requires further investigation. However, the dominant contribution to primary productivity by *Prochlorococcus*[10] is probably due, in part, to its divergence into distinct clades adapted to surface- and deep-water environments.

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Why people gesture when they speak

People use gestures when they talk, but is this behaviour learned from watching others move their hands when talking? Individuals who are blind from birth never see such gestures and so have no model for gesturing. But here we show that congenitally blind speakers gesture despite their lack of a visual model, even when they speak to a blind listener. Gestures therefore require neither a model nor an observant partner.

Gestures are produced by speakers from all cultural and linguistic backgrounds[1–3] and emerge in young children even before the development of language[4,5]. The spontaneous hand movements that accompany speech are not random but convey to listeners information[6] that can complement or even supplement the information relayed in speech[7,8]. Although a great deal is known about when and in what way speakers gesture, little is known about why they do it. We tested two possibilities that were not mutually exclusive.

The first possibility is that speakers gesture simply because they see others gesture, and learn from this model to move their hands as they talk. To test this idea, we studied spontaneous communication in 12 congenitally blind children and adolescents (4 males, 8 females) ranging in age from 9;1 (years; months) to 18;10 (mean, 12;10), and in a comparison group of 12 sighted children and adolescents (4 males, 8 females; ages 9;1–17;3, mean 11;11). The blind participants had minimal light perception at best, and no other known cognitive, emotional or physical deficits. Sighted participants were matched to blind individuals on the basis of age, gender and ethnicity.

Participants were videotaped while responding spontaneously to a series of reasoning tasks known to elicit gesturing in sighted children[9]. Speech and gesture were transcribed and coded according to a system developed previously[9]. Hand movements were coded as gestures only when they did not involve direct manipulation or exploration of the objects, had a clearly identifiable beginning and end, and were temporally correlated with speech. Agreement between coders was 87–90% for identifying gestures and coding their form.

We found that all 12 blind speakers gestured as they spoke, at a rate not reliably different from the sighted group (Fig. 1), and conveyed the same information using the same range of gesture forms. For example, both blind and sighted speakers tilted a C-shaped hand in the air as though pouring liquid from a glass to indicate that a liquid had been transferred to a different container. Blind speakers do not seem to require experience of receiving gestures before they spontaneously produce gestures of their own. Sighted speakers of different languages are known to gesture at different rates[3]. Given our findings, we might expect that congenitally blind speakers of different languages would not mirror these cross-linguistic differences (unless, of course, there are cultural and linguistic influences on gesturing that are transmitted at deeper levels than the eye).

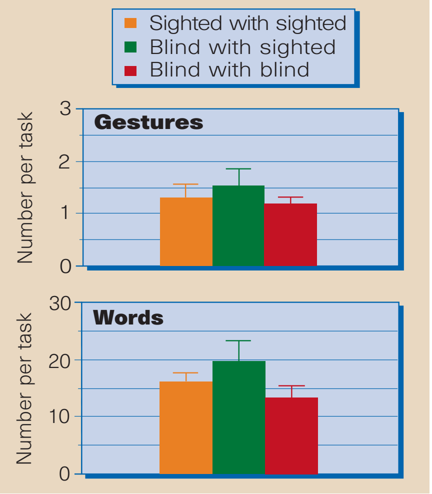

Figure 1 Mean number of gestures and words produced per task by 12 sighted and 12 congenitally blind speakers interacting with a sighted experimenter, and 4 congenitally blind speakers interacting with a blind experimenter. There were no significant differences in either gesture (Mann–Whitney $U = 65$, n.s) or word ($U = 69$, n.s) production comparing blind with sighted speakers, or comparing blind speakers interacting with blind versus sighted experimenters ($U = 21.5$ for gestures, $U = 16$, for words; both non-significant). Error bars show standard errors.

The second possibility is that speakers gesture because they understand that gestures can convey useful information to the listener. To test this hypothesis, we examined whether speakers gestured even when talking to a listener known to be blind, and thus obviously unable to profit from information conveyed by gesture. We asked four additional children (1 male, 3 females; ages 5;0–8;6, mean 7;6), each blind from birth, to participate in the same reasoning task. These subjects were told that the experimenter herself was blind. Nevertheless, all of the blind speakers gestured, and did so at a rate not reliably different from that of sighted-with-sighted or sighted-with-blind pairings (Fig. 1). The 4 blind speakers interacting with a blind experimenter were younger than the 12 blind speakers interacting with a sighted experimenter. We therefore compared them with a subset of the 12 matched for level of performance on the tasks, and again found no differences in gesture or word production. Thus, blind speakers do not seem to gesture solely to convey information to the listener.

The relatively small number of speakers in the blind and sighted groups may have made it difficult to detect a difference in gesture usage. The important point, however, is that all 16 of the blind speakers produced gestures resembling those of the sighted speakers.

Our findings underscore the robustness of gesture in talk. Gesture does not depend on either a model or an observer, and thus appears to be integral to the speaking process itself. These findings leave open the possibility that the gestures that accompany speech may reflect[7], or even facilitate[10], the thinking that underlies speaking.

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