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THE IMPACT OF SIGN LANGUAGE EXPERTISE ON VISUAL PERCEPTION

Margaret Wilson

A widespread belief among nonpsychologists is that the loss of one sense produces an enhancement of the remaining senses. The blind person is thought to have especially acute hearing, the deaf person to have enhanced visual awareness and high sensitivity to vibration, and so on. This popular and appealing idea is easy to dismiss as an urban myth of psychology, along with the belief that we only use 10 percent of our brains and that Eskimos perceive the world differently from other cultures because they have fifty words for snow.

Nevertheless, investigators have recently begun to take this proposal seriously. In the case of blindness, studies have explored spatial localization abilities and the use of echo information (Ashmead et al. 1998; Lessard et al. 1998; Morgan 1999; Millar 1999; Roeder et al. 1999). In the case of deafness, visual abilities such as allocation of attention (Parasnis and Samar 1985; Stivalet et al. 1998), and movement detection in the periphery (Neville and Lawson 1987) have been explored. Although altered sensory experience may not produce changes in actual sensory acuity, it may cause sensory information to be processed in a different manner, a hypothesis that increasingly appears to be viable. This point is critical not merely for our understanding of perceptual and cognitive processes in special populations, but also for our basic understanding of the development and functioning of the human sensory systems.

In the case of deafness, results from such investigations have produced an unexpected twist on the relationship between deafness and visual perception. Some differences in visual processing between the deaf and hearing populations appear to be mediated not by deafness per se, but rather by the use of a signed language (see Emmorey 1998 for a review). For example, sign language experience appears to enhance the ability to reconstruct movement patterns from dynamic point-light displays (Klima et al. 1996). Findings such as this raise profound questions about the current state of our knowledge about sensory processes. Virtually all our knowledge of auditory and visual processing, and the radical differences between the two, derives from the study of hearing indi-

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viduals. For this population, the auditory modality is intimately entwined with language expertise, whereas the visual modality has no comparable form of expertise to influence it. If we wish to understand the full scope of human perceptual processing, we must ask how a similarly intimate relationship to language might affect the visual modality.

The extent to which the use of a visual language might affect visual processing is only beginning to be explored. A number of findings indicate that particular visual judgments or discriminations become faster or easier due to practice with a signed language (see Emmorey 1998 for a review). However, a deeper question is whether signed language expertise can actually alter *what* is perceived. One hallmark of human perception is its active, constructive nature. In general, we do not perceive exactly and only the information present in the stimulus. Instead, our perceptions reflect a great deal of "intelligent guessing" on the part of the perceptual system. Examples include illusory contours, the phenomenal absence of the blind spot, and apparent motion, in the visual domain; and phonemic restoration and the influence of familiarity on judgments of background noise, in the auditory domain. Under conditions of ambiguity, then, lifelong experience with a structured system of visual movement such as sign language might well lead to a different perception than would occur without that expertise.

In support of this possibility, it has been found that signers vs. nonsigners produce different patterns of similarity ratings for point-light motion displays of signs (Poizner 1981). This finding indicates a shift in categorization boundaries due to sign language expertise. It is, of course, possible that this finding reflects conscious, cognitive judgments, rather than a true perceptual effect. Nevertheless, it strongly suggests that perceptual judgments may be altered by sign language fluency.

Visual Completion Effects

To explore this issue more systematically, it is necessary to create conditions of visual ambiguity, in which a stimulus could in principle be seen in two or more ways. Under such conditions, one can look for systematic differences in the perceptual reports of signers vs. nonsigners. Such conditions can be created by using known principles of visual "completion" effects. In these effects, the visual system appears to "fill in" information that is ambiguous or absent in the stimulus. As mentioned earlier, these include illusory contours, the phenomenal absence of the blind spot, apparent motion, as well as figure/ground segregation, neon color spreading, and the Gestalt principles of grouping.

One feature that all these completion phenomena have in common is the low-level, mechanistic nature of the principles that govern the filled-in information. In illusory contours, for example, the form taken by the subjectively supplied contours is determined by the geometry of the inducing stimulus. This stands in striking contrast to completion effects in the auditory domain, where the perception of ambiguous speech frequently involves the filling in of complex or "arbitrary" information. For example, in the phonemic restoration effect, an arbitrarily chosen

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phoneme can be deleted from a word and replaced by noise, and participants will often report hearing the complete word; in fact, they will often have difficulty determining which phoneme was deleted (Samuel 1996; Warren 1970). This is presumably due to the influential role of early language exposure in the development of the perceptual system. Can similar effects occur in the visual domain, provided there is expertise in a visual language?

One way to test this question is to exploit the phenomenon of apparent motion, in which participants perceive a single, moving object when in fact there is only a static stimulus at one location rapidly followed by a static stimulus at another location. Apparent motion is insensitive under most conditions to knowledge about how objects move in the real world. Attributes of the object's identity do not in general influence the perceived path of motion; instead, the object usually appears to take the shortest path between locations, regardless of whether that path of motion is plausible in the real world (e.g., Shepard 1984).

These facts fit well with what is known about the structure of the visual system. The existence of two distinct pathways of visual processing, one devoted largely to processing object identity (the ventral, or "what" pathway) and one devoted largely to processing location and movement (the dorsal, or "where" pathway), suggests that indeed object identity ought not to influence motion perception. In fact, the orientation of an object's longest axis can influence whether the object appears to rotate as it moves (Foster 1975). Nevertheless, it is generally the case that object *identity* does not influence perceived motion (Burt and Sperling 1981). Instead, when the visual system must construct a path of motion based on insufficient information, as in the case of apparent motion stimuli, it does so by inferring "the simplest rigid twisting motion prescribed by kinematic geometry" (Shepard 1984). In most cases, this reduces to a "shortest-path constraint." The visual system chooses among the infinite number of possible paths by assuming the shortest, most direct path.

However, there appear to be certain specific exceptions to this principle, cases in which higher-order knowledge about object identity does influence motion perception. This suggests that apparent motion may be susceptible to the nature of the visual experience that accrues over a lifetime, such as sign language experience. If so, then the contents of visual perception may be partly determined by linguistic experience in that modality.

APPARENT MOTION FOR HUMAN MOVEMENT

In one particular case, it has been found that object identity does influence motion perception (Chatterjee, Freyd, and Shiffrar 1996; Shiffrar 1994; Shiffrar and Freyd 1990, 1993). This special case is biological motion, which growing evidence suggests is treated differently by the visual system from other types of motion (e.g., Johansson 1973; Perrett et al. 1990; Chitty 1990; Shiffrar, Lichtey, and Chatterjee 1997). Shiffrar and Freyd (1990) demonstrated that apparent motion for human figure stimuli sometimes appear to take a longer, indirect path when the shortest path would violate the human body's physical abilities. For example, if a hand is shown first in front of a torso and then behind the torso, the "shortest path con-

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straint" would cause it to appear to pass through the body, and indeed this is what participants report seeing at fast presentation rates. But as the timing parameters of the stimulus presentation are slowed down (across the range of 150–650 ms between presentations), participants become increasingly likely to report seeing the longer but physically possible path in which the hand moves *around* the body. In addition to this "solidity constraint," Shiffrar and Freyd also observed a "joint constraint," in which a long path that was possible given the range of motion of human joints was preferred over a shorter, impossible path.

Further, Chatterjee, Freyd, and Shiffrar (1996) show that the use of the solidity constraint by the visual system depends on the involvement of biological stimuli (or stimuli that have the global structure of a biological form, e.g., a wooden mannequin). When *either* the moving limb or the part of the body it must traverse is replaced by an inanimate object (a board or a chair, respectively), the longer path is perceived more often at slower presentation times. But when *both* are replaced, so that the stimulus is entirely nonbiological, the probability of seeing the longer path remains low across the range of presentation times (figure 1.).

It appears that among the assumptions or "constraints" that the visual system uses to narrow down the problem of interpreting the visual scene, there is a special set of constraints that is specific to the perception of biological stimuli. Motion perception can be influenced by knowledge of possible movements for biological forms. The question posed here, then, is whether additional constraints on apparent motion can be found that are more specific still, relating only to the perception of sign language stimuli and only in participants who are signers.

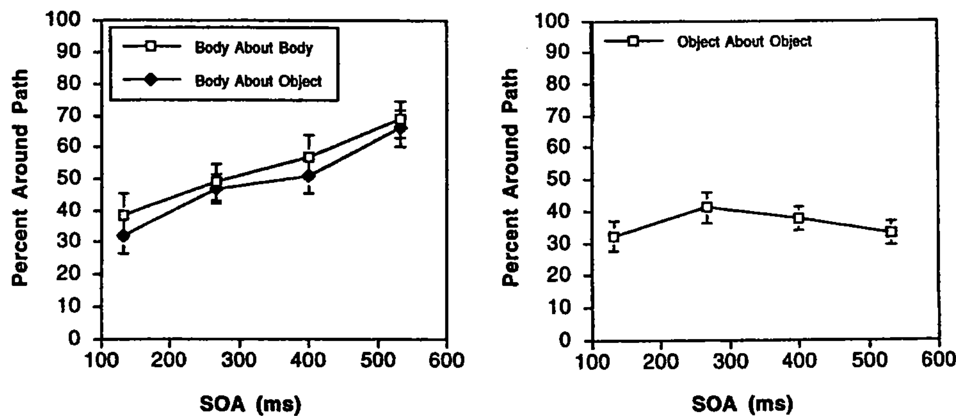

Figure 1. The graph on the left shows probability of reporting one object moving around another rather than through it, when both objects are body parts, and when only one object is a body part. The graph on the right shows performance when neither object is a body part. Adapted from Chatterjee, Freyd, and Shiffrar (1996).

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APPARENT MOTION FOR AMERICAN SIGN LANGUAGE STIMULI

Signed languages, like all languages, possess grammatical structure at several levels. In particular, for our purposes, they possess phonological structure.[1] Signs are not holistic gestures but are constructed from a set of meaningless components (handshape, palm orientation, location, and movement) that are combined in rule-governed ways (Battison 1978; Stokoe 1960). In order to test whether American Sign Language (ASL) expertise can influence the perceived path of apparent motion, two types of ASL signs can be compared. The first set consists of signs whose movement is phonologically specified as two contacts (see figure 2 for an example). That is, the dominant hand (the right hand, in right-handers) makes contact with some other body part, such as the torso, arm, or "base" hand, and then makes contact again at a nearby location. The movement between these two points of contact necessarily involves the dominant hand breaking contact, moving in an arced path to the second location, and reestablishing contact. Depending upon emphasis and style, the degree of displacement from a straight path can be very large or more moderate. The critical point, however, is that these signs are never performed with continuous contact between the dominant hand and another body part. In contrast, the second set of signs does involve exactly such continuous contact (see figure 2). These signs are phonologically specified as a single contact with local movement.

These two groups of signs are of interest because each sign involves two endpoints at which the dominant hand is in contact with another body part. Thus, if only the two endpoints are shown in apparent motion display, either type of movement (two contacts or single contact with local movement) could in principle be seen. By using these endpoints as stimuli in an apparent motion paradigm, one can ask whether perceived motion will conform to the path of motion specified in the sign from which the stimuli are taken. In the absence of other constraints, the

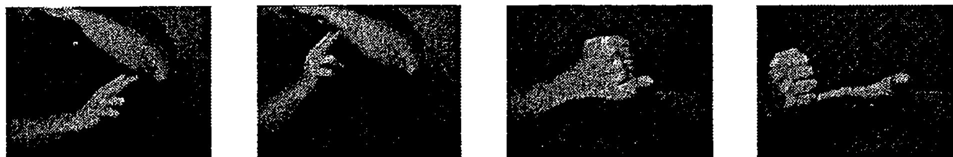

Figure 2. The top two photographs show the endpoints of the ASL sign BRIDGE. The two fingers of the dominant hand touch the forearm, break contact, and touch the forearm again closer to the elbow. The bottom three photographs show the endpoints of the ASL sign CREDIT CARD. The dominant hand slides back and forth along the palm.

1. The sublexical structure of ASL exhibits abstract phonological properties such as hierarchically organized feature classes, autosegmental representations, deletion and segmentation rules, a sonority hierarchy, and syllabic structure. For these reasons, the term "phonology" is used by linguists to characterize the sublexical structure of signed languages as well as spoken languages (Brentari 1995; Corina and Sandler 1993; Coulter 1993; Sandler 1995).

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shortest-path constraint should bias all participants toward seeing the single-contact movement, which involves a virtually straight path, rather than the two-contact movement, which involves an indirect, arced path. But if expertise with a visual language can influence perceived motion, then one would expect deaf participants who are fluent in ASL to perceive the indirect path for stimuli taken from signs that have such a path more often than would hearing participants who do not know ASL. In other words, signers should perceive the stimulus in such a way as to yield a real sign in ASL, rather than a nonsign movement.

In addition, if deaf signers do reveal a bias toward perceiving movements that result in stimuli that conform to ASL signs, we can be sure that this effect is a purely language-based effect and not one based on cognitive reorganization due to deafness. If there were some overall bias introduced by deafness (say, for the sake of argument, less of a tendency to always see straight paths), then this should apply equally to all stimuli, regardless of whether they come from a two-contact or single-contact sign. Thus, any observed bias toward seeing movements that are compatible with signs in the deaf signing population can be attributed to the effects of sign language expertise.

A TEST OF APPARENT MOTION IN NATIVE SIGNERS

In order to test the predictions just described, a study was performed that followed the methods of Shiffrar and Freyd (1990) in all essential respects with the exception of the nature of the stimulus photographs and the participant population. Five deaf native signers of ASL and ten hearing nonsigners were tested. The deaf participants, all deaf from birth, had hearing loss greater than 80 dB. All had two deaf parents, were exposed to ASL from infancy, and considered ASL to be their primary language. None of the hearing participants knew ASL or any communication system using ASL signs (e.g., Signed English).

To generate the stimuli, a deaf native signer was filmed performing sixteen ASL signs. Eight of these signs consist of two points of contact between the dominant hand and another part of the body, with an arced path of motion between the two contacts (BRIDGE, FOUNDATION, IMPROVE, LAW, MILLION, PARAGRAPH, POLICY, TRASH). The other eight signs consist of movement along a nearly straight path (BUSY, CREDIT CARD, FEVER, SOCKS, TRAFFIC, TRAIN, WOOD, XEROX).[2] For each sign, substituting the other kind of movement (replacing two-contact movement with straight movement or vice versa) but retaining all other characteristics of the original sign (handshape, palm orientation, location) would result in a "pseudo-sign." These pseudo-signs are phonologically legal but are not lexical items in ASL. Thus, when movement information is removed, perceived apparent motion will yield either a real sign or a phonologically legal pseudo-sign, depending on the path of the perceived motion.

2. Testing was performed in California. Because of regional differences, the signs listed may not all be two-contact or single-contact signs in other parts of the United States. In addition, some of the signs listed as "single-contact" are sometimes performed without any contact at all (SOCKS, TRAFFIC). Nevertheless, these signs still use a straight movement path, which provides the crucial contrast to two-contact signs.

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From the filmed signs, two still frames were chosen, one from each endpoint of the movement (figure 2). When stimuli of this type are presented in alternation with appropriate spatial and temporal parameters, the result is a subjective impression of motion, in which the body part that changes location appears to move back and forth.

Stimuli were presented as digitized pictures on a computer. On each trial, two stimuli were presented alternately at the same location, with a fixed stimulus onset asynchrony (SOA) for that trial, until the participant pressed a key to terminate presentation. Over the course of the experiment, each pair of stimuli was presented at five different SOAs. The shortest SOA was 133 ms, consisting of 100-ms stimulus duration (SD) and 33-ms interstimulus interval (ISI). Sixty-seven ms was added to both SD and ISI to form the next SOA level of 267 ms, and so on for each SOA up to the longest SOA of 667 ms. The order of the eighty trials (sixteen stimulus pairs at five SOAs) was randomized for each participant.

For each trial, participants were asked to report the path of motion that they saw. Of particular interest was whether they perceived the shortest, direct path (called "sliding" in the instructions) or an arced, indirect path (called "hopping"). The "hopping" and "sliding" paths were illustrated for the participant by arrows drawn on photographs. Additional response options included "can see both," "some other movement," and "no movement." After responding, participants initiated the next trial with a key press. For the deaf participants, instructions emphasized that responses should not be made based on how a real sign would look but instead should be based on what they actually saw. Responses were scored for the number of reports of hopping (figure 3).

As would be expected for the single-contact signs, the number of hop responses was low for both groups. This reflects the fact that, for these stimuli, the movement that yields a true sign percept (i.e., sliding) is compatible with the shortest-path constraint. In contrast, for the two-contact signs, deaf participants were almost twice as likely as hearing participants to give hop responses. Further, the two-contact signs for the deaf participants showed a steep increase in the number of hop responses as a function of presentation speed (SOA), in contrast to the other three conditions (figure 4). Shiffrar and Freyd (1990) argue that slower SOAs allow sufficient time for the longer path to be constructed by the visual system. The SOA data reported here suggest that this type of construction process can be induced not only by biomechanical considerations, as shown by Shiffrar and Freyd, but also by experience with an acquired linguistic movement system.

An unexpected finding is that hearing participants showed a small but reliable difference between two-contact signs and single-contact signs. How were the hearing participants, who knew no ASL, able to differentiate the two types of signs? The answer may have to do with movement information implicit in the visual display. Subtle cues from the angle, orientation, or muscle tension of the limbs may have telegraphed to the participants what motion had just taken place or was about to take place. That is, there may be a phenomenon similar to co-articulation of phonemes in speech that would allow information about prior or upcoming movement to be detected. Such an effect would presumably influence the deaf participants as well, but the effect is small and cannot account for the large difference between two-contact and single-contact signs shown by the deaf participants.

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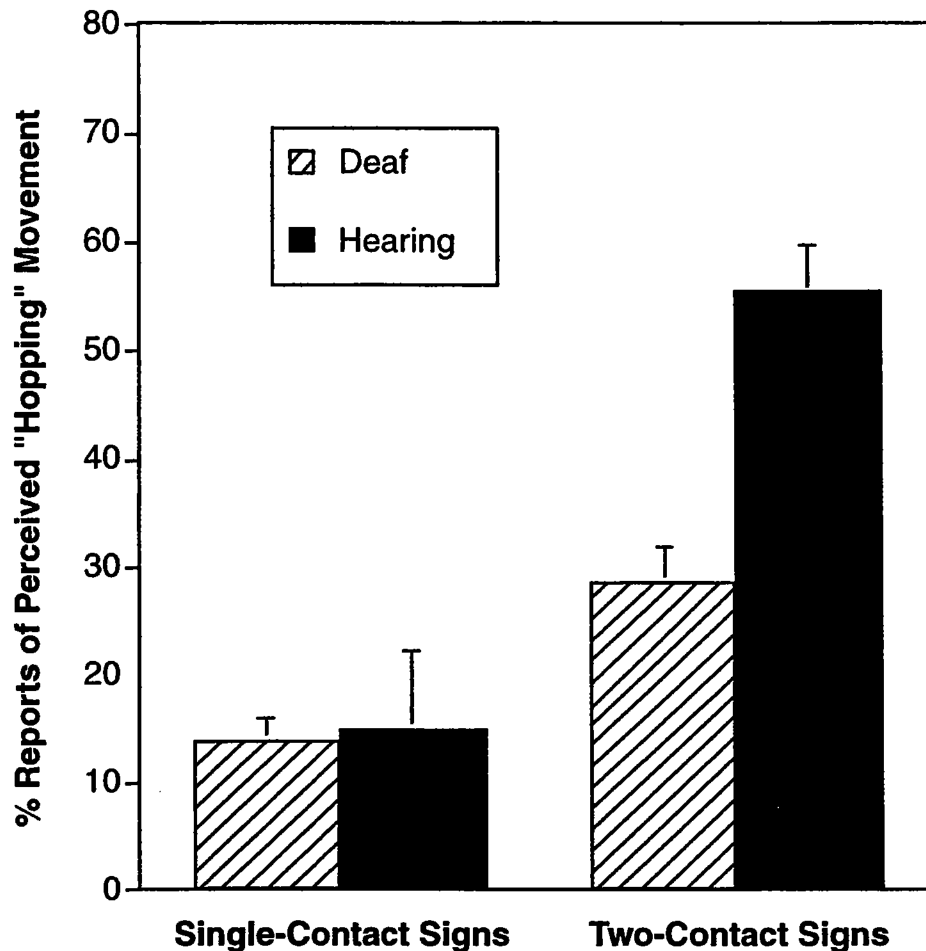

Figure 3. Participants' reports of perceived path of apparent motion, collapsed across SOA. Error bars represent standard error.

Another issue that must be addressed is whether the deaf participants responded based on how they knew the signs should look rather than on what they actually perceived. Several considerations argue against this interpretation. First, the deaf participants were not unwilling to label the two-contact signs as sliding, thus rendering them pseudo-signs. This claim is supported by the fact that deaf participants gave "slide" responses for the two-contact signs on fully 40 percent of trials. Clearly, participants understood that it was acceptable to give responses that corresponded to pseudo-signs rather than real signs. Further, the rather high rate of answers corresponding to pseudo-signs cannot be accounted for in terms of random intermixing of genuinely perceptual shortest-path responses with nonperceptual "how it should look" responses. If participants were mixing strategies in this fashion, the effect size should be constant across SOA. Instead, the tendency to report

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