ISCA Archive
http://www.isca-speech.org/archive

AVSP 2003 - International Conference
on Audio-Visual Speech Processing
St. Jorioz, France
September 4-7, 2003

Developing the TAS: Individual differences in silent speechreading, reading and phonological awareness in deaf and hearing speechreaders

Tara Ellis Mohammed, Mairéad MacSweeney and Ruth Campbell.

Department of Human Communication and Brain and Behaviour Unit, Institute of Child Health, University College London, UK

tara.mohammed@ucl.ac.uk

ABSTRACT

We report new developments in the TAS: the Test of Adult Speechreading, a test designed to be appropriate to the needs of both deaf and hearing users [1]. Profoundly prelingually deaf people outperform hearing users on this test. Subtests of TAS showed different patterns of inter-correlation in deaf and hearing people, suggesting different underlying factors accounting for individual variability in speechreading which depended on hearing status. Although reading was poorer in deaf than hearing groups, it correlated with phonological awareness and with TAS scores. Phonological awareness may have performed a mediating role in the relationship between reading and silent speechreading in deaf participants. There was no relationship between reading and TAS in the hearing users.

1. INTRODUCTION

1.1. The TAS and its development

The **T**est of **A**dult **S**peechreading is a test of silent or audiovisual speechreading, designed to fit the needs and language skills of deaf (as well as hearing) users. For many deaf people speechreading is important as a means to understand a spoken communication, but not in order to reproduce the speech patterns of those who can hear. Thus the TAS is a *perceptual* test. It uses only pictures as response choices. Instructions and communication with the respondent are in their preferred communication mode. The linguistic material in TAS has been refined, with the help of deaf users, to fairly reflect the vocabulary and English syntax accessible to deaf users.

In a previous report [1], we outlined some demographic findings using an earlier, video-based version of the TAS: these included reliably better silent speechreading performance in deaf than hearing users; better performance by hearing people with deaf parents; better performance when regional accents matched those of the speaker – and the expected age and gender effects. The hearing status effect echoes, in the broader community, findings suggesting deaf college students (selected to have speechreading as a socially important skill) are better speechreaders than hearing students [2].

1.2. Refinements of the TAS

The TAS has now been digitised, and the program includes

- Instructions: available in written English or British Sign Language;
- Talker introduction: each talker says the days of the week to introduce users to the stimuli format, and to the talkers' speaking patterns;
- Spoken stimuli from 2 talkers: 1 male, 1 female, recorded in a head and shoulders view;
- Response pictures: users respond to each item by clicking on one of six pictures with the mouse;
- Scoring: a participant's results are available as soon as they have completed the test.

The TAS comprises three linguistically distinct subtests: (a) single word identification, (b) short sentence identification, and (c) comprehension of connected speech. In addition, two further subtests have been developed: *minimal pair* word identification, where the discrimination of two words rests on a single visible phonemic feature, and detecting *lexical stress* in a speechread sentence.

An examination of the inter-correlations and patterns of performance on these tasks should elucidate the relative importance of the different skills underlying speechreading ability for specific groups, in particular, the relative importance of ‘bottom-up’ (i.e. minimal pairs) and ‘top-down’ (i.e. stories) processing in speechreading [3, 4]

1.3. Literacy, deafness and speechreading

One reason for the use of picture-pointing responses in TAS (rather than a written response) is the failure of many deaf people to acquire functional literacy. Recent surveys confirm that most deaf readers lag their hearing peers by at least four years and many leave secondary education with very poor literacy skills [5].

One purpose of this study was to explore the extent to which speechreading performance (uncontaminated by written responses) may be related to reading achievement in deaf speechreaders. We were also interested in the relationship between speechreading and reading in hearing people. Previous studies suggest that dyslexic readers may also have difficulties with silent speechreading (e.g. [6]), or with audiovisual integration [7]. Recent neuroimaging evidence [8] confirms that cross-modal integration deficits characterize dyslexia. In hearing people, the neural organization of silent speechreading may reflect the experience of audiovisual congruence [9]. It would then follow that reading and speechreading abilities should correlate in hearing populations with reading skills in the normal range.

2. METHOD

2.1. Participants

40 deaf and 44 hearing participants took part in this part of the study. All participants were volunteers, and were paid for their time. They were selected to meet the following criteria:

- Aged 18+ yrs
- Reported normal, or corrected to normal vision
- English or BSL as a first language
- No reported disabilities (other than deafness)
- NVIQ not less than 2 standard deviations below the population mean

In addition, the deaf participants were selected to have

- A profound or severe hearing loss
- Early onset hearing loss (prior to 4 yrs)

As Table 1 shows, deaf and hearing participants did not differ significantly in age, gender or NVIQ; however, a significantly greater proportion of the deaf participants had deaf parents.

Hearing Status		Age (yrs;mths)	NVIQ (%ile)	Gender		Parents	
				M	F	H	D
Deaf	N	40	40				
	mean	35;11	80.09	14	26	22	18
	(s.d.)	(9.81)	(21.20)				
Hearing	N	44	44				
	mean	34;9	77.79	15	29	40	4
	(s.d.)	(12.93)	(20.59)				

Table 1: Summaries of the participants’ ages, and non-verbal IQ; the numbers of male (M) and female (F) participants, and the number with hearing (H) and deaf (D) parents.

2.2. Tests

2.2.1. Tests of Speechreading

All speechreading tests were presented silently on a laptop computer in a quiet room.

TAS: As stated above, the Test of Adult Speechreading comprises three core subtests:

(a) Single words: there are 4 practice items, followed by 15 test items (10 monosyllables and 5 spondees). Participants see a word spoken and then select the picture of that word from a choice of six.

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

(c) Connected speech: 1 practice story, followed by 5 test stories. Participants see a short story (2 or 3 sentences) spoken, then they are asked 3 questions about that story in their preferred language (written English or BSL), and they answer each one by selecting a picture from a choice of six (maximum score for this subtest is 15).

Minimal Pairs: This subtest consists of 30 CVC words (with 3 initial practice items). Participants see a word spoken and then select the picture of that word from a minimal pair choice. Ten of the items are from word initial pairs (e.g. ‘bone’, ‘phone’), ten are word final (e.g. ‘kick’, ‘king’), and ten are word medial (i.e. vowels, e.g. ‘sheet’, ‘shirt’). All words have high familiarity and frequency, and these factors were controlled such that there is no significant difference between the target and distracter words, or between the word positions.

Sentence stress: This subtest consists of ten sentences (with 2 initial practice items). Participants see a written sentence with five of the words highlighted and pictured to familiarise them with the sentence to be spoken (e.g. figure 1):

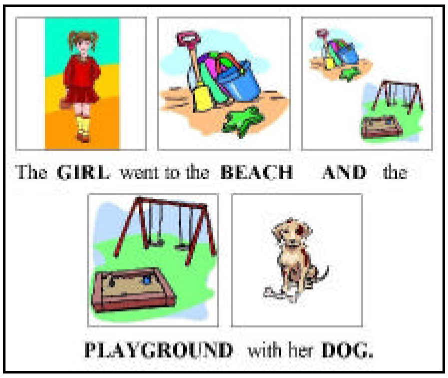

Figure 1: A familiarisation / response screen for the sentence stress subtest.

They then see the talker say the sentence, placing lexical stress on one of the pictured words. The sentence and pictures are then seen again, and the task is to select the picture of the word which carried the lexical stress.

2.2.2. Tests of Reading

No available single reading test was suitable to test the reading age range of both the deaf and hearing respondents. We therefore administered two tests: the Group Reading Test, 2nd edition, (GRT II) form D (NFER Nelson), and the more difficult Kirklees Reading Assessment Schedule (Vernon-Warden Reading Test). Both are tests of reading comprehension and deliver a reading-age score. This allowed a reading age of between 6;8 and 23;0 to be identified for each participant.

2.2.3. Tests of Phonological Awareness

The phonological awareness score reported here is a mean percentage accuracy score from three phonological awareness tasks. The tasks focus on the rhyme, onset and vowel, and initial phoneme of words respectively. They are picture-based, and the pictures are named prior to testing to ensure that each picture is associated with the intended word. Participants make button-press responses to indicate whether the specified part (rhyme, phoneme, or onset and vowel) of a pair of words is the same or different.

2.2.4. Tests of NVIQ and Vocabulary

Non-verbal IQ was tested using the block design task from the WAIS.

A measure of vocabulary was obtained using an adapted version of the Boston Naming Test, from which 30 (non-specifically Northern American) items were selected.

3. RESULTS

3.1. Speechreading: core TAS subtests

Deaf people were better at the TAS (core subtests) than hearing people ($t(82) = 6.29$, $p<0.001$). This advantage survives even when demographic variables are tightly controlled: 20 pairs of deaf and hearing individuals were matched closely for:

- Gender: 7 male, 13 female pairs;
- Age: matched to be within 5 years; mean ages were 38;2 years (deaf participants) and 36;9 years (hearing participants);
- Parental hearing status: 3 pairs had deaf parents;
- Regional spoken accent: 12 pairs had an accent similar to that of the talkers;
- Non-verbal IQ: deaf mean: 80.8, hearing mean: 77.5;
- Level of education: 10 pairs had a higher (tertiary) level education.

The deaf members of this reduced, matched group significantly outperformed the hearing on the TAS ($t(38)=3.58$, $p<.002$; see Figure 2 below).

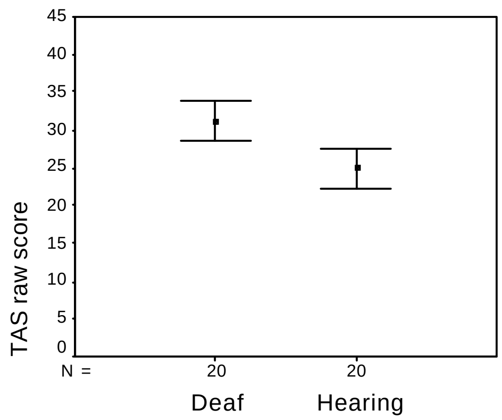

Figure 2: Mean TAS scores achieved by deaf and hearing participants. Error bars show 95% confidence interval around the mean. Deaf participants speechread significantly better than matched hearing participants.

3.2. TAS subtests

All of the core subtests of the TAS and the minimal pair subtest were performed better by deaf than hearing participants (words: t (82) = 6.92, p<.001; sentences: t (82) = 3.98, p<.001; stories: t (82) = 3.85, p<.001; minimal pairs: t (81) = 5.46, p<.001), however, the hearing participants outperformed the deaf group on the sentence stress subtest (t (77) = 3.18, p<.005), (see Table 2 and Figure 3 below). This pattern of results remains true when only the 20 matched pairs of deaf and hearing participants are considered (all differences are then significant at the .05 level).

		TAS core subtests			minimal	sentence
		words (/15)	sentences (/15)	stories (/15)	pairs (/30)	stress (/10)
Deaf	N	40	40	40	40	37
	mean	13.73	11.18	6.03	23.60	7.08
	(s.d.)	(0.93)	(2.44)	(2.94)	(2.19)	(1.89)
Hearing	N	44	44	44	43	42
	mean	11.43	8.93	3.91	20.56	8.31
	(s.d.)	(1.90)	(2.71)	(2.06)	(2.81)	(1.54)

Table 2: Summaries of speechreading subtest scores for deaf and hearing participants.

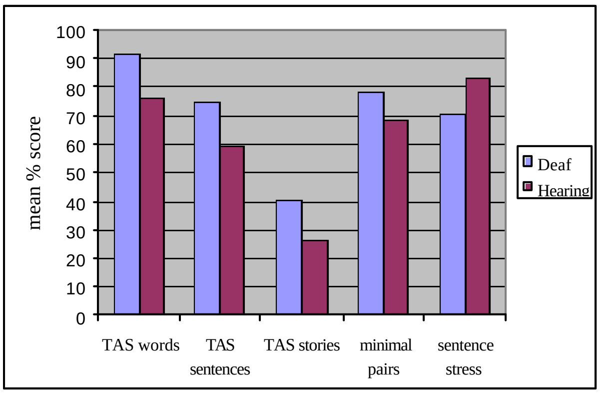

Figure 3: Mean % scores on the 3 core TAS subtests, and on the minimal pair and sentence stress subtests. Deaf participants outperformed hearing on all except sentence stress.

Within the minimal pairs subtest, the deaf and hearing testees showed similar patterns of performance: scores were higher on the word final and word medial items than on the word initial items.

3.3. Correlations between subtests

In the deaf group, the **sentence, story** and **sentence stress** subtests all inter-correlated highly (p<0.01), and also correlated with overall TAS score (the sum of the 3 core subtests). The **word** subtest was close to ceiling, but did correlate significantly with the overall TAS score (p<0.05), (see Table 3 below).

	TAS core	TAS words	TAS sent's	TAS stories	min pairs	stress
core	1	.356	.796	.882	.177	.551
p =	.	.024	.000	.000	.275	.000
words	.356	1	.056	.227	.170	.273
p =	.024	.	.734	.159	.293	.102
sent's	.796	.056	1	.472	.042	.445
p =	.000	.734	.	.002	.796	.006
stories	.882	.227	.472	1	.212	.457
p =	.000	.159	.002	.	.188	.004
min pairs	.177	.170	.042	.212	1	.081
p =	.275	.293	.796	.188	.	.634
stress	.551	.273	.445	.457	.081	1
p =	.000	.102	.006	.004	.634	.

Table 3: Correlations between the speechreading subtests for the deaf participants, red indicates a significant correlation at the .05 level.

In the hearing group, the **minimal pairs** subtest correlated with the overall TAS score (p<0.05). The **word, sentence** and **sentence stress** subtests all inter-correlated highly (p<0.002). All subtests correlated with overall TAS score (see Table 4 below).

	TAS core	TAS words	TAS sent's	TAS stories	min pairs	stress
core	--	.759	.837	.534	.335	.567
p =	.	*.000*	*.000*	*.000*	*.028*	*.000*
words	.759	--	.563	.106	.265	.527
p =	*.000*	.	*.000*	*.495*	*.087*	*.000*
sent's	.837	.563	--	.120	.269	.491
p =	*.000*	*.000*	.	*.437*	*.081*	*.001*
stories	.534	.106	.120	--	.148	.195
p =	*.000*	*.495*	*.437*	.	*.343*	*.215*
min pairs	.335	.265	.269	.148	--	.022
p =	*.028*	*.087*	*.081*	*.343*	.	*.892*
stress	.567	.527	.491	.195	.022	--
p =	*.000*	*.000*	*.001*	*.215*	*.892*	.

Table 4: Correlations between the speechreading subtests for the hearing participants, red indicates a significant correlation at the .05 level.

3.4. TAS, reading and phonological awareness

The deaf participants were significantly poorer readers than the hearing participants (Mann-Whitney tests give p<0.001 in all cases; see Table 5 below). Phonological awareness and vocabulary scores were also significantly lower in the deaf than the hearing group.

		Reading Age (yrs; mths)	PA (mean %)	Vocabulary (/30)
Deaf	N	40	39	40
	mean	14;5	77.22	24.55
	(s.d.)	(3.92)	(10.23)	(3.94)
Hearing	N	44	43	44
	mean	18;9	89.57	28.32
	(s.d.)	(2.48)	(7.67)	(1.43)

Table 5: Summaries of the deaf and hearing participants' reading ages, mean phonological awareness (PA) % scores, and vocabulary scores. One testee did not complete the PA task. The hearing participants outperform the deaf on all of theses measures.

In the hearing group, there was no relationship between the reading, speechreading and phonological awareness scores. In the deaf group, however, these scores related positively. As Table 6 shows, speechreading performance on the TAS core subtests, reading age, and phonological awareness scores are highly correlated (there was no relationship between any of these and the minimal pair subtest for this group):

	TAS	Reading Age	Phonological Awareness
TAS	--	0.60 p<0.001	0.62 p<0.001
Reading Age	0.60 p<0.001	--	0.74 p<0.001
Phonological Awareness	0.62 p<0.001	0.74 p<0.001	--

Table 6: Partial correlation coefficients, controlling for NVIQ (D.F.=36), between speechreading (TAS), reading age and mean % phonological awareness score. All variables are highly correlated.

Within the TAS core subtests, the sentence subtest showed the strongest correlation with reading and phonological awareness ($r = .703$ and $r = .649$ respectively, both $p<.001$). The story subtest was also strongly related to them (r = 407 and r = 477 respectively, both $p<.01$).

Figure 4, below, shows the relationship between speechreading (as measured by the TAS core subtests) and reading age. These significant relationships endure even when both NVIQ and vocabulary score are controlled ($p<0.05$).

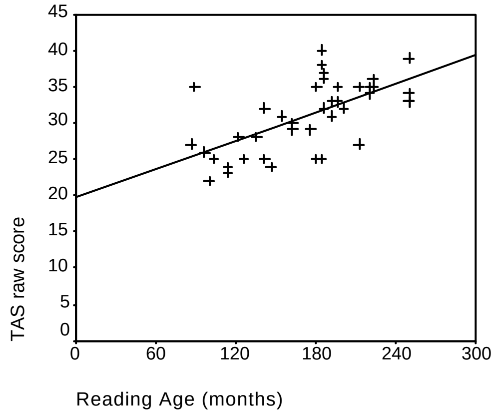

Figure 4: Scatterplot showing the relationship between speechreading performance on the TAS and reading age for deaf participants.

4. DISCUSSION

4.1. TAS in hearing and deaf users: different patterns of subtest performance and relationships

The validity of the TAS as a test of speechreading for both deaf and hearing people has been reaffirmed through the use of this refined version. In a large community-based sample, deaf adults outperformed hearing adults on this test, irrespective of demographic variables. Moreover, all core subtests of TAS showed the same pattern, with marked advantages for deaf respondents. The sentence stress subtest, however, showed a significant advantage for hearing people.

The patterns of subtest correlations suggest different cognitive processes underpinning speechreading in deaf and hearing groups. In the hearing group, phoneme (or viseme) identification (selection from a minimal pair) played a role, correlating significantly with the overall TAS score, and suggesting that hearing people, as a group, may attempt to identify sublexical (visemic / phonemic) segments of the seen speech stream. Deaf people, by contrast, did not show this pattern, but, with high (approaching ceiling) scores on the word subtest, showed strong correlations between the sentence, story, and sentence stress subtests. They also showed superior performance on the minimal pair subtest. Since the hearing group have superior phonological skills (evidenced by their higher phonological awareness scores), and would therefore have been expected to outperform the deaf participants on this task, the deaf group must have an alternate strategy for discriminating between the minimal pairs: probably a whole-word approach; that is, in this group, the seen speech stream may be segmented into lexical (or possibly supralexical, such as phrase) components, rather than sublexical ones. Their superior ability to identify whole words may enable them to more easily identify word boundaries, and so begin to decode connected speech which would otherwise overwhelm them (hence, 14 deaf participants (35%) responded correctly to over half of the story items, compared to only 2 hearing participants (4.5%)).

In the sentence stress subtest, on the other hand, participants are given the sentence before it is spoken, and with knowledge of what the talker is saying the word boundaries can be identified much more easily. Any advantage that the deaf subjects have in identifying lexical items and their boundaries is therefore lost, and the hearing respondents show superior performance, possibly through identifying phonemic components such as long vowels to identify the stressed components in a spoken phrase.

4.2. Reading, speechreading and phonological awareness

Contrary to prediction, hearing people showed no relationship between speechreading and reading. For the deaf respondents, however, there was a strong relationship between these two skills, and it implicated phonological awareness. In accordance with previous findings (e.g. [10]), it seems that silent speechreading for deaf people may be enhanced by literacy skills, with reciprocal 'bootstrapping' of both sets of skills.

5. ACKNOWLEDGEMENTS

Tara Mohammed is in receipt of an ESRC studentship. The digital version of TAS was developed with the support of the following individuals: Mike Coleman, Andy Faulkner, Anke Sennema, Chris Fryer (the male talker), and June Smith (the signer). All are gratefully acknowledged.

6. REFERENCES

1. Ellis T, MacSweeney M, Campbell R (2001) TAS, A new test of speechreading: Deaf people really can be better speechreaders. AVSP2001, International Conference on Auditory-Visual Speech Processing, (Eds. D.W.Massaro, J. Light & K. Geraci), pp 13-17.
2. Bernstein, L.E., Demorest, M.E. & Tucker, P.E. (2000) Speech perception without hearing. Perception and Psychophysics 62, 233-52
3. Demorest ME, Bernstein LE, DeHaven GP.(1996) Generalizability of speechreading performance on nonsense syllables, words, and sentences: subjects with normal hearing. J Speech Hear Res.39:697-713.
4. Rönnberg J, Andersson J, Andersson U, Johansson K, Lyxell B, Samuelsson S.(1998) Cognition as a bridge between signal and dialogue: communication in the hearing impaired and deaf. Scand Audiol Suppl 49:101-8
5. Dyer A, MacSweeney M, Szczerbinski M, Green L, Campbell R. (2003) Predictors of reading in deaf students: a role for RAN? J. Deaf Studies Deaf Education
6. Whittingham A, Campbell R, Frith U (1997) Distinctive patterns of audiovisual speech perception in dyslexics AVSP97
7. de Gelder, B. & Vroomen, J. (1998). Impaired Speech Perception in Poor Readers: Evidence from Hearing and Speech Reading. Brain and Language, 64, 269-281.
8. Virsu V, Lahti-Nuuttila P, Laasonen M. (2003)Crossmodal temporal processing acuity impairment aggravates with age in developmental dyslexia. Neurosci Lett. 23;336(3):151-4.
9. Calvert GA, Campbell R & Brammer MJ (2000) Evidence from functional magnetic resonance imaging of crossmodal binding in the human heteromodal cortex Current Biology 10, 649 –657
10. Ronnberg J (1995) What makes a skilled speechreader? In G. Plant & K.-E. Spens (Eds), Profound deafness and speech communication (pp 393-416). London: Whurr