Students with Visual Disability and Active Touch: Levels of Understanding and Think-Aloud Protocols

Vassilios Argyropoulos, Sofia Chamonikolaou, Magda Nikolaraizi

University of Thessaly, Greece

0753

The Asian Conference on Education 2013

Official Conference Proceedings 2013

Abstract

There is a lot of ongoing research regarding the key functions of the sense of active touch and their links to patterns of conception and cognition, with implementations in the education of students who have visual disabilities. The general research aim of this study was to investigate levels of understanding when individuals with blindness apply haptic exploratory movements to explore small manipulative geometric objects. The knowledge of geometry is crucial for individuals with blindness because it facilitates the formation of conceptual maps which are very important in their daily life as they move from one place to another. Furthermore knowledge of geometry gives them the opportunity to refine their motor control and tactile skills that is also useful in their lives. Twelve individuals with severe visual impairments participated in the study. The data were obtained by a series of experiments wherein individuals with visual disability actively manipulated by both hands the following types of geometric shapes: a. two-dimensional and three-dimensional simple geometric shapes, and b. complex shapes. The findings, were based on video recordings, support on one hand the existence of an integrated mapping of the participants' active touch while they were trying to detect and identify two-dimensional and three-dimensional figures and on the other hand the complexity of tactual shape perception and its uniqueness regarding every student's thinking.

Keywords: blindness, shape perception, haptic exploration, active touch, think aloud protocols, van Hiele, levels of understanding in geometry.

INTRODUCTION

Touch is considered to be a multidimensional sense rather than a single sense. For example, Gibson (1962) divides touch into two main types: a) active touch or touching, and b) passive touch or being touched. In the first case we have impressions on the skin resulting from exploratory movements of the perceiver and in the second, the same but resulting from "some outside agency" (p.447). Katz (1989) suggested that it is misleading to consider touch as a single sense because touch conveys impressions of roughness or smoothness, of dryness or wetness, of hot or cold, of pressure or caress and so on. All these are partly overlapping skin sensations which are attributed to skin receptors.

On the other hand, shape perception by touch requires many factors to be considered; and this is because there are many sources which provide information. Shapes differ in size, depth and composition and at the same time they provide different kinds of cues depending on the type of configuration. More analytically, there are at least six categories of tactual configuration (Millar, 1997). Because of their different types they stimulate the skin receptors in different ways and this implies every time the corresponding reference organisation. Millar (1994) refers to the recognition of shapes from vibrotactile stimulation, flat and outline forms placed on the skin and in the hand, small three-dimensional shapes actively manipulated by hand, large three-dimensional objects which cannot be grasped in the hand, small continuous raised outlines and very small raised-dot patterns (e.g. braille).

In brief, the issue of touch is roughly distinguished in two types: active touch which produces exploratory movements and passive touch which is characterised by non-exploratory movements. The term movement constitutes one of the basic complementary sources in formulating spatial coding. It is suggested that movement falls in two general types; exploratory and performatory. The former type implies perception and the latter behaviour (Gibson, 1966). For instance, grasping an object is an exploratory movement or to be more precise it is a set of exploratory movements. This sequence of exploratory movements was found to be very common in this research. There is awareness on the part of the subject that s/he is trying to find out the shape of the object or the properties of the object or the relationships between the object and environment. Put briefly, the whole organism is in a state to receive and interpret cues from all the available senses (modalities). All this leads to the formation of a perception. The subjects, after this sequence of events can recall the experience and perform the same movements a second time more confidently because now there is an area of prior knowledge about the object in question. The movement is performatory and both kinds of movements are motivated through conscious procedures.

Active touch is considered as one of the dominant senses for individuals with visual disability about the properties of the surrounding environment. Furthermore, an individual with visual impairment uses the respective exploratory movement depending on the information he/she wants to extract from an object. For instance, it seems that exploratory movement *enclosure* is used by individuals with visual disability when they want to extract information about the overall picture of an object, while other movements provide details of the object (Piaget and Inhelder, 1997). Additionally, it has been observed that the identification of geometric shapes by individuals who are blind is based mainly on the exploration of their angles and curves and not of their sides. Also, it seems that the characteristics of three-dimensional objects are learned easier and faster than those of two-dimensional ones (Ittyerah, 2010; Withagen et al., 2011). Finally, it seems that individuals with visual disability prefer to use their indexes and thumbs when they actively manipulate objects (Heller, 1989).

The general research aim of this study was to investigate levels of understanding when individuals with blindness apply haptic exploratory movements to explore small manipulative geometric objects. The research objectives were as follows: a. describe types of blind participants' exploratory movements while dealing with small manipulative geometric objects, b. assess blind participants' ability to recognize small manipulative geometric objects, and c. describe levels of blind participants' levels of understanding while dealing with small manipulative geometric objects.

METHODOLOGY

Participants

Twelve adults from Greece with blindness (total sight loss) participated in the present study (age, M= 38.8). Eight participants were congenitally blind, while the rest were adventitiously blind with no additional disabilities. Furthermore, five participants had light perception.

Stimulus Material

The shapes, which were used in this study, were small three-dimensional ones, able to be actively manipulated by both hands. Forty two shapes were used in the present study. Thirty were simple (Figure 1) and 12 were complex (Figure 2). Most of the shapes were constructed of wood, carton board, plastic and glass.

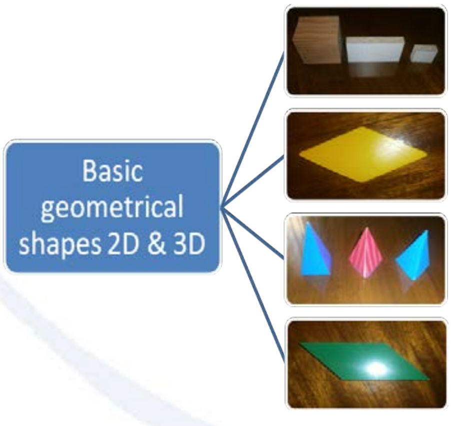

Figure 1. Simple two- and three-dimensional geometric shapes

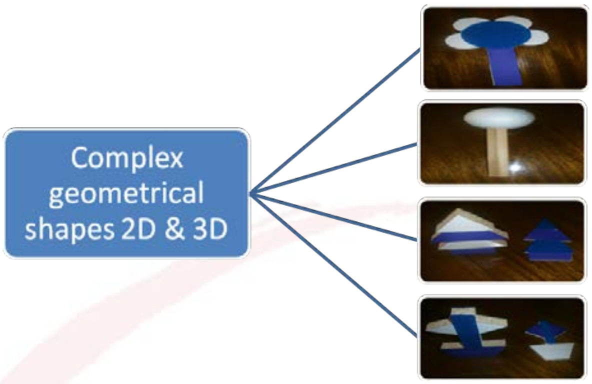

Figure 2. Complex two- and three-dimensional geometric shapes

Research procedure

As mentioned before, 42 shapes were explored by 12 participants with blindness. In specific, the participants were asked to verbally describe the properties of the shapes in question. All experiments were video-recorded and the camera shot focused exclusively in the participants' hands. A preliminary phase took place before the main experiments. During this phase all participants had the chance to work out some shapes – which were not included in the main experiments – and comment on their attributes, texture and material. In turn, the participant was given a tray with all shapes and he/she randomly picked up one by one, without time limit and described the shape.

Data analysis

Data analysis was based on video recording sessions. In order to analyze the data linked to the 1st research objective, the researchers saw the video multiple times and categorized all participants' tactile exploratory movements according to a protocol developed by Lederman and Klatzky (1987). This protocol includes hand movements which can be distinguished as follows: a. *enclosure* (for holistic approach and volume of a object), b. *contour following* (for holistic approach and detailed outline of the shape), c. *lateral motion* (for texture), d. *pressure* (for hardness or softness), e. *static contact* (for temperature), f. *unsupported holding* (for weight), g. *function test* (for main function of the object), and h. *part motion test* (for specific function of the object). The first research sub-aim was met applying the above protocol.

The analysis of the participants' verbal descriptions while manipulating the geometric objects, (2nd and 3rd research objectives), was based on think-aloud protocols. Specifically, the authors transcribed the participants' verbal comments and descriptions, while dealing with the geometric objects and in turn developed protocols. Following, the authors used two scoring systems to analyze the think-aloud protocols. The first scoring method was the bit-by-bit approach. All participants' verbal descriptions (verbal protocols) were transcribed and splitted into geometric ideas (idea unit). The maximum value of a correct idea unit would be 3 while the minimum value was 1 (Mayer, 1985; Nikolaraizi et al., 2012). In essence, the authors assessed all idea units of the participants' verbal descriptions applying the formula: Mean Score (MS) = Total Scoring/Total Number of Idea Units [$MS=S/N_{IU}$].

The second scoring system used was the holistic approach. It is called "holistic" because the scoring was based on the participant's overall response. Again, the maximum value of a correct holistic approach was 3, while the minimum was 1. The point system followed the bellowed structure:

- 3 points = participant provides correct definitions of the shape and its properties
- 2 points = participant provides correct definitions of the shape without defining its correct properties (or vice versa).
- 1 point = participant provides incorrect definitions of the shape accompanied with incorrect properties

Finally, the analysis of the participants' levels understanding during the manipulation of the geometric objects was based on the van Hiele's model (Van Hiele, 1959). In specific, the Van Hiele Model identifies five levels of thinking in geometry:

- Level 0 (Recognition): Recognition of shapes as a whole
- Levels 1 & 2 (Analysis & Ordering): Progressing to discovery of the properties of figures and informal reasoning about these figures and their properties
- Levels 3 & 4 (Deduction & Rigour): Culminating in a rigorous study of axiomatic geometry (Fuys et al., 1988).

Based on the above levels, the authors linked the participants' exploratory movements (1st research objective) to their levels of understanding (3rd research objective). Following, in the results section, the authors describe briefly the participants' types of exploratory movements, while they place strong emphasis on the participants' understanding when dealing with geometric objects. For more analytical data regarding the type of exploratory movements the readers can go through the study conducted by Argyropoulos, Chamonikolaou, and Nikolaraizi, (2013).

RESULTS

Regarding the 1st objective, the authors found that all types of exploratory movements - as mentioned by Lederman and Klatzky (1987) - were present (see analytical research report in Argyropoulos, Chamonikolaou, & Nikolaraizi, 2013). Also, two additional types of complex movements, apart from those mentioned in Lederman's and Klatzky's protocol, were detected through the experiments. That is, a. *the procedure of hitting an object with fingers or hitting on the table* (in this way a sound was produced providing information about the material of the object), and b. *the function test* procedure and the *part motion test* procedure (with this complex movement the participants made use of a third surface, such as the table, in order to determine if the length of the sides of a shape was equal or unequal).

The results of exploratory movements showed that the movement which was favored by all participants (100%) in recognizing the property of shape was *enclosure* (using palms to get a global idea of the shape) and *lateral motion* (using the index finger when the shape was small and the palms for bigger shapes). Also the movement *contour following* was found in high percentages amongst the participants (81.5%) and by this movement the latter could figure out the exact shape of the objects they explored. This movement occurred when the participants followed with their index finger the outline of a shape (see analytical research report in Argyropoulos, Chamonikolaou, & Nikolaraizi, 2013). The rest of the exploratory movements were present at lower percentages.

Regarding the 2nd objective, the authors found that almost all participants did manage to recognize the shapes (as a whole as well as from their properties). Both scoring systems gave similar results. Some extracts are provided below based on the two different scoring systems:

First scoring system: **bit-by-bit approach**

Formula used: $MS=S/N_{IU}$

1=min. value & 3=max. value

Example: (hexagon)

Participant: *it's gotta be hexagon* (3 points-idea unit=hexagon)

Researcher: *which means….*

Participant: *which means 6 sides* (3 points-idea unit=side) *and they are all the same*

Researcher: *when you same the same you mean...*

Participant: *I mean equal* (3 points- idea unit=equality) *and I forgot also 3 acute and 3 obtuse angles* (1 point- idea unit angle)

Mean Score: (3+3+3+1)/4 = **2.5**

Second scoring system: **holistic approach**

Example for a trapezium

Participant (he picked up a trapezium): *Well this shape is kind of parallelogram but these two opposite sides are not parallel* (2 points = participant provides correct definitions of the shape without defining its correct properties).

Total Score = 2

Figure 1, provides information about the participants'' overall recognition based on their think-aloud protocols. Based on Figure 1 only two participants (5th & 6th) had low average (M = 1.85 and M = 1.43 respectively) who were also congenitally blind.

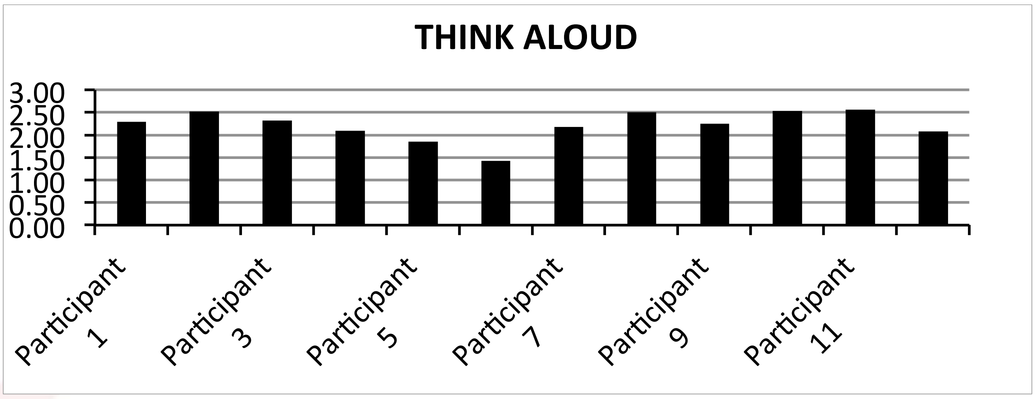

Figure 1: Think aloud protocols and scoring

Regarding the 3rd objective, the analyses of the think aloud protocols provided rich information about the participants' levels of understanding in geometry based on van Hiele's model. A single level seems not to be adequate to describe and classify participants' thinking. Rather, we suggest that a synthesis of levels might provide a more integrated "picture" of participants' understanding in geometry. Table 1 provides information about the participants' levels of understanding based on the van Hiele's model, coupled with their average scores in their verbal descriptions from both scoring systems (think-aloud protocols). It was observed that when the average value from both scoring systems in the think-aloud protocols was below 2, then the corresponding level of understanding was less or equal to level 1; whereas, when the average value in the think-aloud protocols was greater than 2, then the participants' level of understanding was greater or equal to level 1.

Table 1. van Hiele levels of understanding related to think aloud protocols

Participants	Average Think-aloud	Min/max values	SD	Van Hiele's level
1	2,29	1/3	0,69	**1 & 2**
2	2,52	0,5/3	0,64	**1 & 2**
3	2,32	0,5/3	0,57	**1 & 2**
4	2,09	0,5/3	0,84	**1 & 2**
5	1,85	0,5/3	0,77	**0 & 1**
6	1,43	0.5/3	0,77	**0 & 1**
7	2,18	0,95/3	0,62	**1 & 2**
8	2,51	0,62/3	0,66	**1 & 2**
9	2,25	1,1/3	0,65	**1 & 2**
10	2,54	0,87/3	0,53	**1 & 2**
11	2,57	1/3	0,58	**1 & 2**
12	2,08	0,81/3	0,79	**1 & 2**

Note: Level 0 = Recognition (The participant identifies the figures by name according to their appearance as a whole).
Level 1 = Analysis (The participant analyses figures in terms of their properties and discovers properties/rules of a class of shapes empirically).
Level 2 = Ordering (The participant logically establishes the relationships among previously discovered properties/rules by giving or following informal arguments).
Level 3 = Deduction (The participant understands the role of postulates and proves theorems deductively).
Level 4 = Rigour (The participant establishes theorems in different postulates and analyses them).

DISCUSSION - CONCLUSIONS

We can assert that shape perception by touch is an intersensory processing activity, since all the parameters analyzed in the literature review were present in the participants' performances (Ballesteros and Heller, 2008; Fisher and Bornstein, 1982; Lederman et al., 1990; Millar, 1997). Exploratory movements provided kinesthetic information and it worth mentioning that movements such as *enclosure, contour following, lateral motion and hitting the object with fingers or hitting the object on the table*, yielded information about the temperature and texture and the properties of the shape. It seems that the *enclosure* procedure constitutes the active movement by which people with blindness, either congenitally blind or adventitiously blind receive the most information about the whole picture of the object (global approach) and the *contour following* and *lateral motion* procedures aim at specific properties of the shape (feature approach) (Homa et al., 2009; Piaget and Inhelder, 1997).

Also, it is argued that individuals' understanding does not fit neatly into one level or another (i.e. van Hiele's levels). The use of "levels" satisfies the hierarchical structure of geometry or maths in general but it is not sufficiently refined to characterise thinking. This position can be justified by the following points: 1) the number of levels seem to be flexible, 2) performances generally seem to be spread across levels, and 3) performances are determined by what is taught. This implies that the nature of the van Hiele's levels are more psychological than logical and undoubtedly has a bearing on teaching processes (Clements and Battista, 1992). That is to say, that progress from one level to the next is more dependent upon instruction than on age or biological maturation (van Hiele, 1959).

To conclude, the influence of a teaching/learning process may accelerate the progress from a lower to a higher level of thinking. The previous considerations lead to the conclusion that van Hieles' levels are not discrete but there is a dominant level of elaboration and furthermore the phenomenon of transition needs to be investigated in greater detail, especially when the first stage of understanding is haptic and not visual. For this, it is vital to conduct similar studies increasing the size of the sample including students with visual disabilty in order to shape a more integrated protocol of active exploration and correlate its elements to levels of understanding such as van Hiele's levels.

Acknowledgments

This study constitutes a part of the project "Handedness and Braille Literacy in Individuals with Severe Visual Impairments" is implemented under the "ARISTEIA" Action of the "OPERATIONAL PROGRAMME EDUCATION AND LIFELONG LEARNING" and is co-funded by the European Social Fund (ESF) and National Resources.

REFERENCES

Argyropoulos, V., Chamonikolaou, S. and Nikolaraizi, M. (2013) 'Investigating types of active touch in individuals with visual disability during the exploration of geometrical shapes'. *6th International Conference of Education*, Research and Innovation. Seville, 18-20 November. Seville: International Association of Technology, Education and Development, pp. 1626-1632.

Ballesteros, S. and Heller, M. A. (2008) '*Haptic* object identification'. In: Grunwald, M. ed. Human Haptic Perception: Basics and Applications. Boston: Birkhäser Verlag.

Clements, D. and Battista, M. (1992) 'Geometry and spacial reasoning'. In: Grouws, D. ed. *Handbook of research on mathematics teaching and learning*. New York: Macmillan Publishing Company.

Fisher, C. and Bornstein, M. H. (1982) 'Identification of symmetry: Effects of stimulus orientation and head position'. *Perception & Psychophysics*, 1982 (32): 443-448.

Fuys, D., Geddes, D. and Tischler, R. (1988) 'The van Hiele model of thinking in geometry among adolescents'. *Journal for Research in Mathematics Education.* Monograph No. 3

Gibson, J.J. (1962) 'Observations on active touch'. *Psychological Review,* 69(6): 477-491.

Gibson, J.J. (1966) '*The Senses Considered as Perceptual Systems'*. Boston: Houghton Mifflin.

Heller, M.A. (1989) 'Picture and pattern perception in the sighted and the blind: the andvantage of the late blind'. *Perception*, 18 (3): 379-389.

Homa, D., Kahol, K., Tripathi, P., Bratton, L. and Panchanathan, S. (2009) 'Haptic concepts in the blind'. *Attention, Perception and Psychophysics*, 71 (4): 690-698.

Ittyerah, M. (2010) 'Haptic touch and hand ability'. In: Zadeh, M., H. ed. *Advances in Haptics*, 25: 463-475 [Internet]. Available from: http://www.intechopen.com/ [Accessed 10 March 2013].

Katz, D. (1989) *The World of Touch* (edited and translated by L.E.Krueger). Hillsdale, N.J.:Lawrence Erlbaum Associates.

Lederman, S.J. Klatzky, R.L., Chataway, C. and Summers, G.D. (1990) 'Visual mediation and the haptic recognition of two-dimensional pictures of common objects'. *Perception and Psychophysics*, 47 (1): 54-64.

Mayer, R.E. (1985) 'Structural analysis of science prose: Can we increase problem solving performance?' In: B. K. Britton and J. B. Black eds. *Understanding expository text: A theoretical and practical handbook for analyzing explanatory text.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Millar, S. (1997) 'Theory, experiment and practical application in research on visual impairment'. *European Journal of Psychology of Education*, 12: 415-430.

Millar, S. (1994) '*Understanding and representing space: theory and evidence from studies with blind and sighted children'*. Oxford: Oxford University Press.

Nikolaraizi, M., Vekiri, I. and Easterbrooks, S.R. (2012) 'Investigating deaf students' use of visual multimedia resourses in reading comprehension'. *American Annals of the Deaf*, 157(5): 458-473.

Piaget, J. and Inhelder, B. (1997) '*The Child's Conception of Space'*. London and New York: Routledge.

Van Hiele, P.M. (1959). 'The child's thought and geometry'. In: Fuys, D., Geddes, D. and Tischler, R. eds. *English translation of selected writings of van Hiele-Geldof*, D. and Van Hiele, P.M.. Brooklyn, NY: Brooklyn College, School of Education

Withagen, A, Kappers, A., Vervloed, M., Knoors, H. and Verhoeven, L. (2011) 'Haptic object matching by blind and sighted adults and children'. *Acta Psychologica*, 139 (2012): 261-271.

iafor