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# Pattern Perception and Pictures for the Blind

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This article reviews recent research on perception of tangible pictures in sighted and blind people. Haptic picture naming accuracy is dependent upon familiarity and access to semantic memory, just as in visual recognition. Performance is high when haptic picture recognition tasks do not depend upon semantic memory. Viewpoint matters for the ease or difficulty of interpreting haptic pictures of solid objects. Top views were easiest for sighted and blind persons when geometrical solids had constant cross-sections in the vertical axis. The presence or absence of viewpoint effects depends upon the nature of the solids that are represented. Congenitally blind people do not spontaneously produce perspective drawings, but recent data suggests that depictions including linear perspective can be understood after minimal experience. The results suggest that two-dimensional configurations are not necessarily problematic for touch.

Touch is a remarkable sense, and it is just beginning to reveal its secrets to persistent researchers. Much more time and energy have been devoted to the study of picture perception in vision than in touch. Until recently, most researchers have questioned whether touch is capable of getting useful spatial information from pictures, and have argued that the sense of touch is far more suitable for the understanding of three-dimensional objects and the surface qualities of objects (Revesz, 1950; but see Kennedy, 1993). Many blind people around the world have had little formal education in graphics or maps, and most have had no exposure to tangible pictures. In our current society, blind people are increasingly dependent upon the use of computers for communication, as are most of us. Current computer operating systems typically use graphical user interfaces, and so an understanding of spatial perception of blind people and two-dimensional displays take on added importance.

Most researchers in this area have assumed that congenitally blind people only differ from the sighted and late blind in their lack of visual experience, and presumably lack of visual imagery. This notion has been used as a rationale for evaluating the impact of a lack of visual imagery on

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haptic perception. Lower performance by congenitally blind subjects has been interpreted as an indicator of the impact of a lack of visualization (see Heller, 2000, 2002). Unfortunately, this position is problematic for a number of reasons, and this manuscript will try to clarify some of the issues.

Blind people vary greatly in their educational experience and in their perceptual skills. We have tests of spatial skills for sighted persons, since we are aware of their great variability. However, we don't have these norms for visually impaired persons, nor do we even know what normal touch might be. This suggests a great deal of caution in the interpretation of the results of any research with limited samples of blind participants.

## Picture Naming Studies

The results of studies on naming tactile pictures are very mixed. Late blind participants performed at a much higher level than the congenitally blind or blindfolded sighted controls (Heller, 1989). The results of this research were interpreted as showing that late-blind participants had the combined advantage of increased haptic skill and the impact of prior experience with pictures. Congenitally blind people are generally unfamiliar with tangible pictures, and so lower performance could simply reflect a relative inexperience with the rules governing picture perception.

There is a further difficulty interpreting the results of experiments involving naming pictures. Failure to name a picture could indicate an inability to perceive the pattern properly, or a failure to imagine the configuration, or a failure in word finding. Thus, we do not assume that a young child can not see a cat, just because the child calls the cat a "doggy." Naming failures do not necessarily tell us much about perception, but may represent failures in accessing semantic memory (Heller et al., 1996).

In an attempt to distinguish perceptual failures from problems in word finding and semantics, experiments were conducted to eliminate labeling and the influence of semantic memory from picture perception tasks. Heller et al. (1996) asked subjects to feel a tangible picture, and name it. They were either given the relevant superordinate category or this information was denied. For example, when people felt a picture of a table, they were given the superordinate category name of "furniture." Providing the superordinate category significantly aided picture naming and doubled naming accuracy scores. This indicated the importance of categorical information. One may be able to recognize something without knowing the name of the object.

## Picture Recognition Without Naming

In an attempt to rule out the impact of semantic memory, a task was devised that tested recognition, but did not require subjects to name a picture (Heller et al., 1996). Participants felt three picture choices and had to select a designated target; for example, they were told to indicate which one of the three pictures was the "table." Performance was high, with mean accuracy levels of close to 90 percent correct. Thus, the removal of naming from the recognition task greatly improved performance in the interpretation of haptic pictures. These results mean that part of the difficulty that subjects sometimes experience with tangible pictures may derive from a lack of familiarity with them, rather than with any intrinsic limitations in haptics, *per se*.

A more recent study examined picture matching, and completely eliminated the problem of semantic memory from the task (Heller, 2002; Heller et al., 2002a). Figure 1 shows the raised-line pictures used for this experiment. Subjects felt a target picture, and then felt four picture choices. The task was a simple match to sample. Subjects were timed as they felt the target and four picture choices, but were told to try for accuracy. The participants included blindfolded sighted subjects, late-blind subjects (LB), congenitally blind (CB) subjects and others with very low vision (VLV). Almost all of the VLV subjects were Braille readers and used a long cane for mobility. They tended to refer to themselves as blind, since they had no remaining pattern vision, or it was minimal. Most of these persons claimed that they could not see the close hand motion, but a few said that they could. In contrast to the blind subjects, these VLV individuals were able to see the direction of a strong light source (e.g., from a lantern).

Performance was near ceiling. In order, mean number correct out of 15, for the VLV, LB, CB and sighted subjects were 14.9, 13.9, 13.7, and 13.3. Performance was exceptional for the VLV subjects at 99.3% correct, but the CB subjects also had over 91% correct. An ANOVA on number correct yielded a nonsignificant effect of visual status ($p > 0.2$), and the interaction between visual status and type of picture was also nonsignificant ($F < 1$). However, the scores were all near ceiling, and this justified conducting a nonparametric Kruskal-Wallis one-way ANOVA on number correct. The results of this test revealed that the difference between the groups was highly significant, $H(3) = 8.04$, $p < .05$. The superior performance of the VLV subjects explained this significant outcome.

The results of this experiment suggest that two-dimensional picture perception can be excellent. The data can not be explained solely in terms of visual experience or visual imagery. The VLV subjects have excellent perceptual skills. Perhaps, the mere direction of gaze aids haptic perception, even when the subjects are not able to see their hands. It may be possible to point out that subjects may be able to match pictures when they can not tell what they are. This is certainly true, however, performance here was far better than can be found in recent results for three-dimensional pattern matching. Norman et al. (2004) reported much lower performance when subjects attempted haptic matching of natural, three-dimensional objects. Also, Kilgour and Lederman (2002) found relatively low accuracy levels when subjects matched masks of faces to a person's face in a 3 alternative matching paradigm. The present results are not an indication of low 2-D performance, rather, excellent performance was obtained in a haptic picture perception task.

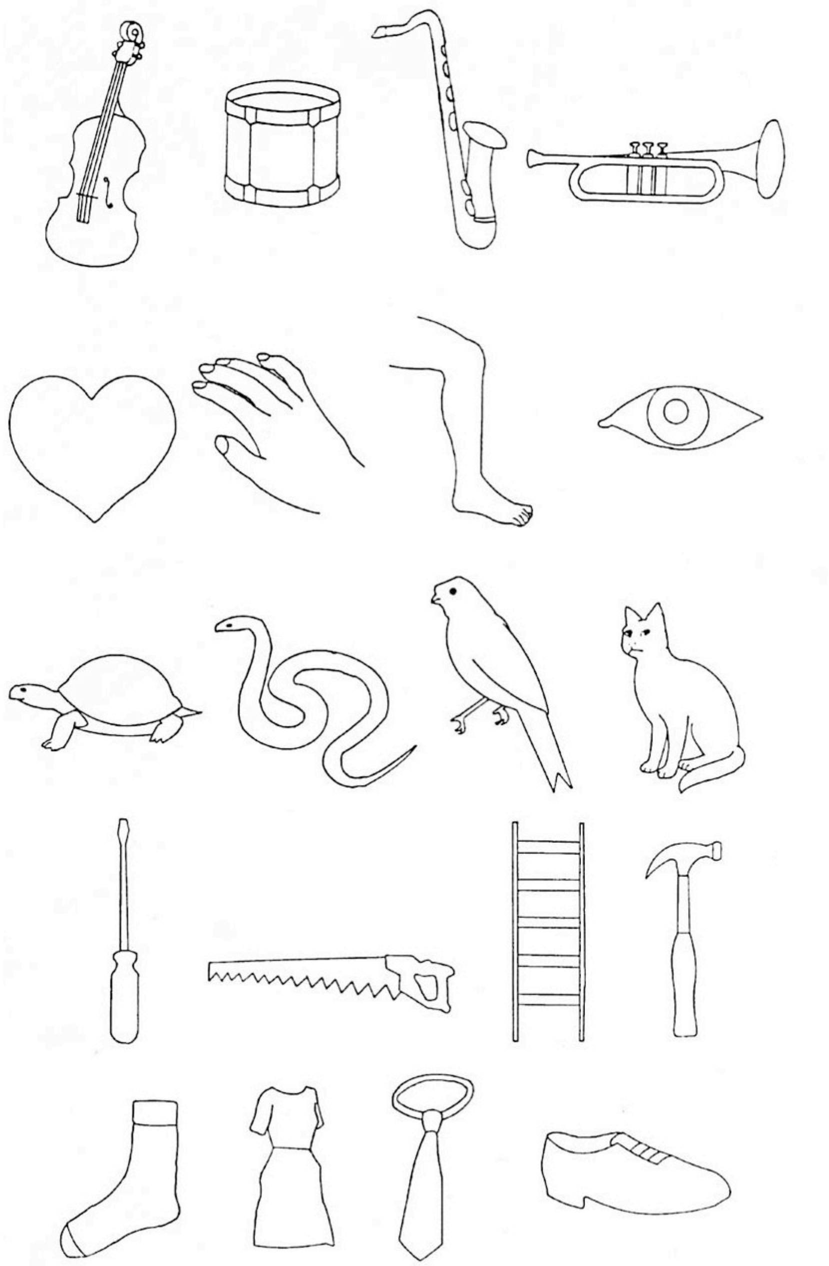

**Figure 1 shows the raised-line drawings used in a matching experiment (Heller et al., 2002a, *Journal of Visual Impairment and Blindness*, *96,* 349-353).**

## Viewpoint, Linear Perspective and Blindness

Congenitally blind people are able to understand some aspects of perspective in raised-line drawings, despite a lack of familiarity with these sorts of displays (Heller et al., 1996, 2002b). In a recent study, CB, LB, VLV and blindfolded sighted subjects felt panels that intersected at $45^0$, $90^0$, or $135^0$. The intersecting panel stimuli were never presented straight ahead, but were placed so that they were $+45^0$ or $-45^0$ from this position. They had to feel one of the standard stimuli and then feel four drawings of the panels. The task was to indicate which stimulus was depicted by tapping their matches (see Figures 2 & 3). The task was extremely difficult, but the VLV vision subjects performed at a relatively high level. Accuracy of the group of CB subjects was comparable to that of the blindfolded sighted subjects. This was consistent with other research reported here and indicated that visual experience is not necessary for understanding perspective. However, it is important to note that the CB subjects did not anticipate the perspective drawings when first asked to draw the panels. Furthermore, one CB subject said after first feeling the drawings shown in Figure 3: “So you sighted people don’t see it as square.” She was indicating her realization that perspective drawings yield some distortion and foreshortening of the images. This foreshortening takes the form of a rectangle being drawn as a short quadrilateral as a function of slant. This individual clearly was unaware of the existence and effects of perspective prior to her participation in the experiment. The results indicate that instruction in the principles governing perspective is likely to prove helpful to CB individuals, just as this instruction is helpful for sighted persons. Note that perspective is a relatively recent historical discovery that dates from the Renaissance.

We have little information about preferred or canonical viewpoints for haptic pictures. However, the viewpoint of a picture is intimately linked to perspective. Clearly, some views may be more informative than others. Recently, Newell, Ernst, Tjan and Bulthoff (2001) reported that haptics "...recognizes the objects best from the back." They argued that haptics is best suited for the recognition of the backs of objects, since we may wrap our hands or arms around three-dimensional solids. Moreover, a blind person has told the first author of this manuscript that blind people are aware that sighted people “see half of a tree” but blind people “imagine the whole tree.” This reflects the idea that blind people may tend to imagine objects as three-dimensional solids. It is not known if this is a necessary condition of haptics and blindness, or is simply a consequence of a lack of experience with pictures and the rules governing pictorial depiction.

It is conceivable that congenitally blind people could have difficulties with some viewpoints expressed in drawings. The most informative views may depend upon the nature of the object that is depicted. Thus, Heller, Kennedy and Joyner (1995) found that congenitally blind subjects had difficulty with top views of a model house, and all subjects had problems with elevated views. One might expect that blind people would have trouble interpreting pictures that are three-dimensional in nature, since they are relatively unfamiliar with the expression of depth relations on a flat surface.

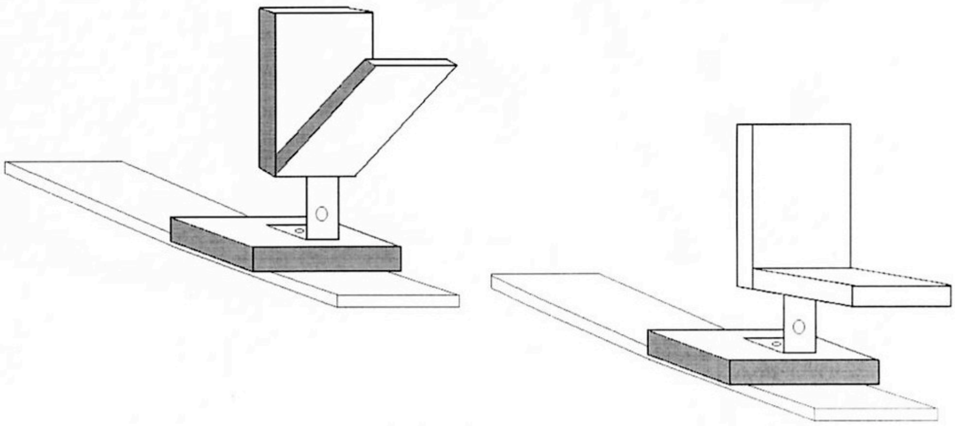

**Figure 2 shows the intersecting planes used to study perspective drawings in blind people. The stimulus on the left depicts the two boards intersecting at 45 degrees, while the picture on the right is of two panels at 90 degrees. A third stimulus (not shown) had the panels intersecting at 135 degrees (from Heller et al., 2002b, *Perception*, *31*, 747-769, Pion Ltd.).**

Heller et al. (2002b) recently tested blind and sighted subjects on their ability to recognize raised-line drawings of solids (see Fig. 4). The study examined frontal views in parallel projection, frontal views with converging lines, top views, and 3-D views. It was especially interesting that all groups of subjects performed better with top views. In addition, performance levels were very high for the VLV subjects, and they did far better than any other group of subjects. They showed extremely high levels of recognition accuracy. The CB subjects performed at a level that was not significantly different than the sighted subjects, but they were much faster. This means that the presence or absence of visual experience is insufficient to predict performance in recognition tasks involving tangible two-dimensional displays.

Additional research attempted to determine the probable cause of the advantage of the VLV subjects. One totally blind person (without light perception) told the author of this manuscript that it helped him attend to touch if he “looked” at his hands as he touched objects or patterns. Gaze direction is an important contributor to haptic performance, and sight of the hand could be a critical variable. Consequently, two groups of sighted subjects had their vision degraded by the use of low lighting and by blurring vision with stained-glass covered goggles. Low lighting and blurred vision alone did not alter performance. However, when these subjects also had light emitting diodes (LEDs) placed on their hands, performance improved to rival that of the VLV subjects. The results suggest that haptic performance may be enhanced if subjects can see the location of their hands in space, even if visual pattern perception is impossible. Blindfolded sighted subjects performed at the level of the VLV participants when extremely low vision was simulated, but only in combination with sight of the location of their hands in space. It is proposed that the typical blindfolded sighted subject is not a proper measure of the capability of the sense of touch.

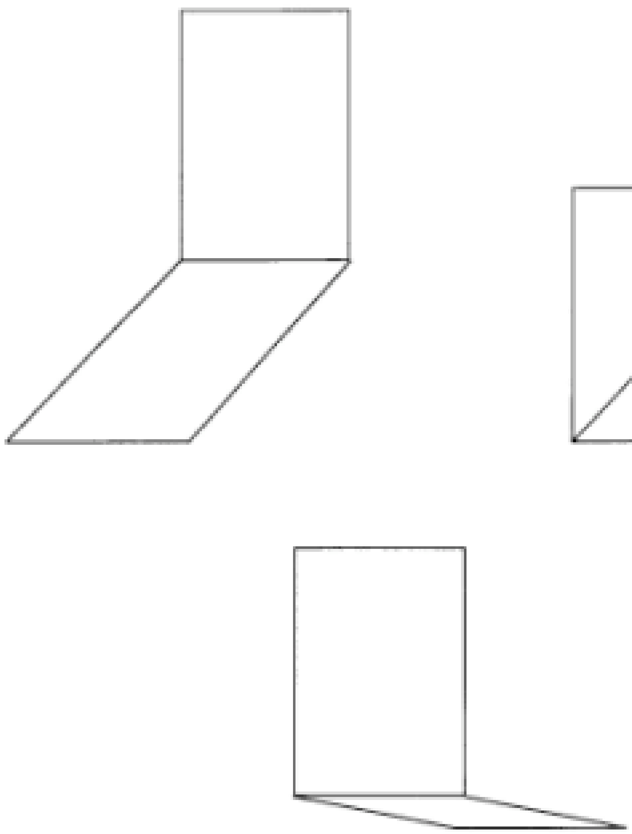

**Figure 3 shows the drawings used in the matching task on perspective. The picture on the top left is of the planes intersecting at 135 degrees, and the one on the right shows the planes intersecting at 45 degrees. The picture on the bottom is of two planes at 90 degrees. (from Heller et al., 2002b, *Perception*, *31*, 747-769, Pion Ltd.).**

## Figure Ground Relations in Haptics: Embedded Figures

The ability to identify a figure in a confusing background display is a measure of perceptual selectivity. It has been used as an indice of field-dependence (see Witkin, 1967). Failures to notice a pattern in a background that acts like camouflage may increase in frequency with age and may be sensitive to the status of one's cortex. Note that much of the earlier research in this area has studied vision or blind children (Witkin et al., 1968), and it was not known if the same processes occur in touch in congenitally blind adults.

Tangible embedded figures stimuli were created by modifying the visually normed patterns taken from Otman et al. (1971). The stimuli are shown in Fig. 5. The CB, LB, VLV, and blindfolded sighted subjects felt target stimuli and then tried to find them among four picture choices. Then they had to indicate their understanding of the location of the pattern in the distracting background by tracing it with their index fingers (see Heller et al., 2003).

Performance was high for the VLV subjects, and they had significantly better accuracy scores than all other groups. Not surprisingly, it was easier to locate targets within the simple backgrounds than the complex backgrounds. The VLV subjects performed at a level that rivaled that of sighted subjects using their vision, but touch was much slower than sight.

## Conclusions

Tangible pictures can convey considerable useful information to blind people. The translation of depth information to two-dimensional surfaces may present some small initial difficulty for congenitally blind persons. However, these problems appear minor and can probably be overcome with minimal experience or explicit instruction.

Blind people generally perform much more quickly than blindfolded sighted controls in the interpretation of complex tangible displays. The robust advantage of the VLV subjects was reliable, and was found for both accuracy and time scores. The VLV superiority probably derived from at least two general causes. First, they have the advantage of some familiarity and experience with pictures, since most of them had some residual vision earlier in life. Second, they had the benefits of increased haptic skills.

The skill of the VLV and LB subjects, indeed all of the blind subjects, derives from practice in the use of touch for the perception of tangible displays, even if only for reading Braille. They tend to select a very efficient strategy for feeling large displays, and this takes the form of using two hands for exploration. This speeds up the acquisition of information and places less of a burden on memory. Sighted subjects are much more likely to use a single finger of one hand to explore patterns (Symmons & Green, 2000). Many blind subjects have objected to instructions to use a single finger to trace patterns in the study of illusions (e.g. Heller et al., 2004). They believed that the use of multiple fingers of one or two hands would be more useful. In addition, some of the VLV subjects may have sufficient remaining residual vision to allow them to see the location of their hands in space. Sight of the hands during haptic exploration of patterns has been known to aid haptic pattern perception.

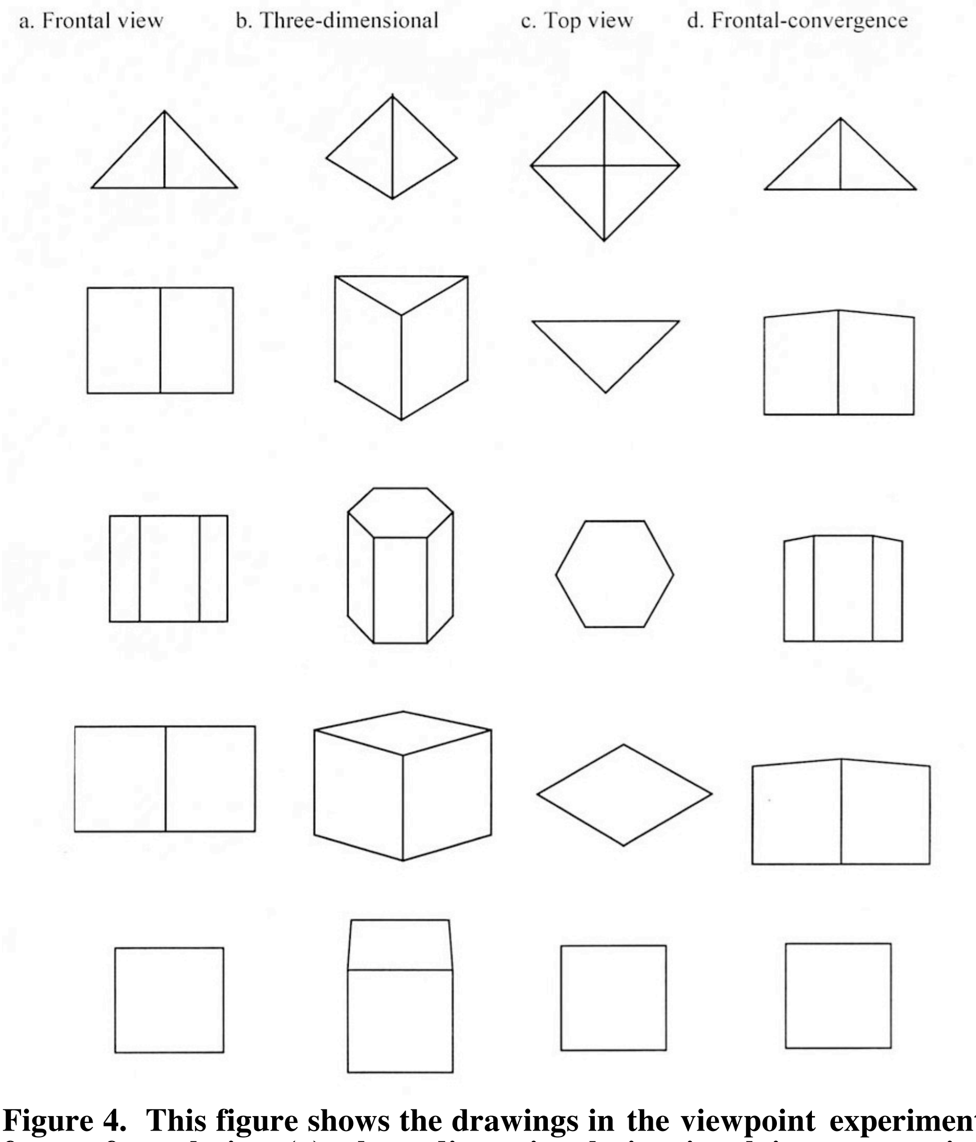


**Figure 4. This figure shows the drawings in the viewpoint experiment from a frontal view (a), three-dimensional view involving perspective (b), and top view (c). Figure 4d. shows the drawings depicting the objects from a frontal viewpoint with converging lines for the top edges, where the bottoms of the objects were at eye-height. (from Heller et al, 2002b, *Perception*, *31*, 747-769, Pion Ltd.).**

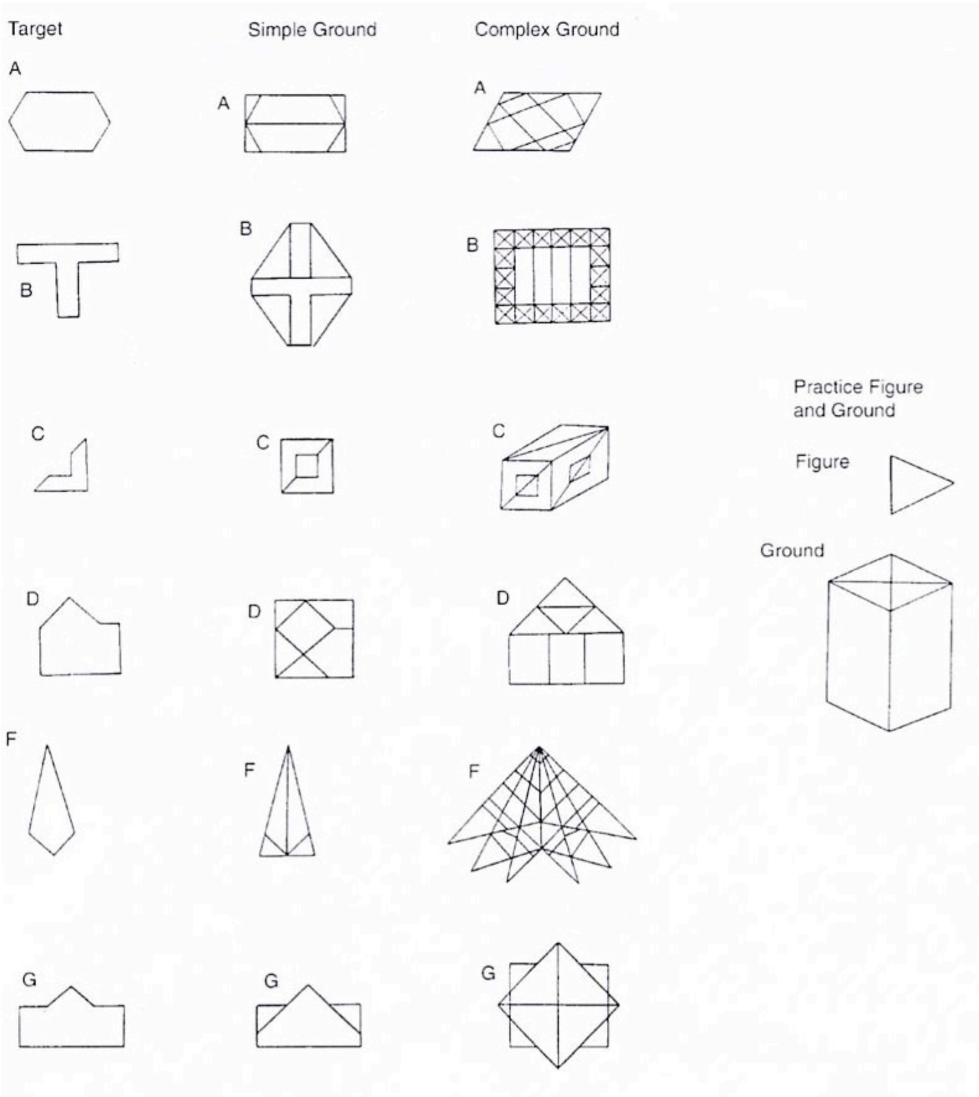


**Figure 5. Figure 5 shows the target stimuli and simple and complex backgrounds. In addition, the practice demonstration figure is present on the right.**

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