 (in %) shows the distribution of all response types to spatial prepositions. Correct responses among sighted children were higher in production (71% to 84%) and especially in comprehension (95% to 97%), while other responses (incorrect, vague, not codable) were relatively rare, with the possible exception of vague responses at 6 years (19%) which decreased at 8 and 11 years (10% and 12%). As for blind children, correct production was higher at 8 and 11 years (74%), but less so at 6 years (30%) where other responses were also quite high (24%). In comprehension, correct responses were high at 8 years (85%) and at 11 years (92%), but less so at 6 years (50%), where non-codable responses were relatively high (31%).

Table 4. All responses to spatial prepositions as a function of age and population (Sighted and Blind) for each task (in %)

		PRODUCTION						**COMPREHENSION**					
		6 years		**8 years**		**11 years**		**6 years**		**8 years**		**11 years**	
		N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
Sighted	Correct	146	71%	144	84%	139	81%	196	95%	164	96%	166	97%
	Incorrect	12	6%	10	4%	10	6%	9	4%	6	4%	4	2%
	Vague	40	19%	17	10%	20	12%	1	0.5%	0	0%	0	0%
	Not codable	9	4%	0	0%	2	1%	1	0.5%	1	1%	1	1%
Blind	Correct	16	30%	40	74%	40	74%	27	50%	46	85%	50	92%
	Incorrect	13	24%	7	13%	7	13%	8	15%	4	7%	2	4%
	Vague	13	24%	6	11%	6	11%	2	4%	0	0%	0	0%
	Not codable	12	22%	1	2%	1	2%	17	31%	4	7%	2	4%

In the first analysis, we found an overall effect of the Population factor (value=0.225, t(1412)=2.52, p=.012), with sighted children producing more correct responses than blind children. Still at the global level, we did not find a significant effect of Age (F(2,1412)=1.597, p=0.203) and Task (F(1,1412)=0.358, p=0.55). However, when planning contrasts between the two populations for each age, we found that it is for the youngest children (6 years old) that this difference is significant (value=0.600, t(1412)=3.178, p=.002). The difference between the two populations disappears at ages 8 and 11, indicating that progressions occur before these ages in blind children. As can be seen in Table 4, correct performance is more frequent among sighted children than among blind children, although this difference is especially striking among the youngest children (6 years in our sample).

Age contrasts in both populations showed a significant increase in correct performance in blind children between 6 and 8 years of age (value=0.460, t(1410)=1.91, p=.05) and also between 6 and 11 years of age (value=0.527, t(1410)=2.37, p=.02). Finally, contrasts between populations according to the task show a significant difference between blind and sighted children in the case of production (value=0.305, t(1412)=2.08, p=.04), which is mainly due to the youngest children (value=0.697, t(1410)=2.76, p=.006). Among blind children, the youngest (6 years) differed significantly from the other two age groups (8 and 11 years).

Table 5 summarizes mean correct responses to specific prepositions as a function of population. As shown in this table, relatively lower scores can be observed in the production of sighted children with *above-CX (complex)* and *under-CX (complex)*, as well as to a lesser extent with *behind-NO (not oriented)*. In contrast, performance is very high and even practically maximal in comprehension among these children. As for blind children, correct production is low for all items except for *in, on* and *under-SP (simple),* but their correct comprehension of these items was relatively high with the exception of *front-NO (not oriented)* and to a lesser extent *behind-OR (oriented)*.

Table 5. Relative frequency of correct production and comprehension (frequency of 1 indicates that all the children in the group of age gave a correct answer) of specific spatial prepositions as a function of population, age (6, 8 and 11 years) and task (production and comprehension).

		PRODUCTION			
		6 years	**8 ye**	**11 yea**	**All**
Sighted	In	0.913	1.000	0.947	0.951
	On	0.826	0.947	0.947	0.902
	Under-SP	0.957	1.000	0.895	0.951
	Above-CX	0.217	0.579	0.632	0.459
	Under-CX	0.478	0.632	0.579	0.557
	Front-OR	0.609	1.000	0.895	0.820
	Front-NO	0.783	0.895	0.895	0.852
	Behind-OR	0.957	0.895	0.947	0.934
	Behind-NO	0.609	0.632	0.579	0.607
Blind	In	0.833	1.000	1.000	0.944
	On	1.000	1.000	1.000	1.000
	Under-SP	0.333	1.000	1.000	0.778

	Above-CX	0.167	0.667	0.667	0.500
	Under-CX	0.000	0.833	0.833	0.556
	Front-OR	0.000	0.667	0.667	0.444
	Front-NO	0.000	0.667	0.667	0.444
	Behind-OR	0.167	0.667	0.667	0.500
	Behind-NO	0.167	0.167	0.167	0.167
COMPREHENSION					
Sighted	In	1.000	1.000	1.000	1.000
	On	0.957	1.000	1.000	0.984
	Under-SP	1.000	1.000	0.947	0.984
	Above-CX	0.870	1.000	1.000	0.951
	Under-CX	0.870	1.000	1.000	0.951
	Front-OR	1.000	0.947	1.000	0.984
	Front-NO	0.870	0.737	0.789	0.803
	Behind-OR	0.957	1.000	1.000	0.984
	Behind-NO	1.000	0.947	1.000	0.984
Blind	In	0.833	1.000	1.000	0.944
	On	0.833	1.000	1.000	0.944
	Under-SP	0.333	0.833	1.000	0.722
	Above-CX	0.500	0.833	1.000	0.778
	Under-CX	0.500	0.833	0.833	0.722

Front-OR	0.333	1.000	1.000	0.778
Front-NO	0.167	0.667	0.833	0.556
Behind-OR	0.500	0.667	0.667	0.611
Behind-NO	0.500	0.833	1.000	0.778

SP: simple; CX: complex; NO: not oriented; OR: oriented

A detailed analysis of these data reveals the following key observations. First, for sighted children, correct responses were lower overall in production than in comprehension, although relatively high performance was observed in production overall, except for *above-CX (complex)* (.459) and *under-CX (complex)* (.557).

In the blind population, correct production is excellent for *in* (.944) and *on* (maximal performance), as well as high for *under-CX (complex)* and *under-SP (simple)* (.722 in both cases), but otherwise it is generally low (between .167 and .500). As for comprehension, it is generally lower as compared to sighted children. Correct comprehension in this population is almost maximal for *in* and *on,* but lower for *under-CX (complex)* (.556), *above-CX (complex)* (.50), *front-OR (oriented)* (.444), and *behind-NO (not oriented)* (.167).

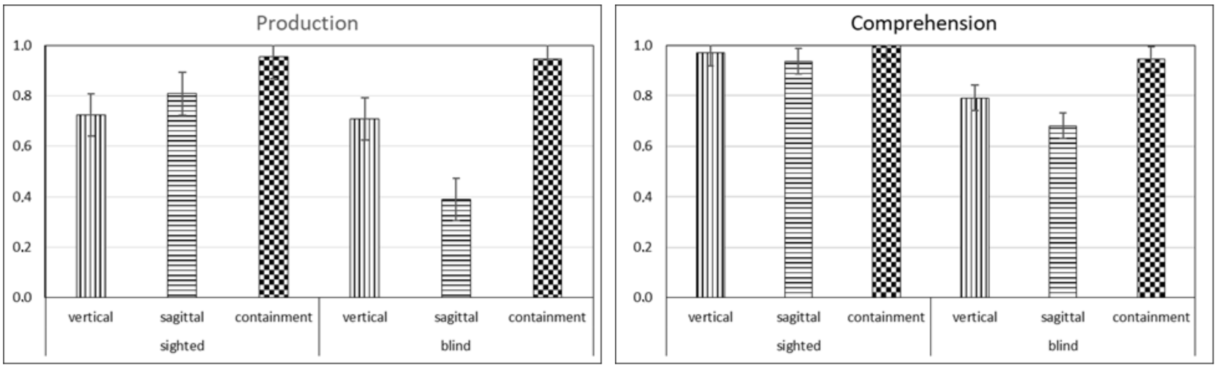

Figure 2. Relative frequency of correct production and comprehension of prepositions grouped by type as a function of population.

Image description: Figure 2 shows on the left the production results (vertical, sagittal, containment) of the two groups (Blind and Sighted) with a bar graph; on the right the same graph for the comprehension results.

The figure shows that the best performance of sighted children at all ages and in both tasks concerned containment, followed by sagittal and/or by vertical prepositions. In the blind population, correct responses to containment are also frequent for both production and comprehension, followed by vertical prepositions, then by sagittal ones. Note that some variation occurred in both the sighted and blind populations, especially in the production task for both populations but also for comprehension among blind children.

Motion verbs

Table 6 shows (in %) the distribution of all responses to motion verbs in both populations. A glance at this table shows that there are more correct responses overall in the sighted children than in the blind population. Although this result is observed at all ages, it is particularly obvious at ages 6 and 8 in production where responses other than correct ones were relatively frequent among blind children. In comprehension, correct responses increased with age among blind children (60% at age 6, 97% and 83% at ages 8 and 11). Although this population difference is most evident in production, it can also be observed to some extent in comprehension.

Table 6. All production and comprehension responses to motion verbs as a function of age (6, 8 and 11years) and population (Sighted and Blind) (in %).

		PRODUCTION						COMPREHENSION					
		6 years		**8 years**		**11 years**		**6 years**		**8 years**		**11 years**	
		N	***%***	***N***	***%***	***N***	***%***	***N***	***%***	***N***	***%***	***N***	***%***
Sighted	Correct	96	83%	84	88%	87	92%	110	96%	95	100%	95	100%
	Incorrect	0	0%	0	0%	0	0%	5	4%	0	0%	0	0%
	Vague	9	8%	6	6%	8	8%	0	0	0	0%	0	0%
	Not codable	10	9%	5	5%	0	0%	0	0	0	0%	0	0%
Blind	Correct	13	43%	11	37%	22	73%	18	60%	29	97%	25	83%
	Incorrect	6	20%	5	17%	1	3%	1	3%	0	0%	0	0%
	Vague	6	20%	5	17%	4	13%	3	10%	1	3%	0	0%

Not codable	5	17%	9	30%	3	10%	8	27%	0	0%	5	17%

The second analysis shows a significant effect of the Population factor (value=0.132, t(778)=2.09, p=.04), with sighted children producing more correct responses than blind children. There was no significant effect of Age (F(2,778)=1.901, p=0.15) and Task (F(1,778)=1.877, p=0.171). When planning contrasts between populations by age, we find that this overall effect is mainly due to the youngest children (6 years) (value=0.378, t(778)=1.98, p=.05). As in the case of prepositions, this indicates that beyond this age, progressions make blind children less distinct from sighted children.

Still planning contrasts between populations according to tasks, we observe a significant effect in the production task (value=0.307, t(778)=2.16, p=.03). Although there was no significant effect of age, overall, there was a significant difference between 6-year-olds and 11-year-olds among blind children (value=0.378, t(778)=1.98, p=.05).

Table 7. Relative frequency of correct responses (frequency of 1 indicates that all the children in the group of age gave a correct answer) to specific motion verbs as a function of population, (6, 8 and 11 years) and task (production and comprehension)

		PRODUCTION			
		6 years	**8 years**	**11 years**	**All**
Sighted	Ascend	1.000	1.000	1.000	1.000
	Descend	1.000	1.000	1.000	1.000
	Enter	0.739	0.737	0.895	0.787
	Exit	0.435	0.684	0.684	0.590
	Jump-over	1.000	1.000	1.000	1.000
	Ascend	0.667	0.833	1.000	0.833

Blind	Descend	0.833	0.500	0.833	0.722
	Enter	0.333	0.167	0.833	0.444
	Exit	0.333	0.167	0.333	0.278
	Jump-over	0.000	0.167	0.667	0.278
			COMPREHENSION		
Sighted	Ascend	1.000	1.000	1.000	1.000
	Descend	1.000	1.000	1.000	1.000
	Enter	0.783	1.000	1.000	0.918
	Exit	1.000	1.000	1.000	1.000
	Jump-over	1.000	1.000	1.000	1.000
Blind	Ascend	0.833	1.000	0.833	0.889
	Descend	0.667	1.000	0.833	0.833
	Enter	0.667	1.000	0.833	0.833
	Exit	0.333	1.000	0.833	0.722
	Jump-over	0.500	0.833	0.833	0.722

Table 7 provides a more detailed analysis. The analysis of the average correct responses (column "all") for each movement verb within each task shows that, for sighted children, the average correct production is maximal except for lower averages for *enter* (0.787) and especially for *exit* (0.590). This average production is also practically maximal with all verbs in comprehension (from *enter*=0.918 to *exit*=1.000). In the blind population, the average correct production is maximal for *ascend* (0.833) and *descend* (0.722), but lower for all other verbs (*enter*=0.440, *exit*=0.278, *jump over*=0.278). The average correct understanding is relatively high for all verbs (between 0.722 and 0.889).

When examined by age, correct production in the sighted population was highest at all ages for the verbs *ascend*, *descend* and *jump over*. It was lower for the other motion verbs but increased with age for *enter* and *exit*. Thus, boundary crossing appears to be more difficult than other types of movement, a result already found in previous studies (e.g., Hickmann et al. 2018). For the blind population, correct production was clearly lower at all ages compared to sighted children, but increased with age (especially for *ascend*) or showed variation (for *descend*).

Correct comprehension performance in the sighted population is maximal with all verbs despite a somewhat lower performance with *enter* at 6 years. As with the blind population, correct production increases with *ascend* from 6 to 8 years and reaches maximal performance at 11 years. Performance is also relatively high with *descend* (except for a drop at 8 years). At 6 and 8 years, blind children encounter some difficulty with *enter* and *exit*. For 11-year-olds the difficulty is not resolved for *exit*, but correct performance is higher for *enter*. Finally, young children produce little correct performance for *jump over* but performance with this item increases at 11 years. In comprehension, correct performance at 8 years is maximal (100%) and relatively high with *ascend, descend, enter, exit*, and *jump over* (83%). Scores are also relatively high at 11 years with all verbs (83%). At 6 years correct performance was high with *ascend*, somewhat lower with *descend* and *enter*, and even lower with *jump over* and especially with *exit.*

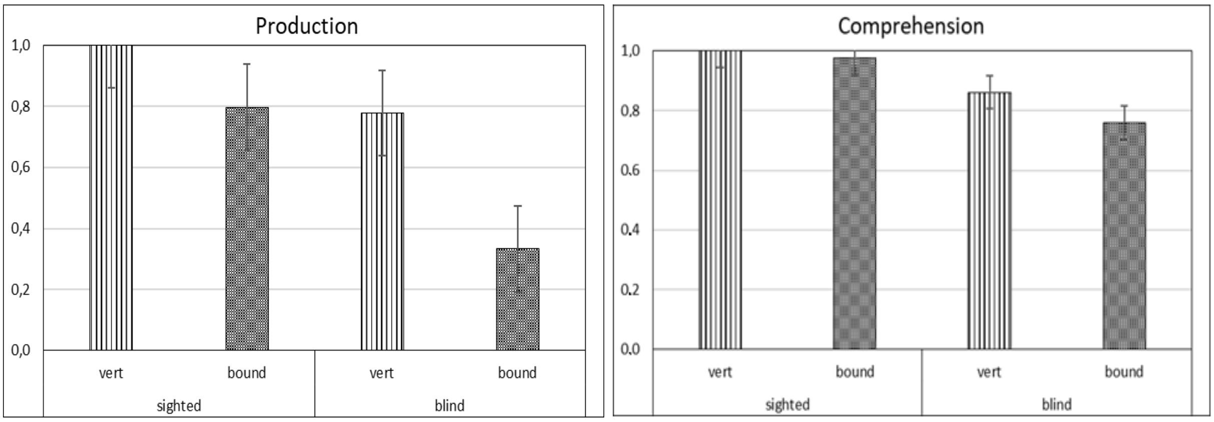

Figure 3. Mean correct production and comprehension of motion verbs grouped by type in each population.

Image Description: Figure 3 shows on the left the production results of motion verbs (vertical motion and boundary crossing) of the two groups (Blind and Sighted) with a bar graph; on the right the same graph for the comprehension results.

A simpler version of these data is shown in Figure 3 where correct responses to motion verbs have been grouped into two types: those involving vertical motion (*ascend*, *descend*) vs. those involving boundary crossing (*enter*, *exit*, *jump over*). In production, in sighted children, vertical motion elicits maximum overall performance and boundary crossing elicits lower correct responses. For correct comprehension, vertical movement elicits maximal performance in sighted children and near maximal performance for boundary crossing. In the blind population, Figure 3 also shows an advantage of vertical motion over boundary crossing in production, but almost no difference between item types in comprehension.

Discussion

This study compared French-speaking sighted and blind children's comprehension and production of two types of markers: spatial prepositions and motion verbs. The results show some common patterns across the two populations as well as some major differences.

First, as expected, the results confirm our first hypothesis. Indeed, blind children presented delays in production and comprehension of both propositions and verbs. Sighted children generally showed a better performance in production and comprehension than blind children, but mostly at 6-8years, while population differences decreased or even disappeared with age thereafter. This latter result corroborates observations made about the development of blind children. Indeed, the language development of these children is sometimes connoted by delays in acquisition that disappear over time (Pérez-Pereira & Conti-Ramsden, 2013; Galiano et al., 2014). Similarly, some studies on spatial prepositions find delays that tend to disappear at an older age (e.g. Mulford, 1988).

Second, comprehension was easier than production for both groups over the entire observation period and more particularly at age 11. However, the comprehension scores of sighted children were better than those of blind children. Understanding of propositions and verbs has improved but never reaches the maximum score for blind children (92% correct answers at 11 years old for propositions and 83% for motion verbs).

Third, we expected differences in markers requiring complex processing. For the spatial prepositions production in blind children, correct performance was best for the marker of containment (*dans* 'in') and it was better for prepositions involving a vertical plane (*sur* 'on', *sous* 'under', exception for *au-dessus* 'above') as compared to those involving a sagittal plane (*devant* 'in front of', and *derrière* 'behind'). This result is consistent with that of Landau (1991) in English who finds that the term 'in front of' is better understandable for sighted children than for blind children. Unlike the sighted child who can often perceptually differentiate front from back, blind children must touch the object to identify the front and back.

Furthermore, the results of this study suggest that the property of oriented/non oriented objects does not influence the production and comprehension of prepositions *devant* 'in front of' and *derrière* 'behind', with the exception of *derrière* 'behind NO' (not oriented) for the production task. For this preposition, unlike sighted children, blind children produced a very low average. Prepositions *devant* 'in front of' and *derrière* 'behind' convey information about the direction in which one object is located with respect to the other (relational prepositions, Clark, 1973). Blind children therefore seem to have difficulty with the preposition 'behind' when objects that are not oriented.

With respect to verbs, performance was better for vertical motion (*monter* 'ascend', and *descendre* 'descend') as compared to boundary crossing (*entrer* 'enter', *sortir* 'exit', and *sauter par dessus* 'jump over'). It is likely that blind children find it easier to express vertical motion (more consistent) as compared to boundary crossing (which implies a categorical change of location). A similar result was found in other studies (e.g., Hickmann et al. 2018). However, note that correct performance was better when motion was in the upward direction than when it was in the downward direction.

In order to understand the differences observed on the spatial markers and in particular between the vertical and boundary crossing markers some methodological questions should be raised. With respect to spatial prepositions (most relevant for static space), although grouping items into distinct types can be informative, it misses some important differences within types. For example, correct uses of some prepositions involving a vertical plane (*sur* 'on') are easier than other types of prepositions, e.g. those involving a sagittal plane (*devant* 'in front of'). In addition, according to Bigelow and Bryan (1982), prepositions involving simple forms are easier than those involving complex ones (e.g. *sous* vs. *en-dessous* that both mean 'under'*)*. Note that the use of a preposition such as *sur* 'on' requires some understanding of the notion of *contact* (e.g. as compared to *au-dessus* 'above', which mostly implies the absence of contact). With respect to motion verbs, the item *sauter par dessus* ('jump over') has a special status which should be considered when interpreting the results. Thus, in order to ensure a reading that invites a change of location, and given that *par-dessus* ('over') is potentially ambiguous between a static and a dynamic reading, a motion verb (*sauter par-dessus* 'jump over') was used with this particular item which was not the case with other stimuli.

Another alternative explanation of the observed differences in spatial language concerns a consequence of impaired haptic identification (Thinus-Blanc & Gaunet, 1997). This explanation provides insight into the delayed acquisition of symbolic and functional play of blind children (Lewis et al., 2000). Here, haptic skills may have an influence on performance. Indeed, before carrying out the two tasks, we asked the children to touch the miniature objects used. Despite this, perhaps the children did not properly explore the objects and got the answers wrong. Indeed, some studies show that blind children have difficulty with understanding miniatures of larger objects: dollhouse- real house; doll- person (see Lewis et al., 2000). Unlike sighted children, blind children cannot rely on their visual memory of objects.

Finally, this study presents a theoretical interest and a clinical interest. Theoretical point of view concerns the understanding of the influence of lack of vision on the emergence of spatial language. We have shown that to some extent visual impairment, and more particularly blindness, interferes with the production and understanding of spatial language. Despite this, the differences observed between blind children and sighted children tend to disappear over time. Thus, it would seem that the cognitive and linguistic capacities inherent in the localization of objects in space develop more slowly and gradually and this until the age of 11 for children who do not have access to visual information. This trend corroborates studies which show the same phenomenon in the acquisition of language (see Peltzer-Karpf, 2012) but also other skills (motor skills, theory of mind, etc.). In other words, these developmental results indicate that the rate of acquisition of children with visual impairments may differ from those of sighted children. No study is available to understand the nature of this phenomenon. However, it is generally acknowledged that language is enriched depending on the context in which it emerges: the richness of environmental stimulation, cultural factors, bilingualism, etc. (for a summary, see Hoff, 2003, 2006). In the absence of visual spatial information, the blind child depends on the verbal descriptions provided by the adult watch. Language therefore plays an important role in the construction of spatial knowledge. Thus, from a clinical perspective, specific programs should be put in place to allow the child to understand spatial relationships existing between elements present in environments. In addition to work on spatial relationships, this program could include an intervention promoting spatial awareness and proprioception, i.e. perception or sensory awareness of the position and movement of our body.

Limitations and future work

Further research is clearly necessary in the future with larger samples of children, particularly in the blind population, which only contained six children in each age group and showed some variation. Also, in order to eliminate bias linked to the device and in particular to the use of dollhouses and miniature objects which could penalize blind children, it would be preferable to replicate this study with real-sized objects. It would be interesting to assess the performance in identifying haptic patterns with an adapted methodology.

It is also necessary to include new tasks comprising new items, including non-verbal presentation of stimuli, such as categorization and memory of location and motion. It would also be relevant to investigate earliest phases - prelinguistic period, emergence of language. Does innate knowledge and/or linguistic input in adult-child interaction influence infants' conceptual representations before and during the emergence of language production?

It is important to clarify that the results of this study can only be partially compared to previous scientific literature. Indeed, the few studies carried out on this issue were carried out in English and Spanish. However, it has been shown that language influences children's learning of spatial propositions and verbs of movement. More precisely, the specific linguistic structures of each language influence the way children perceive and describe space (Hickmann, 2006; Hickmann et al., 2009). It would be highly interesting to compare blind and sighted children in different language groups in order to test the relative impact of language on children's performance. It would be to understand the relative weight of perceptual/cognitive vs. language-specific constraints, e.g., types of devices (verbs, adjuncts, morphology), types of distinctions (spatial relations). The objective would be to see if the absence of vision combined with linguistic specificities influence not only the way in which concepts are expressed, but also how they are perceived and understood.

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