Institut Nazareth & Louis-Braille

Spatial orientation in adolescents with visual impairment: related factors and avenues for assessment

Information Monitoring Summary

Documentary research
Josée Duquette, Planning, Programming and Research Officer
Francine Baril, Documentation Technician

Prepared by
Josée Duquette, Planning, Programming and Research Officer

March 26th, 2012

Notice to readers

The information in the following pages is not intended to be an exhaustive review of the literature. The goal was to make directly relevant selected information more readily available. Accordingly, not all articles or documents dealing with the topic have been reviewed.

Spatial orientation in adolescents with visual impairment: Related factors and avenues for assessment

Summary

Spatial orientation is a person's skill in using the information received through their senses to determine their position in space and their destination in relation to significant objects in the environment [3; 16]. In the context of visual impairment, this term refers more specifically to knowledge of distances and directions that relate to objects in the environment and have been observed or memorized, and the ability to commit these spatial relationships to memory when they change as the person proceeds (Blasch, Wiener & Welsch, 1997, cited by Long & Giudice, 2010). Spatial skills are defined by putting in place and using spatial relations between a particular place and oneself (e.g. in a given fixed position) or between different places (independently of one's own position) [18].

Orientation integrates perceptual and cognitive learning [3]. Integrating the sensory information needed for orientation requires **conceptual development** that includes among others, body scheme, the body-to-object relationship, spatial updating, the object-to-object relationship, the environment and time, as well as conceptual understanding of objects [2].

Spatial orientation may be affected by dysfunction of any of the **basic sensory systems** (touch, proprioceptive, vestibular, olfactory, auditory or visual). The development of orientation skills and the construction of a mental representation of the environment are also related to various cognitive faculties such as attention capacity, short-term, long-term and topographic memory, and language skills [6].

At an integration level, **mental representation of space** involves localizing the stimulus, spatial memory, inference skills, and using symbolic representations and cognitive maps [6; 18].

Regarding what is observable, some authors have determined that generally speaking, **an adolescent with visual impairment (VI) should be able to** describe the areas they are in, develop cognitive maps, follow route directions, demonstrate spatial actualization skills and the ability to estimate a time/distance relationship, and employ problem-solving strategies when they are disoriented [2]. Fazzi & Naimy (2010) have established guidelines regarding the skills expected of children and adolescents with VI, among others students in grades 10 to 12 (age 15-17). These skills fall into different categories (mobility, orientation, concepts and sensory skills) [5]. Finally, there are various ways to evaluate factors associated with spatial orientation, ranging from the simplest (e.g. localizing the stimulus) to the most complex (e.g. externalizing mental representations).

Spatial orientation in adolescents with visual impairment: Related factors and avenues for assessment

The initial question posed by clinicians in the Enfance-Jeunesse program was this: *What behaviours observable during daily activities may indicate a spatial orientation problem in a visually impaired adolescent?* The goal was to develop an analysis grid for these behaviours. However, the literature consulted did not provide a direct answer to this question.

The most relevant information available deals with adapted sport, and provides lists for evaluating behaviours or actions associated with spatial skills. For example, the Goalball Game Performance Assessment Checklist features criteria such as "correctly determines if ball is left or right" or "lies on side parallel to goal line, legs extended and together, arms above and in front of head" [15]. This type of tool offers some inspiration for developing an observation grid applicable to daily activities, but it is restricted to sports.

Publications about orientation in *adolescents* are few and far between; most of the material focuses on children or adults. Information about *behaviours observable during daily activities* is particularly hard to find, because the literature tends to deal with the behaviours displayed while a person is mobile.

Because there were no studies to review focusing directly on the initial question, this article provides an overview of the basic literature concerning 1) individual factors associated with orientation skills, 2) certain avenues and methods for evaluating these factors, and 3) the spatial orientation skills that should be displayed by an adolescent with visual impairment (VI) in the locomotor space. The elements listed here can serve as a starting point for devising ways to identify behaviours observable during daily activities that may indicate a spatial orientation problem in an adolescent with visual impairment.

1. Spatial orientation

Spatial orientation is a person's ability to use the information received via their senses to determine their position in space and their destination in relation to significant objects in the environment [3; 16]. In the context of visual impairment, this term refers more specifically to knowledge of distances and directions that relate to objects in the environment and have been observed or memorized, and the ability to keep track of these spatial relationships as they change during locomotion (Blasch, Wiener & Welsch, 1997, cited by Long & Giudice, 2010). As regards *spatial skills*, these are defined as putting in place and using spatial relationships between a location and the person themselves (e.g. in a given fixed position) or between different locations (independently of the person's own position) [18].

2. Fundamental concepts for spatial orientation

Orientation integrates perceptual and cognitive learning [3]. Integrating the necessary sensory information for orientation first requires conceptual development including, among others, body scheme and the concepts of body-to-object relationship, spatial actualization, object-to-object relationship, environment and time, as well as the conceptual understanding of objects [2].

- ***Body scheme.*** Various authors regard body scheme as an indispensable factor for good spatial orientation [16]. Two major elements underpin this concept: body awareness and body image. *Body awareness* is the information a person has about their body, its position in space, their body parts (form, function, length), their position in relation to each other and their movements (direction, intensity and result) [2; 3; 17]. *Body image* is the individual's subjective assessment of their own body awareness, which stems from their knowledge of their own motor and physical capacities and limitations.

  Inaccurate body scheme may undermine the integration of sensory information during travel, such as rotation of the body or assessment of the distance covered in terms of the speed and duration of travel [18]. It may also affect learning how to use the long cane. For example, incomplete integration of body movements may affect the person's ability to respond appropriately when the orientation and mobility specialist instructs them to flex the wrist or not rotate it while moving the cane from side to side [2].

- ***Body-to-object relationship*** *(spatial concepts).* These include spatial relationships (above/below, right/left, in front/behind, horizontal/vertical); topographic signs; cardinal directions (north, south, east, west); positional concepts (next to, between, toward, forward), degrees (90°, 180°, 360°) ; clock face positional concepts; use of the sun to establish direction [2; 6]. Note that the meaning of certain instructions or descriptions may depend on what they refer to. For example, the prepositions "in front of" or "behind" do not have the same meaning when they refer to objects in the environment as they do when referring to the person [18].

  Body-to-object relationship involves the *egocentric reference frame*. In this system, information is perceived, remembered and put into action by the individual, from the perspective of their current location and body, which becomes the reference point for all spatial relationships, mainly via proprioceptive information [4; 6; 8; 14; 16]. This is what enables an individual to determine their distance and direction in relation to surrounding elements they have observed or memorized, and to keep track of changes in spatial relationships as they travel [3]. This type of relationship is put into practice, for example, when a person describes the location of a building in relation to the place where they are standing at that moment (e.g. it's in front of me, to my right) [8]. This relationship is more easily organized cognitively from a fixed position, using objects that are close by rather than further away [16]. The person's baseline references are body-related and serial rather than spatial. This is an unstable relationship because it only holds true for as long as the person remains stationary [6].

The egocentric reference frame is useful for remembering a specific route to be taken, with sequences of instructions indicating changes in direction during travel (e.g. turn right, then turn left) [18]. Although this form of representation lacks adaptive properties, people use it every day when they take familiar routes to school, work, and so on.

Awareness of the body-to-object relationship may be evaluated for example by asking the person to point to various reference points in the environment [3].

- ***Spatial updating.*** This is the process whereby an individual can keep track of changes in the distance and direction of objects or points that result from self-movement [8]. Evaluating spatial actualization abilities usually involves navigation activities, e.g. asking the person to follow a route and then retrace their steps.
- ***"Object-to-object" relationship.*** This concept refers to localizing objects in relation to each other, regardless of the person's position in the space. It calls upon topographic information (landmarks, unique features of the environment), cartographic information (location patterns, shapes, numbering systems), and relationships between locations expressed as cardinal directions [3; 9].

  The concept of object-to-object relationship is associated with the ***allocentric reference frame*** (also called exocentric). Construction of this concept is critically reliant on external references and the perception of external and distal indicators, rather than those based on oneself [6; 8; 18]. It enables the individual to encode, after prior experimentation, the relationships of direction and distance between places or objects, and to make a link between their respective locations, independently of the path that links them, from the individual's own position or from the direction from which they are approaching [6; 8]. The environment is thus used as a reference frame; this type of relationship is stable because it holds true even when the body is moving. Compared to the egocentric frame, using the allocentric frame is more challenging. However, it is potentially more useful when detours are involved or routes have to be planned between different places. Because it represents the whole picture, it allows a person to select the most suitable orientation strategy for the particular activity or purpose [6; 8].

- ***Environmental concepts.*** These include interior concepts (textures, doors, floor surfaces, corridors, building shapes, stairways, elevators, etc.); residential zone concepts (block, sidewalk, parking lot, street, intersections, etc.); commercial zone concepts (street furniture, complex intersections, address system, shopping malls, stores, etc.).

  A student's grasp of environmental concepts may be assessed, for example, by asking them to describe how a stamped letter will reach its destination (e.g. their friend's house); or to identify, using a photo, the key characteristics of a particular environment and describe their functions (e.g. mall information counter), etc. [2]

- ***Temporal concepts.*** These refer to knowledge of time and time planning. Because orientation depends among others on integrating the distance travelled in terms of speed and travel duration, these are important concepts [3].

- ***Conceptual understanding of objects.*** This involves the mass, shape and size of objects. These concepts are key for acquiring visual and tactile cues used for orientation when moving around [3].

3. Importance of sensory skills in spatial orientation

Dysfunction in any of the basic sensory systems can disrupt spatial orientation. To reach the desired destination, a person with VI must have an understanding of their environment and make efficient use of the information they receive via all their sensory systems. They have to [3]:

1) perceive the sensory information available;
2) analyze and categorize the information based on previous experience;
3) select the information relevant or important to the task that best fulfills the orientation needs;
4) develop an hypothesis based on the information and a subsequent plan of action;
5) execute the plan of action in order to test the hypothesis, in relation to the constant influx of new information;
6) return to the information perception phase to start the processing loop over again.

When evaluating someone's spatial orientation, we obviously need to take into consideration the degree and nature of their ***visual*** impairment (acuity and functional visual fields, visual function under various lighting conditions, visual skills, use of vision aids); these factors will have a major influence on how the person uses their functional vision to help with their orientation [2]. For example, to find their classroom, a student who can see light will be able to use their residual vision to locate fluorescent ceiling lights and the corridor midpoint; another student with better functional vision will be able to view classroom features from the doorway in order to find their way around the room more easily; a student with very limited peripheral visual fields will face different challenges than one with low vision [2].

In a blind person, ***hearing*** becomes the main sense used to judge distance. Together with the other senses, it is critical for the perception and gauging of cognitive representations [3]. A person's hearing enables them to locate, identify, distinguish and track sounds in their natural environment, both indoors and outdoors (e.g. sounds from traffic or pedestrians; echoes from stairways, bathrooms, doors opening and closing; echolocation). Hearing also allows them to use the sounds in forming their cognitive image of the environment and in orientation and mobility activities (appropriately adjusting the body position in relation to the sound source) [2].

Impairment of the other sensory systems may also affect orientation.

- Impairment of the ***discriminative tactile*** system can affect among others a person's body mapping and their exploration of objects or the environment (e.g. tactile cues on the walking surface) [3; 12].
- ***Proprioceptive***[1] impairment may make it harder to perceive inclines and declines, and plan movement accordingly [3; 17]. In this respect, posture affects sensory integration and mobility. For example, a blind person has to rely on proprioceptive and vestibular cues in order to maintain a stable correspondence between their body and the environment. According to Sleeuwenhock, Boter & Vermeer (1995), once the person has a postural problem, they may have inaccurate perception of verticality and other spatial directions that depend on it [16].
- Impairment of the ***vestibular*** system can ***potentially*** cause problems of various kinds: balance; controlling the speed and direction of movements; spatial perception (position and orientation); visual tracking of objects; interpreting movements (*What is moving? Is it the object, my head or my whole body?*); head position (*Is it straight or tilted?*); maintaining a stable visual field [11]. Spontaneously adjusting the body then becomes more difficult [11].
- An ***olfactory*** impairment may interfere with the acquisition and integration of information used for orientation (e.g. smells from familiar places or objects) [3].

4. Cognitive capacities and spatial orientation

The development of orientation skills and construction of a mental representation of the environment are related to various cognitive faculties such as [6]:

[1] Proprioception: the perception an individual has of the position of their limbs, muscle tone and motion in space, without having to see them.

- attention capacity;
- short-term memory;
- long-term memory, such as episodic memory (ability to recall personal experiences in a space-time context), semantic memory (effortless, fast-access knowledge base) and procedural memory (the unconscious, automatic acquisition and use of skills);
- topographic memory (ability to describe routes and the spatial organization of the environment);
- language skills.

Clearly the diversity of environments that a person has had to cope with, and how often they have had to navigate within them, will influence their spatial organization, adaptive skills, how they grasp the environment, and the way they travel [6].

5. Spatial processing

The level of a person's spatial processing will influence their knowledge of their environment [6]. According to the review of literature by Thinus-Blanc & Gaunet (1997), the basis for spatial processing is localizing the stimulus; this is followed by spatial memory, inferential abilities and the use of symbolic representations [18].

- Incorrect initial encoding of ***stimulus localization*** in the proximal space may result in a deficit in tasks requiring high levels of spatial processing (construction of a representation) [18]. These stimuli can constitute landmarks used in decision making that call upon the senses; these landmarks enable the person to make decisions as they proceed and confirm they are on the right track [6]. Most of them are communicable. Examples of these landmarks are familiar objects, sounds, smells, temperatures or easily recognizable visual or tactile cues that are constant, permanent features of the traveller's environment [8]. These points are linked to the individual through relationships of proximity and continuity (egocentric system).
- ***Spatial memory*** is associated with two types of spaces: 1) space of manipulation, the space within arm's length in which a person performs actions and movements starting from a fixed point (recalling the location of the manipulated objects) and 2) locomotor space, through which the person is able to travel and thereby modify their perception of the environment and at the same time construct a representation of it (recall a path) [6; 18]. By memorizing the order and orientation of reference points and understanding how they interrelate, the individual is able to create routes between two places [6]. However, an orientation problem arises when their perceptions of the environment do not match their expectations based on prior experience [8].

- ***Inferential abilities*** involve computation and estimation of spatial relations. They enable the person to reorganize an incomplete spatial representation that new spatial links are inferred. This reorganization has an adaptive function: it enables the person to cope with unexpected spatial modifications (e.g. make a detour when the usual path is obstructed or unavailable, take a shortcut, etc.). Inference skills can relate to the space of manipulation (e.g. evaluating the absolute distance between two objects with the fingers) or the locomotor space (e.g. finding different locations in a familiar urban neighbourhood) [18].
- ***Use of symbolic representations*** such as maps and plans involves the ability to transfer an abstract spatial representation from one scale to another (e.g. using a map).

  At this higher level of mental representation there are also ***cognitive maps***. These preserve spatial properties such as landmarks, paths, directions, distances and the general relationships between the elements, regardless of the path linking them, or the person's position or direction from which they are approaching [8; 10; 18]. Based on experience, cognitive maps can guide the person when they are planning a route and solving complex spatial problems (e.g. determining detours), and can make it easier to communicate spatial information to other people [6; 8]. Cognitive maps are characterized by a high degree of plasticity and are based on an allocentric reference frame. Although vision controls many of the behaviours required for constructing the internal spatial representation, other sensory channels such as hearing, smell, touch and proprioceptive feedback also feed information into the person's spatial knowledge as they move around [18].

6. Evaluating factors associated with mental representation of space

The literature discusses various ways of evaluating factors associated with the mental representation of space. These methods can be used, among others, to help pinpoint the nature of the spatial orientation problem.

6.1 Stimulus localization

The ability to localize the stimulus can be expressed in various ways, such as pointing, moving or turning the body towards the target; drawing a plan; building a model of the location, etc. We can also ask the adolescent to identify and use landmarks and information points in the environment (e.g. asking them to name corridors, rooms, landmarks, streets, etc. as they point to them; describe the characteristics of the walls; localize the corridor using nearby sounds) [3].

6.2 Pointing to a target

A task involving pointing to a target, first from the initial position and then from a different position within the space, can be used to assess spatial memory in the space of manipulation. However, it should be noted that certain factors may affect the accuracy of the response, e.g. how far away the object is, which hand is used for pointing, length of time between tactile location of the object and the moment when the response is requested (e.g. imposed delay). Ittyerah, Gaunet & Rossetti (2007) conducted a study of children aged 6 to 12 who were congenitally blind or sighted but blindfolded and were asked to perform pointing tasks close to the body. Responses with the right hand were more accurate than with the left, for which they were closer to the body and angled more egocentrically (underestimating the distance) [7]. Moreover, responses to the immediate pointing task were more accurate than those for which a delay was imposed [7].

When dealing with pointing tasks, Thinus-Blanc & Gaunet (1997) suggest linking the subject's exploration behaviours to the accuracy of their response [18].

6.3 Target localization

Spatial memory in the space of manipulation may also be evaluated by asking the subject to localize a target on a raised-line route presented on a tactile map [10]. For example, after familiarizing themselves with the map, the person has to find certain places that they have been shown. The difficulty level depends on, among other factors, the body's position in relation to the map. For instance, the task is easier if the body's relative position remains the same as during the exploration phase (egocentric reference frame). It may be more difficult if this relative position is modified, e.g. if the plan is facing a different direction than initially (e.g. rotated 90°). Millar & Al-Attar (2004) studied blindfolded adolescents and young adults who were asked to explore a tactile map featuring five reference points along a route [10]. They then had to localize these references on another map that showed only the route. Rotating this second map by 90° doubled the number of localization errors due to disruption of egocentric references. However, when external references were added (e.g. frame around the map), there were fewer errors and their number was comparable to that in the rotation-free condition.

Spatial memory in the locomotor space can be evaluated by asking the student to reproduce a path in the actual space after being guided along it [18].

6.4 Reproducing an arrangement of objects

Tasks involving the reproduction of an arrangement of objects are often used in research with people who have visual impairment. The difficulty level of this type of task depends among other things on the configuration of elements in the space, particularly for a child. An environment crowded with objects, for example, will be harder to memorize than a setting featuring only a few items. We also have to consider where the model is to be explored, and where the subject has to reproduce it, in relation to the subject's midline. For instance, a child will find it easier to reproduce the model if both it *and* the reproduction space are in front of their midline. On the other hand, if the two bases are one on each side of the child, (e.g. base to explore on the left, base to reproduce on the right), this involves crossing the midline, and makes reproduction of a mirror image more likely [19]. Having to rotate the image mentally also makes the task more difficult [19]. The difficulties tend to be even more pronounced if the person is congenitally blind [19].

It may be worth observing the child's exploration pattern. For example, some researchers have found that a better spatial representation of the environment is produced when there is a combination of global exploration pattern (discovering the environment's overall configuration and the topological characteristics of the objects within it), more systematic, methodical exploration of individual objects, and repeated back and forth movements between the different pairs of objects (establishing interrelations) [18; 19].

A Tactile 3D Constructions Test based on the Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1983), was used in a study by Stuart (1995) [17]. A fixed arrangement of 3 to 7 blocks was presented to the subject, who had to reproduce it using individual blocks of the same size as in the model. Stuart also used a Tactile Maps Test in which the subject had to explore a 2D shape comprising bent aluminum rods glued to a base, and then draw the shape on paper. The shapes varied in complexity. The individual also had to reproduce the outline of the shape explored as they walked. Stuart's study showed that the results of the Tactile 3D Constructions Test and the Tactile 2D Map Test could predict the results for spatial orientation obtained by orientation and mobility specialists as well as those obtained for reading braille text.

6.5 Mental pathway task

Cornoldi et al. (2009) adapted the Mental Pathway Task for people with VI. This uses a 2D grid of 25 wooden blocks (5 x 5). The evaluator verbally describes the path to be taken by providing spatial references (e.g. left, right, towards me, towards you); the person being assessed then has to recall the entire path or its final destination [3]. These authors also took the opportunity to ask the subject what strategies they had used spontaneously during the task (e.g. verbal strategies, such as verbal recapitulation of the information or recoding of the spatial information; spatial strategies, such as visualizing or imagining the information in order to perform the task; a blend of both types of strategies).

6.6 Verbal description of plans

A verbal description of a route or other types of spatial tasks provides us with useful information about the cognitive and sensory strategies people use for understanding space and solving problems [1; 6; 18]. This method has the advantage of highlighting the individual's capacity to select, qualitatively and quantitatively, the relevant reference points they need for travel, and the way in which they memorize their sequence, relative distance and orientation, which they then structure and link with their spatial and environmental knowledge in an overall vision of the route [1; 6; 18]. It may, for example, involve a description of the tactile, auditory and kinesthetic information used to estimate the dimensions of a room based on references to external objects, the auditory environment, self-reference systems, the forming of mental images of the space, analogical thinking, deductive reasoning, etc. [1; 18]. However, this method is limited by the individual's ability to express in words their knowledge of the space and transcribe certain spatial dimensions (configuration of a place, complex arrangements) [6]. There is also a danger of the examiner biasing the representations with their questions, which may help the person to reorganize their knowledge and summarize the information, thereby restricting the validity of the narrative [6].

6.7 Reproduction of plans

Plan reproduction allows for a preliminary analysis of how the individual grasps their environment and sees it mentally. This method elicits information about the type of representation the person has at their disposal and the way they structure their knowledge in an overall representation (relative position, relative orientation, distance between landmarks) [6]. This reproduction can be produced in various ways: drawing, 2D or 3D reproduction, such as reproducing a map of neighbourhood streets with drawings, colouring, modelling clay or Lego bricks; adding significant visual landmarks, buildings, sidewalks, etc. to a "skeleton" plan of the school [2; 6]. However, the person's experiences and emotions may be limiting factors. For example, gauging functional distances will integrate both experience and subjective information (effort required to cover the distance, and the related feelings); this may result in distortion in the position of elements and the spatial relationships, i.e. undersizing or oversizing of the representation of the environment, depending on the events experienced in it [6]. Cognitive distortions also occur. For instance, how much attention the person pays to their surroundings while travelling will affect the selection of reference points and the gathering of information, and their information processing capacity will influence the type of representation [6]. Moreover, if the number of information items in the environment exceeds the memory span, the subject will group them into fewer items; this enables them to structure the representation but also distorts it [6].

In all these tests, the delays between memorization and the testing phase are obviously a major factor.

6.8 Mental imaging

Early blind individuals create and use mental images of their environment and the objects around them. Thinus-Blanc & Gaunet (1997) cite a number of studies that have focused on evaluating their level of mental imaging. Various methods were used: the subject could be asked to perform a mental rotation of the object they had just touched; draw certain objects previously explored with touch, but from a different spatial point of view; follow an imaginary path varying in complexity, based on verbal instructions from the researcher [18].

More recently, Vanlierde & Wanet-Defalque (2004) used a task based on verbal presentation of spatial configurations within 2D matrices [20]. This study showed that blind people without visual experience used spatial representation strategies based on encoding organized in a system of horizontal/vertical coordinates in X, Y, whereas individuals with prior visual experience based their judgment on visuo-spatial strategies (maintaining in memory the image of the spatial configuration).

7. Specialized video games

The classic assumption is that blind people, particularly those who become blind at an early age, have cognitive difficulties with forming a mental representation of their spatial environment and that this affects their navigation skills [9]. However, a review of the literature by Merabet & Sánchez (2009) reveals contradictory findings, particularly as regards the role of prior visual experience. These authors also question the conclusions of earlier studies; they wonder whether these differences in terms of mental constructions of the environment are due not only to visual deprivation in itself and the associated developmental factors, but also to poor or incomplete acquisition of the necessary spatial information via other sensory channels. From a rehabilitation angle, say these authors, the missing factor may be a better way of accessing, manipulating and transferring the acquired information, and this gap could potentially be filled by new technologies.

Using this hypothesis, Sánchez and his colleagues developed various electronic games producing virtual environments based on sounds. These are designed to develop and improve basic cognitive functions such as auditory perception, laterality and spatial concepts, temporal-spatial orientation and spatial navigation skills, etc. [12; 13]. An array of games was developed ranging from the simplest (e.g. Digital Clock Carpet game; 2D video game) to the most complex and elaborate (e.g. video game with 3D graphics and sounds). Players can navigate freely through the virtual environment, for example labyrinths, in order to find hidden objects, identify the position of various characters, avoid certain characters, and find the way out [9; 13; 14]. They were tested on children and adolescents to evaluate the usability of the games as well as the users' acceptance and degree of satisfaction. The researchers found that the seven children tested, aged 8 to 11 and with profound VI, were able to accurately reproduce the route they had navigated during the game, using Lego blocks. They therefore suggest that via auditory information, children with VI are able to acquire spatial information that can provide cues to the description of spatial environments and the way objects relate to each other [9]. Other software developed by this team includes AudioMetro, which simulates a journey on the Santiago subway system. Although these games seem to be of interest and are based on neuroscience, there have so far been no studies of how they impact the development and use of orientation and mobility skills. The Chilean team is planning to conduct this research.

8. Orientation skills in the locomotor space of an adolescent with visual impairment

According to Bina, Crouse, Fazzi & Naimy (2010), adolescents with VI should be able to describe the areas they are in, develop cognitive maps, be capable of following route directions, demonstrate spatial updating skills and the ability to estimate the duration/distance relationship, and employ problem-solving strategies in situations where they are disoriented [2].

Fazzi & Naimy (2010) have established guidelines for the skills that children and adolescents with visual impairment can be expected to display, based on their age. These skills fall into different categories, namely mobility, orientation, concepts and sensory skills [3]. According to these authors, students in grades 10 to 12 (age 15 to 17) should possess the following skills:

- *Mobility:* e.g. independent crossing in light business zones; cross at complex intersections under supervision; crossing in urban zone; independent travel in markets, malls and stores; look for independent transport options (e.g. shared transport, taxi, private driver, etc.); use public transit independently, including transfers; analyze complex intersections, etc.

  Example of evaluation: Using role reversal, the student teaches a technique by demonstrating it to their instructor.

- *Orientation:* e.g. create multimedia presentations of a familiar city and their reference points that can be used for orientation; plan routes to an unfamiliar destination, using public transit; orient self after getting off a bus or other mode of transport, in a familiar business environment; use GPS technology to establish orientation and find exterior destinations; be familiar with auditory signals.

  Example of evaluation: The student acts as a “tourist guide” in a familiar location (e.g. their school campus, community setting).

- *Concepts:* e.g. identify and describe the atypical characteristics of a light business zone (e.g. construction areas and scaffolding); identify and describe atypical travel features (e.g. pedestrian bridge); identify and describe features of an urban environment (e.g. skyscraper); plan a complex route independently using the indoor and outdoor numbering system; apply the numbering system used on commercial maps; identify configurations of complex intersections (e.g. roundabout); describe highway systems, railway networks, etc.

Example of evaluation: The student places screws, nuts and bolts in a compartmented organizer, while referring to spatial terms; adds labels or environmental characteristics to an incomplete map of a familiar environment.

- *Sensory skills:* e.g. use visual cues independently; integrate selective use of visual and auditory skills; select the appropriate optical and non-optical aids.

  Example of evaluation: The student identifies the location of objects dropped on the floor.

9. Conclusion

The literature reviewed did not provide a direct answer to the initial question, namely *what behaviours observable during daily activities may indicate a spatial orientation problem in a visually impaired adolescent?* However, the information found does highlight the factors that may affect spatial orientation. They are of three main types:

1) Integration of the fundamental concepts required for mental representation of the environment (body scheme, concepts of "body-to-object" relationship, spatial updating, the object-to-object relationship, environment, time; conceptual understanding of objects);
2) Sensory skills (tactile, proprioceptive, vestibular, olfactory, auditory, visual);
3) Cognitive capacities (attention, memory, language).

Assessing these factors can help to identify the deficits underlying a spatial orientation problem.

Observation or evaluation may also take a more integrative form, via the skills used for mental representation of the space — localizing the stimulus, spatial memory, inference skills, using symbolic representations and cognitive maps.

At a more observable level, it has been determined that overall, an adolescent with VI should be able to describe the areas they are in; develop cognitive maps; follow route directions; demonstrate skills in spatial updating and estimating time/distance relationships; use problem-solving strategies if they find themselves disoriented [2]. The specific competencies they should demonstrate in terms of mobility, orientation, concepts and sensory skills are described by Fazzi & Naimy (2010), and could be a useful basis for devising an observation grid for observable behaviours in this population.

There are many methods of evaluating factors associated with spatial orientation, ranging from the simplest (e.g. localizing the stimulus) to the most complex (e.g. mental representations). It is worth exploring how some of these could be adapted for integration in an observable behaviours evaluation grid that could be used to pinpoint orientation problems in adolescents with visual impairment.

10. References

1. Andreou, Y., & McCall, S. (2010). Using the voice of the child who is blind as a tool for exploring spatial perception. *British Journal of Visual Impairment, 28*(2), 113-129.

2. Bina, M. J., Crouse, R. J., Fazzi, D. L., & Naimy, B. J. (2010). Administration, assessment, and program planning for orientation and mobility services. In W. R. Wiener, R. L. Welsh & B. B. Blasch (Eds.), *Foundations of Orientation and Mobility: Vol. I. History and Theory* (3rd ed., pp. 389-433). New York: American Foundation for the Blind.

3. Bozeman, L., & McCulley, R. M. (2010). Improving orientation for students with vision loss. In W. R. Wiener, R. L. Welsh & B. B. Blasch (Eds.), *Foundations of Orientation and Mobility: Vol.II. Instructional Strategies and Practical Implications* (3rd ed., pp. 27-53). New York: American Foundation for the Blind.

4. Cornoldi, C., Tinti, C., Mammarella, I. C., Re, A. M., & Varotto, D. (2009). Memory for an imagined pathway and strategy effects in sighted and in totally congenitally blind individuals. *Acta Psychologica, 130*(1), 11-16.

5. Fazzi, D. L., & Naimy, B. J. (2010). Teaching orientation and mobility to school-age children. In W. R. Wiener, R. L. Welsh & B. B. Blasch (Eds.), *Foundations of Orientation and Mobility: Vol. II. Instructional Strategies and Practical Implications* (3rd ed., pp. 208-262). New York: American Foundation for the Blind.

6. Godard, E. (2009). *Mise en place d'un protocole d'évaluation des troubles de l'orientation spatiale : intérêts de l'observation en milieu écologique.* Unpublished Mémoire, Université Paul Sabatier, Toulouse.

7. Ittyerah, M., Gaunet, F., & Rossetti, Y. (2007). Pointing with the left and right hands in congenitally blind children. *Brain and Cognition, 64*(2), 170-183.

8. Long, R. G., & Giudice, N. A. (2010). Establishing and Maintaining Orientation for Mobility. In W. R. Wiener, R. L. Welsh & B. B. Blasch (Eds.), *Foundations of Orientation and Mobility. Vol. I. History and Theory* (3rd ed., pp. 45-62). New York: American Foundation for the Blind.

9. Merabet, L. B., & Sánchez, J. (2009). Audio-based navigation using virtual environments: Combining technology and neuroscience. *AER Journal : Research and Practice in Visual Impairment and Blindness, 3*(2), 128-137.

10. Millar, S., & Al-Attar, Z. (2004). External and body-centered frames of reference in spatial memory: Evidence from touch. *Perception & Psychophysics, 66*(1), 51-59.

11. Ricketts, L. (2008). Occupational therapy and sensory integration for visual impairment. *SenseAbilities, 2*(4), 16-24.

12. Sánchez, J., Jorquera, L., Muñoz, E., & Valenzuela, E. (2002). *VirtualAurea: perception through spatialized sound*. Paper presented at the The Fourth International Conference on Disability, Virtual Reality and Associated Technologies. Retrieved from http://www.icdvrat.reading.ac.uk/2002/papers/2002_26.pdf

13. Sanchez, J., & Saenz, M. (2006). Three-dimensional virtual environments for blind children. *Cyberpsychology & Behavior, 9*(2), 200-206.

14. Sánchez, J., Sáenz, M., & Ripoll, M. (2009). *Usability of a multimodal videogame to improve navigation skills for blind children.* Communication presented at ASSETS '09: Eleventh international ACM SIGACCESS conference on Computers and accessibility, Pittsburgh, Pennsylvania, USA.

15. Shapiro, D. R., Lieberman, L. J., & Moffett, A. (2003). Strategies to improve perceived competence in children with visual impairments. *RE:view, 35*(2), 69-80.

16. Sleeuwenhock, H. C., Boter, R. D., & Vermeer, A. (1995). Perceptual-motor performance and the social development of visually impaired children. [Review]. *Journal of Visual Impairment and Blindness, 89*(4), 359-367.

17. Stuart, I. (1995). Spatial orientation and congenital blindness: A neuropsychological approach. *Journal of Visual Impairment and Blindness, 89*(2), 129-141.

18. Thinus-Blanc, C., & Gaunet, F. (1997). Representation of space in blind persons: Vision as a spatial sense? *Psychological Bulletin, 121*(1), 20-42.

19. Ungar, S., Blades, M., & Spencer, C. (1995). Mental rotation of a tactile layout by young visually impaired children. *Perception, 24*(8), 891-900.

20. Vanlierde, A., & Wanet-Defalque, M.-C. (2004). Abilities and strategies of blind and sighted subjects in visuo-spatial imagery. *Acta Psychologica, 116*(2), 205-222.