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Examining Explanations for Differences in Two-Dimensional Graphic Spatial Representation of Cubes Among Totally Blind Subjects

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This essay examines the earlier findings regarding the final stages of development of two-dimensional graphic spatial representation among congenitally blind individuals. Using the "draw a cube task," our study probes into the spatial representation by participants aged 17 and above and with different visual conditions. Nine totally blind participants, ages between 17 and 21, represent five visual conditions. Only one among them, a subject who lost his vision at 9 years of age and who loved to draw prior to loosing his vision, adopted the final stage of graphic development, the oblique projection system. Remaining participants used the orthographic projection system or earlier stages. These results contradict Kennedy's assumptions and developmental model that purports that congenitally blind individuals may attain the final stages of graphic development through tactile experience. We offer the explanation that participants' (of earlier studies conducted by Kennedy) past visual experience, their passion to learn drawing, and specific education are possible crucial reasons why these totally blind subjects adopted oblique perception or linear perspective; and we argue that the tactile sense alone cannot replace the visual sense when it comes to either obtaining visual information or two-dimensional graphic representational strategies. Other insights include consideration of implications for the art and education of blind children.

Spatial representation development in sighted children has been studied for nearly 120 years in psychology, education, anthropology, and art. As researchers in neurophysiology and psychology have emphasized, studies related to multisenses (D'Angiulli & Maggi, 2003; Van Boven, Hamilton, Kauffman, Keenan & Pascual-Leone, 2000), the manner in which blind or visually impaired people interpret and depict visual images has received limited attention. Some studies have shown that blind and blindfolded individuals both can use their tactile senses to understand two-dimensional representations of three-dimensional objects (Heller, 2002; Shimizu, Saida, & Shimura, 1993). Blind people can also use tactual pictures to represent three-dimensional objects, and it is now believed that congenitally blind people have drawing capabilities and can express three-dimensionality on a two-dimensional plane (I, 2002; I & Shiu, 2001; Kennedy, 1983, 1984, 1993, 2003; Shiu, 1999).

A Lowenfeldian-inspired developmental model of blind individuals' spatial representation has been suggested, although there is no definitive view regarding purported final stages of development. Studies of individuals' perceived pictorial aesthetic value and vision limitations suggest that graphic information is not built merely on visual sense (Hopkins, 2000; Lopes, 1997, 2002), yet there is very little understanding of the nature of individuals' spatial representation development centered on the tactile sense. Based on the few studies conducted in this area, there are two opposing prevailing points of view. One argues that the tactile sense can replace the visual sense and that blind individuals' spatial representation can attain the developmental stage of linear perspective similar to that of sighted individuals (Kennedy, 1980, 1984, 1993, 2003; Kennedy & Juricevic, 2003, 2006). Another viewpoint purports that the tactile sense has its limitations for which it cannot fully replace the visual sense. This view argues that linear perspective or even orthographic projection, which are closely related to visual perception, are aspects of a graphic representational stage that congenitally blind individuals cannot naturally develop (e.g., Hiroshi, 1955, cited in Yasumasa, 1983; I & Shiu, 2001).

Kennedy (1984) proposes a developmental model consisting of six stages of graphic representation by blind people, a model that he argues also applies to sighted people. Of them, the fourth stage, *vantage point*, is similar to Lowenfeld's so-called visual realism stage. One of Kennedy's studies reveals that a congenitally blind individual who had no experience of drawing or looking at a drawing could draw a trapezoidal surface of a table and the two slanting table legs nearest to him. A later study (Kennedy, 1983) found that adult blind people with and those without light sense could use convergent lines to represent a plane that slides away, while simultaneously using boundary lines of different thickness to differentiate between near and far. Kennedy (1993) also found that blind people's use of different locations of convergence is significantly related to relative distance. Kennedy's studies in 2003 revealed that a blind girl aged 12 could use spatial representation strategies such as partial occlusion, parallel projection, and inverse projection. In another study (Kennedy & Juricevic, 2003), a 40-year-old who lost her eyesight at a young age could draw houses with right-angle perspective. She could represent distance with the use of size and show accurate relative positioning of top and bottom, left and right, as used by sighted people to represent different objects in a space. In another study (Kennedy & Juricevic, 2006), a 47-year-old totally blind man employed similar special representation strategies used by sighted people (foreshortening, parallel perspective, and front-back occlusion). Based on these studies Kennedy claims that the tactile sense can provide the same spatial syntax as the visual sense, arguing that blind and sighted individuals can both directly perceive linear perspective and represent it two-dimensionally.

Other studies disconfirm Kennedy's conclusions. Hiroshi (1955, cited in Yasumasa, 1983, pp. 44–47) asked 10 congenitally blind people aged 17–28 to draw eight geometric models, including cubes. None of them adopted an advanced stage of graphic development in terms of showing linear perspective systems. I and Shiu (2001) show that 4- to 18-year-old congenitally blind persons with no light sense experience and almost no experience in drawing show a spatial development stage for drawing a cube and cylinder in the following order (see Figure 1): (a) unstructured dots and lines, (b) clustered lines appear as some features, (c) multifaced partial features appear simultaneously, (d) refinement, and (e) concordance of the whole (orthographic projection system). No perspective (see Figure 2e) was detected in any of their drawings, nor was there use of previous-stage oblique projection (see Figure 2d). The order of the stages of spatial representation development of these participants, their characteristics, and their speed all differ much from those for sighted people. After excluding those subjects with visual experience from their studies, I and Shiu found that the final stage of spatial representation amongst these subjects was a "concordance of whole," whose characteristics is that the drawings' overall spatial relationships tend to be uniformly rationalized, and that these subjects could coordinate different viewpoints. That is, drawings by these subjects showed a significantly rational concept of direction, displacement, and proportion, but these drawings retained only their perceived object's most typical characteristics, represented by simple but complete shapes. Moreover, most of the 18-year-old participants subjectively adopted the most representative angle to represent objects in their drawings. Precisely, orthographic projection (see Figure 2b) suits this angle. Owing to visual deficiencies, the final stage of spatial representation development of single geometric objects stayed almost at the intelligent realism stage, not the stage of visual realism.

In matching tasks, I and Shiu's (2001) participants opted for lower developmental-level drawing strategies based mainly on the orthographic projection system to represent three-dimensional models. This result differs from that in studies conducted with sighted children and adolescents in which, at age 7, the subjects mainly used orthographic projection; by age 11, they already did oblique projection well; and, at age 13, the majority could use perspective under only specific

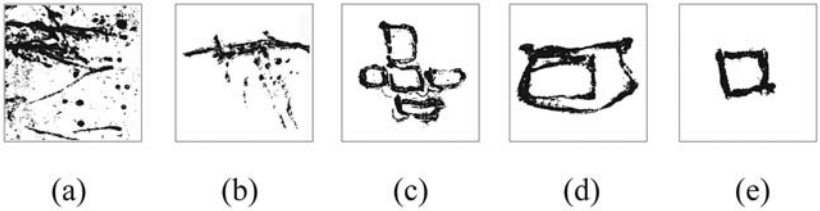

Figure 1. The five stages of spatial representation development of blind people proposed by I and Shiu (2001): (a) unstructured dots and lines, (b) clustered lines appear as some features, (c) multifaced partial features appear simultaneously, (d) gradual rid of strange partial relation, and (e) concordance of the whole (orthographic projection system).

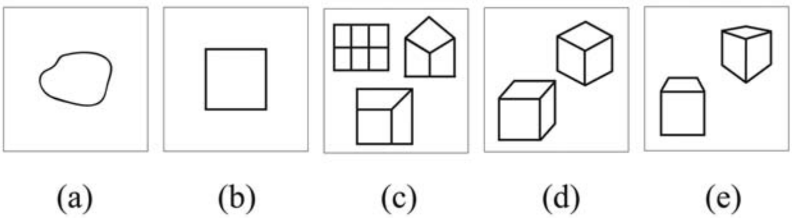

Figure 2. Order of development of sighted people's spatial representation according to previous studies: (a) no projection, (b) orthographic projection, (c) transition, (d) oblique projection, and (e) perspective.

conditions (I, 1995). Additionally, in the matching task, regardless of age, these sighted children and adolescents tended to choose higher-level projection systems (e.g., oblique projection or perspective) that were not limited to projection systems they could already use.

Related to the strategy of projection systems used by sighted and visually impaired or blind individuals, relevant studies on tactual pictures (I & Chen, 2002; Shimizu et al., 1993) show that drawings created by sighted people may not be directly made into tactual pictures for use by the blind. Rather, such drawings must first undergo orthographication, simplification, form embossment, and other processes to help blind individuals better differentiate the drawings. This implies that when blind individuals read by touch, their process of understanding is not necessarily the same as that of sighted people.

Recent studies demonstrate that the tactile sense and vision only partially convey an objects' features, and that the ability to distinguish tactual drawings is not inborn (D'Angiulli, 2007). Projection methods for drawing, the optimization of touch, and haptic exploration process all have to be learned with the use of tactual pictures (Dulin, 2007). Congenitally blind or early-blind individuals develop their spatial ability slowly, and that may be enhanced through education using tactual pictures (Dulin, 2007; Dulin & Hatwell, 2006). These studies suggest a positive influence of tactual drawing education on blind individuals' spatial intelligence.

Further comparing with Nicholls and Kennedy's (1992) research on spatial representation development in sighted people, this study required children, adolescents, and adults draw a small cube and found that sighted people have generally acquired the oblique projection system as their final stage and do not naturally reach the final stage of perspective. We therefore asked the question, why is it that the blind can use a visual projection system that sighted people do not reach on their own? The most obvious explanation is that studies by Kennedy fail to account for either the influence of education on learning, the visual conditions of that learning, or personal motivation. Kennedy misses an important insight that is revealed in his own studies. The subjects of his three case studies (Kennedy, 2003; Kennedy & Juricevic, 2003, 2006) all had strong motivation to make an effort over a long time to learn projection systems of sighted people, as well as perspective. These examples show that strong motivation and deliberate learning make a difference. With the exception of one of his subjects, Gaia, who has light sense, some of Kennedy's studies (1980, 1983, 1984) also fail to acknowledge the influence of ages at which vision has been impaired or lost, or levels of vision of individuals.

Totally blind individuals have lost their vision for different reasons and at different times in their lives. Remnant visual capabilities and their individual visual experiences also differ. Not all blind people are in total darkness. Some may still experience faint light sense and, under the right external conditions, can see stationary or mobile lights and shadows. These capabilities may enable them to better obtain an overall idea of objects' visual features. Thus, limited light sense, residual visual experience, and memory early on in their youth can all alter results of one's spatial representation development. We believe that these differences have all has contributed to disparities across different studies.

Golomb (1973) believes that immature representation factors in children's drawings are related to cognition, memory, knowledge, and techniques, among other factors. Freeman (1980) argues that, after receiving a stimulus, children use knowledge and concepts deliberately to engage message processing, and then use drawing techniques to represent the message in two-dimensional graphic representational form, while using internal strategies to solve transition problems between the conceptual (mental) and representational (visual). Blind individuals lack visual image stimuli, making their understanding and cognition of objects different from that of sighted people. This explains why their spatial representation development is different.

As mentioned previously, for visually impaired or totally blind persons, past visual experiences, visual conditions at that time of vision loss, and factors such as education, personal motivation, and learning can all serve to assist them in spatial representation and interpretation processes. These heretofore overlooked aspects of two-dimensional graphic visual representation strategies of blind individuals had led researchers to conclude that the tactile sense can adequately replace visual perception. Testing our speculation further, we designed a study in which we investigated whether congenitally blind individuals who were provided with tactile models but absent the aforementioned conditions, experiences, and learning opportunities still adopted spatial representation strategies usually carried out by sighted people. In such a case, Kennedy's theory would be confirmed.

In our study, the "draw a cube task" often used in spatial representation studies was adopted, with strict control of such conditions as earlier visual sense and prior drawing experience, to look for final stages of blind individuals' two-dimensional graphic spatial representational development.

Method

Subjects

All subjects were from a special school for the visually impaired in Taipei, Taiwan. Subjects included individuals who fit particular visual conditions, and who were also not multihandicapped. A total of nine totally blind subjects, ages ranging between 17 and 21 (M = 18; 8), were chosen. Their visual conditions were classified into (1) congenitally blind (no light sense since birth): two persons, CN01 and CN02; (2) congenitally blind with light sense: one person, CL01; (3) congenitally blind with light sense and light movement: one person, CLH01; (4) congenitally blind with sense of light movement: two persons, CH01 and CH02; and (5) acquired blindness with sense of light and light movement (blind who had 6–9 years of visual experience): three persons, ALH01, ALH02, and ALH03. With the exception of participant ALH01, who loved to draw before becoming blind at 9 years old, the other subjects had no drawing experience whatsoever.

Stimulus and Instrument

The stimulus is a wooden cube measuring 3.7 cm on each side. Participants used a wooden stylus to draw lines on a clay plate with a dimension of $20 \times 20 \times 0.5$ cm^3.

Procedures

An isolated classroom was chosen as the study site. Subjects participated in the experiment individually. Each participant was introduced with the stimulus and the drawing tools on the table, and was made familiar with those materials. Then, they were told the following: "There is no standard answer in the exercise that is to follow. There is no time limit, as well." Subjects were allowed to touch the stimulus as much as they wanted and revise their drawings as needed. The instructions were "Please carefully touch the object in front of you" and "Please draw the object." The proceedings were recorded by videotape and chronicled in notes. Subjects' drawings on the clay plates were photographed digitally. Hard copies of the images were also printed out for analysis. In drawing analysis, the blind spatial representation stages used by I and Shiu (2001) were used as classification standards, supplemented by existing spatial representation development stages applicable to sighted people (see Figure 2).

Results

Results of the study showed that seven (77%) of the nine participants adopted an orthographic projection system (see Figure 3). No use of perspective was observed in any of the drawings. Only ALH01, whose blindness was acquired, used oblique projection (see Figure 3g). In the process of drawing, he told the researcher, "If one is drawing a facet, one 'looks' at the surface. When drawing three-dimensionally, the cube must be 'viewed' from an angle." Moreover, one 18-year-old congenitally blind participant, CL01, adopted a drawing strategy similar to a folded-out box (see Figure 3c). This is purported by researchers to be the peak stage of differentiation in blind persons' spatial representation and comes before the stage of orthographic projection or oblique projection (I & Shiu, 2001).

Based on these findings, we discovered that, disregarding prior drawing experience, totally blind participants 17–27 years old, whether their blindness was

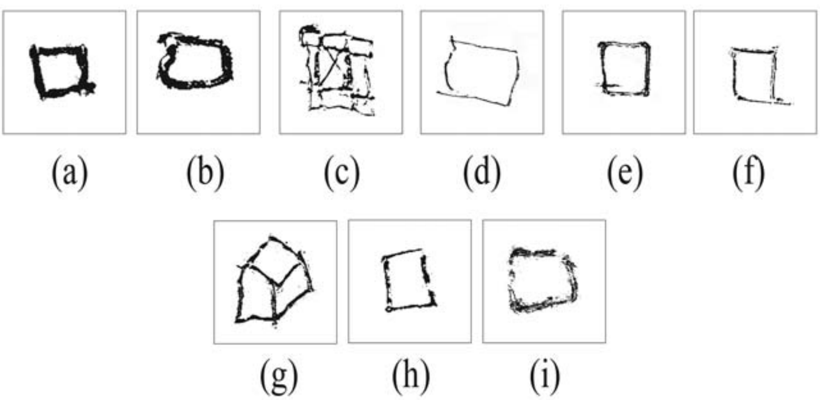

Figure 3. Cubes drawn by subjects with different visual conditions: (a) CN01, female, age 17 years 11 months; (b) CN02, male, age 18 years 10 months; (c) CL01, female, age 18 years 5 months; (d) CLH01, male, age 18 years 1 month; (e) CH01, female, age 18 years 2 months; (f) CH02, male, age 18 years 4 months; (g) ALH01, male, age 19 years 1 month, vision loss at age 9; (h) ALH02, male, age 19 years 4 months, vision loss at age 9; and (i) ALH03, male, age 21 years 4 months, vision loss at age 6.

congenital or acquired, and under any visual conditions, all adopted the orthographic or even lower-level projection system. This orthographic projection system is commonly used by 6- to 7-year-old sighted children. When they turn 8–9 years old, sighted children gradually replace it with the oblique projection system. This finding is consistent with I and Shiu's (2001) results. Our finding was and remains that, in the minds of totally blind persons, it seems that the preservation of the physical shape properties of objects' facets, such as sides of equal lengths and direct angles, is more important than presenting visual spatial representation depicting relationships of objects' visible facets based on traditional fixed linear perspective depictions typically preferred and sometimes given by sighted individuals.

Discussion

In this study, we found that individuals cannot easily use the tactile sense to depict the distortion of objects' shapes by using nonorthographic visual angles, such as foreshortening and convergence. The latter is a special experience obtained through the retina and further reinforced in graphic conventions relating to culturally favored visual representation. Such a distortion convention makes all facets in a cube appear to become irregular quadrilaterals that join one another nonorthographically. These ways of seeing three-dimensional objects and the corresponding ways of depicting them two-dimensionally fully depart from objects' individual lateral appearances and the physical principle of right-angle crossing. However, through proper linking of the distorted facets visually, individuals seem to form strong monocular static depth cues. This explains why even though young children with normal eyesight have difficulty drawing these ways without specific instruction, they still are able to intuitively select, from many drawings of different projection systems, oblique projection or perspective to represent the three-dimensional model they see.

Experiences derived from the senses of vision and touch can be consistently represented in drawing mainly because of the contour features obtained from the object. This means that when the contour is obtained from orthographic projection, and not by oblique focal point, it leads to the depth features that arise from the fusion of all the facets. In case the orthographic projection of an object's given facet possesses the said object's crucial features (e.g., a square represents a cube or a line represents a stick), the contours of this orthographic projection become more convincing. Some of the blind subjects in our study liked to position the three-dimensional model's facet with the most prominent feature directly on the clay plate in order to draw the contour. However, when the facets of objects had different features (e.g., a cylinder's base facet and its sides), our blind subjects tended to draw two facets by using the orthographic projection system but would be unable to link them logically or visually because this process necessarily involves distortion and shape change associated with the visual perception of fixed linear perspective and oblique projection.

Importantly, the performance of ALH01 significantly goes beyond the final stage of blind persons' drawing development mentioned by I and Shiu (2001) and already proceeds to the oblique projection stage of sighted people. This participant was not the oldest but was the one who lost vision the latest. Also importantly, he loved to draw before losing his eyesight. Through our conversation with ALH01, we gathered that he previously had used fixed-viewpoint drawing strategies of a person with full eyesight instead of using his tactile sense experience to devise his drawings when he became blind. The vision he had for 9 years provided a critical opportunity for him to learn a visual realism stage of two-dimensional graphic development that our congenitally totally blind subjects never experienced. This is the key reason why his performance differed from the rest.

Congenitally blind people beyond adolescence and those that have reached adulthood insist on retention of objects' modal features that are not distorted or morphed. For instance, a square represents a cube. Here, this simple mode manifests an individual's understanding of the overall substance of the drawn object, and not merely some facet separately represented from a fixed sight point. It also matches the features of the "overall coordination stage," the last in the spatial representation development of totally blind individuals. This implication may be explained also in terms of Golomb's and Freeman's understandings of graphic representation: Underlying and shaping the drawings of congenitally blind individuals' drawings, conceptual knowledge is most important. But, importantly, we cannot ascertain congenitally blind individuals' cognitive development based only on forms that appear in their drawings.

In previous research, congenitally blind individuals have been to be shown capable of adopting oblique projection, converging lines, foreshortening, and perspective, and evidently these capabilities do not arise from tactile sense information. We have argued here that visual experience and conditions, the intervention of education, and passion for learning explain why they could draw the aforementioned. This finding, on the one hand, clarifies misconceptions on the possibility of tactile sense replacing visual sense. On the other hand, it emphasizes the crucial influence of education and learning, especially for educators of blind people's parents and blind individuals themselves.

Yet, compared with those individuals with full eyesight, blind individuals' spatial representations may be interpreted by others as slow and showing great differences. This phenomenon has led to a tendency in education for blind people in Taiwan to drop the idea of drawing lessons for the blind. Many blind individuals, especially the congenitally blind, abandon efforts to learn drawing. Drawing is not a required area for learning among blind students, and for this reason, congenitally blind participants in this study had not even tried drawing. Even those with acquired blindness and who may have the talent for drawing stopped drawing altogether after becoming blind.

In summary, it is extremely difficult for the congenitally blind to reach the level of oblique projection and perspective. This is true even if they have optical perception and hand-movement perception if they have never learned oblique perception and perspective methods adopted by sighted people. Education is a crucial factor in the congenitally blind and the early-age blind adopting oblique projection and perspective systems. Two-dimensional graphic spatial representation is just a small aspect of the potential art education of blind individuals. Much has yet to be studied in the artistic representation of images, emotion, perception, and aesthetics of blind individuals and, within the realm of three-dimensional creative expression and representation, very little is currently known. The development of appropriate pedagogical models will enable teachers to help blind individuals learn and express themselves more creatively and effectively. We hope that more researchers will devote efforts in these areas so as to remedy insufficiencies in the contemporary art education of blind children.

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