
Speechreading skill and visual movement sensitivity are related in deaf speechreaders

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Abstract. Individual speechreading abilities have been linked with a range of cognitive and language-processing factors. The role of specifically visual abilities in relation to the processing of visible speech is less studied. Here we report that the detection of coherent visible motion in random-dot kinematogram displays is related to speechreading skill in deaf, but not in hearing, speechreaders. A control task requiring the detection of visual form showed no such relationship. Additionally, people born deaf were better speechreaders than hearing people on a new test of silent speechreading.

1 Introduction

Speechreading is the ability to understand natural speech from the visually perceived actions of the talker. For hearing people listening to clear speech, its utility may seem limited. This is primarily because many of the informative articulatory actions of speech, involving movements of the tongue within the mouth, are hidden from view. Nevertheless, seen speech can support speech comprehension to some extent and can be an important source of information when following natural speech in noise. Having sight of the talker in a noisy environment can improve the intelligibility of the message by a value equivalent to an increase of 15 dB in signal-to-noise ratio (Sumby and Pollack 1954). For people born deaf, and for those with acquired hearing impairment, speechreading (with or without hearing aids) is the major source of speech, allowing access to the spoken language of the community.

How can silent speechreading be achieved? Some features of seen speech are relatively unambiguous (eg labiodental consonants, English point vowels). Usually, a seen speech event maps onto several (acoustically defined) phonological categories. Visually confusable phonemes can be considered to constitute a phonemically equivalent class (PEC—Auer and Bernstein 1997). The number of PECs will vary from person to person, depending on their speechreading skill and on the visibility of the talker's speech. Using a computational modeling approach, Auer and Bernstein (1997) found that 12 PECs were sufficient to identify most English words. This number corresponds well with theoretical studies suggesting this number of distinctions should suffice for useful visual speechreading (Jackson 1988) and contrasts with estimates of around 40 phonemes available 'by ear' in spoken English. The reason why a relatively small number of PECs can, in principle, suffice for identifying individual spoken words is that most words in English are relatively unique in their segmental and syllabic structure. That is, the 'lexical space' of English is relatively sparsely occupied and well-distributed (MacEachern 2000). Heard speech can, on this type of analysis, be considered to be overdetermined, containing a great deal of structural redundancy. In theory, therefore, some people may attain good speech comprehension by sight, at least under optimal talking and viewing conditions.

In addition, most speech that we perceive is uttered in a context that is limited by sentential, thematic, and pragmatic constraints. In principle this, too, can make the comprehension of seen speech less formidable than it might first seem.

Which visual characteristics of the seen speech event are used by the speechreader? One means of exploring this question is by measuring the effects of dubbed vision on heard speech segments in hearing people. The best known of these was first demonstrated by McGurk and his colleagues (McGurk effects; see McGurk and MacDonald 1976). In this illusion, a heard bilabial syllable such as 'ba' or 'pa' is dubbed to a visual clip of 'ga' or 'ka' appearing to be spoken. The perception is that 'da' or 'ta'—syllables intermediate in place of articulation between the heard and the seen event—was spoken, and this is what perceivers report when asked to say what they heard. When the visual characteristics of the display are altered, the illusion may be reduced. Such changes in susceptibility to visual influences on audition are usually considered in terms of the changes in visual form of the seen articulators, such as the visibility of the tongue between the teeth (th/v), and the shape of the lip configuration typical of a specific vowel, or of the role of the configuration of face features within the overall facial contour (eg Hietanen et al 2001). However, time-varying changes in face displays that lack delineated visual form are also implicated in McGurk illusions. Rosenblum et al (1996) showed that point illuminations on the surface of a talker's face could generate McGurk effects in the perceiver. In such displays there is no indication of the shape or extent of facial features such as lips, tongue, and teeth, but only the perception of localised movement patterns on the face surface.

Neuropsychological dissociations also suggest that the dynamic, time-varying characteristics of seen speech are important in audiovisual and visual speech processing. One patient with a profound deficit in identifying visual forms due to damage to occipito-temporal brain regions (damage to the ventral visual stream) was nevertheless susceptible to the McGurk illusion, although he was unable to identify any speech gestures from photographs of the mouth and face alone (Campbell 1992). By contrast, a patient with an acquired cortical blindness for visual movement was unable to speechread natural speech, despite good identification of speech patterns from photographs (Campbell et al 1997). Visible movement patterns of the mouth, face, and head are systematically correlated with auditory components of the speech signal produced by the talker. Some aspects of the auditory speech signal can even be predicted from visible signal kinematics. Yehia et al (1998) demonstrated reasonably accurate 'recapture' of an auditory message from analysis of the temporal patterning of head and face movements during speech.

These considerations all suggest that, among other perceptual factors, sensitivity to visual movement may be a correlate of individual speechreading skills. We explored the extent to which a perceptual test of motion-coherence sensitivity might relate to individual differences in speechreading ability in adults, using a newly devised speechreading test for British adults.

Speechreading is a skill that varies greatly as a function of the type of test and the people tested (Jeffers and Barley 1971; Kricos and Lesner 1982). The new test was designed to be particularly appropriate for use with Deaf⁽¹⁾ as well as hearing individuals. Deaf people, many of whom are bilingual in speech and British Sign Language (BSL), can show marked differences from hearing people in their vocabulary and syntactic skills (Bishop 1983; Geffner and Freeman 1980). In this new speechreading test, the Test of Adult Speechreading (TAS—see Ellis et al 2001; Mohammed et al 2003), the use of a simple vocabulary and syntax familiar to Deaf adults ensured that Deaf participants were not disadvantaged. The response mode, with picture choices only, similarly ensured that no

⁽¹⁾Deaf with an upper case 'D' is a widely accepted way of denoting cultural deafness and describes people who choose to identify with the Deaf community; 'deaf' with a lower case 'd' is a broader term which can refer to anyone with a hearing loss. Not all people who are deaf choose to be Deaf.

advantages would accrue to fluent users of written or spoken English (predominantly hearing people). That is, the test was designed to be sensitive to the *perceptual* abilities that may underlie efficient speechreading, while holding the speech and linguistic requirements at an appropriate level.

In a college population of profoundly deaf ($n = 72$) and hearing ($n = 90$) individuals, measures of phonetic accuracy of report of silently spoken items were consistently higher in the hearing-impaired than the normal-hearing group (Bernstein et al 2000). On the basis of the principled exposition above on the relatively meagre requirements for identifying words in English from sight alone, and given the 'Deaf-friendly' changes in test design from those that stress spoken output, we predict that, as in Bernstein et al's study, the deaf participant sample may outperform hearing people on this new test.

To date, individual differences in speechreading skill have been investigated mainly in relation to specific cognitive and psycholinguistic factors, rather than visual ones. Thus, although many studies suggest that (nonverbal) IQ is a poor predictor of speechreading efficiency (eg Elphick 1996; Jeffers and Barley 1971), the ability (in hearing people) to comprehend noisy auditory speech does predict speechreading skill (Watson et al 1996). Verbal working memory for subjects of varied age and hearing status has been shown to be better in good than in poorer speechreaders (eg Lidestam et al 1999). Among more purely visual predictors, cognitive style has been implicated. Good speechreaders show more field independence in the rod-and-frame test (Mead and Lapidus 1989). Interestingly, in the light of the concerns of the present study, Shepherd et al (1977) reported visually evoked electrophysiological responses that showed peak-latency differences as a function of speechreading skill in a population of naïve hearing participants. In hearing-impaired people, some ERP measures of early occurring visual responsiveness (VR16 responses) were faster and more pronounced than in hearing people (Samar and Sims 1984). Although these findings are not always replicated, they suggest that speechreading skill may be related to individual differences in low-level visual processing. A robust finding is that sensitivity to visual movement in the peripheral visual field is greater in deaf than in hearing people, and may be modified by early exposure to a signed language (Bavelier et al 2001; Neville and Lawson 1987). However, behavioural sensitivity to visual movement that is not confined to the periphery appears to be no better in deaf than in hearing people (but see Armstrong et al 2002), and has not hitherto been tested in relation to speechreading.

Could visual-form sensitivity contribute to speechreading skill? There are reasons to doubt that individual differences in visual-form sensitivity, in normally sighted people, are a particularly critical aspect of speechreading. Although the viewer has to have sight of the mouth, lips, teeth, and tongue of the talker to gain most from speechreading (Summerfield 1979), this may solely set a lower limit on the visibility characteristics of the talker's face for speechreading. On the basis of an auditory speech study (Strange et al 1983), Yakel and Rosenblum (Yakel 2000; see Rosenblum in press) have shown that the lipreading of VCV bisyllables was best when *only* the time-varying, co-articulated portions of the syllable were visible. Subjects had sight of the relatively unchanging, sustained mouth pattern of the vowel nucleus of each syllable; this impaired accurate speechreading when compared with viewing clips where these portions of the articulation were excised and replaced with a dark screen. Speech, whether heard or seen, appears to rely critically on information carried in its dynamic properties—properties associated with its articulation (Summerfield 1987). On the basis of such reports, and in the absence of reports of associations between form perception and speechreading, we predict no association between individual speechreading abilities and visual tests of form discrimination.

What of group differences in sensitivity to visual form? There are some, slight, indications that (adult) deaf people can sometimes outperform matched individuals with normal hearing at some visual-form detection tasks, suggesting a slow-developing compensation

for hearing impairment (Rettenbach et al 1999). These small effects were confined to attention-demanding target search. In the domain of face processing, McCullough and Emmorey (1997) found that face features can be better recognised by Deaf than by hearing adults. However, such positive findings are remarkable for their scarcity. Many investigators have tried, and failed, to find ‘compensatory superiority’ for deaf people in visual task performance. We predict no group differences in sensitivity to visual form.

We used a test of visual motion coherence in which random-dot kinematograms generate images of coherent motion, continuously moving from right to left and then left to right. By varying the proportion of coherently moving dots in each test image, individual thresholds for detecting movement can be determined. The motion-coherence test has been shown to be sensitive to a number of developmental conditions, including reading disability (Conlon et al 2004 for review; Solan et al 2003), autism (Milne et al 2002; Spencer et al 2000), and Williams’ syndrome (Atkinson et al 1997, 2003; Nakamura et al 2002). As a test of sensitivity to global second-order motion, the test of motion-coherence threshold (MCT) has psychological validity and reliability and is sensitive to individual differences within and across a range of tested groups. A similarly structured visual form-coherence test (FCT) is usually administered in the same session as the MCT task, and follows an identical testing procedure. In this task, a visual form (a circle) has to be discriminated by its visual texture, which is composed of a large number of short, aligned lines among unaligned line elements. As the alignment of these texture elements decreases, so the visual form becomes increasingly hard to distinguish from the visual noise. FCT can also be differentially sensitive to group differences. O’Brien et al (2002) report that FCT, but not MCT, was impaired in a group of dyspraxic children compared with normal controls.

The questions addressed here are as follows: Do deaf people perform better than hearing people on the speechreading test? Are individual differences in speechreading skill predicted by visual threshold test scores in either group? We speculate that, in this test of speechreading, deaf people may outperform their hearing peers and, also, that their developmental dependence on visual sources of speech might be reflected in a closer relationship between speechreading and MCT scores. The relationship between FCT and speechreading was also of interest, but no predictions were made concerning an association with speechreading in either the hearing or the deaf group.

2 Methods

2.1 Participants

Fifty-eight adults, aged between 15 and 76 years, undertook both the speechreading test and two tasks of visual functions—a test of coherent visual motion and a corresponding test of visual form perception (see descriptions below). Twenty-nine participants had a profound or severe hearing loss (the deaf group), and twenty-nine had normal hearing (the hearing group). Participants were volunteers, recruited through deaf clubs, college sources, and acquaintances. All participants were screened. The first screening requirement was for first language. In hearing and oral deaf participants, English was required as a first language. For people with BSL as a first language and who had hearing parents, their spoken first language was required to be English. Deaf offspring of deaf parents were required to have been born in the UK or Eire. Participants were also screened for nonverbal IQ. Only those with IQ above 80 were selected for further analysis. Reports of audiological testing (pure tone audiometry) of the deaf participants as adults indicated that all the tested individuals had a hearing loss greater than 88 dB (unaided) in their better ear when averaged over all tested tones (typically 0.5, 1.2, and 4 kHz). All participants had normal or corrected-to-normal vision and no additional disabilities.

This sample was randomly selected from a much larger population (approximately two hundred people) whose speechreading has been investigated. It includes a relatively large proportion of hearing people with deaf parents who were recruited for brain-imaging studies of BSL (MacSweeney et al 2004) and whose speechreading skill was determined for secondary reasons. The twenty-nine hearing participants self-reported normal hearing through a questionnaire and the twenty-nine deaf participants had a profound or severe hearing loss reported from birth or within 5 years of birth. Given that many severe profound hearing losses are progressive in adulthood, some of the deaf participants may have experienced milder impairments in early childhood than they experience now; in other words, we cannot rule out early hearing experience as a factor in any of the results with deaf participants. Five deaf participants reported 'early' hearing loss (under the age of 2 years) rather than congenital hearing loss. All five had hearing parents and, of the five, one was male. The major demographic characteristics of the two groups are summarised in table 1.

Table 1. Demographic characteristics of the two groups of participants.

	Deaf	Hearing
Number of participants	29	29
Age in months (standard deviation)	441 (118)	405 (165)
Gender (number of males)	13	9
Parental hearing status (number of hearing parents)	18	21
NVIQ centile (and range)	82.6 (25–99)	75.4 (25–99)
Number who had completed higher (degree-level or equivalent) education	13	15

The deaf participants in this study were drawn from a variety of schooling and language backgrounds. Further demographic and educational characteristics of the deaf group (eg schooling, literacy, nonverbal IQ, vocabulary skills, and language preferences) which may have a bearing on speechreading ability are discussed elsewhere (Ellis et al 2001; Mohammed et al 2003). Preliminary analyses indicated that these factors do not affect visual function as tested here. Further, the major demographic variables (age, gender, parental hearing status) did not affect the pattern reported below with respect to the relationship between motion-coherence detection and speechreading.

2.2 *Speechreading test*

The Test of Adult Speechreading (TAS) required participants to view a short speech segment—a word, a sentence, or connected speech—and to match it to one image from an immediately following set of six pictures. The dependent variable was accuracy of match. Test instructions and practice feedback were delivered in the preferred communication mode of the respondent (English, or British Sign Language), and the vocabulary and syntax used in the speech segments was selected, following screening by a panel of Deaf advisors, as being appropriate for use with Deaf people (see Ellis et al 2001). Items were spoken by two native British English talkers, one male and one female, seen speaking each item alternately, in a head-and-shoulders full-face view (Mohammed et al 2003). Talkers were recorded audiovisually under frontal illumination as they spoke the test items using natural speech patterns. The video clips were digitised and displayed on a laptop computer, where our own experimental software was used to display each clip, followed by its corresponding picture-response set, and to record each participant's choice of response item (see figure 1 for example). Participants were instructed that they would be required to identify a speech event by matching it to a subsequent picture. They were given some exposure to the speech patterns of the two talkers, who were not familiar to any of the participants: the laptop

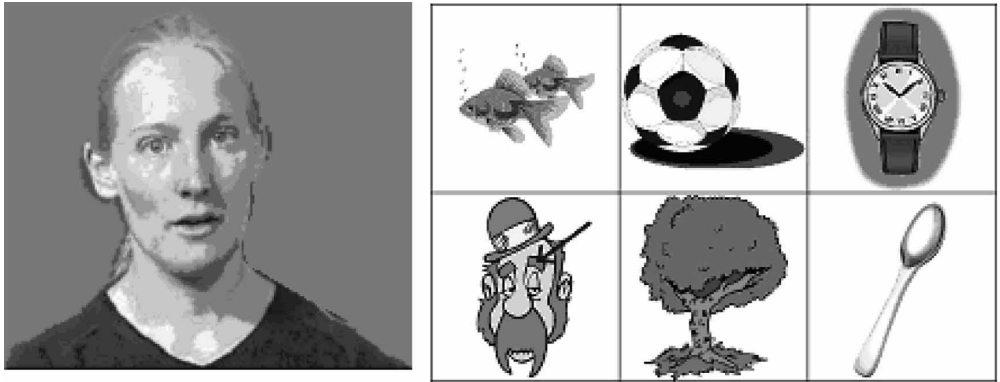


Figure 1. Still image of the practice test item ‘fish’ being spoken by one of the talkers, as she appeared in the test, and the corresponding response grid of picture choices.

display showed each talker in turn speaking the seven days of the week. This was followed by specific instructions, practice items, and then test items in each subset.

The scored test comprised three core subtests occurring in the following fixed order:

(a) *Single words*: there were 4 practice items, followed by 15 test items (10 monosyllables and 5 spondees). Participants saw an isolated word as it was spoken and then selected the picture of that word from a choice of six.

(b) *Sentences*: 3 practice items, followed by 15 test items. Participants saw a short sentence (of 3 to 6 words) spoken and then selected the picture of that sentence from a choice of six.

(c) *Connected speech*: 1 practice story, followed by 5 test stories. Participants saw a short story (2 or 3 sentences) spoken; then they were asked 3 questions about that story in their preferred language (written English or BSL), and answered each one by selecting a picture from a choice of six.

Each participant completed the test individually on a laptop computer in a quiet room, which took around 20 min. Since each subtest comprised 15 items, the maximum score was 45. The sum score (out of 45, or its percent transform) was used as the dependent variable.

2.3 Motion-coherence and form-coherence tasks

We followed the procedure outlined by Hansen and colleagues to determine psychophysical thresholds for coherent motion and form detection (Hansen et al 2001). The visual tests were displayed on a 17 inch PC screen, at a viewing distance of approximately 50 cm, and were administered to each participant in a quiet, darkened testing room.

2.3.1 Motion-coherence threshold (MCT). A standard random-dot kinematogram stimulus was used, consisting of two horizontally adjacent panels of moving dots. Each panel contained 300 white dots of high Michelson contrast ($\sim 90\%$) superimposed on the black background of the computer screen. The dots were 1 pixel in size, approximately $0.1 \text{ deg} \times 0.1 \text{ deg}$, and each panel was rectangular, subtending $10 \text{ deg} \times 14 \text{ deg}$ and separated horizontally by 5 deg. One panel contained a variable proportion of target dots that moved coherently (at 7 deg s^{-1}) from left to right and right to left over successive screen refreshes, whilst the remaining noise dots in the panel moved with the same speed but in a direction that randomly changed between refreshes (Brownian motion). The other panel contained only noise dots. To prevent tracking of individual dots, the lifetime for each dot was fixed at three animation frames (85 ms) after which time the dot was regenerated at a random position inside the same panel.

2.3.2 Form-coherence threshold (FCT). The form-coherence threshold task was designed to be similar in application to the motion task. As before, two rectangular panels were presented side by side, matched in size and overall luminance to the motion task. Each panel consisted of 600 short, high-contrast (Michelson contrast $\sim 90\%$) line elements, with each element being 0.4 deg in length. In one panel there was a coherent form signal, defined by line elements that were oriented tangentially to an imaginary concentric circle within an area of 8 deg diameter. At 100% coherence, therefore, all line elements within the 8 deg boundary were perfectly aligned and the circle was easy to perceive. Elements outside the 8 deg area, and all elements in the alternative panel, were oriented randomly.

In both tasks signal coherence was varied by modifying the percentage of coherent elements. Initial coherence was set at 75% and then adjusted with a weighted (1.5 : 0.5 dB ratio) one-up, one-down adaptive staircase (Kaernbach 1991). The procedure terminated after 10 reversals and final threshold was calculated as the geometric mean of the last 8 reversal points.

Both the motion and the form task contained a percentage of catch trials. These were trials in which the form or motion was presented at 75% coherence, which is easily perceivable to a typical observer. Figure 2 shows a schematic illustration of stimuli from the motion and form tasks.

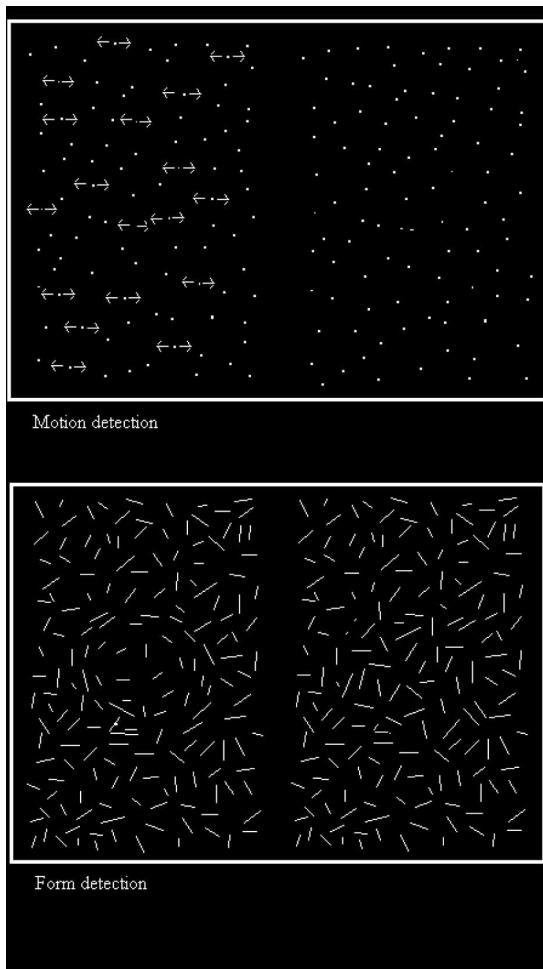


Figure 2. Schematic illustration of stimuli from the motion and form tasks. In both images, the panel on the left shows the coherent form or motion.

3 Results

3.1 Statistical treatment of dependent variables—motion-coherence threshold (MCT) and form-coherence threshold (FCT) scores

3.1.1 *Coherence threshold measures.* Two MCTs and two FCTs were measured for each participant. The Pearson correlation between first and second performance was 0.61 ($p < 0.001$) for the MCT and 0.27 ($p < 0.05$) for the FCT. The mean of the two thresholds was the dependent measure for each test.

3.1.2 *Normalisation of dependent variable.* The distribution of MCT scores was positively skewed⁽²⁾ (1.137). In order to obtain maximum statistical sensitivity in these analyses of individual difference, a base-10 logarithmic transform was applied to these data, which restored normality (skew = -0.035 ; Shapiro–Wilk statistic = 0.99, $df = 56$, $p = 0.84$; see Shapiro and Wilk 1965). Unless otherwise indicated, $\log(\text{MCT})$ was the dependent variable examined. FCT scores did not require normalisation (skew = -0.060 , Shapiro–Wilk statistic = 0.99, $df = 56$, $p = 0.86$), and the raw mean score was used in all analyses.

3.1.3 *Group comparisons.* Independent t -tests were used to explore group differences in performance in speechreading and the visual tasks. These results are summarised in table 2. They show that the deaf group were better speechreaders than the normally hearing group. No other differences approached significance. In particular, the psychophysical tests of motion and form coherence were similar in the two groups.

Table 2. Summary of the results.

	Mean		Standard deviation		Standard error mean	
	deaf	hearing	deaf	hearing	deaf	hearing
Speechreading (TAS accuracy/%)	67.82	57.70	11.69	11.12	2.17	2.06
Motion-coherence threshold	11.68	10.93	5.69	4.28	1.06	0.81
Form-coherence threshold	16.22	16.18	3.03	4.08	0.56	0.77

3.1.4 *Speechreading—correlations with visual test scores.* In the deaf group as a whole, the motion-coherence score [$\log(\text{MCT})$] correlated with speechreading skill ($r_{29} = -0.31$, $p < 0.05$, one-tailed). Lower motion coherence was associated with good speechreading. When the five individuals who reported onset of deafness in early life rather than from birth were excluded, the correlation was even greater ($r_{24} = -0.44$, $p < 0.02$, one-tailed). In the hearing group, the correlation, although negative, was not significant ($r = -0.10$). The scattergrams for these scores are shown in figure 3. The form-coherence score failed to correlate significantly with speechreading ability in deaf ($r = -0.13$) or in hearing ($r = -0.14$) groups.

3.1.5 *Predictors of variance in speechreading: regression analyses.* Simple regression (SPSS procedure) was used to test the hypothesis that motion coherence and form coherence contributed, separately, to variance in TAS. These analyses were performed separately for each group, with the prediction that the visual tasks, especially $\log(\text{MCT})$, may predict TAS performance in the deaf group. For a group of (approximately) thirty participants, two predictors per analysis allow reliable inferences to be drawn from the regression model (Tabachnick and Fidell 2000). In each regression analysis the dependent variable was TAS score, and the predictors were the $\log(\text{MCT})$ and FCT scores.

⁽²⁾ Following these results, we have re-examined previous studies using this variable (Solan et al 2003) and find those data to be skewed. Future analyses should transform appropriately.

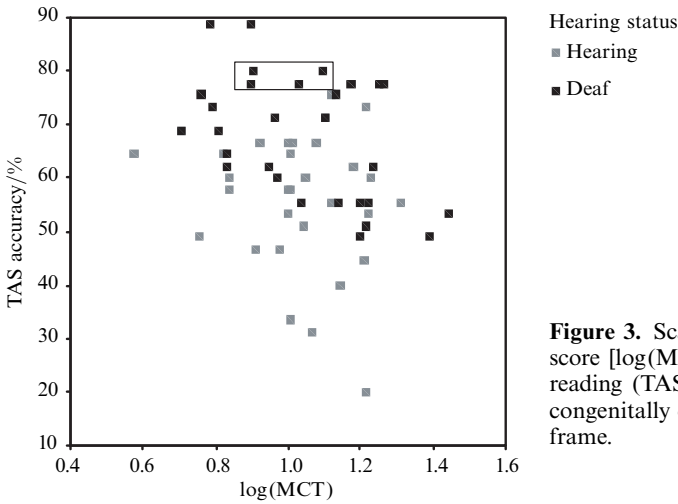


Figure 3. Scattergram of motion-coherence score [$\log(\text{MCT})$] and Test of Adult Speechreading (TAS) score. The five early but not congenitally deaf are shown within the small frame.

(i) *Deaf.* The model comprising the two predictor variables accounted for a significant amount of variance in TAS scores (R^2 change = 0.235, $F_{2,28} = 3.99$, $p < 0.03$). Examination of the coefficients showed that only $\log(\text{MCT})$ score was critical to the prediction, with $\beta = -0.47$, $t = -2.72$, $p < 0.02$. The FCT score had no significant effect.

(ii) *Hearing.* No combination of $\log(\text{MCT})$ and FCT scores predicted variance in TAS scores in this group.

4 Discussion

Deaf people outperformed hearing people on TAS. We have reported elsewhere on the superiority of deaf speechreaders compared with hearing speechreaders on TAS (Ellis et al 2001; Mohammed et al 2003). As the test was designed to optimise perceptual aspects of speechreading, this finding was not unexpected, and confirms and extends studies showing that deaf people can speechread better than hearing people (Bernstein et al 2000). These demonstrations counter earlier generalisations suggesting that hearing people outperform deaf people at speechreading (Mogford 1987). Different tests deliver different findings dependent on a number of test factors (tests may load differentially on auditory speech competence or on visual skill) and participant factors (age of acquired deafness, parental language, schooling). The superiority of deaf speechreading in this test, as in some others, suggests that, when these factors are reasonably well controlled, deaf people may make better use of visible cues to lexical identification than hearing people. This, too, is unsurprising: hearing people have access to very reliable and detailed speech information by ear—their experience in relying on seen speech is less consistent and less extensive than that of someone born deaf whose speech perception experience reflects her/his use of seen speech and hearing aids.

The new finding, however, was that a simple test of visual motion coherence was significantly associated with good speechreading skill in the deaf participants. A task of form coherence with identical testing procedures and very similar parameters showed no such relationship with speechreading, despite evidence that visual speech forms deprived of natural visual movement can affect reports of auditory events (Cathiard and Tiberghien 1994) and can show patterns of cortical activation that do not differ greatly from those of naturally moving speaking faces (Calvert and Campbell 2003). Nor were FCT thresholds lower in deaf than hearing participants. It is unlikely that this null result simply reflects reduced sensitivity of the FCT test compared with the MCT task. One study (O'Brien et al 2002) has shown that dyspraxic children were impaired on FCT but not MCT. It would seem, therefore, that individual differences in form sensitivity

are less important for speechreading than sensitivity to movement, and that form sensitivity (at least as tested by this procedure) is no better in deaf than hearing people.

While these findings suggest that sensitivity to coherent visual motion in the central visual field under conditions of attentive report is associated with speechreading, they do not tell us much about the direction of the relationship, or its links with other possible factors. Do practice and experience at speechreading help to develop sensitivity to motion coherence, or does prelingual deafness itself 'reset' visual processing abilities to effect a range of compensatory behaviours for hearing loss? A hint that very early hearing loss itself may be a key factor comes from consideration of two aspects of the data. First, the correlation between the log(MCT) score and speechreading skill was elevated when the five individuals who reported early, but not congenital, hearing loss were excluded from the data set (figure 3). Impaired hearing *in infancy* may be critically related to speechreading skill. Second, speechreading differences in deaf and hearing people can be affected by parental hearing status. Hearing offspring of Deaf parents are better speechreaders than other hearing people (Mohammed et al 2003). Thus, speechreading skill is sensitive to the early communication environment of the speechreader as well as individual hearing status. This was reiterated in the present study, where only one of the eight hearing participants with deaf parents had TAS scores below the median. However, motion-coherence thresholds in the eight hearing participants with deaf parents were slightly, but not significantly, *higher* than those of hearing people with hearing parents. Very-early-onset deafness, rather than early-life communication environment, may be the main determinant of the link between individual MCT scores and speechreading.

The MCT task has been characterised as a task of global second-order motion detection, as it reflects not just a difference in local luminance caused by movement of elements in the visual field, but also the spatial displacement of a texture pattern, requiring integration over a large part of the visual field to determine whether movement occurs. In turn, this form of movement processing is assumed to be associated with a range of higher-order visual functions, including the perception of biological motion. In people born deaf, there is evidence that some forms of motion processing are enhanced as a result of early auditory deprivation. A robust finding is of greater behavioural and cortical sensitivity to movement, and of enhanced attention to motion in the peripheral visual field in deaf compared with hearing people (Armstrong et al 2002; Bavelier et al 2000, 2001; Neville et al 1982; Neville and Lawson 1987). A further finding is that regions that subserve audition in hearing people can be activated by dynamic visual movement in people born deaf (Finney et al 2003). In studies of the behavioural sensitivity to movement in different regions, including the central visual field, no results have been reported that suggest that deaf people have greater behavioural sensitivity than hearing people. The present study was no exception to this: MCTs were no lower in deaf than in hearing people. Deafness only impacted on the *association* between speechreading and MCT.

The MCT task is generally taken to indicate the contribution of magnocellular, and especially dorsal stream, function, notwithstanding some contribution from the ventral processing stream (and parvocellular processing) to movement perception. Dorsal stream function appears to be relatively sensitive to developmental influences, showing anomalies in a range of genetic conditions that are evident in infancy and childhood (Braddick et al 2003). Dorsal stream function may develop differently in deaf than in hearing people, so that deaf people can make relatively greater use of dynamic visual information than hearing people (Bavelier and Neville 2002). The finding in the present study that the association between relatively low-level visual dynamic motion processing and a high-level speechreading task was stronger in congenitally deaf than in hearing people suggests that the cortical events supporting these processes also differ as a function of hearing status. The delineation of these events awaits further research.

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