SL CODEC Project

Eye-gaze during sign language comprehension

Matt Dye[1], Jim Kyle, Helen Twyford[2], Nishan Canagarajah, Dimitris Agrafiotis[3], Mick Canavan[2] and Dafydd Waters[2]

[1] NTID, Rochester Institute of Technology, New York,
[2] Centre for Deaf Studies, University of Bristol, UK,
[3] Image Communications Group, Department of Electrical and Electronic Engineering, University of Bristol, UK

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Abstract
The needs of video telecommunications have identified the importance of understanding how Deaf people perceive and process the sign language commonly in use in the UK. Not only will this aid our attempts to compress and transmit sign language, but it offers also to provide us with insight to improve our analysis of the language itself. In this paper, the initial work on eye gaze of viewers of sign language is described in terms of the central point of fixation and the variations around this. The eye gaze behaviour of signers is described and the consistency of deaf native signers is noted. The comparison of inexperienced signers with these results is also informative. Deaf native signers focus on the area between the nose and the mouth and tend to track the signer's movements in terms of grammar rather than physical aspects. Deaf signers virtually never fixate on the hands.

Introduction
In 1997, there were an estimated 400,000 deaf people in Europe who use a signed language as their first or primary means of communication (Kyle and Allsop, 1997). These sign language users have been excluded from the Telecommunications revolution, still relying upon archaic textphone technology and current text messaging services for communication at a distance. The advent of video-telephony, and forthcoming 3G telecommunications networks, means that sign language users may soon be able to communicate 'anytime, anywhere' and participate more fully in a society increasingly supported by ICT.

Video-telephony and Signed languages
In order to facilitate this involvement, attention is currently focusing upon the development of mobile videophones (Kyle, 2002). As well as the development of hardware capable of sending and receiving streamed 'live' video, there are network issues to consider. New 3G networks will have a limited bandwidth (64 kB/s uplink, 128 kB/s downlink). Furthermore, it is not yet clear what

priority video datastreams will have in relation to voice transmission. Signed languages involve more than hand and arm movements. The eyes, mouth and other parts of the face provide grammatical information; body movements indicate verb agreement or role shifts; head nods can be used as topic markers. (Sutton-Spence and Woll, 1998). As a result, high quality images seem essential for comprehension of signed languages in transmitted video, and appropriate compression techniques are required to allow delivery of high quality video over limited bandwidth networks.

The research reported here was conducted in the context of developing a scalable signed language codec[1]. Encoding video data-streams will always result in some information being lost; this is unavoidable given the need to *lose* information in order to transmit e.g. over 3G networks. However, it may be possible to localise information loss, i.e. allow information to be lost where it does not significantly impair signed language comprehension, and keep information where it is essential for comprehension. In order to be able to do this appropriately, we need to be able to identify which aspects of the signed language video stream that viewers used to comprehend transmitted messages. Strangely, we do not know exactly where the viewer looks in order to extract the information. In this study, we presented deaf signers with uncompressed video of short, sign language narratives (approximately one minute), and recorded their eye-gaze using eye-tracking equipment. Viewers are required to watch the signer – where they look will determine the density and distribution of sign language information.

Visual Attention and Signed Languages

In order to comprehend signed language, it is necessary to attend to the signer visually. Anecdotal reports indicate that signers maintain their visual attention on the face of the person signing. Indeed, the signer will stop signing if he/she senses that the viewer is not maintaining eye contact. It is important to note here that hearing people cannot reliably tell if a person is looking at the eyes even if they believe this to be the case (Chen, 2002), although there has been no attempt to replicate this with Deaf people or signed language users generally.

So, why might viewers fixate on the eyes/face of the signer? The rapidity of linguistic information production may favour non-saccadic eye movements. During saccades (‘leaps’ from one fixation point to another fixation point) very little visual information is collected due to (a) blurring, as the visual image moves quickly across the retina, and (b) neural ‘shutdown’ during the saccade Bruce, Green and Georgeson (1996). Given this requirement to maintain steady eye-gaze, signed languages seem to have evolved to meet the requirements of the visual system. Signs located on the face (i.e. in the region

[1] ‘Codec’ is an abbreviation for compression-decompression. A codec allows data to be compressed by the sender, transmitted in a compressed format, and then uncompressed by the receiver. This can be achieved using either software or hardware.

of maximum visual acuity) use a wider range of handshapes, are co-located in proximal areas and can involve fine motor movements initiated by distal joints. Signs in the periphery (i.e. the region of least visual acuity) use a narrower range of 'unmarked' handshapes, are co-located more distally, and involve larger motor movements initiated by proximal joints. Consider the examples given below from British Sign Language (BSL). The BSL signs AGE (Figure 1) and MISTAKE (Figure 2) are located on the face and involve a fine motor movement – 'wiggling' of the fingers. They differ only in location with the former articulated on the nose and the latter on the chin. Such a fine visual discrimination is rarely seen for signs located in the periphery, such as SIGN (Figure 3) and CRITICISE (Figure 4). These two signs differ in terms of their handshapes, but in terms of movement both have large circular movements. The handshape difference, however, is larger and more salient, and may thus be detected in the periphery without the need to re-fixate. However, one can argue that this analysis is not based on evidence and it could be equally the case that the difference is only partly seen and mostly predicted by the grammatical knowledge of the viewer.

Figures 1 to 4 about here

Allocating Visual Attention

The point of fixation (i.e. the locus at which eye-gaze is directed) and the location of visual attention may not be one and the same thing. It seems possible to distribute one's attentional resources to the periphery (while fixating a central point). Recent research has suggested that deaf people may be better at allocating visual attention to the periphery, although there appears to be a cost – this requires fewer attentional resources being allocated to the centre of fixation (Bavelier et al., 2000). This data suggests that the eye movements of deaf and hearing signers may differ. Furthermore, Bavelier et al. conducted their research with deaf native signers, and drew inferences about deaf people generally based upon earlier research findings. Therefore, it may be the case that such flexibility in visual attention allocation does not extend to deaf signers who acquired a signed language later in life (and not from birth via deaf parents). Such signers form the majority (90-95%) of the deaf signing population. Furthermore, interviews with deaf signers have suggested that their eye gaze behaviour can vary depending upon the linguistic skill of the producer. Native signers report that they make more saccades to the hands of the producer when s/he is not a fluent user of the language.

Although eye-gaze fixation is not a direct measure of visual attention allocation generally, it is a measure of the location of central attention allocation. Signed language has evolved such that fixation on the facial region still allows linguistic information to be obtained by using peripheral attention and not necessarily re-fixating upon an area of interest in the periphery. This study sets out to examine under what linguistic conditions re-fixation might occur. The two main types of factor manipulated were (a) linguistic features, and (b) linguistic fluency.

Signed language narratives presented to participants contained examples of fingerspelling, placement and classifier use within verbs of motion and location. These linguistic features require fine discriminations to be made by the receiver, although they are often articulated away from the facial region. If signers do re-fixate during sign language comprehension, then these are among the most likely triggers. Linguistic fluency (and acquisition history) may also influence eye gaze behaviour, based upon anecdotal evidence and research on visual attention allocation (Bavelier et al., 2000).

One native deaf signer produced the narratives. The viewers were drawn from four groups of participants – deaf of deaf parents, deaf of hearing parents (i.e. later learners of sign language), experienced BSL hearing users, inexperienced BSL hearing users. They were asked to observe the narratives and answer some questions on the narrative content at the end of their viewing sessions. During narrative observation, eye gaze fixation was recorded using eye-tracking equipment and software.

Method

Participants

We monitored the eye gaze of eleven participants while they watched 4 short BSL narratives. There were the following breakdowns of participants:
DD: Deaf signers who learned BSL as children from their Deaf parents (n=3)
DH: Deaf signers who had hearing parents, and learned BSL after the age of 6 years (n=3)
HS: Hearing signers who learned BSL later in life (n=3)
HB: Hearing signers who were beginners in BSL (n=2)[2]

Design

There were four different narratives (each a fabricated news story). All four narratives were observed by all participants. Deaf participants were required to sign a summary of each narrative after viewing it, although these summaries were not recorded. These were assessed to determine whether the overall gist of the story had been understood. Hearing beginners were not expected to understand the whole story. Recordings were made of the eye movements made by participants during observation of the narratives.

Materials

English transcripts of the narratives are shown in Appendix 1. The sign model was filmed wearing plain clothing, against a blue-screen background in a well-light filming suite.

[2] In order to ensure fluency levels were similar with the DH group, the HH group consisted of fully qualified sign language interpreters, unfortunately, only two could be recruited at the time of testing.

For presentation, video clips were edited and presented as uncompressed avi files. The following information is taken from Agrafiotis et al. 2002, p 13. “The video material used for the trials was captured with ICG’s Digital S (D9) video camera. Three sign language video clips were recorded at CDS. The D9 format uses a mild DCT-based intraframe compression to store the video sequences (compression ratio 3.3:1 - bit rate of 50Mb/s) and samples the luminance and chrominance components with a 4:2:2 resolution.

The stored video clips were converted to the CCIR 601 format with size 720x580 and 4:2:0 sampling and were stored as YUV frames. The frames were then filtered down to the CIF and QCIF formats. The CIF sequences were the ones used for the experimental trials with size 352x288.”

The study was performed in a darkened room, with a 20W bulb used to provide a controlled level of illumination. The room was fully lighted for instruction and recall phases of the procedure (see below).

Apparatus

System Overview

Figure 5 shows a schematic diagram of the Eyelink system used to test eyetracking (developed by SR Research Ltd).

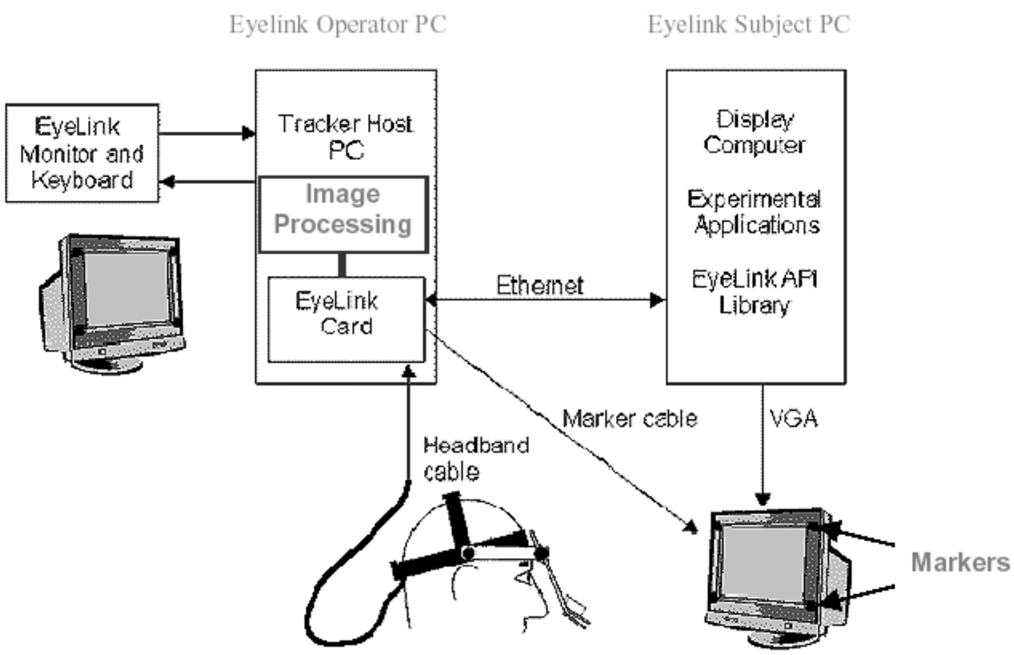


Figure 5 The Eyelink system (copied from Agrafiotis et al. 2002)

The system consists of the following components (description taken from Agrafiotis et al., 2002 pp 7 to 10):

Eyelink Headband
The actual eye tracking system. Two miniature high-speed cameras take 250 images/second of both eyes simultaneously to provide binocular eye-tracking. A third camera tracks 4 IR markers mounted on the visual stimulus display for head motion compensation and true gaze position tracking. Two IR LED’s provide the required illumination for each eye camera.

Eyelink Operator PC
The operator PC hosts the DSP card that analyzes the images from all 3 cameras in real time at 250 Hz sampling rate and determines pupil position of both eyes and marker position. Pupil and marker positions are then processed in real time to compute gaze position. Binocular gaze position data in display co-ordinates is available after calibration, as well as pupil size and eye position. Gaze position accuracy is around 0.50 (average error) measured by calibration accuracy validation. Eye movements are parsed into saccades, blinks and fixations by the operator PC and all the data is recorded in a file.

Eyelink Subject PC
The subject PC runs the user’s application that displays the experimental stimuli e.g. images video etc. It is connected to the operator PC via an Ethernet link and can control and receive the data produced by the eye tracker via the Eyelink Application Interface - API .

System Layout
The layout of the eye tracking system in the ICG “dark room” is depicted in the following figure. In order to ensure that the best possible gaze position accuracy was obtained, windows were blocked, lighting was kept to a minimum and a chin rest was constructed. The chin-rest eliminates any gross movements of the head which can degrade the accuracy of the system.

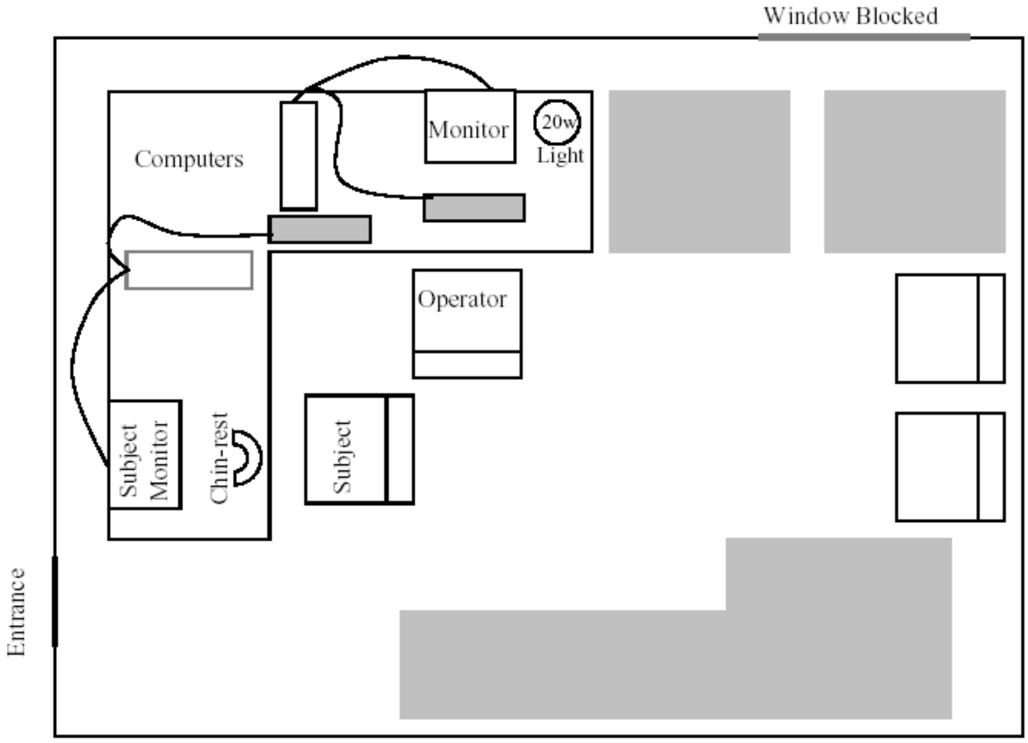


Figure 6 The Eyelink system layout (copied from Agrafiotis et al. 2002)

The distance of the chinrest to the screen was set to 60 cm. This ensures that 1cm of screen width corresponds to one degree of visual angle. With the resolution of the screen set to 640x480 and the width of the active display area being 390 mm we get a horizontal resolution for gaze position data of 1/(*width*/640) = 17 pixels per visual degree (PPD) at the centre of the screen and a total field of view of 360 degrees. The resolution of gaze position data changes depending on subject head position and point of gaze. The average reported horizontal and vertical gaze position resolution for these values was 21 and 40 PPD respectively. A reported average gaze position error of around 0.20 can thus be translated into an average gaze position accuracy of around 4 and 8 pixels horizontally and vertically respectively.

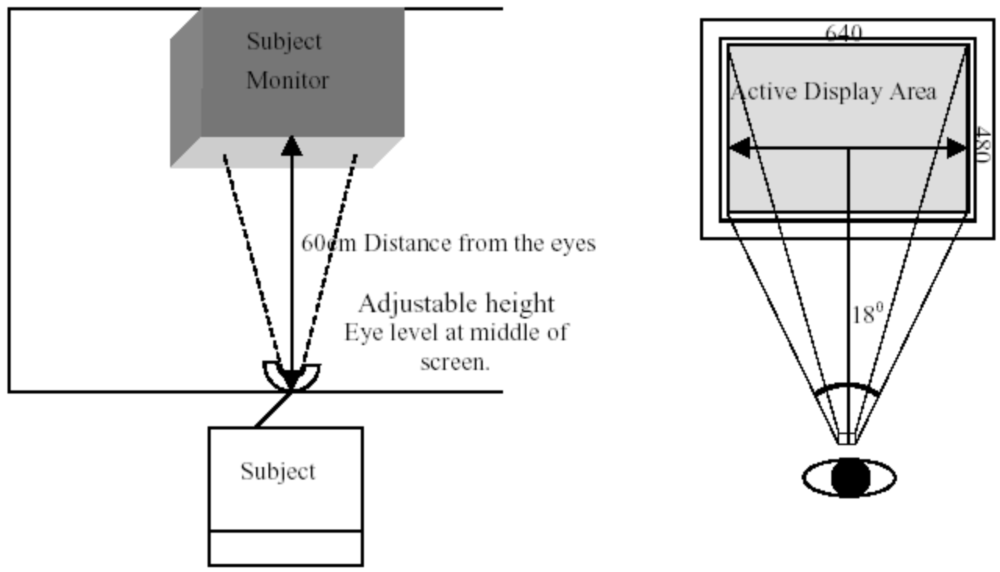


Figure 7 Summary of subject sitting position and screen parameters (copied from Agrafiotis et al. 2002).

Summary of Subject screen and measurement parameters.

Distance to screen 60 cm
Screen resolution 640 x 480
Active visible area width x height 39 x 29 cm
Average horizontal PPD. (reported) 21 pixels
Average vertical PPD. (reported) 40 pixels
Average horizontal gaze position accuracy 4 pixels
Average vertical gaze position accuracy 8 pixels

System Set-up and Calibration

A number of steps are taken each time an experiment takes place in order to set up the eyelink system to track the position of the pupils and of the markers. This involves fitting the headband on the subject's head, adjusting the eye and head cameras and choosing a threshold for pupil tracking. A list of the set-up steps preceding each experiment can be found in appendix 2. Calibration of the Eye tracker is achieved by displaying several targets for the subject to fixate on. The pupil position for each target is recorded and the set of target and pupil positions is used to compute gaze positions during recording. Binocular calibration and recording is used so that backup data exist if one eye's setup is poor. After calibration, a validation step is performed in order to rate the accuracy of the system in predicting gaze position from pupil position. Again targets are displayed and when fixation takes place, calibration is used to estimate the gaze position of the subject and the error – the difference between target position and computed gaze position – is estimated. Gaze position errors result largely from errors in fixation data gathered during calibration. Fixation errors come from two sources: the eye tracking system and physiological eye-movement. Errors from the eye tracking system are generally very small to insignificant, but physiological errors such as the natural variability in fixation position on targets can be significant." (Taken from Agrafiotis et al. 2002).

Procedure

Participants were seated in front of the video display monitor, and the procedure was outlined to them. A practice trial was conducted before the main trials in order to familiarise participants with the procedure. For all deaf participants, instructions were provided in BSL; hearing participants used speech.

For each trial, the participant was seated facing the video display monitor and required to place his/her head on a chin rest. The chin rest was used to minimise head movement during the trial and prevent calibration of the eye-tracking slipping. It also ensured that the participant was seated 60 cm away from the screen, such that the video image subtended 13.55 degrees of visual angle for the whole body image of the signer and 4.67 degrees for just the head. Participants were also required to rest their forearms flat upon the table, to further improve stability and reduce movement.

When ready to commence the calibration phase of each trial, participants were asked to tap twice on the table with their fingers. The calibration protocol was then conducted, with participants required to fixate upon white discs that appeared in nine different locations on the display screen. After the final disc had appeared, on-screen instructions asked participants to keep their heads still and not to move. The next screen asked them to watch a short video clip of BSL and be prepared to summarise the narrative at the end. The BSL narrative was played after the participants indicated they were prepared by tapping their fingers on the table. After the narrative, a screen indicated that the participant could relax and summarise the narrative to the experimenter. The main lighting was switched on to enable this. This procedure was repeated fourteen times in two sessions. In each session, there was one practice trial, followed by four main trials from which data was collected for analysis. The text displayed to participants during each trial is given in Appendix II.

Results

A great deal of data can be generated by an eye tracking experiment. For the purpose of this study it seems prudent to report the data in two simple ways: a) general statistics about the eyetracking data generated for each participant, b) an overview of where subjects are looking during the trials.

General statistics

Several measures can be generated from the data (averaged across all four clips presented) to display different aspects of visual behaviour for each participant group. For saccades these include: the mean number, duration (in ms), length (in pixels) and speed (in pixels per second) of saccades. The duration of fixations and lastly the mean fixation locations on the screen will also be investigated. The following table presents the mean values (with standard deviation in brackets) for each of the 4 groups of participants:

Table 1. Mean eyetracking measurements for different participant groups

	Participant Group			
Measurement	**DD**	**DH**	**HS**	**HB**
Number of Saccades	24.25 (17.59)	49.00 (45.67)	10.88 (7.95)	68.92 (24.07)
Saccade Duration (ms)	10.17 (2.78)	17.36 (2.16)	12.45 (3.23)	26.22 (9.33)
Saccade Length (pixels)	10.25 (4.42)	26.79 (14.68)	13.21 (7.52)	33.92 (2.61)
Saccade Speed (pixels/ms)	0.90 (0.30)	1.43 (0.66)	1.08 (0.43)	1.40 (0.46)
Fixation Duration (ms)	4372.86 (4969.40)	3612.26 (4656.87)	5650.96 (5500.22)	1718.99 (1697.20)
X Location of Fixation (pixels)	312.25 (1.61)	322.06 (3.38)	317.87 (1.87)	312.52 (7.72)
Y Location of Fixation (pixels)	184.61 (28.27)	197.90 (31.49)	206.09 (14.73)	241.44 (9.39)

If the means for each participant within each of the 4 groups are compared via one-tailed t-tests interesting between group comparisons can be made (only the statistical comparisons which were found to be significant will be reported). Comparing all of the measurements for the DD group with the HB group reveals the highest number of statistically significant differences. DD participants were found to make significantly less saccades than HB (t (5) = 2.02, $p < 0.03$), which lasted for shorter durations of ms than HB participants (t (5) = 2.015, $p < 0.04$) and were significantly shorter in length (t (5) = 4.03, $p < 0.005$). Furthermore, DD participants' average fixation location was significantly higher on the screen than HB participants (t (5) = 2.01, $p < 0.03$), illustrating the point that DD participants may be looking mostly at the mouth area, whilst HB participants looked at lots of differently locations on the video clips.

Comparing performance for DD participants with DH there were fewer significant differences in performance than for the DD vs. HB comparison. However, some differences still were seen in that DH participants' duration of saccades were significantly longer than DD (t (5) = 3.365, $p < 0.01$). Also there seemed to be a significant difference in terms of the x axis general location of the average fixation location (t (5) = 3.4, $p < 0.01$), however, this may have been due to error/drift in the data.

Contrasting DD with HS a significant difference was seen in that HS participants seem to be taking longer to make saccades (t (4) = 3.365, $p < 0.01$) and also that the x location of the average fixation point was different (t (4) = 3.365, $p < 0.01$) in that HS participants seem to be looking at a lower point overall than DD. Some caution must be given to these results as there were not equal numbers of participants in each group (n=2 HS, n=3 DD).

No significant differences were seen in any of the contrasts of data measures between DH with HS and DH with HB. This intriguingly suggests that DH participants are performing more congruently to hearing participants than they are to their DD counterparts. This finding may also explain why there was only one significant difference between all deaf and all hearing participants (for y location of mean fixation (t (5) = 2.571, $p < 0.02$), suggesting that the are simply looking at a lower area than deaf BSL viewers. However, with a small sample size such as in this study such strong conclusions cannot be taken. Last of all, only one significant difference was seen between the HB and HS groups in that the HS group seem to be making significantly less saccades than the HB (t (5) = 2.31, $p < 0.03$), this may mean that they are used to watching BSL and are not distracted by the hand movements as much as the HB participants who have limited experience with viewing BSL.

Where fixations are occurring:

All fixations recorded for each participant were plotted onto a figure which represents the screen viewed by the participant. A general area for the location of the signer's mouth/lower face and also lower body/hand area was plotted on each figure. Each participants' Figure for each clip is attached in Appendix III, however, Figures 8, 9, 10 and 11 provide examples of participants' viewing behaviour for clip 1 for each of the 4 groups of participants (DD, DH, HS and HB).

Figure 8 Example of DH participants' fixation points.

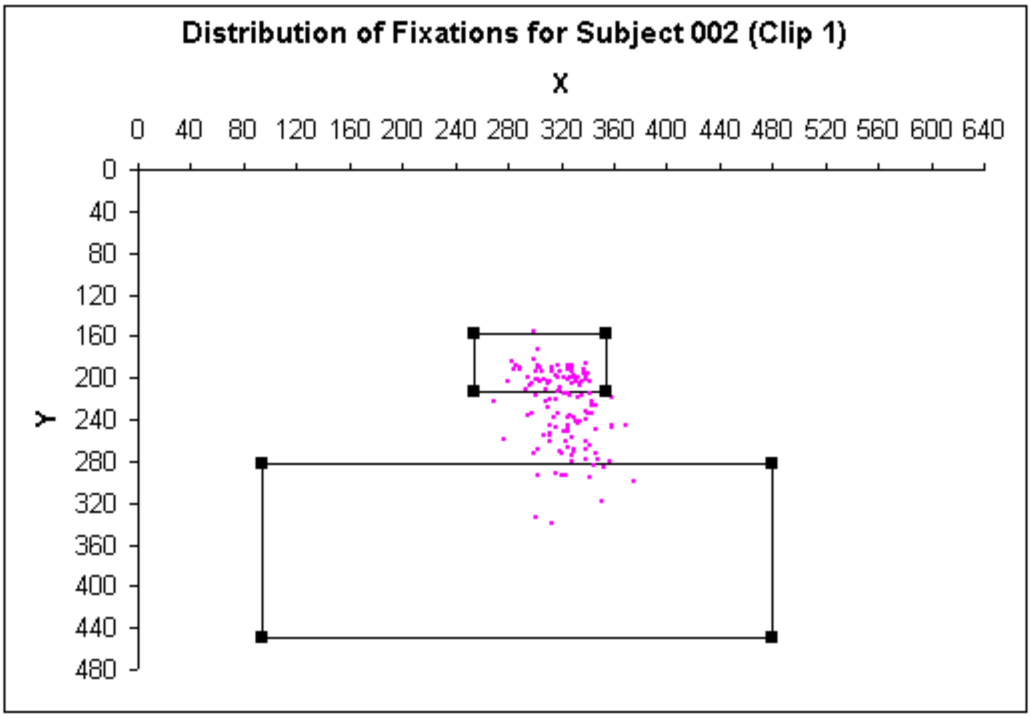


Figure 9 Example of HS participants' fixation points.

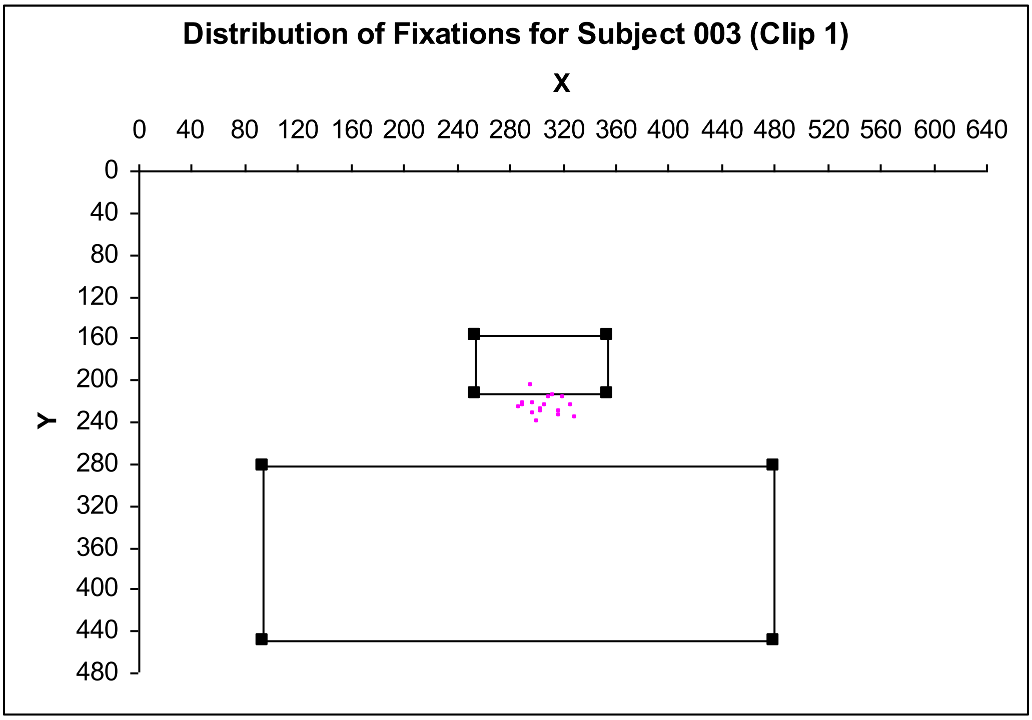


Figure 10 Example of DD participants' fixation points.

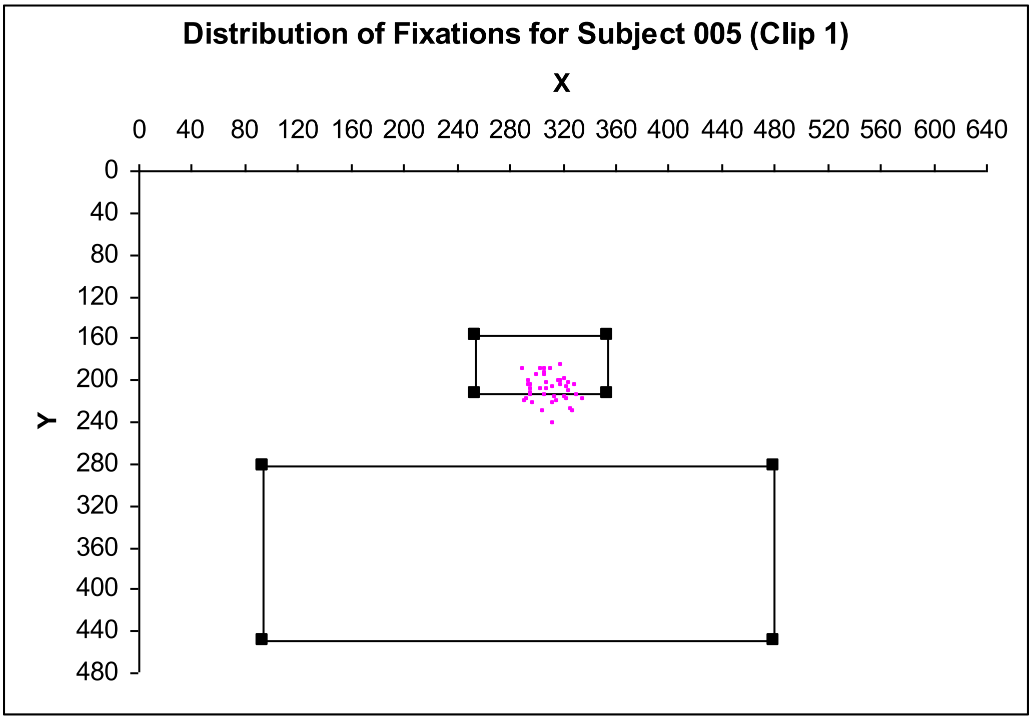
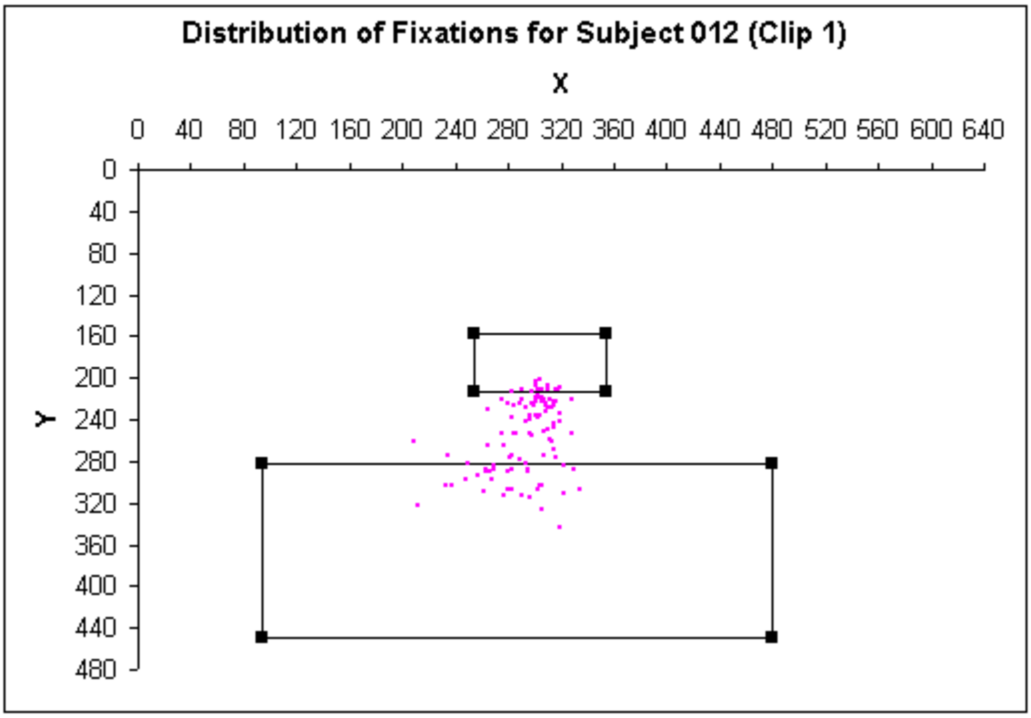


Figure 11 Example of HB participants' fixation points.



From the Figures above it is possible to see that there are differences in the location of fixation points for the different groups of participants. The following table shows the mean number of fixation points in the mouth/face and hands/lower body areas for the four groups of participants.

Table x

	Participant Group			
Measurement	**DD**	**DH**	**HS**	**HB**
Face/Mouth	16.83	21.58	4.88	31.50
Body	0	2.58	0	11.42
Neither	7.42	24.83	6	26

These results indicate that DD participants never look at the hands of the signer and concentrate around the facial area, especially the mouth. The same is true for HS participants who behave very much like DD viewers. DH participants look predominantly at the face/mouth area in general (with a little bit of extra spread in the data) and show a small tendency to look at the hands. Lastly, HB participants look mostly at the head area but also pay attention or (get distracted by) the body/hands, and this is probably due to the novelty of watching BSL.

Concentrating on whether participants look at the body a significant difference was seen between DD and HB participants in that DD did not ever/rarely looked at the hands, whilst HS did (t (5) = 2.51, $p < 0.02$). The same significant difference was seen for a contrast between HS participants who never looked at the hands and HB who frequently did (t (5) = 2.01, $p < 0.03$).

In total, it is apparent that some level of skill with BSL allows viewers to watch only the face and not fixate on the hands. This finding is strengthened by the responses to a somewhat introspective question in the SL CODEC comprehension study (Twyford et al. 2002) which found that deaf people think that they look at the mouth/face region when they are viewing BSL.

Discussion

This paper represents a unique piece of work which is amongst the first in its field. The statistics obtained provide a profile of Deaf people's eye gaze when viewing BSL which can now be applied to the generation of an intelligent CODEC which can economically transmit only the information genuinely needed by users of BSL. The results show that in general deaf participants look at the mouth area of another signer when viewing BSL (this finding has also been replicated by Muir and Richardson (2002), but with fewer participants. However, this pattern is not totally consistent for DD vs. DH participants who have different backgrounds (deaf vs. hearing). DH participants were recorded to occasionally look at the hands of the signer, whilst it seems that this type of viewing behaviour is very rare in DD participants. However, both types of deaf participant contrast with HB (completely naïve signers) in that the latter group of participants looked at the hands nearly as much as the signer's face.

The results from this paper suggest that deaf viewers are indeed relying on their peripheral vision to comprehend BSL. Typically it is thought that 5 degrees of visual angle is the foveal/attentional capacity of vision at any one time (Guilchrist, 2002). It is interesting to note that the visual angle subtended by the face of the signer in the clips is around the five degree mark (4.57 degrees) therefore, if this area is kept constantly in the fovea the hand movements must be processed by peripheral vision only. Bavelier et al.'s (2000) theory that deaf viewers are able to allocate attention to the periphery supports the findings of this present study. Furthermore, a number of other papers investigating the parameters of deaf vision support Bavelier et al.'s views that peripheral vision abilities are heightened after auditory deprivation (Bedford, 1999; Bosworth and Dobkins, 2002). Interestingly, it seems that there is quantitative difference between the viewing behaviour of DD and DH participants, perhaps reflecting that more experience/immersion within sign language leads to more peripheral vision skills and the ability to fixate on the face and never on the hands. To fully test this theory it would be perhaps advantageous to test more DD and DH participants and more fully investigate the degree to which signing is part of their culture.

As well as auditory deprivation leading to improved peripheral vision, it could also be true that sign languages have evolved around the implicit basis that viewers fixate on the face/mouth area. Perhaps Siple (1978) is correct in her prediction that larger, more gross signs occur in the periphery, whilst more fine, distal signs occur nearer the face, however, to fully answer this question a full analysis of the location of signs in BSL must be undertaken.

A detailed linguistic analysis of eyetracking from BSL clips would also be advantageous in the field of further research in to the use of BSL, however, due to time and resource constraints this was not possible for the SL CODEC project at this phase. Future study suggestions may be to be contrast the eyetracking performance of participants when presented with a DH signer or even a novice signer who may make many mistakes. Furthermore, the clips used for this present study are news items and it may be interesting to change the context of these clips by using informal clips about a more relaxed topic (e.g. "Where I went on holiday"). Furthermore it may be interesting to test out whether different type of viewing behaviour occurs for live and interactive signing online versus watching a pre-recorded 2D image. Perhaps when watching a live signer directly interacting with the viewer this may change the eye gaze pattern in someway. If the mobile video-phone it to be used for 2-way communication this may be an important factor to consider.

One final point to make is that some error may have occurred within the data collected. Each clip was quite long (approximately 1 minute) and due to the weight of the headset, towards the end of the minute there may have occurred some drift in the data. The data has been drift corrected for, however an average error of 0.26 did occur. For the purpose of the analyses contained within this paper of fixation location either being the mouth or the body/hands this does not have any great effect on the results. All that should be remembered is that in any one trial the results obtained may be subject to a slight amount of noise in the data.

Overall, the results presented above provide an interesting starting point for the development of an intelligent CODEC which can utilise the finding that skilled viewers of BSL fixate mainly on the face/mouth area. What should now be ascertained in future studies is to what extent the peripheral information of the hands can be filtered out, or whether this peripheral information is just as important as the facial image.

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Appendix I

News Clip 1

The Arts Council of England has today announced a grant of £6 million for a new arts centre to be built in Brighton. Fundraising committee chairman Gregory Bishop welcomed the news, saying that this is the dawn of a new era for the arts in the Brighton and Hove area. Controversy rages however, with some community groups condemning the award on the basis that the money would be better spent addressing social problems such as homelessness and drug dependency. Sara Diederichs of the organisation 'People not Projects' said that this was just another example of the Labour government pandering to the middle classes.

News Clip 2

The Muriel Fletcher Memorial Trust is paying for free hot air balloon rides for sick children in the Bristol area. Balloons will depart from near the water tower on Clifton Downs at 2 pm every Saturday during the months of June, July and August. Before she died, Muriel Fletcher worked tirelessly on behalf of children facing long hospital stays. A charitable trust in honour of her memory was set up shortly after her death and her husband Winston says that she would have been "absolutely delighted" to see the happy faces on the children as they set sail in their balloons.

News Clip 3

Wiltshire environmental campaigners have been lobbying both the government and the military to preserve the habitat of a rare snail that can live only in the tracks left by tanks travelling back and forth across Salisbury Plain. Speaking on behalf of the Wiltshire Wildlife Trust, Katherine Scaife explained that the snail populations depend on the tank track depressions because the conditions there are uniquely suited to their breeding behaviours. When pressed by the media, Ms. Scaife did admit that an environmental organisation calling for continued tank activity on Salisbury Plain was a bit like a turkey voting for Christmas, but she stressed that the welfare of the snails had to be the organisation's first concern. Commander Gareth Morgan of Wiltshire's own Prince of Wales Regiment was unavailable for comment.

Appendix II

1. Instruction: “Keep your head still. Remember not to move until asked.”
2. Instruction: “Watch the +’s closely.”
3. Instruction: “Tap the table when you are ready to start.”
4. Calibration protocol
5. Instruction: “Keep your head still. Remember not to move.”
6. Instruction: “Watch the person signing. You will be asked to summarise at the end.”
7. Instruction: “Tap the table when you are ready to start.”
8. Video protocol
9. Instruction: “Part 1 of 4 finished.”

Appendix III

All plots of participant’s fixation points.