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# Visual and "Phonetic" Coding of Movement: Evidence from American Sign Language

Abstract. *Hearing subjects unfamiliar with American Sign Language and deaf native signers made triadic comparisons of movements of the hands and arms isolated from American Sign Language. Clustering and scaling of subjects' judgments revealed different psychological representations of movement form for deaf and hearing observers. Linguistically relevant dimensions acquired modified salience for users of a visual-gestural language. The data indicate that the modification of natural perceptual categories after language acquisition is not bound to a particular transmission modality, but rather can be a more general consequence of acquiring a formal linguistic system.*

American Sign Language (ASL) is the visual-gestural language used by deaf communities in the United States. The language is passed from one generation of deaf people to the next as a primary native language. Since the language has developed outside the auditory modality, its study can provide basic clues to the nature of language and to those psychological processes on which the comprehension and production of language rest. The principal aim of this experiment was to evaluate whether experience with a visual-gestural language could modify perception of the meaningless formational elements of the language.

Signs from ASL have at least three major formational attributes: configuration of the hands, location of the hands relative to the body, and movement of the hands and arms (*1*). Each attribute comprises a large inventory of discrete representatives, which are themselves essentially without meaning. Representatives are combined simultaneously but function separately to contrast minimally different signs, much as the phonemes of spoken languages minimally contrast words.

Experiments on the perception of speech indicate that a speaker's perception of phonemes can be determined either by natural nonlinearities of the auditory system or by the speaker's particular phonological experience (*2*). Human infants, for example, discriminate acoustic differences that cue the distinction between the phonemes /r/ and /l/ much as do English-speaking adults, in whose language the distinction is phonologically contrastive (*3*). Infants and adult English speakers are much better able to discriminate the same physical difference for stimuli across the English phoneme boundary than for stimuli within either phoneme category. The distinction between /r/ and /l/, however, is not contrastive in Japanese phonology, and unlike infants and English-speaking adults, Japanese-speaking adults fail to discriminate the acoustic differences (*4*). Linguistic experience has in this case modified innate auditory sensitivities. Is the modification of perception due to linguistic experience bound to the oral-auditory transmission modality? The differences between visual and auditory perception seem, after all, more striking than the similarities (*5*).

To evaluate effects of experience with

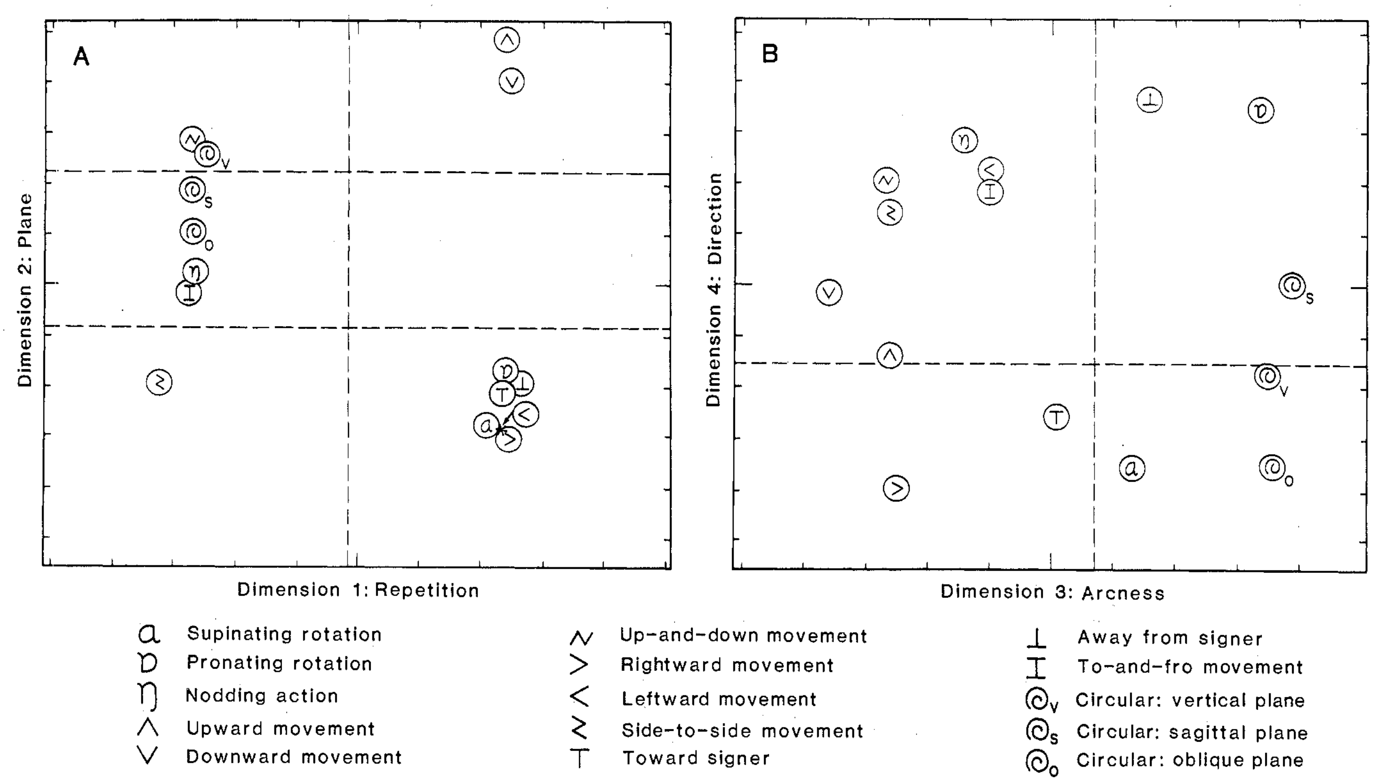


Fig. 1. Configurations of stimuli. Scaling was performed according to the individual differences scaling model (*10*) implemented with the SINDSCAL computer program (*11*). Fifteen one-handed movements were used as stimuli.

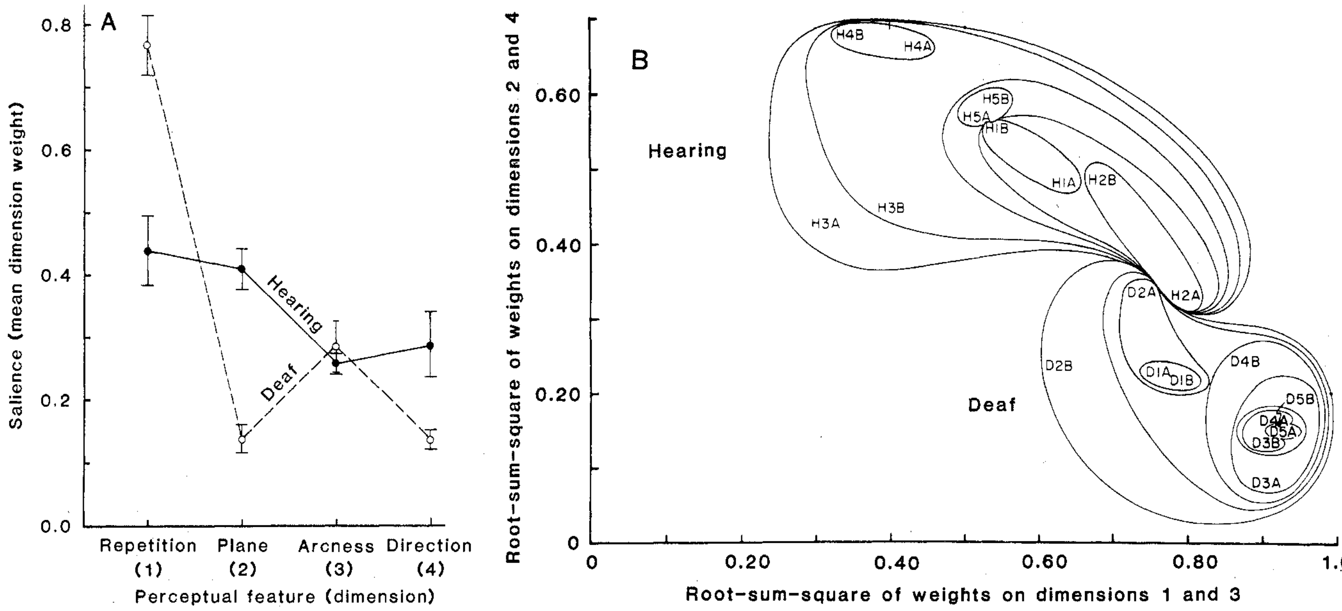


Fig. 2. (A) Perceptual salience of each dimension of the scaling solution for deaf and for hearing subjects (± 1 standard error of the mean). (B) Hierarchical clustering of intersubject correlations (closed contours) superimposed on the subject space from the INDSCAL analysis. The position of each replication (*A* or *B*) of each deaf subject (*D1* through *D5*) and each hearing subject (*H1* through *H5*) was determined from each subject's combined weights on dimensions 2 and 4 versus his combined weights on dimensions 1 and 3 of the scaling solution (*9*). The clusterings were obtained by using Johnson's HICLUS procedure (complete-link option) (*12*).

a visual-gestural language on perception of its meaningless formational elements, one of the components of lexical signs—movement of the hands and arms—was selected for study. Five congenitally deaf native signers of deaf parents, and five normally hearing adults unfamiliar with signing were asked to make triadic comparisons of videotaped movements isolated from lexical signs (*6*). Subjects made a single judgment for each triad by deciding which two of the three movements were most similar. The entire experiment was replicated to measure the reliability of the data.

Similarity matrices were constructed for all pairs of movements for each replication of the experiment and analyzed with multidimensional scaling procedures (*7*). Such scaling provides a geometric model of the psychological representation of a stimulus array by representing the stimuli as points in a multidimensional space (*8*). The distance separating any two stimuli in the spatial solution corresponds to the judged similarity of that pair. Recovered weights reflect the importance or salience of a given dimension for a given subject, and the dimensions themselves generally correspond to psychologically significant processes (*9*).

Multidimensional scalings were performed in one through six dimensions. The four-dimensional solution was selected, accounting for 70.0 percent of the variance in the data. Figure 1 presents the group scaling solution for both deaf and hearing subjects.

Stimuli project discretely to two points along dimension 1 (Fig. 1A). Stimuli on the left all have repeated movements, whereas all stimuli to the right have a single, unrepeated movement. Dimension 1 was thus labeled "repetition."

Projections along dimension 2 fall into three broad categories defined by the plane in which the movements occur. The four uppermost stimuli occur in a plane parallel to the front of the signer's body, the seven stimuli in the lowermost portion of the figure occur primarily in a horizontal plane, and the four stimuli projecting to the center of dimension 2 occur either in a sagittal plane or in a plane oblique with respect to the signer's body. Dimension 2 was thus labeled "plane."

Stimuli project virtually along the entire axis of dimension 3 (Fig. 1B), becoming increasingly arced. The mean values of arcness projected on the face of the television monitor for each of the 15 movements were correlated with the coordinates of each movement along dimension 3 of the scaling solution. The correlation of $r = .91$ ($P < .01$) indicates that dimension 3 reflected continuous variation in the degree of arcness of the movement forms "arcness."

Stimuli also project continuously along dimension 4. Stimuli below the horizontal dashed line in Fig. 1B have movements directed toward the right of the signer's body, that is, toward the left of the television monitor. Stimuli above the line have movement components toward the signer's left side, that is, toward the right of the monitor. Dimension 4 was thus labeled "direction."

Deaf and hearing subjects exhibited different patterns of weights on the four dimensions (Fig. 2A). A mixed design analysis of variance yielded a significant interaction between the weights of the deaf and hearing subjects [$F(3, 24) = 8.9$, $P < .001$], reflecting the statistical reliability of the differential salience of dimensions of subjects in each group. The dimension most salient to the deaf subjects, repetition, figures strongly in the structure of lexical signs (*1*).

Individual deaf and hearing subjects, as well as the groups as a whole, differed dramatically in perception of these movement forms. Two complementary analyses of individual subject differences were performed. (i) The similarity matrix for each replication of each subject (deaf and hearing) was correlated with every other similarity matrix. The resulting matrix of correlations specifying relationships among subjects was hierarchically clustered, yielding discrete groupings of subjects. (ii) These clusterings were superimposed on a spatial configuration from the scaling solution showing the distribution of individual subjects in terms of each subject's weightings on the four dimensions (Fig. 2B). The distribution falls into two groups, based entirely on whether the subjects were deaf or hearing. The pattern of dimension weights for a given subject seems reliable, since both replications for a given subject tended to be positioned close together.

Dimensions important to the hearing subjects provide clues to the natural visual categories into which the sign movements fall. Apparently, repetition of movement, plane of movement, degree of arcness, and direction of movement are salient psychophysical properties to observers for whom these stimuli are not part of a phonological system. These natural visual categories are of different perceptual salience, however, to deaf signers who have acquired ASL as a first and primary language. The difference in perception of sign movement is dramatically illustrated by the complete separation of the groupings of deaf and hearing subjects (Fig. 2B). The differences between deaf and hearing subjects (Fig. 2A) indicate that some psychophysical dimensions (for example, repetition) are more perceptually salient to deaf subjects, whereas others are less so. Thus, experience with a visual-gestural language can modify natural visual categories for some meaningless formational elements of ASL. Whether forms acquire distinctiveness or similarity remains to be investigated. However, effects of linguistic experience on natural perceptual categories are modality-independent consequences of language acquisition, whether spoken or signed.

HOWARD POIZNER
*Salk Institute for Biological Studies, La Jolla, California 92037*

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6. Movements of the hands and arms were isolated from signs by attaching small incandescent bulbs to the major joints of the arms of a signer (index fingertips, wrists, elbows, shoulders, and a point on the head). Recordings were made in a darkened room, so that during playback only patterns of moving spots of light were visible. These dynamic point-light displays convey ASL movement veridically, and do so when presented in two-dimensional as well as in three-dimensional displays (H. Poizner, U. Bellugi, V. Lutes-Driscoll, *J. Exp. Psychol. Hum. Percept. Perform.*, in press). The advantage of this technique lies in its dramatic reduction of cues other than that of movement: the configuration of the hand, the expression on the face, and the body of the signer are not displayed, thus allowing direct focus on movement.
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## Sex Differences in the Effects of Unilateral Brain Damage on Intelligence

Abstract. *A sexual dimorphism in the functional asymmetry of the damaged human brain is reflected in a test-specific laterality effect in male but not in female patients. This sex difference explains some contradictions concerning the effects of unilateral brain damage on intelligence in studies in which the influence of sex was overlooked.*

For some 30 years neuropsychologists have reported contradictory findings concerning deficits in performance on the intelligence tests of patients who have suffered unilateral brain damage. Investigators such as Andersen (*1*) found that left hemisphere damage significantly reduces scores on verbal tests and right hemisphere damage significantly reduces scores on nonverbal tests; we call this the positive case of the test-specific laterality effect. Other investigators such as Reitan (*2*) reported a significant effect only in the case of left hemisphere damage on verbal test scores; this is an example of the equivocal case. Still others, such as Smith (*3*), failed to find any differential effects of lateralized brain damage on either verbal or nonverbal cognitive test performance; this we call the negative case. Some of these apparent contradictions can be resolved by taking the sex of the patients studied into account. This has not been the practice, with the exception of some work by Lansdell (*4*).

McGlone (*5*), however, reported that only the male patients in her studies showed a significant lateralized effect of brain damage, those with left hemisphere damage being impaired on the Verbal Scale and those with right hemisphere damage being impaired on the Performance Scale of the Wechsler (*6*) intelli-

Table 1. The composition of the patient groups in the positive and equivocal or negative cases of the test-specific laterality effect of brain damage.

| References | Male patients | | Female patients | |
|---|---|---|---|---|
| | Left lesion | Right lesion | Left lesion | Right lesion |
| *Positive cases* | | | | |
| Andersen (*1*) | 15 | 15 | 0 | 0 |
| Klove and Reitan (*7*) | 19 | 28 | 3 | 8 |
| Klove (*8*) | 33 | 33 | 9 | 4 |
| Fitzhugh, Fitzhugh, Reitan ("current" cases) (*9*) | 15 | 21 | 3 | 4 |
| Fields and Whitmyre (*10*) | 18 | 23 | 0 | 0 |
| Total | 100 | 120 | 15 | 16 |
| *Equivocal or negative cases* | | | | |
| Meyer and Jones (*11*) | 11 | 5 | 9 | 6 |
| Fitzhugh, Fitzhugh, Reitan ("chronic" cases) (*9*) | 7 | 12 | 13 | 13 |
| Klove and Fitzhugh (*12*) | 12 | 19 | 12 | 16 |
| Fitzhugh and Fitzhugh (*13*) | 14 | 11 | 14 | 13 |
| Dennerll (*14*) | 11 | 22 | 18 | 9 |
| Meier and French (*15*) | 8 | 14 | 7 | 11 |
| Zimmerman, Whitmyre, Fields (*16*) | 23 | 31 | 0 | 0 |
| Reitan and Fitzhugh (*17*) | 15 | 15 | 0 | 0 |
| Todd, Coolidge, Satz (*18*) | 45 | 27 | 23 | 19 |
| Total | 146 | 156 | 96 | 87 |


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