How does learning sign language affect perception?

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Abstract

Everyone uses emotional facial expressions, but people who sign American Sign Language (ASL) use a different kind of facial expressions as an essential part of the language. Does all of this signing affect perception? To determine whether learning ASL has an effect on visual discrimination, we test deaf signers, hearing signers and hearing non-signers with three groups of faces: emotional facial expressions, linguistic ASL facial expressions and faces of different people. The deaf observers perform half as well as hearing signers for all stimuli. When compared to the efficiencies of hearing non-signers, these results show that learning ASL improves visual discrimination and being deaf impairs it. The observers who know ASL perform best with linguistic facial expressions. Thus, learning ASL improves one's ability to identify facial expressions.

Introduction

Linguistic facial expressions are an essential part of American Sign Language (ASL). Everyone uses emotional facial expressions, but signers use linguistic facial expressions as well. Does all this extra attention to faces improve their ability to discriminate them?

ASL is a visual-gestural language that serves as the primary means of communication for the North American deaf population (Baker-Shenk & Cokely, 1980). Although, in the past, it has been incorrectly viewed as a pantomimic representation of English, ASL has a different structure with its own distinctive grammar and means of expression (Namir & Schlesinger, 1978). Manual, body and facial gestures take the place of spoken word in signed languages. ASL contains a large vocabulary of signs that are used to express a broad range of ideas (Sperling, Cohen, Landy & Pavel, 1985).

ASL is more than a language of the hands. Its grammar incorporates the entire body. In addition to the manual elements, the signer's face, head, torso, and eye gaze play key linguistic roles (Baker-Shenk, 1985). The face is an important channel for expressing grammatical information. Facial expressions are a vital component of the grammar and are used to indicate far more than emotional disposition (Craft, Hinkle & Sedgewick, 2000). Movements of the signer's eyes, face, and head can act as adverbs, adjectives and various other grammatical signals (Baker, 1979). When these movements are combined they indicate whether a sentence is a question, an assertion, a command, or a conditional.

The facial expressions used in ASL are unlike emotional expressions in that they are required for communication. While it is possible to understand the meaning of an English sentence without seeing facial expressions, this is not the case for ASL. Facial expression in ASL is analogous to intonation. In spoken language, raised pitch at the end of a sentence indicates a question (Campbell, Woll, Bension & Wallace, 1999). The two questions types, *yes/no* and *wh*-questions, require certain facial behaviors without which questions would be undistinguishable. For example, the required non-manual signals for *wh*-questions include furrowed brows and a tilt of the head (Hickock, Bellugi & Klima, 1996). The *yes/no* question requires a head tilt forward and the raising of the eyebrows (Baker-Shenk, 1985).

Deaf people express emotion much in the same way as hearing people. For deaf signers, facial behaviors function in two distinct ways: providing grammar and emotion. Linguistic and emotional markers differ in ASL in measurable ways (Baker & Padden, 1978 and Baker-Shenk, 1985). Emotional expressions may co-occur with grammatical signals (Baker-Shenk, 1985) and are not necessary for comprehension of ASL. Linguistic expressions are rule governed with specific onset and offset times, whereas emotional facial behaviors are continuous and used arbitrarily. Emotional expressions vary in intensity and do not have clear starting and ending points (Corina, Bellugi & Reilly, 1999). There are striking differences in the way the brain processes these expressions. For deaf individuals, emotional expressions are primarily mediated by the right hemisphere whereas linguistic expressions are mediated by the left (Bellugi, Corina & Reilly, 1999).

Studies of deaf children indicate that emotional and linguistic facial expressions are learned independently of each other. Linguistic facial expressions are acquired along with other aspects of language in a rule-governed way. Toddlers can often make the expression required for a *wh*-question in an emotional context by their first birthday (Reilly, Mcintire & Bellugi, 1990), but do not begin to signify grammar until the age of four (Hickock, Bellugi & Klima, 1996).

Liddell (1980) gives contrasting examples of the usage of linguistic vs. emotional expressions. Necessary facial expressions mark conditional clauses in ASL. Compare sentences (1) and (2):

<u>__conditional__</u>
(1) ASL: TODAY STORM, SCHOOL CANCEL
English translation: 'If there's a storm today, school is canceled.'

(2) ASL: TODAY STORM, SCHOOL CANCEL
English translation: 'There's a storm today and school is canceled.'

In sentence (1), the words "TODAY STORM" are accompanied by a brow raise, a slight head raise and tilt, a shift of eye gaze, and an eye blink. These behaviors are required to mark conditional sentences (Fig. 1).

Figure 1. In ASL, conditional sentences are accompanied by brow raise, a slight head raise and tilt, a shift of eye gaze, and an eye blink. In this example of a conditional sentence, the first facial expression co-occurs with the main clause, the second with the dependent.

Note that in sentence (2), when these behaviors are lacking, the same manual expressions are interpreted as conjoined prepositions. The facial markers make example (1) a complex sentence with a subordinate clause.

Emotional facial expressions co-occur with ASL and spoken English. Example (3) expresses a signer's surprise:

surprise
(3) ASL: HER DAUGHTER COOK DINNER
English translation: 'Her daughter is cooking dinner!?'

The shape of the line above the word "surprise" is an approximate indication of the muscular activity involved in this emotional expression. Unlike linguistic expressions, the activity varies arbitrarily across the sentence.

There is evidence that experience with sign language may enhance certain visual abilities. Bettger, Emmorey, McCullough, and Bellugi (1997) report that native deaf and hearing signers perform significantly better than hearing non-signers in certain tasks of facial discrimination. They believe this result is caused by the reliance of signers on the linguistic aspects of facial expression. When signing, people focus on "the signing window," an area including the face and chest, not just the hands (Fig. 2).

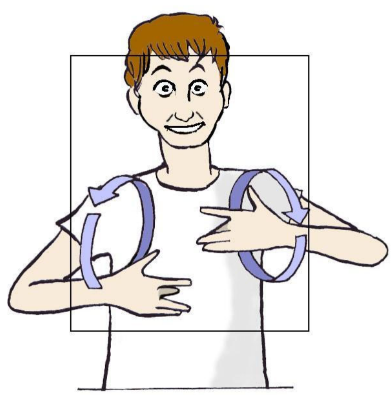

Figure 2. The signing window is the area of a signer's body, including the face and chest. Signers focus on this area when signing. Signs are identified peripherally.

Most attention is paid to the face while signs are generally picked up peripherally. The deaf have larger visual potentials than non-signers and faster reaction times in visual discrimination tasks when processing brief peripheral stimuli (Neville &

Lawson, 1987a, b). This suggests that using vision for language, expands its capacity (see Green & Bavelier,, 2003).

There are differences in the way that faces conveying identity and emotion are processed. Brain lesions selectively affect the recognition of either facial identity or emotion (Humphreys, Donnelly & Riddoch, 1993), which indicates that the two tasks involve different parts of the brain. Linguistic expressions are unfamiliar to hearing non-signers whereas they are meaningful linguistic symbols to signers. Is this difference evident when signers are asked to discriminate between linguistic expressions and other faces? Does using facial expression as a part of language result in differences in discriminating between emotional facial expressions, linguistic facial expressions and people?

In this paper, we focus on the differences between the abilities of signers and non-signers to identify facial emotion and person. We compare face identification among three groups: hearing signers, deaf signers, and hearing non–signers. We ask whether the visual capacity can be expanded and whether it is a result of deafness or knowledge of ASL.

Methods

Stimuli

Three sets of stimuli are used in this experiment. The first, "emotional" facial expressions, are from the Paul Ekman face photo database (http://www.paulekman.com). The database contains the facial expressions of the eight basic emotions (Ekman, 1992). We use happiness, sadness, fear and disgust. The second, "linguistic" facial expressions, is a set of four facial expressions used as part of the grammar of ASL. M.J. Bienvenu modeled the facial expressions for a book and we scanned the photos (Baker-Shenk & Cokely, 1980). The third, "people," is made up of four of Paul Ekman's neutral faces of different models. We chose two male and two female faces that seemed most different. Each face photo is called a "signal" when displayed during the identification task.

We modified all stimuli in Adobe Photoshop. We set them to grayscale (no color) and cut them just above the eyebrows and below the mouth into 2.56-inch x 2.56-inch squares.

Observers

Observers include profoundly deaf individuals, hearing signers and non-signers. We recruit many of the deaf observers through internet e-mail groups for the deaf and friends of previous observers. We choose all observers on the basis of availability and pay them for their voluntary participation. There are 15 observers in all, 9 hearing and 6 deaf.

Noise

Just as auditory noise interferes with hearing, visual noise interferes with vision. “White” noise looks like the static on a television screen. It contains all spatial frequencies and orientations (Fig. 3).

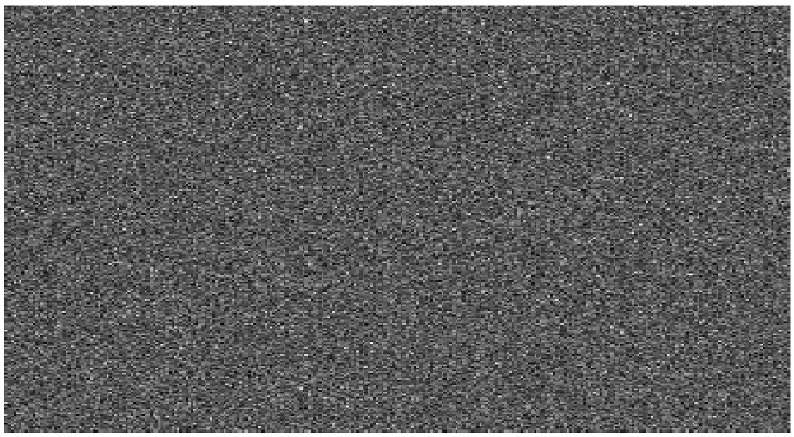

Figure 3. “White” noise, containing equal energy at all frequencies.

The white noise used in this experiment is made up of square checks, each a luminance increment sampled independently from a Gaussian distribution truncated at ±2 standard deviations.

Procedure

The experiment is performed on Apple Power Macintosh computers using MATLAB software with the Psychophysics Toolbox extensions (http://psychtoolbox.org) (Brainard, 1997, Pelli, 1997). Stimuli are displayed on a gamma-corrected grayscale monitor (Pelli & Zhang, 1991), with a background luminance of 16 cd/m^2. The fixation point is a 0.15 deg black square positioned at the same height as the center of the mouth. The signal is always presented for 200 ms.

The experimenter is fluent in ASL and is present throughout every session. The experimenter chats with the observers between trials, clarifies any misunderstandings and in general, makes them feel comfortable. The instructions are signed for the deaf and understanding is supplemented by answers to all the observer's questions in the observer's language of choice. We give the observer as much time as necessary to practice the task until they understand what they are being asked to do.

In each trial a fixation point is shown on the screen and upon clicking the mouse the fixation point disappears. It is replaced by the signal. The signal is a face, randomly sampled from the stimulus set. A response screen follows display of the signal, showing all the possible signals at 80% contrast without noise. One of the faces on the response screen is identical to the signal (Fig. 4).

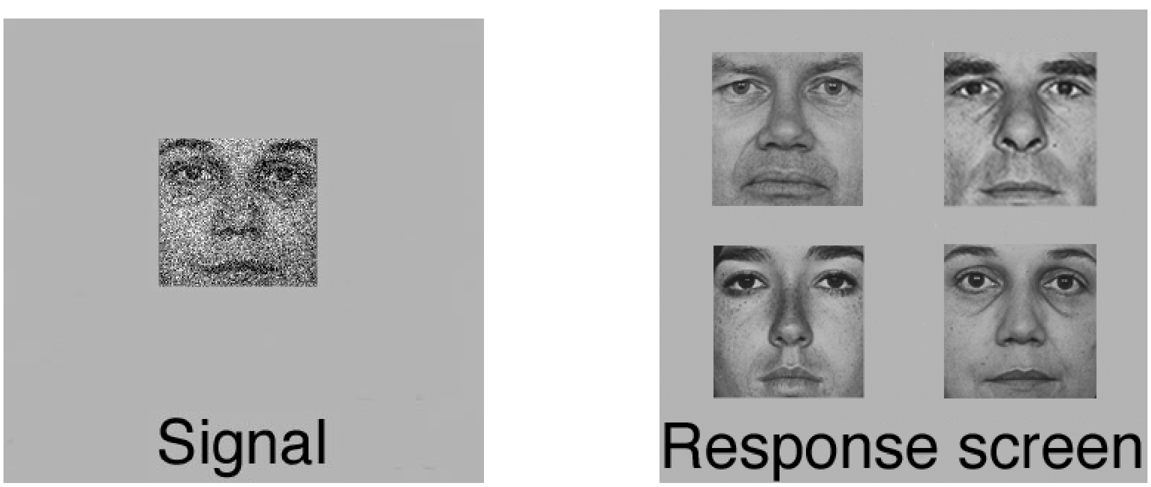

Figure 4. The signal is shown for 200 ms, followed by the response screen. Except for contrast and noise, the signal is identical to the face in the bottom right corner of the response screen. We instruct observers to identify the signal by clicking one of the choices on the response screen.

For each set of stimuli, a run consists of 40 trials. Each run yields an estimated contrast threshold. Two runs of each set, emotional facial expressions, linguistic facial expressions and people, are repeated, in that order, five times for a total of 30 runs.

Signal contrast is defined as the ratio of luminance increment to background luminance (Fig. 5). We calculate the observer's contrast threshold using the QUEST program (Watson and Pelli, 1983). QUEST estimates threshold by interpolating data from all of the observer's trials in a run. If the observer correctly identifies the signal, QUEST lowers the contrast of the signal, making the task more difficult. If the observer incorrectly identifies the signal, QUEST increases its contrast. The end result is an estimate of the contrast threshold at which the observer correctly identifies the signal 82% of the time. If the observer needs 100% or more contrast to identify the stimulus 82% of the time, we disregard the data from that run. If we disregard more that one run for a stimulus group, we do not use that observer's data.

Efficiency

Contrast energy E is the squared contrast summed over the area of the object. Efficiency η is the fraction of the energy used by the human observer that is required by the ideal observer, i.e. the ratio of their thresholds.

$$\eta = E_{\text{ideal}} / E \qquad (1)$$

Because human observers have intrinsic visual noise that adds to the display noise, we prefer to compute high-noise efficiency, which discounts the effect of the observer's internal noise. High-noise efficiency η^{+} is the ratio of the ideal's threshold to the observer's threshold in noise relative to that on a blank field.

$$\eta^{+} = E_{\text{ideal}} / (E - E_0) \qquad (2)$$

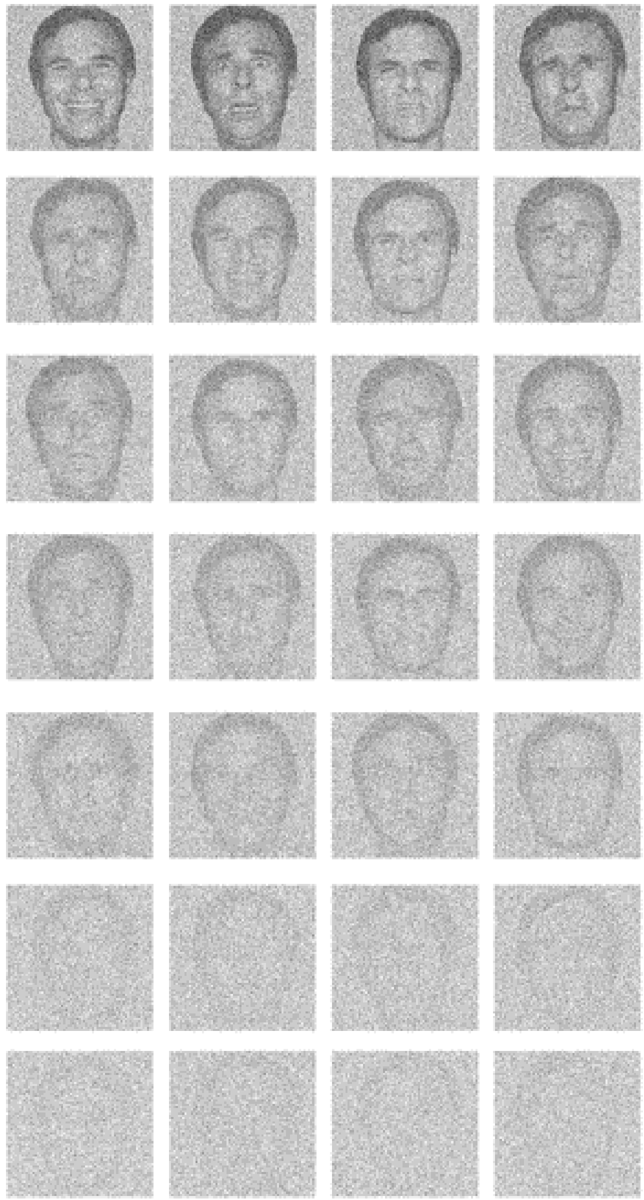

Fig 5. Faces of decreasing contrast (from top to bottom) in noise.

Results

As shown in Figure 6, hearing non-signers perform equally well with all face sets.

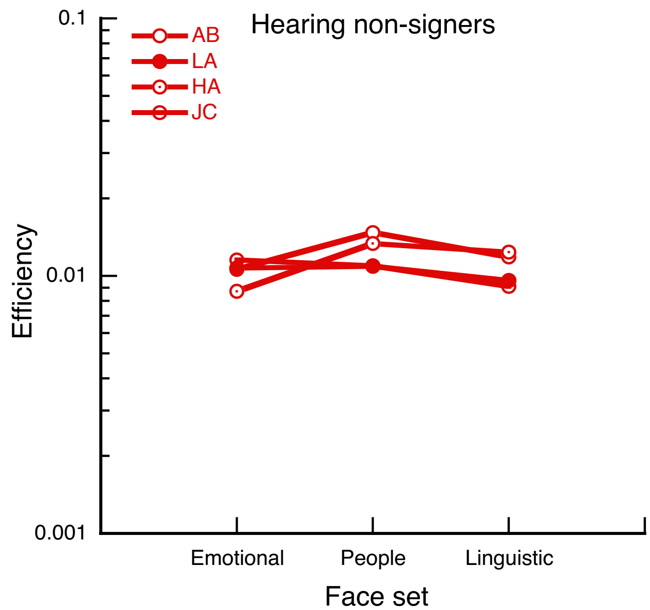

Fig 6. Efficiencies for hearing non-signers. Hearing non-signers perform equally well with all face sets.

Figure 7 shows that deaf observers perform equally well with emotional facial expressions and people, and best with linguistic facial expressions.

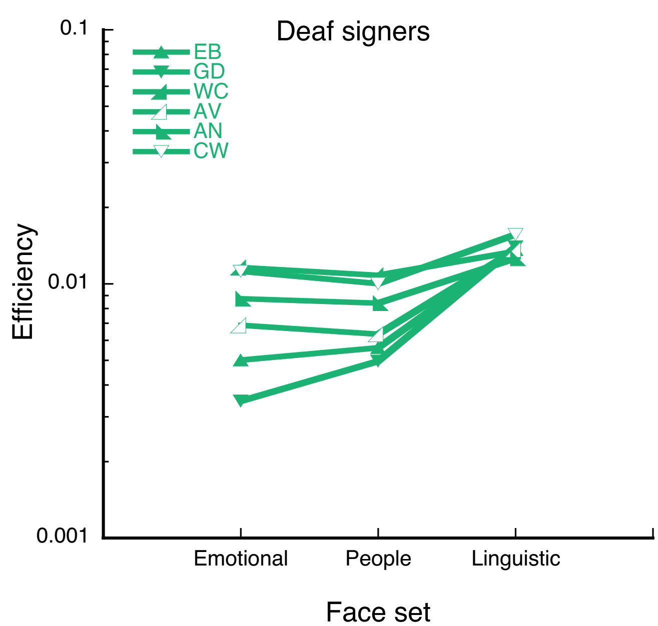

Fig 7. Efficiencies for deaf observers. Deaf observers perform best with linguistic expressions.

Figure 8 shows hearing signers perform best with linguistic facial expressions.

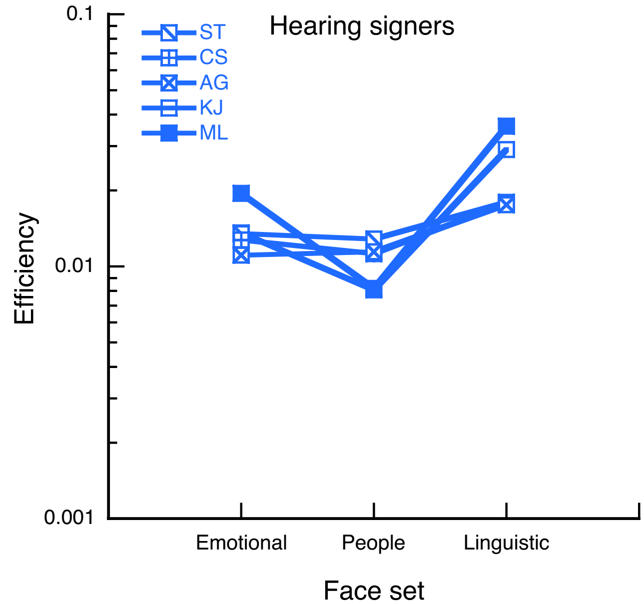

Fig 8. Efficiencies for hearing signers. Hearing signers performed equally well with emotional expressions and people, and best with linguistic expressions.

Figure 9 shows group averages.

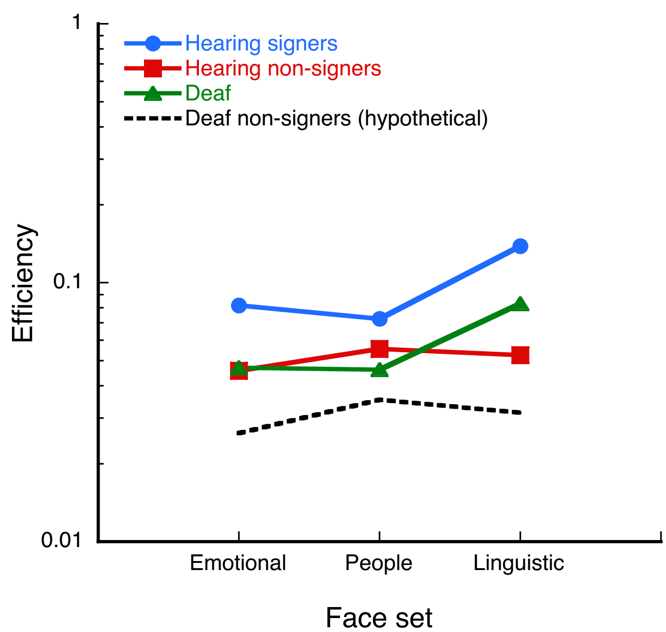

Fig 9. Average efficiencies for hearing signers, hearing non-signers, deaf observers and, hypothetically, deaf non-signers.

Comparing hearing signers to hearing non- signers, we see learning ASL increases efficiency most (2.6x) for linguistic expressions, and still substantially for emotional expressions (1.7x) and people (1.3x). Hearing signers and deaf signers both know ASL. The efficiency of hearing signers, however, is about twice that of the deaf across the board. We did not expect this effect of deafness.

Discussion

We expected that because deaf people depend on ASL as their main method of communication they would be best at identifying the facial expressions that they use when signing. Indeed, whereas hearing non-signers are equally efficient with all face sets, the deaf signers are best at identifying linguistic facial expressions. However, the deaf achieved only 0.6 the efficiency of hearing signers over all face sets. Thus, learning sign language improves visual discrimination, but being deaf impairs it. These effects are equal and opposite, canceling each other out for discrimination of emotions and people, i.e. the deaf have the same efficiency as the hearing non-signers (Fig. 9).

The dotted line in Figure 9 is a hypothetical estimate of the efficiency of deaf non-signers assuming that deafness would reduce the efficiency of non-signers by the same factor as it reduces the efficiency of signers. It would be difficult to find appropriate observers to perform this task because profoundly deaf individuals who do not know ASL have no fluent means of communication.

Conclusion

Hearing signers perform better than non-signers with all face sets. This shows that learning ASL improves face discrimination. The effect is greatest for the faces they have the most practice with, yet broad enough to apply to other face sets.

The hearing signers performed better than deaf signers with all face sets. All our deaf observers learned ASL at age 18 or older. Prior to this they were deprived of a fluent language. Presumably, being unable to converse competently restricted their social lives, resulting in less exposure to faces and, therefore, less practice with them, and thus lower efficiency. This conjecture predicts that second-generation deaf people, who learn ASL early and have normal social lives would perform as well as hearing signers do.

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