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Can touch substitute vision? An empirical study about how the visually impaired comprehend shapes

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Abstract. Generally, it is assumed that the visually impaired people are unable to comprehend the make-up of physical environment and its spatial characteristics due to lack of vision. This study aims to reassess the contention that vision limits comprehension of form and examines the relationship vision loss, learning ability and comprehension of form vocabulary. It explores the role of tactual depth perception in shape comprehension and examines how different shape categories are understood by the visually impaired people. The most significant inference is that visual impaired people prefer textual information in relief rather than in recess. Similarly, circular shapes easier to comprehend over angular shapes needs to be tested with larger population of visually impaired people.

Keywords. Vision impairment, Sense of touch, Tactual shape comprehension

Introduction

The present day world is unfriendly to the needs of the visually impaired which is evident from their invisibility in the public realm of life. Generally, it is assumed that the visually impaired people are unable to comprehend the make-up of physical environment and its spatial characteristics due to lack of vision. Historically, the vision is regarded as the most important of all five senses and hence the development of physical environment has taken place with a clear bias towards the need for vision and visual perception for successful comprehension and navigation through the space. This has ignored the role of and the potential for other sensory abilities in the development of physical environment and has created excessive dependence on visual perception, without which individuals with vision impairment are limited not by their ability but by the design of the environment. Such an approach has created attitudinal arrogance and created physical barriers that deny the people with visual impairment - limited vision, low vision, visual impaired and the blind - the opportunities to experience and participate with others in public places.

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Contrary to the viewpoint, researchers like Juhani Pallasmma believe that instead of mere vision, several realms of sensory experience interact and fuse into each other while perceiving the physical environment. As per James J Gibson, it is the collaborative mechanism of all the sensorial systems in our body that enable us to comprehend the world. It is also proposed that vision loss may result in abilities which are qualitatively different from, but functionally equivalent to, those of sighted people (the 'difference' theory) [1,2].

This questions the importance of vision impairment and how it limits perception and comprehension of the physical environment. Do other sensory abilities compensate for vision loss and help develop coping mechanisms needed to achieve effective comprehension? How effective is touch-perception of people with visual impairment and how well can they gauge shapes and forms? What is the accuracy level related to touch-perception and what role it plays in comprehending the world around them? This study draws objective from these fundamental questions and seeks answers through an empirical study that examines the sense of touch by visually impaired people for comprehension of the form and the understanding of meaning in the physical environment.

1. Why 'sense of touch?'

The sense of touch is supreme and all senses are regarded as specializations of the skin and extensions of the sense of touch [3]. The sense of touch is best suitable for comprehending three-dimensional objects and the surface qualities of objects [4]. Also recently established studies have theorized that the blind have superior active, self-guided tactile exploration skills. On one end, lower performance by congenitally blind subjects has been interpreted as an indicator of the impact of a lack of visualization [5,6], while on the other end there seems to be a fundamental similarity in the way that persons who are blind and the sighted process and use pictorial information [4]. Haptics enable a person to 'deduce' the shape of an object by going beyond perceptual experience. Tactile beliefs imply elaborate mental representations that build on haptic experience but are unrelated to vision [7]. Based on body movement, Morton Heller [5] distinguishes three ways of touching - active, passive and dynamic touch [8]. This study concentrates on comprehension by active touch.

Most published research focus on understanding tactual shape comprehension in the form of raised line drawings or real objects of daily use. Researchers have studied how blind and sighted participants identify raised line and how clearly they understand tactile information [7,9]. Such studies have been criticized for lack of depth in raised line drawings and that the drawings do not represent real environmental conditions.

Very few studies have examined haptic communication through touch (internationally) and how objects are identified by people with vision impairment; little is known about communication as none of these studies involved Indian people and they were not carried out in India. Few studies have compared haptic communication with visual identification of raised forms, two and three dimensional unfamiliar shapes [10-12]. These studies demonstrate that either touch is ineffective for reading, comprehension and shape identification or that touch is so dependent on vision that pattern perception and understanding of shapes are minimal. A study based on haptic identification of hand sized real objects argued that touch can help identify very common forms with considerable competence [14]. Though very useful, these studies neither confirm the ability of people with vision loss to comprehend three dimensional representational shapes nor are there empirical studies which satisfactorily inform the effects of tactual depth on the speed and accuracy of form comprehension and characteristics people with vision loss.

2. THE STUDY

In India, 2.1% of the total population are people with permanent disabilities out of which 48.54% are people with vision impairment that is almost half of the total disabled population [15]. Along with the swelling numbers, vision impairment in India has unique sociological and cultural dimensions. Lack of vision is understood as a disability attained as a result of past life sins and has become one of the social taboos leading to neglect at the community level. Public transport and most public places are inaccessible to people with vision impairment, and those venture out are at a serious risk of accident and death, and the remaining are imprisoned in their own homes. Thus, visually impaired people in India live a dependent life within the family, which is either neglect or over-supportive of their needs, leaving very less room for them to perform on their own, live independently or make visual judgments for themselves. The visually impaired population has minimal exposure to tactile environments and the sense of touch is an untapped potential for them.

This study aims to reassess the contention that vision limits comprehension of form and examines the relationship vision loss, learning ability and comprehension of form vocabulary. This study explores the role of tactual depth perception in shape comprehension and examines how different shape categories like simple, complex, very complex, familiar shapes are understood, and how the form vocabulary and shape characteristics influence level of comprehension by the visually impaired people.

3.Research Questions

Can people with visual impairment comprehend shapes through touch? How accurate is touch perception for shape recognition? What texture – relief or recess – is best suited for shape recognition through touch? What shape type is easier to comprehend through touch – geometric or natural shape?

4.Method

The study consisted of four stages as listed below, through which participants were asked to comprehend:

- Basic geometrical shapes in recess and relief
- Moderately complex geometric shapes in relief and recess
- Very complex geometrical shapes in relief and recess
- Shapes of familiar or known objects.

Data was collected using two methods:

- Participant performance observed and recorded using still photographs and videos
- Open ended interview with participants followed observation to understand problems and preferences

The study involved two groups of 10 visually impaired participants, 17-30 years and 50 to 70 years. The first group consisted of only female participants of which, 7 totally blind and 3 partially sighted. The second group consisted of 8 male and 2 female participants, of which 5 totally blind and 5 partially sighted. The study was conducted for the first group at their blind home while for the second at their place of study and work place; both in Pune, India. Two different age groups and vision impairment types were chosen to determine the role of age and vision on performance and shape perception.

4.1 Stimuli and Apparatus

For stage 1, 18 tactile boards were made using thermocol and mountboard, depicting 3 simple shapes - *the circle, triangle and square* separately with 3 different depths for each in relief and recess, 6 boards per shape. This was done to understand the relationship of tactual depth of a shape with the level of comprehension of the same, based on a study as per which the size of the stimulus changes the rate at which it can be explored [16]. The maximum relief/recess chosen were 20 mm and minimum 2 mm. For stage 2 and 3, a plastic tactile board with 10 mm deep cut outs of shapes and respective three dimensional plastic shapes were used. Five samples of moderately complex shapes - *oval, semicircle, parallelogram, hexagon and octagon* and two samples of very complex shapes - *cross / plus and star / stellate* shape were used for shape identification. For stage 4, wooden tactile board, 4 mm deep cut outs of familiar fruit shapes along with three dimensional wooden fruit shape like *apple, banana and mango* were chosen for the experiment.

4.2 Procedure

Participants were invited to the study, explained the process, encouraged to ask questions and given the option to decline. All participants were taken through each stage one by one, and were asked to identify/comprehend given shapes on tactile boards through touch and active exploration. No practice session was conducted before, and the time taken for identifying and naming was recorded for each participant. Wherever participants required, category-related information or prompting, they were given and the assistance offered was recorded to inform inference. No set sequence was followed for showing the shapes at every stage, to avoid patterning.

After the identification and observation round, questions like the following were asked:

Which shape was easiest to comprehend? Which one was most difficult to comprehend? What made it easy to comprehend? What makes comprehension difficult?

Figure 1. Photographic recording of participants comprehending shapes through touch

5.Results

5.1 By Observation (Refer Table 1, 2, 3)

All participants attempted identifying given shapes using touch irrespective of their vision level - partial vision or not.

Almost all participants across both groups could identify the simple geometric shapes correctly and within 3-5 seconds for both relief and recess. No significant pattern for identifying shapes in relief versus shapes in recess across varying depths was observed. Most participants from both the groups identified the moderately complex shapes correctly without being prompted though took more time than they needed to identify simple shapes – ranging from 5 to 20 seconds. Participants from the second group (age 50-70 years) required more time for identifying all shapes in comparison to the younger group.

Almost all participants with total blindness could not comprehend the very complex shapes – plus and star, while some partially blind participants were successful at describing the same shapes. They took advantage of partial vision in addition to touch to identify the shapes. Interestingly, most participants could not state the common names for the very complex shapes they were identifying; rather they described the shapes to explain them and associated the shapes with objects in their daily living. For example, semicircle was described as an almond or half-moon. Almost all participants could not comprehend correctly the very complex shapes in spite of being prompted and they offered no descriptive responses. Those who identified took almost 2-3 minutes to identify the shapes with some known object, For example, the star shape was identified as a flower. In spite of the information category like fruit family was given, only 50% of the participants could identify the shapes correctly, and they needed additional time and prompting.

Table 1. Comprehension accuracy and speed recording by observation for simple shapes

Pr no	Type of vision impairment	Literacy	Age	Comprehension of primary shapes in relief		Comprehension of primary shapes in recess		Comprehension with	
				<5 secs	>5 secs	<5 secs	>5 secs	Convention -al term	Promp- ting
1	no sight	graduate	30	●		●		●	no
2	partially sighted	graduate	25	●		●		●	no
3	no sight	12th	17	●		●		●	no
4	partially sighted	12th	21	●		●		●	no
5	no sight	12th	21	●		●		●	no
6	partially sighted	10th	17	●		●		●	no
7	partially sighted	graduate	21	●		●		●	no
8	no sight	12th	18	●		●		●	no
9	no sight	graduate	26	●		●		●	no
10	partially sighted	graduate	25	●		●		●	no
11	no sight	4th std	66		●		●	●	no
12	partially sighted	7th std	58		●		●	●	no
13	no sight	nil	53		●		●	●	no
14	no sight	10th	63		●		●	●	no
15	no sight	nil	55		●		●	●	no
16	partially sighted	10th std	50		●		●	●	no
17	no sight	5th std	58		●		●	●	no
18	no sight	nil	60		●		●	●	no
19	no sight	7th std	70		●		●	●	no
20	partially sighted	8th std	55		●		●	●	no

All participants used their fingers and finger tips to move around the object outline to identify shape; most of them counted sides to identify complex shapes. They could differentiate between a relief and recess and also change in depths without much difficulty. They could identify material variations in the tactile boards.

Table 2. : Comprehension accuracy and speed recording by observation for moderately complex and very complex shapes

Pr no	Type of vision impairment	Literacy	Age	Comprehension of complex shapes		Comprehension of very complex shapes		Comprehension with		
				<10 secs	>10 secs	< 20 secs	>20 secs	Conventional term	Description	Prompt-ing
1	no sight	graduate	30	●					●	yes
2	partially sighted	graduate	25	●			●	●	●	yes
3	no sight	12th	17	●			●	●		yes
4	partially sighted	12th	21	●			●	●		yes
5	no sight	12th	21	●				●		yes
6	partially sighted	10th	17	●				●		yes
7	partially sighted	graduate	21	●			●	●		yes
8	no sight	12th	18	●				●	●	yes
9	no sight	graduate	26	●				●		yes
10	partially sighted	graduate	25	●			●	●		yes
11	no sight	4th std	66		●		●		●	yes
12	partially sighted	7th std	58		●				●	yes
13	no sight	nil	53							yes
14	no sight	10th	63							yes
15	no sight	nil	55		●				●	yes
16	partially sighted	10th std	50				●		●	yes
17	no sight	5th std	58							yes
18	no sight	nil	60							yes
19	no sight	7th std	70		●				●	yes
20	partially sighted	8th std	55		●				●	yes

Table 3: Comprehension accuracy and speed recording by observation for fruit shapes

Pr no	Type of vision impairment	Literacy	Age	Comprehension of fruit shapes		Comprehension with		
				<10 secs	> 10 secs	Conventi onal term	Descrip- tion	Prompt- ing
1	no sight	graduate	30					yes
2	partially sighted	graduate	25		●	●		yes
3	no sight	12th	17		●	●		yes
4	partially sighted	12th	21	●		●		yes
5	no sight	12th	21		●	●		yes
6	partially sighted	10th	17					yes
7	partially sighted	graduate	21		●	●		yes
8	no sight	12th	18		●	●		yes
9	no sight	graduate	26					yes
10	partially sighted	graduate	25		●	●		yes
11	no sight	4th std	66					yes
12	partially sighted	7th std	58					yes
13	no sight	nil	53		●	●		yes
14	no sight	10th	63		●	●		yes
15	no sight	nil	55		●	●		yes
16	partially sighted	10th std	50					yes
17	no sight	5th std	58					yes
18	no sight	nil	60		●	●		yes
19	no sight	7th std	70					yes
20	partially sighted	8th std	55		●	●		yes

5.2 By Interview

Almost all participants had no experience in the past with tactile boards used for the study. All but one participant could identify shapes in relief; shapes with maximum depth were easier than shapes in recess. They preferred relief shapes though recess shapes with greater depth are comprehendible.

In terms of shape complexity, majority participants found that identifying simple shapes is easier than complex and very complex shapes; the reason being the lack of knowledge and previous experience with little known shapes like the star and fruits. All participants mentioned that circular shape was easier to comprehend than angular shapes like triangle, square, and rectangle; and shapes that have more number of sides created confusion and visualization difficulty. For example a square shape is easily confused with a rectangular shape. Most participants felt that higher accuracy could be achieved if shape categories were presented before the identification process began to reduce guess work and to streamline cognitive deduction of the shapes.

6.Discussion (Refer Figure 1 and 2)

The study underscores the ability of visually impaired people to comprehend shape characteristics while outlining the limitations like error, time and need for prompting.

The poor performance in comprehending complex shapes is important though not necessarily critical because some blind participants successfully comprehended these shapes. It highlights the importance of haptic exposure to pictorial representations and the practice needed to comprehend new and unknown shapes.

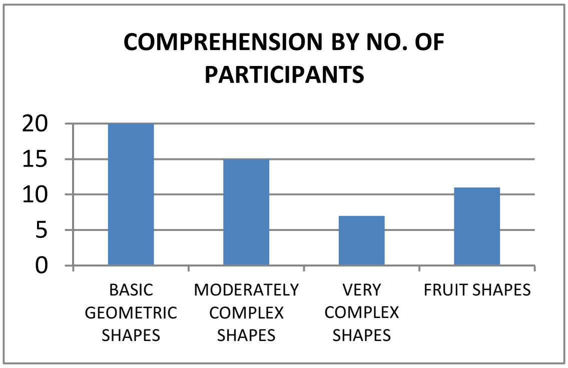

Figure 2: Successful comprehension of given shapes by number of participants

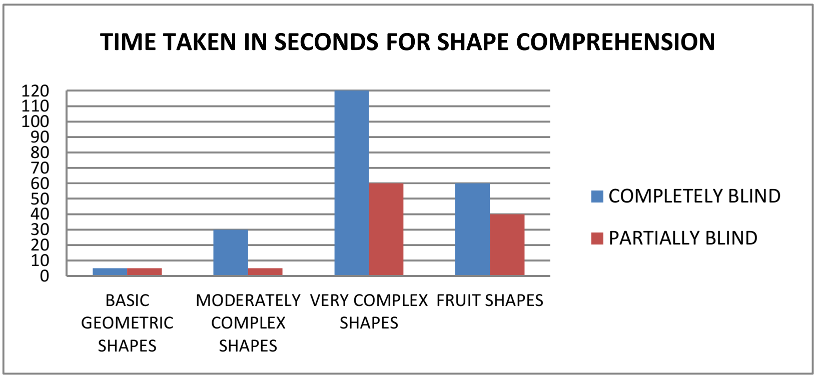

Figure 3 : Comprehension speed of given shapes by participants

The results suggest that visually impaired people identify simple geometric shapes accurately and fast, and that employ similar methods as the sighted people to identify shapes through counting number of sides, alignment, and variation. The results also show that shapes can be understood in variety of ways and that totally/partially blind people can successfully comprehend complex shape through prompting of information category and guided exploration.

The most significant inference is that visual impaired people prefer textual information in relief rather than in recess. According to the interviews, more depths in tactile models help touch perception. This inference needs to be tested with a larger group of visually impaired people to generalize this information for practical applications. Similarly, circular shapes easier to comprehend over angular shapes needs to be tested with larger population of visually impaired people.

The results do not show significant performance difference between partially sighted and totally blind participants, except the former is a little faster in shape comprehension over the latter. This suggests that visual perception is not necessarily an essential requirement for shape comprehension and that shape can be understood through other senses like 'the touch'. There also seems to be an influence of the literacy level of the participant with his/her comprehension level. Better literacy appears to enable better comprehension of shape. There are no significant performance differences between male and female participants in touch perception, and gender characteristics offers no advantages in touch perception. What seems evident is the relationship between age and time required for comprehension, younger participants are speedier at comprehending shape through touch though not high in accuracy.

The study offers important information related to touch perception for visually impaired people that can influence fields like the education, product and architectural design, and leisure and tourism. The results will help design and detail tactile displays, graphics and public signage for easy comprehension and enhanced experience for the visually impaired people. The study offers the opportunity to redefine the learning process for visually impaired children through tactile pictures and drawings.

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