



Emotional Engineering of Artificial Representations of Sign
Languages

By
Saduf Naqvi

This thesis is in partial fulfilment of the requirements
for the degree of PhD in Computing
in the
Department of Mathematical and Computing Sciences
Goldsmiths College
University of London
New Cross, London SE14 6NW, UK.

Abstract

The fascination and challenge of making an appropriate digital representation of sign language for a highly specialised and culturally rich community such as the Deaf, has brought about the development and production of several digital representations of sign language (DRSL). These range from pictorial depictions of sign language, filmed video recordings to animated avatars (virtual humans). However, issues relating to translating and representing sign language in the digital-domain and the effectiveness of various approaches, has divided the opinion of the target audience. As a result there is still no universally accepted digital representation of sign language.

For systems to reach their full potential, researchers have postulated that further investigation is needed into the interaction and representational issues associated with the mapping of sign language into the digital domain. This dissertation contributes a novel approach that investigates the comparative effectiveness of digital representations of sign language within different information delivery contexts. The empirical studies presented have supported the characterisation of the prescribed properties of DRSL's that make it an effective communication system, which when defined by the Deaf community, was often referred to as "emotion". This has led to and supported the developed of the proposed design methodology for the "Emotional Engineering of Artificial Sign Languages", which forms the main contribution of this thesis.

Dedication

This dissertation is dedicated to the memory of my parents, Mr Mushtaq Ahmed Naqvi, my father, who taught me the importance of perseverance, strength and tenacity. And my mother, Mrs Mubarka Nasreen Naqvi, who's charm, grace and commitment to her family has empowered us for the rest of our lives. Although you're not here to see me complete this thesis, this work is dedicated to you.

“We created you from a single soul, male and female, and made you into nations and tribes, so that you may come to know one another.” Quran [49:13]

Acknowledgments

I acknowledge with the warmest and sincerest gratitude the role played by my supervisor, Dr. James Ohene-Djan, in the research reported in this dissertation. Your guidance, patience and invaluable support has been greatly appreciated. A very special thank you is reserved for Dr. Herbert Blumberg, my second supervisor, your patience during this research and kindness as an individual will always be fondly remembered.

I would especially like to thank Anthony Rabin for his encouragement when I started researching in the area of artificial sign languages. His warm welcome of me into the Deaf community, encouraged me to try and untangle a facet of the complex issues around this research that ultimately shaped my thesis contribution. I am also grateful to many active members of the Deaf community and their involvement in their work, especially Penny Beschizza and Shahab Reza. Not only did they help me to understand the concerns of the community but they had lengthy conversations with me about the barriers faced by the Deaf community. These made me realise the need for widespread recognition of their distinct needs and that this requires a more focused understanding, encompassing not only the culture and history, but the modern day needs for information systems. In particular I would like to thank the Deaf community for allowing me to see more of their world, the culture and the beautiful structure of sign language. It is hoped that the research presented here will go in some way to thank you for all your support.

It is difficult to list all my wonderful friends who have supported me in a sometimes emotionally charged experience of research, I just simply want to say thank you for all the long conversations, the reassurances, the laughs, support and fun I have had from you. You make the world a better place.

The Department of Computing of Goldsmiths College, University of London is an excellent environment for research. I acknowledge with gratitude the help and support provided by its members and thank them for their dedication to the support of my research. The research reported in this dissertation was funded by a Goldsmiths College bursary. I wish to thank the College for awarding me this bursary and supporting me whilst conducting this research.

I would like to thank Mehreen Naqvi, whose first meeting with me started my journey in this research, making me realise that communication can be isolating as well as liberating, this is so you know, that this research happened because of you. Finally, but far from least, thank you to Shehzad Ahmad Naqvi and Zamurrad Yousuf Naqvi, for your emotional support, patience and understanding. Without you two there this couldn't have happened.

Declaration

I hereby declare that I composed this thesis entirely myself and that it describes my own research.

Saduf Naqvi

Department of Mathematical and Computing Sciences

Goldsmiths College, London University

July 20, 2009

Contents

Abstract	i
Dedication	ii
Acknowledgments	iii
Declaration	iv
1 Introduction	1
1.1 Introduction	1
1.2 Background	1
1.3 Motivation	3
1.4 Challenges	4
1.5 Aims of the Research: Central Question	6
1.5.1 Derived Problems	6
1.6 Research Contribution	8
1.6.1 Thesis Structure	9
1.7 Conclusion and Summary	10
2 Deafness and Technology	11
2.1 Introduction	11
2.2 What is Deafness?	11
2.2.1 Assistive Listening Devices for Deafness	12
2.3 History of Deaf People	12
2.3.1 Deaf Community	19
2.4 Deaf Culture	19
2.4.1 What is the difference between deaf and Deaf?	20
2.4.2 What is Deaf Pride?	20
2.4.3 What does the Deaf/Hard of Hearing community think of different Education Methods	21
2.5 What is Sign Language?	23

2.6	Deaf Issues Today	24
2.6.1	Problem	25
2.7	Sign Language Technology	25
2.8	What is Sign Language Technology?	26
2.8.1	Data Capture Methods of Sign Language Systems	26
2.8.2	Typical Characteristics	26
2.8.3	Examples	27
2.8.4	Data Manipulation for Sign Language Systems	31
2.8.5	Typical Characteristics	31
2.8.6	Example	31
2.8.7	Digital Representations of Sign Language	32
2.8.8	Digital Representation of Sign	32
2.8.9	Notation Systems for Sign Language	33
2.8.10	Typical Characteristics of Notation Systems of Sign Language	33
2.8.11	Examples of Notation Systems of Sign Language	34
2.8.12	Video Systems for Sign Language	36
2.8.13	Typical Characteristics of Video Systems of Sign Language	36
2.8.14	Examples of Video Systems of Sign Language	37
2.8.15	Animation Systems for Sign Language	38
2.8.16	Typical Characteristics of Animation Systems of Sign Language	39
2.8.17	Examples of Animation Systems of Sign Language	39
2.8.18	Notation Systems vs Streaming Video Systems	51
2.8.19	Notation Systems vs Animation Systems	52
2.8.20	Streaming Video Systems vs Animation Systems	53
2.9	Roles of Digital Representations of Sign Language	54
2.9.1	Notation Systems: Depiction Style	54
2.9.2	Notation Systems: Pictorial Style	55
2.9.3	Video Systems: Filmed Content	55
2.9.4	Animation Systems: Captured Generation	56
2.9.5	Animation Systems: Synthesised Generation	56
2.10	Conclusion and Summary	56
3	Preliminary Work for Research	59
3.1	Introduction	59

3.2	Introduction to Testing the Effectiveness of Digital Representations of Sign Language Content	60
3.2.1	Background	60
3.2.2	Experimental Methodology	61
3.2.3	Results	64
3.2.4	Discussion of Findings	64
3.2.5	Conclusion of Study	66
3.3	Experimental Research Design for the Deaf: Approaches for Obtaining Accurate End-User Feedback	66
3.3.1	Background	67
3.3.2	Framework and Experimental Document Design Rules	68
3.3.3	Visual Language Translation Rules	68
3.3.4	How to use these rules	70
3.3.5	Implications	73
3.3.6	Conclusion and Summary	74
4	Investigation: Comparative Evaluation of Digital Representations of Sign Language for Different Information Delivery Contexts	75
4.1	Introduction	75
4.2	Background	76
4.2.1	Which Types of Information Require Translation into Sign Language?	77
4.2.2	Are Combinations of Digital Representations of Sign Language More Effective for Information Delivery?	78
4.2.3	What is Good Quality Signing and How can this be Represented on the Digital Domain?	78
4.2.4	Why Choose these Systems for this Research?	79
4.3	Experimental Methodology	81
4.4	Pilot Study One	87
4.5	Pilot Study Two	88
4.6	Pilot Study Three	88
4.7	Pilot Study Four	89
4.8	Results	89
4.8.1	Static vs Real-time	89
4.8.2	Descriptive Statistics for Static Presentations	92
4.8.3	Inferential Statistics	92

4.9	Discussion	98
4.10	Conclusion and Summary	99
5	Investigation: Establishing the Rules of Emotional Software Design	103
5.1	Introduction	103
5.2	Background	104
5.3	Experimental Methodology	105
5.4	Pilot Study One	106
5.5	Pilot study two	107
5.6	Results	109
5.7	Conclusion and Summary	110
6	Emotional Engineering of Artificial Sign Languages	114
6.1	Introduction	114
6.2	Rules	116
6.2.1	Rule One - Linguistic Emotional Representation in Lip Patterns . .	116
6.2.2	Rule One - Symbolic Emotional Representation in Lip Patterns . . .	117
6.2.3	Rule One - Explanation about the importance of Lip Patterns . . .	117
6.2.4	Rule One - Linguistic Emotion Measure of Lip Patterns	118
6.2.5	Rule One - Symbolic Emotion Measure of Lip Patterns	118
6.2.6	Rule Two - Linguistic Emotional Representation of Facial Expression	118
6.2.7	Rule Two - Symbolic Emotional Representation of Facial Expression	125
6.2.8	Rule Two - Explanation of the importance of Facial Expression . . .	125
6.2.9	Rule Two - Linguistic Emotion Measure of Facial Expression	126
6.2.10	Rule Two - Symbolic Emotion Measure of Facial Expression	126
6.2.11	Rule Three - Linguistic Emotional Representation of Torso	126
6.2.12	Rule Three - Symbolic Emotional Representation of Torso	129
6.2.13	Rule Three - Explanation of the importance of the Torso	129
6.2.14	Rule Three - Linguistic Emotion Measure of Torso	129
6.2.15	Rule Three - Symbolic Emotion Measure of the Torso	129
6.2.16	Rule Four - Linguistic Emotional Representation of Handshape . . .	129
6.2.17	Rule Four - Symbolic Emotional Representation of Handshape . . .	133
6.2.18	Rule Four - Explanation of the importance of Handshape	133
6.2.19	Rule Four - Linguistic Emotion Measure of Handshape	134

6.2.20	Rule Four - Symbolic Emotion Measure of Handshape	134
6.2.21	Rule Five - Linguistic Emotional Representation of Signer's Space	134
6.2.22	Rule Five - Symbolic Emotional Representation of Signer's Space	140
6.2.23	Rule Five - Explanation of the importance of Signer's Space	140
6.2.24	Rule Five - Linguistic Emotion Measure of Signer's Space	140
6.2.25	Rule Five - Symbolic Emotion Measure of Signer's Space	141
6.3	User Interface Emotional Design Process Cycle	141
6.3.1	Establish Base Rules for the User Group	141
6.3.2	Breaking Down Information for Processing	141
6.3.3	User Centred Evaluation and Feedback on rule design	141
6.3.4	System Development Steps	143
6.4	Architectural Model	144
6.5	Conclusion and Summary	145
7	Investigation: Linguistic and Symbolic Rules Assessment	146
7.1	Introduction	146
7.2	Background - Traditional Approach to Accessible Design with the Deaf Community	146
7.2.1	Working with Deaf End-Users	149
7.2.2	Deaf Awareness Training	151
7.2.3	Communication Issues	151
7.2.4	The Problem	152
7.3	Experimental Methodology	152
7.4	Pilot Study One	155
7.5	Pilot Study Two	155
7.6	Results: Categories, Comparison and Differentiation	155
7.6.1	Linguistic Representation of Correct Sequence	157
7.6.2	Linguistic Representation of Sequence Minus Rule One	157
7.6.3	Linguistic Representation of Sequence Minus Rule Two	157
7.6.4	Linguistic Representation of Sequence Minus Rule Three	157
7.6.5	Linguistic Representation of Sequence Minus Rule Four	158
7.6.6	Linguistic Representation of Sequence Minus Rule Five	158
7.6.7	Symbolic Representation of Correct Sequence	158
7.6.8	Symbolic Representation of Sequence Minus Rule One	159

7.6.9	Symbolic Representation of Sequence Minus Rule Two	159
7.6.10	Symbolic Representation of Sequence Minus Rule Three	159
7.6.11	Symbolic Representation of Sequence Minus Rule Four	160
7.6.12	Symbolic Representation of Sequence Minus Rule Five	160
7.7	Conclusion and Summary	160
8	Discussion and Summary of Contributions	162
8.1	Introduction	162
8.1.1	How does the Deaf Community feel about the Digitisation of Sign Language	164
8.1.2	Marginalisation of Deaf Society from Mainstream Culture, Communication and Education	164
8.2	Principles of Design	167
8.3	A Summary of Research Contributions	169
8.3.1	Motivation Revisited	169
8.3.2	Challenges Revisited	170
8.3.3	Summary of Contributions	170
8.4	Application of Research and Future Directions	170
8.4.1	Application of Research	171
8.4.2	Applicability to other Sign Languages	171
8.4.3	Originality, Impact and Timeliness of the Research	171
8.4.4	Relevance to Beneficiaries	171
8.5	A Summary of Research Conclusions	172
	Appendices	173
A	Experimental Research Design for the Deaf	174
A.1	Framework and Experimental Document Design Rules	174
A.2	Visual Language Translation Rules	175
B	Final Design of Investigation: Comparative Evaluation of Digital Representations of Sign Language for Different Information Delivery Contexts	177
B.1	Experimental Methodology	177
B.2	Hypothesis	177
B.3	Sampling	178
B.4	Incentives and Procedures	178

B.5	Data Collection Method Used	179
B.6	Materials	180
C	Detailed Descriptions of the ANOVAs and <i>t</i>-tests Conducted on the Static and Real-time Presentations of the Artificial Representations of Sign Language	181
C.0.1	<i>Levels of Acceptability in Video, Animation and Notation in Static Mode</i>	181
C.0.2	<i>Levels of Acceptability in Video, Animation and Notation in Real-time Mode</i>	182
C.0.3	<i>Levels of Usability in Video, Animation and Notation in Static Mode</i>	182
C.0.4	<i>Levels of Usability in Video, Animation and Notation in Real-time Mode</i>	182
C.0.5	<i>Levels of Likeability in Video, Animation and Notation in Static Mode</i>	183
C.0.6	<i>Levels of Likeability in Video, Animation and Notation in Real-time Mode</i>	183
C.0.7	<i>Levels of Comprehension in Video, Animation and Notation in Static Mode</i>	183
C.0.8	<i>Levels of Comprehension in Video, Animation and Notation in Real-time Mode</i>	184
C.0.9	<i>Levels of Linguistics in Video, Animation and Notation in Static Mode</i>	184
C.0.10	<i>Levels of Linguistics in Video, Animation and Notation in Real-time Mode</i>	184
C.0.11	<i>Levels of Linguistic Rating with Handshapes in Video, Animation and Notation in Static Mode</i>	185
C.0.12	<i>Levels of Linguistic Rating with Handshapes in Video, Animation and Notation in Real-time Mode</i>	185
C.0.13	<i>Levels of Linguistic Rating with Morphology in Video, Animation and Notation in Static Mode</i>	185
C.0.14	<i>Levels of Linguistic Rating with Morphology in Video, Animation and Notation in Real-time Mode</i>	186
C.0.15	<i>Levels of Linguistic Rating with the Distance of the Arm from the Body in Video, Animation and Notation in Static Mode</i>	186
C.0.16	<i>Levels of Linguistic Rating with the Distance of the Arm from the Body in Video, Animation and Notation in Real-time Mode</i>	186

C.0.17	<i>Levels of Linguistic Rating with Lip Movement in Video, Animation and Notation in Static Mode</i>	187
C.0.18	<i>Levels of Linguistic Rating with Lip Movement in Video, Animation and Notation in Real-time Mode</i>	187
C.0.19	<i>Levels of Linguistic Rating with Facial Expression in Video, Animation and Notation in Static Mode</i>	187
C.0.20	<i>Levels of Linguistic Rating with Facial Expression in Video, Animation and Notation in Real-time Mode</i>	188
C.0.21	<i>Levels of Linguistic Rating with the Correct Sentence BSL Structure in Video, Animation and Notation in Static Mode</i>	188
C.0.22	<i>Levels of Linguistic Rating with the Correct Sentence BSL Structure in Video, Animation and Notation in Real-time Mode</i>	188
C.0.23	<i>Levels of Linguistic Rating with the Correct Placement in Video, Animation and Notation in Static Mode</i>	189
C.0.24	<i>Levels of Linguistic Rating with the Correct Placement in Video, Animation and Notation in Real-time Mode</i>	189
C.0.25	<i>Levels of Linguistic Rating with the Correct Signing Context in Video, Animation and Notation in Static Mode</i>	190
C.0.26	<i>Levels of Linguistic Rating with the Correct Signing Context in Video, Animation and Notation in Real-time Mode</i>	190
D	Final Design of Investigation: Establishing the Rules of Emotional Software Design	191
D.1	Experimental Methodology	191
D.2	Hypothesis	191
D.3	Sampling	191
D.4	Incentives and Procedure	192
D.5	Data Collection Methods Used	193
D.6	Materials	193
E	Linguistic and Symbolic Rules, System Development Steps, Architectural Model and Principles of Design of Emotional Engineering of Artificial Sign Languages	194
E.1	Rules	194
E.1.1	Rule One - Linguistic Emotional Representation in Lip Patterns	194
E.1.2	Rule One - Symbolic Emotional Representation in Lip Patterns	195
E.1.3	Rule Two - Linguistic Emotional Representation of Facial Expression	196

E.1.4	Rule Two - Symbolic Emotional Representation of Facial Expression	196
E.1.5	Rule Three - Linguistic Emotional Representation of Torso	197
E.1.6	Rule Three - Symbolic Emotional Representation of Torso	197
E.1.7	Rule Four - Linguistic Emotional Representation of Handshape . . .	197
E.1.8	Rule Four - Symbolic Emotional Representation of Handshape . . .	198
E.1.9	Rule Five - Linguistic Emotional Representation of Signer's Space .	198
E.1.10	Rule Five - Symbolic Emotional Representation of Signer's Space . .	199
E.2	System Development Steps	199
E.3	Architectural Model	200
E.4	Principles of Design	200
F	Emotional Engineering within Nielsen's Usability Heuristics	203
G	Emotional Engineering within Shneiderman's Eight Golden Rules	207
	Bibliography	211

List of Figures

2.1	Generic architecture of sign language technology, assisting in categorising past, present and future technologies	26
2.2	Datacapture Method Used for “TESSA” the Avatar [Cox et al., 2002]	28
2.3	Data capture Method Used for “Simon-the-Signer” [Bangham et al., 2000]	28
2.4	Example of an avatar which uses motion capture and replay [Bangham et al., 2000]	29
2.5	Example of animation made by the motion capture broken down into frames [Cadiz and Salvador, 2000]	29
2.6	Examples of images synthesized in a test sequence [Malciu and Preteux, 2000a, Malciu and Preteux, 2000b]	30
2.7	Example of a system which allows for linguistic analysis of signs [Neidle, 2004]	33
2.8	Examples of SignWriting Symbols [Sutton, 2004]	34
2.9	Examples of Makaton Symbols [Walker, 1970]	35
2.10	Example of the syncWRITER system [Hanke and Prillwits, 1995]	35
2.11	Example of a streaming video system available online [Stewart et al., 2002]	37
2.12	Example of an ASL fingerspelling system made in a Virtual Reality Modelling Language [Su, 1998, Nakamura, 2002]	39
2.13	Example of Visia the avatar that signed the weather [Verlinden et al., 2002]	40
2.14	Modelling and Generating Sign Language as Animated Line Drawings [Godenschweger and Strothotte, 1998]	42
2.15	Modelling and Generating Sign Language as Animated Line Drawings [Godenschweger and Strothotte, 1998]	42
2.16	Modelling and Generating Sign Language as Animated Line Drawings [Godenschweger and Strothotte, 1998]	43
2.17	Example of the signing avatar designed by DePaul University [Davidson, 2002]	44
2.18	Avatar system to teach Auslan [QDS, 2004] demonstrating real-time 3D graphics for human modelling and teaching sign language [Yeates et al., 2002]	45
2.19	Example of an animated tutoring system for mathematics [Adamo-Villani and Beni, 2002a, Adamo-Villani and Beni, 2002b]	45
2.20	Example of an Avatar system where users can make sign animations [EMMA, 2004]	46

2.21	Example of sign language synthesis project in the University of New Mexico [Ipke Wachsmuth, 2002]	47
2.22	Picture of Andy-the-Avatar [NSF, 2001]	47
2.23	Example of a VCOM3D Avatar [NSF, 2001]	48
2.24	Example of a VCOM3D avatar	48
2.25	THETOS (Text into Sign Language Automatic Translator for Polish) Avatar animation in real time [Suszczanska et al., 2005, Francik and Fabian, 2002, Fabian and Francik, 2001]	49
2.26	Example of the Narrative Use of Sign Language by a Virtual Character for the Hearing Impaired [Thomas Rieger, 2003]	50
2.27	Types of digital representations of sign language, broken down further	54
3.1	Framework of Experimental Design for the Deaf	69
3.2	Example of Implementation of Rule One of Experimental Design for the Deaf	70
3.3	Example of Implementation of Rule Three of Experimental Design for the Deaf	71
3.4	Example of Implementation of Rule Four of Experimental Design for the Deaf	71
3.5	Example of Implementation of Rule Eight of Experimental Design for the Deaf	72
3.6	Example of Implementation of Rule Nine of Experimental Design for the Deaf	73
4.1	Video System Used in the Experiment	81
4.2	Animation System Used in the Experiment	81
4.3	Notation System Used in the Experiment	82
4.4	A bar graph displaying descriptive statistics for static presentations. The above scale is 1 for Excellent to 5 for Poor ratings	94
4.5	A bar graph displaying descriptive statistics for real-time presentations. The above scale is 1 for Excellent to 5 for Poor ratings	95
5.1	Example of difference between English, SSE and BSL	104
5.2	Stickmen Images used in Experiment	107
5.3	Stickmen Face Image used in Experiment	108

6.1	<i>Rule One: Mouthing Words Linguistically</i> - An example of a signer with and without mouthing words. In example one the signer is signing, but without lip patterns, it appears as an “S”. If this motion is tapped twice it could then be interpreted as September. With example two the same sign with lip patterns has changed the meaning to a name. In this example the signer is signing “Sarah”, the word said while the “S” is signed.	118
6.2	<i>Rule One: Mimicking Sounds Linguistically</i> - An example of a signer with and without mimicking sounds. In example one the signer signs a phone. In example two the addition of the lip patterns indicates that the phone is ringing, which in a different context can have direct implications on what action is taken on communication of such information i.e. the phone needs to be answered.	119
6.3	<i>Rule One: Movement of Objects Linguistically</i> - An example of a signer with and without lip patterns for the movement of objects. In example one we understand the signer is explaining that something is being carried; in example two we can understand that the signer explains that something heavy is being carried through the lowered puffing of his cheeks. This has direct implications for how a subject or conversation is understood by a viewer of signed information.	119
6.4	<i>Rule One: Characters Linguistically</i> - An example of a signer with and without lip patterns when signing about characteristics. The first example shows the sign without lip patterns, although this can be understood it can be ambiguous. However with the second example the facial expression clarifies the meaning of the sign, which loosely translates to “prim and proper/reserved”. This is indicated by the facial expression, which include the lip patterns. Both of these are important to clarify the meaning of the sign. Facial expression in signing is almost analogous to tone and intonation of voice.	120
6.5	<i>Rule One: Questioning Linguistically</i> - An example of a signer with and without lip patterns when questioning. Example one is when a signer is signing the word “what” without lip patterns. This is the incorrect way to sign this and holds no emotional meaning. However in example two the lip patterns that are part of the facial expression provide emotional meaning. These lip patterns can be lessened and exaggerated depending on the context/emotive mood in which the sign is being used.	120
6.6	<i>Rule One: Expressing Feeling Linguistically</i> - An example of a signer with and without lip patterns when expressing feeling. Example one is an ambiguous sign and can mean intention or something related to the heart. With example two the facial expression clarifies the feeling as “shock”. . . .	121

6.7	<i>Rule One: Mouthing Words Symbolically</i> - This presents two correct ways to use and introduce new vocabulary, as done linguistically in BSL lip patterns. One can be a text with the new word next to the image of the individual. This example shows an image of an individual/cartoon image of a character. This method can also be used with images of objects, locations or other things that may be unfamiliar to the target audience as shown in the second image, which has been circled in red. This red circle can then be used throughout the information system providing an indication to the viewer of new vocabulary.	121
6.8	<i>Rule One: Mimicking Sounds Symbolically</i> - In the first image, there is a telephone but the second image shows that the telephone is ringing just by adding an indication of sound coming from the object itself. If there was a need to indicate the phone was ringing the second image would be correct use of this rule	122
6.9	<i>Rule One: Movement of Objects Symbolically</i> - The first image shows the car with a driver inside. In the second image it becomes clear that the car is moving forward, due to the additional symbols of smoke behind the car's exhaust pipe. This gives the indication of movement. This symbol could be altered to indicate high speed or a slow moving vehicle. The second image is the correct use of this rule.	122
6.10	<i>Rule One: Characters Symbolically</i> - This example clearly shows the dialogue between two individuals. There is use of colour and images to label the text to specified individuals in the conversation. Thus allows for a clearer understanding of the character shift, but also indicates the emotion/tensions being presented by the characters in the conversation, being that one is calm and the other frustrated.	123
6.11	<i>Rule One: Questioning Symbolically</i> - An example of a symbolic way to present a question, where the character's face and the way the question has been written could imply that there is confusion around a given topic. This provides more information about a subject than plain written text, where we are able to establish that the character is confused and asks "what?" . .	124
6.12	<i>Rule One: Expressing Feeling Symbolically</i> - In this example, using additional images allows for a clearer understanding of the emotion experienced. In image one it says "I love you" and in the second image, the additions say "I hate you", two very clearly different feelings. The feelings have been exemplified with symbols, words and colours, which visually enhance their meaning.	125

6.13	<i>Rule Two: Forehead Linguistically</i> - Example one demonstrates the sign for “why?” but the emotion is not expressed in the face; with example two the forehead provides a clear sign of the word “why?” and also the emotional emphasis in the questioning. Thus provides clarity to the meaning of the sign.	126
6.14	<i>Rule Two: Cheeks Linguistically</i> - Example one is an ambiguous sign, with example two it becomes clear that the sign is a description and it means someone is “very thin”, the cheeks drawn in are used to emphasise the thinness of the individual.	127
6.15	<i>Rule Two: Forehead Symbolically for Questioning</i> - An example demonstrating that by changing the styling of the text, the emotional meaning has been established. Example one is without the emotional symbolic transformation, and example two is with the symbolic emotional translation.	127
6.16	<i>Rule Two: Forehead Symbolically for Feeling</i> - In this example there is one character, with different symbols. The meaning of the same character is changed because of the input of the symbols.	128
6.17	<i>Rule Two: Cheeks Symbolically</i> - An example of an image where the alteration of the person within the image changes the size of the cake. In image one the slice of cake would be considered smaller, as opposed to the second image	128
6.18	<i>Rule Three: Emphasis Linguistically</i> - An example of a signer using his torso to bring emphasis to his signing.	130
6.19	<i>Rule Three: Character Shift Linguistically</i> - An example of a signer using his torso to demonstrate character shift when describing a conversation.	130
6.20	<i>Rule Three: Emphasis Symbolically</i> - In this example the same sentence has been symbolically represented in two possible ways. One with textual description and the other with image description. Both demonstrate how emphasis can be used within a symbolic representation of BSL.	131
6.21	<i>Rule Three: Character Shift Symbolically</i> - This image provides a symbolic way of presenting character shift, much like the example in <i>Rule One: Characters Symbolically</i> . When presenting character shift, several sign language linguistic components are used to make the signing accurate. As demonstrated here, this can overlap into different areas of emotional awareness in information system development.	132
6.22	<i>Rule Four: Size Linguistically</i> - An example of a signer showing a small and large size object. Example one is the smaller size of the object and example two is larger size of the object.	134

6.23	<i>Rule Four: Weight Linguistically</i> - An example of a signer showing a light and heavy object. Example one is the lighter object and example two is heavier object. Note also that facial expression has also changed, and this should highlight the overlapping and the interaction of the linguistic rules.	135
6.24	<i>Rule Four: Direction Linguistically</i> - An example of a signer showing direction. Example one is showing the direction sign for right and example two is showing the direction sign for left, it should also be noted that there is a change in lip patterns to express this sign.	135
6.25	<i>Rule Four: Shape Linguistically</i> - An example of a signer showing the shape of a box. Example one is the first part of the sign, and example two last part of the sign	136
6.26	<i>Rule Four: Vocabulary Linguistically</i> An example of a signer showing the sign for aeroplane. This is an example of how hand shape can form vocabulary, the wrong handshape can make the sign ambiguous	136
6.27	<i>Rule Four: Size Symbolically</i> - An example of how size can be demonstrated with different symbols within an image. Changing the proportions of the two symbols has altered the understanding of how large the tree is. Image one shows a smaller tree and image two shows a larger tree.	137
6.28	<i>Rule Four: Weight Symbolically</i> - An example of a man lifting a heavy object. The demonstration of feeling on the face and the size of the actual object that he is lifting demonstrates that he is lifting a heavy weight.	137
6.29	<i>Rule Four: Direction Symbolically</i> - An example of a map in this image is a clear way to provide directions and would be a symbolic way to represent directions in sign language.	138
6.30	<i>Rule Four: Shape Symbolically</i> - When representing the shape of an object in symbolical form, it is best to show the object itself. In this example an image of a box is shown to describe the shape of a box. This can be done with any object/person, for example the person was tall and thin.	139
6.31	<i>Rule Four: Vocabulary Symbolically</i> - In this example the word can either be shown as text or its image equivalent (as shown in the example above), depending on the target audience and their level of literacy. If the words are more complicated, it is better to introduce the image with the word, and as the users get used to the word, the image can be used to reference the word symbolically, or the text can be used, again depending on the user group of the information system.	139
6.32	<i>Rule Four: Layout of Story and Structure Linguistically</i> - In this example the images used demonstrate how a signer would use his signing space to layout information. This provides a layout and structure to the information in the signing sentence.	140

6.33	<i>Rule Four: Layout of Story and Structure Symbolically</i> - In this example, the information is laid out. Firstly it identifies the three main characters within the dialogue, and then uses those images within the text to clarify who was speaking. This allows for clarity of what is being said and by whom. This could also be used with locations, objects or other significant elements to a conversation/discussion/dialogue.	142
6.34	Emotional System Design	144
7.1	A bar graph displaying descriptive statistics for the assessment of varied Symbolic and Linguistic representations of information systems.	156
A.1	Framework of Experimental Design for the Deaf	174
E.1	Emotional System Design	201

List of Tables

4.1	Descriptive Statistics of Notation Systems Static Presentation in the Categories of Usability, Likeability, Acceptability, Comprehension and Linguistic Ability NOTE: Min represents minimum values, Max represents maximum values and SD represents Standard Deviations. The above scale is 1 for Excellent to 5 for Poor ratings. The above table presents descriptive statistics for the notation system in static presentation mode. Data summarised here provides the basic features of the data in this study. The sample group was a total of 20 participants, and we are able to establish from the data there was a strong dislike of the system that was presented.	92
4.2	Descriptive Statistics of Animation Systems in Static Presentation in the Categories of Usability, Likeability, Acceptability, Comprehension and Linguistic Ability NOTE: Min represents minimum values, Max represents maximum values and SD represents Standard Deviations. The above scale is 1 for Excellent to 5 for Poor ratings. This table also presents descriptive statistics, but for the animation system in static presentation mode. Data summarised here provides the basic features of the data in this study. The sample group was a total of 20 participants, and we are able to establish from the data there was a dislike of the system that was presented, but it was rated better than the notation system.	93
4.3	Descriptive Statistics of Video systems in Static Presentation in the Categories of Usability, Likeability, Acceptability, Comprehension and Linguistic Ability NOTE: Min represents minimum values, Max represents maximum values and SD represents Standard Deviations. The above scale is 1 for Excellent to 5 for Poor ratings. This final table, presents descriptive statistics, but for the video system in static presentation mode. Data summarised here provides the basic features of the data in this study. The sample group was a total of 20 participants, and we are able to establish from the data that participants liked this presentation the best out of the three systems in static mode.	93

4.4	Descriptive Statistics of Notation Systems in Real-time Presentation in the Categories of Usability, Likeability, Acceptability, Comprehension and Linguistic Ability	NOTE: Min represents minimum values, Max represents maximum values and SD represents Standard Deviations. The above scale is 1 for Excellent to 5 for Poor ratings. The above table presents descriptive statistics for the notation system in real-time presentation mode. Data summarised here provides the basic features of the data in this study. The sample group was a total of 20 participants, and we are able to establish from the data there was a dislike of the system, similar to the results found in the static presentation in table 4.2.	93
4.5	Descriptive Statistics of Animation Systems in Real-time Presentation in the Categories of Usability, Likeability, Acceptability, Comprehension and Linguistic Ability	NOTE: Min represents minimum values, Max represents maximum values and SD represents Standard Deviations. The above scale is 1 for Excellent to 5 for Poor ratings. The above table presents descriptive statistics for the animation system in real-time presentation mode. Data summarised here provides the basic features of the data in this study. The sample group was a total of 20 participants, and we are able to establish from the data there was a strong dislike of the system that was presented and the results were not much different from the static data set presented in table 4.1.	94
4.6	Descriptive Statistics of Video Systems in Real-time Presentation in the Categories of Usability, Likeability, Acceptability, Comprehension and Linguistic Ability	NOTE: Min represents minimum values, Max represents maximum values and SD represents Standard Deviations. The above scale is 1 for Excellent to 5 for Poor ratings. The above table presents descriptive statistics for the video system in real-time presentation mode. Data summarised here provides the basic features of the data in this study. The sample group was a total of 20 participants, and we are able to establish from the data there was a liking of the system, similar to the results found in the static presentation in table 4.3. As noted from the three above tables they are very similar to the descriptive statistics shown in the three tables for static presentation.	95

4.7	Correlations Between Static and Real-time Presentations of Digital Representations of Sign Languages for the Respective Variables NOTE: Sig represents Significance and column entries with 0.000 denote a value smaller than three decimal places. A statistical relationship between two variables (static and real-time) identified a few correlations of a high positive correlation. Means are shown in order to indicate that - the high correlations are not withstanding the variables were generally high (poor understanding). The main significant differences and correlations were found only in animation and notation, video did not show any statistical significance in terms of difference or correlation. This was data found again on the same 20 participant sample group.	97
4.8	Summary of Significance Levels of ANOVA's Testing for the Differences Between the Three Systems (Animation, Notation and Video) in Static Presentation Modes in Respect of Varied Categories. Further post hoc analysis was conducted in the form of t-tests between the groups, and significantly relevant results are shown (<i>p</i> -values denote the results from varied <i>t</i> -tests. V represents video, A represents Animation and N represents Notation.	101
4.9	Summary of Significance Levels of ANOVA's Testing for the Differences Between the Three Systems (Animation, Notation and Video) in Real-time Presentation Modes in Respect of Varied Categories. Further post hoc analysis was conducted in the form of t-tests between the groups, and significantly relevant results are shown NOTE: (<i>p</i> -values denote the results from varied <i>t</i> -tests. V represents video, A represents Animation and N represents Notation.) . . .	102
5.1	Data from the Final run of the Feedback Session with members of the Deaf Community, Stating the most Important areas of Communication on a signer when Communicating NOTE: It can be noted that some participants did not mark a third area of importance on a signer.	111
5.2	Data from the Final run of the Feedback Session with members of the Deaf Community, Stating the most Important areas of Communication on a signer when Observing the Face NOTE: It can be noted that some cells are blank because participants either chose between the forehead or cheeks as the second most important area of the face, and also did not mark a third area of importance on a signer, therefore those cells are empty in the table	112

Chapter 1

Introduction

1.1 Introduction

The introduction comprises an overview of all the research that will be reported in this dissertation. It outlines the background, motivation and challenges of the research and provides a preliminary survey of related work. The central question that drives the research is stated together with the methods through which a solution will be achieved. The introduction closes with a summary of the contribution that will be made by this dissertation.

1.2 Background

Deaf end-users experiences are an integral to this research. For many people who are born deaf, deafness is part of their identity. They are proud to be Deaf and use sign language communication both as a natural language, and as a statement of this pride. (Some members of the d/Deaf community use a capital D when referring to themselves, hence the use of “d/Deaf”, please see chapter 2 for more details.) For example British Sign Language (BSL) in the UK, is used in preference to speech (also known as the oral method of communication). One of the main concerns of the Deaf community is the preservation of sign language, as echoed in these remarks by a participant [Naqvi, 2005]:

Sign Language is my language, I don't want to accept an artificial form of the language that does not match to our needs, as this will only water it down. If we accept it, it may be pushed in all ways of communication: television, internet, radio or train stations. Then you may end up with a whole generation of children learning this way of signing, and our language in its natural form is disappearing... It is like the British and when they went to India and tried to make everyone speak English, they affected the natural culture and way of life and caused division. I don't want that for us (Deaf people/community).

This dissertation focuses on ways in which information systems are developed for sign language users who are d/Deaf or Hard of Hearing (HOH). It categorises and investigates

digital representations of sign language (DRSL) in order to comparatively evaluate their properties. DRSL's aim to replicate sign language in its physical form and style through digital medium. Three main types of DRSLs have been categorised, these are notation, animation and video systems.

Notation systems are a method in which graphical alphabets and images are used to either depict the physical sign (i.e. the sign for driving a car is a person steering the wheel) or to demonstrate a concept (i.e. a picture of the car in motion). Notation systems that depict sign language are able to document sign language movement in a graphical written form, which can be later used for reference and to recreate a sign and its movement [Hanke, 2004]. Notation systems that use images assist in creating a visual alternative to textual descriptions, which can explain a particular concept/topic [Carter, 2006].

Video systems are filmed sequences of signing that are edited and can be used in a variety of areas, such as television [C4, 2005], the Internet [Booth, 2003], CD ROM's or video cassettes. These two-dimensional (2D) sequences are able to demonstrate signing in its natural flow and are often used for learning and information delivery.

Animation systems use 3D avatars (virtual humans) which are able to demonstrate signing from several angles and view points. These systems are usually designed in two different ways; one is synthesised where the avatar is heavily programmed, and the other is captured, where the signing avatar is a replication of an actual human signer. These systems are fairly new and are being used and applied in many different areas, such as from education [Multimedia, 2006] to online weather reports [Verlinden et al., 2002].

Although work has been conducted into isolating the problems related to the functionality of particular DRSLs, there is no consensus regarding the design strategies for improving and eradicating common reoccurring errors of systems design for the d/Deaf. These systems should not simply arise as a consequence of coupling different DRSLs together in hope that have a working end result. Each system has a different approach to presenting a DRSL, and each holds its own benefits and drawbacks. These have been examined in forthcoming chapters.

The overall mixed opinions of these systems demonstrate that more needs to be understood when representing this complex and culturally rich three-dimensional (3D) language that is sign language. This issue is fundamental not only to understanding what DRSLs should be dealing with, but also how their essential characteristics might be exploited to increase their effectiveness for information delivery. More generally, if research is to be conducted into digital representations of sign language then it is first necessary to clearly identify the aspects which are unique in DRSLs, which is the aim of this research.

As empirical studies demonstrate, advanced technical solutions to addressing the information access needs of the Deaf community do not guarantee their ability to communicate information well, there are more fundamental things that need to be understood. This

thesis focuses on a reoccurring issue raised by Deaf participants, namely the concept of “emotion” and the lack of it in failing DRSL systems. The concept of “emotional” content, what this means to the end-user and how to translate it so that it is understood by the system designer is explored. Further a design methodology for future systems is proposed. This design methodology is referred to as the “Emotional Engineering of Artificial Sign Language” and forms the main contribution of this thesis. The remainder of this introduction comprises of motivation and challenges, aims and contribution of the research.

1.3 Motivation

Research into DRSLs is motivated by the need (both scientific and commercial) to increase the effectiveness of DRSLs for affective information delivery within the digital domain.

In current systems, the following issues affect the overall design and delivery of DRSLs.

1. There is no universally accepted digital representation of sign language.
2. Should there only be one DRSL to fit all communication needs?
3. Systems that are made often assume that all d/Deaf people have similar communication needs.
4. DRSLs have been refined and developed without comparison to alternative approaches.
5. There is no existing design methodology for developing information systems for the d/Deaf.

It is now generally understood that individuals with different information retrieval needs view and interact with systems differently. For example different deaf people have different language needs depending on their deafness and their preferred communication modes. Prelingually d/Deaf people often prefer structured sign languages with lip patterns. Whereas hard of hearing(HOH) deaf people may prefer clearer lip patterns because they still have some residual hearing and can therefore match some sounds with lip patterns. However there is little literature around the appropriate approach for designing information systems for the d/Deaf, so that technologists are unable to take such guidelines into account and develop systems of their own.

This suggests that there might be gains if it were possible to know more about the language needs of the target audience and how that can transfer into the digital domain. It is common knowledge amongst users of sign language that there is no universally accepted form of sign language. For example in the UK, forms of sign languages range from British

Sign Language to Sign Supported English and furthermore each has dialectal differences. Therefore it is difficult to design software systems that can apply to all language groups when the communication needs are so clearly different.

Users may also differ in their information representation needs, some may feel very comfortable with simply having textual information, other users may prefer BSL and therefore they will need a visual representation to suit their needs. It should also be considered that users may have different pre-conceived views of DRSLs and therefore this may affect how DRSLs are perceived and received by the d/Deaf community. For example, video systems may be a preferred system choice, as they are widely used as a digital platform for sign language delivery. Animation systems are fairly new and still mainly in research and development, therefore the exposure of these systems to the target audience is limited. It could be suggested that people may view these systems differently. Not only are these differences dependent on the users exposure to different DRSLs but also to the level and type of language in which the user is proficient.

As a consequence of the fact that these decisions are unilateral and irreversible (i.e., design decisions on systems cannot be easily changed once the system is fully implemented), it can be said that the designer owns the system that is made. Thus, in systems using DRSLs designers can lack an understanding of the target audiences needs, and in turn the target audience may feel that they have not been consulted in the final decision making of the system's delivery platform. This disempowerment in the design stages of the systems development has an impact on the system's overall acceptance and use within the d/Deaf community. This is the primary motivation for the research undertaken in this dissertation.

The research in this dissertation is motivated by the view that merely providing users with DRSLs does not realise the potential effectiveness of DRSLs in information delivery tasks. The current lack of a methodology for the design of DRSL's to guide designers and implementers further motivates the work proposed here. Through a comparative evaluation of DRSLs and a detailed empirical investigation into the needs and perceptions of potential users, a methodology will be proposed.

1.4 Challenges

This methodology will have to address the following challenges:

1. Which DRSL would users prefer and why?
2. Is there a combination of DRSL's that can be used for information delivery purposes? and what are they?
3. What are the d/Deaf or HOH community's concerns about DRSL's?

4. What needs to be done in order to develop an accurate representation of sign language on the digital domain, and for designers to incorporate more effective strategies to producing systems for the d/Deaf?

It is important to address not only what DRSLs are, but also how their essential characteristics might be exploited to increase their effectiveness. In this dissertation it is argued that a characterisation of sign language and its key properties can be used in the design of information systems to increase the overall acceptance of these systems by the d/Deaf community.

It has been noted that most systems have been designed and evaluated in a unilateral method, without comparison to other more widely accepted DRSL systems. The lack of large-scale comparative empirical studies into the effectiveness and efficiency of DRSLs, suggests that a descriptive stance is more advisable at this stage in the research. As there is no prior reason to constrain the space of possibilities, one is led to conclude that in principle, all the decisions that designer's make when making systems for the d/Deaf or HOH audience, are potentially within the scope of individual studies of DRSLs. As far as the author is aware this has not been investigated and is not offered by any of the studies into DRSLs.

One of the challenges of this dissertation is to address the varying acceptance rates that DRSL's have received. For example video systems are often favored over the more technically advanced systems because they clearly show an exact replica of the native signer. Video systems can clearly show two-dimensional signing, however they are not interactive, they are difficult to modify once recorded and they are less cost-effective than the other two comparable systems. Whereas an animation system would be more cost affective on resources as it can dynamically generate sequences of signs and allows for modification within sequences. However, previous studies have suggested that animation systems lacks facial expression [Verlinden et al., 2002] and therefore the signing becomes ambiguous.

When examining this issue further it has been found in recent studies that native signer's have a type of peripheral vision, [Agrafiotis et al., 2003] such that signer's will focus mainly on the face while communicating. Outside of that main signing area, sign shapes become simpler and less intricate. Therefore it can be safely assumed that signer's focus mainly on the face when watching signing, thus a lack of facial expression on avatars is an important issue in the design of this type of DRSL, and the reasoning behind its low acceptance could be attributed to this. This is touched on within the studies presented in this thesis, where it was found that facial expression was a key element to the "emotion" that the participants said they needed for the system to be affective in its communication.

However, it is recognised that the introduction of comparatively evaluating DRSLs can add an extra layer of complexity, as these systems represent the concept of information delivery in the digital domain, and are presented and designed differently. This study

will not be examining the deeper cognitive processes of how these systems are being received, but more so the way in which to identify acceptability criterion for future system design through user-led evaluation. These systems are being tested on their ability to communicate information to the target audience they have been designed and promoted for. This thesis looks at the ability of these systems to deliver information to the d/Deaf, and which current DRSL's are able to facilitate high levels of comprehension.

Although there are many existing DRSLs within the three broad categories of notation, video and animation systems, there is still little acceptance of newer and more technically efficient systems. The translation of sign language onto the digital domain, although appearing quite simple to replicate sign language movement, is hampered by the lack of understanding of the intricacies within the facial expression and what these mean for a signer. However not all system designers consult effectively with the d/Deaf community. With oral languages, the task is to design a character set appropriate for the spoken language, with sign languages there needs to be an understanding of the visual structure of the physical signing and then find its appropriate digital alternative. The first question that therefore must be addressed is, what are the essential characteristics of a DRSL that will allow a system to be accepted by the d/Deaf or HOH community?

In order to address this question, it is important to understand the following:

1. What is sign language?
2. How is it formed?
3. What makes communication happen in sign language?
4. What is lacking in newer designs of DRSLs?

1.5 Aims of the Research: Central Question

How does one design an effective information system for the d/Deaf community, and how does one measure its level of effectiveness?

A set of design rules has been proposed as a solution, that should be used when designing DRSL's alongside a process cycle and a set of principles of design for good practice. These are presented in the concluding chapters of this dissertation.

1.5.1 Derived Problems

In answering the central question, the following derived problems present themselves:

1. What is currently available in DRSLs?

2. How to evaluate the comparative effectiveness of DRSLs?
3. What are the essential characteristics of DRSLs that make a system effective?
4. How to design experiments for the d/Deaf?
5. How to propose an appropriate framework with the knowledge and experience gained?
6. How to evaluate the effectiveness and accuracy of the framework once completed?

An analysis of existing responses to these problems elicits the following shortcomings:

1. It can be argued that the predominant approach has been to choose a DRSL and then implement it using a new or existing system. Such an approach means that it is often difficult to definitively question whether the DRSL selected was the most appropriate one, and whether changing the DRSL will effect the acceptance rates of the system. Also there has been a greater focus on the information translation process rather than the effectiveness in information delivery of the particular DRSL selected. DRSL's can never be directly comparable as their natures are different; however their ability to communicate information to a target audience can be compared.
2. The motivation and design decisions made in the process of implementing DRSLs can often fall into the hands of the designer's and there is little evidence suggesting consultation with the target audience (d/Deaf community) before hand. The effectiveness of the information systems ability to communicate can only be evaluated by the d/Deaf community. This assists in highlighting all shortcomings and successful features, but this consultation is often not done at the earlier stages of design.
3. Often the options of DRSLs can become overwhelming and system designer's might base their decisions on various cost factors.
4. It is difficult to analyse and measure the presumably distinct, independent effects of particular DRSLs as there are no guidelines to evaluate the DRSL against. The need for a standardised design criteria to evaluate a system is important and the creation of one is central to the contribution of this thesis.
5. Movement representations of sign language such as Animation and Video are commonly compared by the target audience, where animation is often remarked as the lesser form of the video. This is due to common reoccurrences of problems with facial expression, lip movement and mimicry. This will be investigated in further detail, and also if notations systems can either help with this problem or provide an alternative method of delivery.

In order to respond to these, the research undertakes the following:

1. To characterise DRSLs from the viewpoint of the users
2. To empirically evaluate the comparative effectiveness of DRSL's
3. To identify what characteristics of DRSLs determine its success
4. To provide a design methodology for system designers

In short, this research aims to provide an account of what DRSLs are, what is essential to make a DRSL successful, and how to develop systems better and more accurately for the needs of the d/Deaf or HOH.

1.6 Research Contribution

The main contribution is the methodology, which is referred to as the emotional engineering of artificial sign languages. Through the incremental steps towards this design methodology, several other aspects needed to be investigated and understood before reaching this final stage of research.

The initial challenge was the experimental design approaches, and their appropriateness for the d/Deaf. There was no literature available to support new researchers within this field. Through exploration of this issue, design rules were established, which founded the appropriate approach for experimental investigation with the d/Deaf community. This initial finding developed a deeper understanding of the language needs, but also highlighted the need for the participants to feel comfortable to allow for expressive responses within experimental conditions (in chapter 3). Since the main investigation in this thesis comparatively evaluated existing systems against each other, it was important not only to have d/Deaf people involved in the initial investigation but throughout the entire research process. This ensured that the work done reached the needs of the community. This process helped to identify what was missing in current DRSL's i.e. that which did not meet their communication requirements. Participants started to use the word and concept of "emotional expression" through signing (in chapter 4). Understanding what "emotional expression" truly is, took further and more precise investigation where d/Deaf people themselves identified these "emotional" characteristics (in chapter 5). These were then placed in an hierarchy of importance and formed the basis of the rules that supported the methodology design for information systems for the d/Deaf (in chapter 6). Throughout the entire scope of the research particular principles of good practice were identified and used, these have also been included in the final chapter of this thesis.

In summary this research provides the following:

1. Experimental Design for the d/Deaf

2. Investigation into artificial/digital representations of sign languages
3. Comparative evaluation of digital representations of sign language for different information delivery contexts
4. Emotional engineering of artificial sign languages
5. Principles of design with the d/Deaf

1.6.1 Thesis Structure

1. **Chapter 2** is dedicated to outlining the relationship between deafness and technology. This chapter looks at deafness from the point of view of the community, its history, the evolution of deaf education and how technology addresses communication today.
2. **Chapter 3** this chapter presents the initial findings of testing for differences of perceptions of two different DRSLs against each other within a hearing based learning context. These findings posed questions that related differently for Deaf users and were addressed by developing a rule rule-based translation of regular text experimental documents into a visually rich alternative that works well for Deaf participants.
3. **Chapter 4** investigates the comparative effectiveness of three different digital representations of sign language against each other in a Deaf context. This investigation has identified a relationship between the acceptability criteria and the linguistic criteria essential to make a system successful to the user-group. This finding has had a direct impact on the development of the methodology proposed in this research.
4. **Chapter 5** offers an initial investigation that establishes the rules for emotionally aware systems. These investigations explore in more detail the concept of “emotion” and where this is represented on a signer and what this means.
5. **Chapter 6** presents the system framework, rules and process cycle for Emotional Engineering within systems. This design methodology provides a novel approach to examining and developing systems for the d/Deaf.
6. **Chapter 7** provides a study to assess the rules of design for emotional systems. The investigation presented in this chapter uses the design methodology provided in chapter 7, to design and present some “emotionally aware” DRSL presentations. This tests and evaluates the validity of the methodology proposed.
7. **Chapter 8** is the concluding chapter and discusses the work presented, alongside principles for system design and directions for future work.

1.7 Conclusion and Summary

The natural language of the d/Deaf community (sign language) is 3D (using the hands, body and space in front and around the signer to communicate) and unlike spoken language systems. Research and development has been done in order to design communication aids for the d/Deaf which cater for signing audiences. Such DRSL systems include video recordings, notated signing (that uses pictorial alphabets) and animation systems that create artificial characters that can sign. This thesis challenges the way in which information systems for the d/Deaf have been developed so far. There has been a very blinkered perspective on system development and design, where technologists have understood and worked on one type of DRSL, without a critical understanding of what makes older DRSL's so widely accepted by the community that uses them. The current approach has always worked within its own knowledge domain of one particular DRSL, whereby there is a linear approach to design which revels in its own potential for wide-scale use and application. Despite the fact that the more advanced systems provide a wider range of options to encourage information dissemination on a larger scale, the community still holds onto the less advanced and less versatile older approaches.

In order to identify the aspects of the older technology that shape this preference, this thesis engages in an in-depth analysis and categorisation of the technologies for the d/Deaf community but in particular the technologies/information systems that aim to facilitate communication with an audience whose language is sign language. This research aims to comparatively examine the systems against each other to identify what elements encourage higher acceptance levels of a particular system over another. Once these characteristics were identified they formed the basis of the major contribution of this thesis, namely the "Emotional Engineering of Artificial Sign Language" methodology. This presents a set of rules and a process cycle which aim to encourage more apt systems that embody the language characteristics of the d/Deaf community. It is hoped that they can help define better and more effective communication tools for the d/Deaf, irrespective of the final delivery platform/information system.

Chapter 2 discusses the meaning of Deafness, and its historical-cultural reception with regards to education and acknowledgment of Deaf rights. As such the obstacles that this community faces and the essential need to bring Deaf culture into sign language technology/information systems will be addressed.

Chapter 2

Deafness and Technology

2.1 Introduction

This chapter aims to provide a context for an understanding of deafness, or rather, as it is used by the Deaf community. It will discuss the terminology used by this community, as well as its historical significance. It will introduce the types of technologies that have been made available to this community as well as the aspects of technology that underpin this research. The analysis will highlight both the aims and main motivations of this thesis.

This chapter opens with a discussion of Deafness: what it means and what it entails. Deafness is not simply a medical condition but a cultural identity with a history. This raises several issues that need to be addressed before conducting the work: for example, why the community has attached such importance to the preservation of Deaf education, or how the community has fought for the preservation of sign language. Following this discussion, this thesis identifies the types and categories of technologies and outlines its area of research. It is hoped that this analysis goes some way in illustrating how the needs of the Deaf community have thus far not been addressed and the changes that need to be made in order to create greater inclusion and acceptance of the user group involved. This understanding will aim to maintain and preserve the identity of the community within the technologically-developing world.

2.2 What is Deafness?

In order to work with the Deaf community, it is important to understand how Deafness is seen in terms of the medical and social perspective. Deafness is defined as partial or complete hearing loss, or the loss of ability to hear normally [Killion and Fikret-Pasa, 1993].

There are two types of deafness, conductive and sensori-neural [Killion and Fikret-Pasa, 1993]. These can happen separately or together, and can affect one (unilateral) or both ears (bilateral). There are varying degrees of hearing loss, from slight to profound deafness. Conductive deafness is due to interference with the conduction of sound across the middle ear to the inner ear. Sensori-neural deafness is due to reduced function of the inner ear (cochlea) or the nerve fibres leading to the brain [Door, 2003].

2.2.1 Assistive Listening Devices for Deafness

Assistive listening devices, also known as ALDs, describe a family of devices designed to enhance audibility in particular listening environments. There are two main types of ALDs, where some are used with hearing aids or cochlear implants (CIs), and others are designed to be used alone. Many of the ALDs that are used with hearing aids require telecoil (T-switch) [Web, 2005].

There is a large selection of microphones, pickups, earphones etc., all interested in enhancing audio signals. This signal can be a faraway voice (e.g. lecturer in an auditorium), or a relatively near signal that gets lost in other sounds (e.g. listening to the radio in a car where there are passengers talking to each other, and traffic noise from outside the car).

ALDs amplify sound. However modern ALDs are not designed to make signals uniformly louder, but to be placed close to a particular sound source and make that particular noise signal louder compared to the other sounds. ALD's can improve an individual's ability to hear because they can make the desired sound stand out from a background of several sounds.

2.3 History of Deaf People

Many have tried to “fix” deafness with ALDs as medically it seems like the correct thing to do. However when you examine the history of Deaf people, an unlikely community has formed composed of individuals suffering the same isolation of sound, a grouping together that accepts their Deafness as a major part of their lives rather than as a hindrance. This is a very altered perspective of the medical understanding of and solution for Deafness, and provides a completely altered view of being Deaf.

This history is marked with the early documentations of the Deaf community as far back as Aristotle [Lauri, 2005], the first documented books of sign languages [Bonet, 1620]. Thereafter sign language education was instituted using a manual fingerspelling alphabet. This led to an official recognition of sign language education and the rise of significant figures, many of whom will be discussed in the ensuing sections. Their contribution has been widely documented because of their impact not only in the Deaf world, but also on the perspectives of the hearing world. Despite the noted contribution by educationalists, most of Deaf history has not been well documented and is vast. The following is therefore only a small insight into the diverse and ever-expanding culture of the Deaf.

People with Deafness have been noted as far back as the Old Testament book of Exodus, 4:11 which states: “Who hate made man’s mouth? Or who maketh the dumb, or deaf, or the seeing, or the blind? Have not I the Lord?” There are other books in the Bible, both Old and New Testament, that mention the Deaf: Leviticus 19:14, Proverbs 31:8, Isaiah

29:18 and Micah 7:10 to name a few.

Ancient Greeks and Romans, amongst those of other ancient civilisations, acknowledge Deaf people. Socrates (269-399 BC) for example mentions (in *Cratylus*, 422 BC) the existence of sign language when he enquires, “If we have no voice or tongue and wished to make things clear to one another, should we not try as the dumb do to make signs with our hands...?” [Lee, 2004]

It was the Swedish monks in 1190 who brought about the beginnings of the documented use of body gestures, hand movements and facial expressions, forming of the first recognised document of the visual communication phenomena now known as sign language.

Some monastical orders did not allow their members to speak in the sleeping hall, the kitchen, the dining room, and the church. Instead of speaking, the monks used signs to communicate with each other. Among Swedish monks there were two systems of signing - that of the Dominicans from Sigtuna and that of the Birgittins from Vadstena. [Renate Fischer, 1996]

Documented information about Deafness and its understanding started when the hearing community gave more acknowledgements to the learning ability of the Deaf. For instance Fischer and Vollhaber note that it was the humanistic discourse of the Renaissance and the Reformation that created a climate in which the educational ability of the deaf was recognised. [Fischer and Vollhaber, 1996]

There was a sudden shift of attention, because this once inaccessible community was now given the opportunity to demonstrate its ability to learn and function in mainstream society. Rudolphus Agricola, 1443-1485 [Akkerman and Vanderjagt, 1988], was interested in the Deaf and wrote a book “*De Inventione Dialectica*”. He wrote that people who are born Deaf can express themselves by putting down his thoughts in writing. The book was only published 100 years later.

In 1501-1576 Girolamo Cardano (also known as Geronimo Cardano) [Morley, 1854, Lee, 2004], an Italian physician concerned about his Deaf child, claimed that deaf people can learn. Building upon Agricola’s work, Girolamo asserted that by associating combinations of symbols with the actual thing they represent, deaf people can learn. When Cardano came across Agricola’s book, he agreed that the “sense of hearing and the use of spoken words were not indispensable to understanding ideas.” [Deaf and Information, 2005]

Cardano believed that the Deaf need to learn to read and write, and said it is “True, it is difficult but possible... We can, in reality, manifest our thoughts either with words or with gestures.” [Deaf and Information, 2005]

Cardano invented a code for teaching but did not pursue it, and instead went on to study other medicines. Later in 1620 Juan Pablo de Bonet wrote and published the

first book about teaching sign language to the Deaf; it contained information about a manual alphabet to assist learning. However it was in Spain that the Benedictine monk Pedro Ponce de Leon (1520 to 1584) established the world's first school for the Deaf at the Monastery of San Salvador near Madrid: "He taught the Deaf mutes from birth to speak...while showing them with his finger the object which was named by the written characters; then drilling them to repeat with the vocal organs the words which correspond to these characters." [Deaf and Information, 2005]

Using this method, Ponce de Leon allegedly taught ten to twelve individuals how to speak. Although it has been documented that only two had shown signs of speaking, it was also noted that the rest could sign [Fischer and Vollhaber, 1996].

Juan Pablo Bonet published his book *Simplification of Sounds and the Act of Teaching the Deaf to Speak* in 1620 [Bonet, 1620]. This approach first used pictures to show the Deaf/Hard of hearing (HOH) how to position their hands for a one handed alphabet before they were being taught how to speak and lipread. More literature was produced when John Bulwer (1614-1684), an English physician, published his first two books in 1644, *The Natural Language of the Hand* [Bulwer and Cleary, 1974] and then "The Art of Manual Rhetoric" [Bulwer and Cleary, 1974].

Bulmer was convinced that sign language, then referred to as "the language of the hand" was "the one language that was natural in all men especially for the deafened in the use of a manual alphabet" [Deaf and Information, 2005]. In 1648, Bulwer published his famous book titled *The Deaf and Dumb Man's Friend* [Bulwer, 1648]. This was the first English book explaining Deafness and the language problems associated with it, but it did not address the issue of Deaf education. It was only in 1680 that George Dalgarno, published a book titled *The Deaf and Dumb Man's Tutor* [Dalgarno et al., 2001]. In this book, he had proposed many theories and techniques of teaching language to the Deaf. He knew from previous practices that the Deaf could be taught to speak and lipread, but he felt that the manual alphabet was more effective. Therefore he advised mothers to spell on their fingers the names of various objects and at the same time point to the object.

Johann Konrad Amman (1698 - 1774), a medical doctor had a particular interest in educating "Deaf mutes". Working only with 8 to 15 year olds his educational focus was to ensure that pupils had "a good clear voice and [learned] to control it well." His method involved students placing "their hands on his throat as he taught" so that they "could feel the vibrations of his voice" [Marschark and Spencer, 2003]. To further assist speech practice Amman made the students use mirrors so they could imitate oral communication. He successfully taught the pupils to lipread and published his work, first in Latin in 1692 and later in 1700 called *A Dissertation Speech* [Amman, 1965].

Another key figure in the Deaf community was Jacobo Rodriguez Pereira (1715 - 1780) who was regarded as one of the greatest teachers of the Deaf in France [Ripley and Dana, 2006].

Never taking more than twelve pupils at one time, Pereira offered two courses: one for a larger economically depressed group which covered basic life skills and ran for fifteen months. The second course was created for wealthier students who were deemed more intelligent and ran for four or five years. The latter was more intense and considered superior to the former. However, he kept his methods private and they died with him, and no one knew how to continue his work. He believed that “There will be no more Deaf mutes. There will be Deaf speaking ones.” [Deaf and Information, 2005].

Deaf education in France found its next major figure in Charles Michel De L’Epe (1712 - 1789), born in Versailles, France, who was a priest for 25 years and then later became interested in teaching the Deaf [Adams and Rohring, 2004]. He set-up a shelter for the Deaf in Paris (1760) and started teaching Deaf children in a school setting at Truffaut, France (1762). Living with the children, he provided them with food, clothes and shelter. In 1776, he published a book *Instruction of Deaf and Dumb using Methodical Sign* [Fay, 1893]. He also produced a book called *The Dictionary for the use of Deaf Mutes* [Kiddle and Schem, 1876]. The latter book contained more detailed explanations than actual physical signs/representations and he was famous in all of Europe for his work with Deaf mutes. Other French teachers included Abbe Roch Sicard (1742 - 1822), who was chosen by the Archbishop of Bordeaux to be trained by De L’Epe to teach the Deaf. He was then elected director of the school and eventually opened a school for the Deaf in Bordeaux, France (1782). Sicard almost lost his life in September of 1792 when he was imprisoned during the Massacres of the French Revolution and at this point he went into hiding for two and a half years. While in hiding he wrote a detailed dictionary of signs titled the *Theory of Signs* [Sicard, 1818].

Samuel Heinicke, born April 14th 1727, in what is now known as eastern Germany, met a Deaf mute boy in 1754 and became interested in Deaf education [Heinicke et al., 1968]. He taught the young boy with the use of a manual alphabet, however was strongly against the use of sign language and only used the oral methods. He started to teach the boy subsequent to reading Amman’s book *Surdus Loquens* also known as *The Speaking Deaf* [Amman, 1692]. After teaching a boy in Eppendorf, Germany he was very successful and the boy learnt to speak, lipread and write. The results were so promising that Heinicke decided to teach other Deaf individuals and eventually opened an Oral School for the Deaf in Germany.

When Heinicke started to use writing, sign and gestures, he soon felt that this was not enough and wanted to enhance the learning experience. He began using speech and lipreading to teach what was fundamental to communication. Like Amman, he taught speech by making students feel the throat. Ironically Heinicke taught the method now referred to as the oral method by the use of signs, which are now regarded as two opposing systems. He did use signs and gestures in the initial stages of learning. There is a source that mentions Heinicke had developed a “Language Machine” to represent the mechanisms of speech; he also used food to teach speech. He was creative in his approach and successfully taught

speech and lipreading to his students.

During 1773 and 1775, Heinicke wrote several newspaper articles on deaf education about his use of speech and he named his approach "Oralism". Heinicke became a fulltime teacher of the deaf and he wrote a textbook about it. An interesting fact about Heinicke's career as a deaf educator is he was in contact with another famous educator of the deaf, Abbe de L'Epee. Heinicke is remembered as the "Father of the German method" as he developed the oral method mainly in Germany. Consequently the oral method is known as the "German method" [Kyle, 1987] and de L'Epee is remembered as the "Father of the sign language". As he developed the signing method in France, it is also referred to as the "French method" [Baker-Shenk et al., 1991].

By 1777 Heinicke's reputation as an educator for the deaf was so widespread he was asked to open an oral school for the Deaf that achieved government recognition in Leipzig, Germany. Originally called the "Electoral Saxon Institute for Mutes and Other Persons Afflicted with Speech Defects" and today it is known as "Samuel Heinicke School for the Deaf". The school is home to an extensive library on hearing loss that is over a hundred years old. After he died his wife took over the school, and long after his death Heinicke was honored by East Germany in 1978 on a postage stamp.

In Paris Abbe Charles Michel de L'Epe established the first free school for the Deaf in 1755. His approach to Deaf education was to allow the Deaf people at his school to develop communication themselves, between them and the hearing world. De L'Epe's creative approach helped document a sign system that was being used in Paris, at that time. He first recognised and then learnt the signs that were being used, this resulted in a signed version of spoken French, and established the beginnings of a more structured understanding of the language of the Deaf, thus forming the basis of French Sign Language (FSL). Through the use of conventional gestures, hand signs and fingerspelling, De L'Epe developed a signing system called "methodical signs" that he used to help students learn French. This system was carried on by Abbe Roch-Ambroise Sicard; however Sicard greatly modified the system.

The modern equivalent of De L'Epe's methodical signs would be Sign Exact English (SEE) or Sign Supported English (SSE), which is no longer regarded as native signing, but more an oralist approach to signing. Laurent Clerc wrote that the Deaf never used methodical signs outside the classroom, they always used FSL.

Thomas Braidwood (1715-1806) founded the first private British academy for the Deaf in Edinburgh but the school eventually moved to Hackney in London, England in 1783. At the start of the school, Braidwood accepted gestures and signs and recommended a two-handed alphabet which is used by the British signing community today. On the basis of the gestures and two-handed alphabet he established oral communication. In 1812 his grandson John Braidwood founded the first School for the Deaf in the United States of

America (USA) in Cobb, Virginia. However the influence of this method was cut short due to Braidwood's death [Gallaudet, 2006].

A German pastor named J.F.L. Arnoldi based in America, taught lipreading, speech, reading and writing. He believed that there was no real difference between a hearing and hearing-impaired child's educational development and that children of four to five learn the articulation of speech faster and easier, but the "development of ideas were more rapid in ten and eleven year olds." [Gallaudet, 2006]. He mainly wanted to teach Deaf children to read and published his methods in 1777.

Thomas Hopkins Gallaudet (1787 - 1851) is famous around the world, for being the hearing man who brought education to deaf children in America [Gallaudet, 2006]. Gallaudet, who suffered from ill health all his life, first made contact with the deaf world when he met Alice Cogswell, a deaf child who had no language. While interacting with the child he discovered teaching and sign language. He visited England to study the oral methods of the Braidwoods. He applied for admission but was denied. At this time Sicard was in Paris lecturing.

Gallaudet was immediately invited to the school in Paris where he trained by attending classes and receiving private lessons. He returned to the USA with Laurent Clerc whom he met in Paris. Later in life he met, fell in love and married one of his former pupils, starting a large family of CODAs (children of deaf adults). One of his CODA sons, Edward Miner Gallaudet, grew up to be the first president of Gallaudet University. Thomas Hopkins Gallaudet's life was short, but he left a landmark in deaf education [Gallaudet, 2006]. Laurent Clerc, (1785-1869), was a Deaf student who studied under De L'Eppe and Sicard. After that he was at the Royal Institution for the Deaf in Paris where he taught and met Gallaudet. Gallaudet referred to Clerc as "a master teacher". [Carroll and Lane, 1991]

Together they raised the necessary funds to open a School for the Deaf in Hartford, Connecticut. This opened April 15th 1817 and was the first American school for the Deaf. Clerc's career of 41 years left a lasting influence on education for the Deaf in the first half of the nineteenth century. [Carroll and Lane, 1991, Deaf and Information, 2005].

Horace Mann, (1796 to 1859), a believer in state school, became secretary of state in 1837, and became the secretary of the first Massachusetts school board [Mann and Mann, 2007]. Mann visited the schools for the Deaf in Europe with Samuel Gridley Howe (1801-1876). Howe had a Deaf-blind child who he taught with the use of a manual alphabet. They were astounded to see Deaf children lipreading and using speech in German schools. When Mann returned to America and published his findings in a report, parents were very attracted to this idea and began demanding speech for their Deaf children [Howe et al., 1909].

The most controversial and heavily debated events in the history of Deaf education took place in Milan on September the 6th 1880 where an international congress was held.

The topics of discussion included school building, teaching and methods. The first two subjects were quickly addressed, but the final topic was discussed at great length. Each representative spoke about the methods they used, many used speech, others used the combined system of speech and sign. The congress came to a close and a ruling was put into action. The oral method was favored and conditions were agreed. Children of 8 to 10 years would be admitted into the "Pure Oral Program", and there should be no more than ten children in the class. New pupils were screened and placed in classes of their ability, they were not to work with more advanced students, and their study course would be at least seven to eight years. The developments of the congress were thought to have positive affects on the education of the deaf.

This single event's repercussions were powerful: it had a great impact on the lives and education of the Deaf, and it is regarded that the conference outcomes almost destroyed sign language. The resolution passed in effect banned sign language; the only countries that opposed this ban were the United States and Britain. The supporters of sign language tried to have their opinion heard but they failed. Below are the first of the eight resolutions that were passed;

1. The Convention, considering the incontestable superiority of articulation over signs in restoring the deaf-mute to society and giving him a fuller knowledge of language, declares that the oral method should be preferred to that of signs in the education and instruction of deaf-mutes.
2. The Convention, considering that the simultaneous use of articulation and signs has the disadvantage of injuring articulation and lip-reading and the precision of ideas, declares that the pure oral method should be preferred.

The other resolutions dealt with the following:

1. The instruction of impoverished deaf students.
2. How to instruct deaf students orally.
3. The need for instructional books for the deaf oral teachers.
4. The long-term benefits of oral instruction.
5. The optimal ages for oral instruction and length of instruction.
6. Phasing out of manually instructed students.

To date it is heavily discussed [Padden and Humphries, 1988] how this could have passed: it is speculated that the outcome of the conference was predetermined as the organising committee was against the use of sign language, and over half of the representatives

famous oralists from France and Italy. There were other topics covered at the presentation, but the focus was on the methods of instruction, and from the invited speakers the main methods of instruction that were discussed were oral, and oral with sign. The repercussions of the Milan conference were wide-scale: Deaf teachers lost their jobs, and Deaf people actively contacted supporting organisations to ensure the preservation of sign language deaf culture. The president of Gallaudet College (now known as Gallaudet University) decided to continue the use of sign language on its campus; this immeasurable decision has thought to have helped immensely in the survival of sign language. The Milan conference has left such a strong and lasting impression in Deaf history that it has been remembered in artwork, such as the work of artist Mary Thornley, who has done a painting showing hearing “hunters” seeking to shoot down ASL (American Sign Language) [Adams and Rohring, 2004]. In October 1993 Gallaudet University held a conference called, “Post Milan ASL and English literacy”.

It is notable that there has been an ongoing battle between teaching in sign language and the use of oralism. This heated and very sensitive topic continues today amongst the Deaf community and practitioners within the Deaf community.

2.3.1 Deaf Community

The terms “Deaf community” and “Deaf culture” refer to persons who are culturally Deaf as opposed to those who are deaf from medical/audiological/pathological perspective. The Deaf Community is a group of people that have a common heritage; their mode of communication is sign language, and the community comprises of both Deaf and hearing individuals who respond with varying views to different Deaf-related issues. When used in the cultural sense, the word deaf is often capitalised. Being unable to hear is only part of being Deaf. In fact, when the word is used in the cultural sense hearing is one of the least important criteria used to delineate memberships within the group, many persons who would be labeled as hearing are also heavily involved and part of the community. The community may have varied opinions and views on several issues, but the community in the United Kingdom focuses on Deafness as a positive state of being [Carter, 2006].

2.4 Deaf Culture

Deafness, when approached by health care, is seen simply as a disability with a great focus on its medical aspects. However the Deaf community find this view limited and that it does not embody the sociological implications of deafness. Labels such as “hearing impaired”, “deaf and dumb”, and “deaf mute” are considered undesirable because they refer to a presumed disability. The Deaf community prefers not to view themselves as disabled but more as a linguistic minority, rich in culture and a sense of community, and

is inclusive of those hearing people strongly involved in the community.

2.4.1 What is the difference between deaf and Deaf?

There is a continual debate in the Deaf community about “big D” of Deaf and the “small D” of deaf. The difference between the two is the association with deaf community. “Small d” deaf people do not always associate with the Deaf community; they strive to identify themselves with hearing people and regard their hearing loss in purely medical terms. In contrast, “Big D” Deaf recognise themselves as culturally Deaf, and have a strong Deaf identity. When writing about deafness, many writers will use a capital D when referring to aspects of Deaf culture and a lower case d when referring to hearing loss and some just simply use d/Deaf [Valentine and Skelton, 2003].

2.4.2 What is Deaf Pride?

Deafness was continually seen as an illness that could be cured, or in need of medical attention. This approach still common amongst the hearing community today, is something that the d/Deaf community generally find patronising [Naqvi, 2005]. The d/Deaf community stopped apologising for this “illness” and started to revolt, demanding more respect and recognition in society, for their community, culture and language. They are proud of who they are, what they have overcome and their own cultural identity [Naqvi, 2005]. There is a divide in the d/Deaf community, where some view deafness as a hinderance, and others view it as a difference. This divide is reflected in the concept of Deafness from the view of one its community members “deafness is a disability which is so unique, its very nature causes a culture to emerge from it. ” [Drolsbaugh, 1996]

This cultural exclusiveness is manifested in the Deaf pride movement: the issues raised, the d/Deaf role models, d/Deaf heritage, d/Deaf identity, and recognition of this group of people has emerged within and alongside the hearing community. Its pride is affirmed in popular d/Deaf motto: “deaf people can do anything...except hear”. [Naqvi, 2007b]

Over time several Deaf role models have surfaced giving the community more recognition and pride amongst the hearing world: individuals such as Dr Andrew J. Foster, who was instrumental in founding twenty-two deaf schools and an equal number of religious programs for deaf children in more than twenty countries [Lane, 1994]. Alexander Graham Bell invention’s of the telephone and microphone were initially made to assist the deaf. Bell taught at schools in London and Boston [MacKenzie, 2003]. Others who have aided deaf awareness include Thomas Hopkins Gallaudet [DPN, 1997], Beethoven [Lockwood, 2005] and Helen Keller [Keller, 1970] to name a few.

The community has changed and come to realise and recognise their place in society is alongside their hearing counterparts and not as subordinates. Deaf people find that being

part of their community gives them a sense of strength and position; there is a common bond and understanding of struggle, success and acknowledgement. Some view the Deaf community as a shelter from mainstream society, where others feel it gives them identity and prepares them for the real world.

2.4.3 What does the Deaf/Hard of Hearing community think of different Education Methods

There has been a long lasting, and controversial debate between Oral communication (which generally aims to educate deaf children to facilitate integration into mainstream hearing society of their country), and Manual (sign-language based education, which focuses on introducing the deaf child into Deaf culture). Which option is better is the basis of the debate. On the internet and in public this discussion has many threads and titles, and often can become very heated and serious [ASD, 1915, Weisel, 1998].

This topic is so sensitive because it goes to the heart of deaf education. Parents who have a deaf child have to make very serious educational decisions in the first few years of that child's development. If they are hearing parents with little to no exposure to the Deaf/HOH community, their knowledge base of the subject is limited, and often the oral approach is seen as appropriate. Unless the parents are exposed to Deaf culture, how can they understand the most appropriate educational route? But the question is do many parents know about Deaf culture/community? Many hearing individuals are ignorant of this community because of a lack of exposure and education on the subject. So often children are taught using Oral approach; some flourish in the system but some feel a sense of misplacement and are unable to cope with the pressure and a lack of Deaf/HOH peer group. It has often been noted that with the Oral approach language development is extremely slow, and this limits the child's educational progress [Weisel, 1998, Monaghan et al., 2003]. However with the manual method, the child develops language and vocabulary far faster, and is therefore on the learning path quicker and on equal footing with his/her hearing counterparts. There may be children who have used the Oral approach and have favored it over the manual approach, but each case is individual and the child's success with either approach depends on their circumstances, environment and support.

There are various reports released in favor of either approach and condemning the opposition, so many feel torn and forced to choose one approach over the other. Another method to deaf education is total communication (TC) which incorporates all facets of both Oral and Manual education. However some feel that the development of sign and speech together is dangerous, as the child does not fully develop one language, but interchangeably relies on both, therefore limiting their language development. Again this is also a very heavily-debated topic [Kyle, 1987, Marschark and Spencer, 2003, Knight and Swanwick, 1999].

As previously mentioned, the International Congress in Milan and its resolution against sign language and in support of oralism created a major crisis in deaf education - one that almost saw the extinction of sign language. However, the experience of enforcing an exclusively oral approach produced less than favorable results, and it was found that oral education negatively affected most children's educational development and confidence, a situation that unsurprisingly angered the Deaf/HOH community who justifiably felt their needs had not been addressed [Monaghan et al., 2003, Bloomer et al., 2005]. The community generally holds the view that the Manual approach is more appropriate, as it gives the child some recognition and a place in a community where there is a common understanding of the isolation experienced. Signing provides a way to overcome this: it shows how to overcome this, how to have your own language and culture, and responds to the problems and solutions that the community faces in day-to-day activities. Irrespective of the Oral or Manual approach, the child needs to have a peer group to help with the development of social interaction and skills that are vital for personal development and understanding of how to cope with social situations.

The level of speech and sign development is also dependent on the individual's deafness, when it was acquired and what level it is at. This extract from a web article is very useful in placing this concept into context:

I happen to be postlingually deaf and speak quite well. When I have to, I use my voice in situations like ordering food in a restaurant. My mother, on the other hand, is prelingually deaf and never has been able to speak despite years of speech therapy as a child. She always signs or writes on paper. Technically speaking, in terms of ability, I should be considered the least sheltered member of my family because I can use the mode of communication used by hearing people. However, it doesn't work out that way; what usually happens is that the minute I use my voice, hearing people inadvertently assume I can hear better than my mother and they begin to talk faster. In no time, I'm lost. I have to say "whoa, wait a minute, back up a bit here..." and the hearing person has to repeat the whole thing. And they usually have to repeat often. My mother, on the other hand, writes down her question on a piece of paper and establishes from the get-go that she's completely deaf. With that understood, the hearing person is usually more accommodating and writes back on the note pad. In no time, my mother has the information she wants, while I'm still going "eh, what did you say?" with my superior (but worthless in this situation) speaking skills.

[Deffman, 2005]

2.5 What is Sign Language?

Sign language is a language of hand shapes, facial expressions, and movements used as a form of communication [Kyle and Woll, 1985]. There are as many sign languages as there are spoken languages, with variations in signing communities around the world, ranging from country, to district and even to dialectal influence. As sign language developed, a more formal understanding was required and more formal grammatical structures were identified that document the three-dimensional nature of sign language. It is important to note that British Sign Language is a language in its own right, as is English. There is a development in teaching practice to encourage bilingualism with the use of the two languages. However as noted by Byram that it is difficult “to deal with bilingualism in a society which is still largely monolingual in outlook” [Byram, 1994, Achiba et al., 2002]

Evidence of the long use of sign language to communicate around mutually unintelligible languages exists for Africa, Australia, and North America [Deafblindness, 2005]. The most well known signing in this style is that of the Plains Indians of the 19th century North America. Their languages were unlike, but their life styles and environment were alike, therefore it was reasonably easy to find common symbols to communicate with. For example:

...a cupped hand leaping and bobbing away from the speaker was familiar to all as the rump of a bounding deer, a circle drawn against the sky meant the moon or something as pale as the moon. Two fingers astride the other index finger represented a person on horseback, two fingers spread and darting from the mouth like the forked tongue of a snake meant lies or treachery; and the gesture of brushing long hair down over the neck and shoulder signified a woman. This form of signing became so familiar and complex that long narratives in monologue and dialogue could be signed and understood within large groups of Indians otherwise unable to communicate. [Deafblindness, 2005]

The Plains Indian Sign Language was coded into an explicit vocabulary of gestures representing or depicting objects, actions, and ideas, but the language made no attempt to “spell out” or otherwise represent words that could not be conveyed in gestures. Associates of religious orders who have taken vows of silence, as well as others who for reasons of piety or humility have forsworn speech, are known to use sign languages to communicate. Often in silent monastic orders, natural gestures of passing food or pointing to some needed object have sufficed for effective communication, leaving little need for specially coded signs.

In India a man named Meher Baba [Deafblindness, 2005] abstained from speech in the last decades of his life, but he dictated voluminous writings to his disciples. He started by first pointing to letters on an English-language alphabet board; but after some time he

evolved a suitable sign language of gestures, and he relied on this alone. There was also Venerable Bede [Deafblindness, 2005] a medieval English cleric who worked out a coded sign language based on manual signs that represented numbers in turn signifying letters of the Latin alphabet in sequence, i.e., 1 for A, 9 for I and so on. It is not known whether Bede devised this system to communicate with the Deaf or merely to maintain silence.

There are many documented pieces of information about sign language, its origins, its history, different forms, how they have evolved etc. There is no clear route to the sign languages we know today, but we understand how they have come about, most spoken history is documented and only the fascination with the silent world of sign brought about its documentation. Before this it is clear that the Deaf community was active as far back as Socrates and before, however despite this, there is little to no documented proof of this. Today not only does the Deaf community use sign language, but other disability groups use sign language and there is also a new phenomena on teaching babies (both hearing and non-hearing) to sign, as it allegedly develops the child's IQ and language skills faster than oral methods of teaching.

2.6 Deaf Issues Today

Many Deaf issues today are based around communication and information access. As technology is advancing and people have access to more information resources, individuals are aware of their rights and are protesting for their privileges in the developing and predominantly hearing world. Issues on teletext services, signed performances in theaters, and sign language interpreted tours in museums and galleries are becoming more available. However information access not only in terms of written English (which is often a second language to many d/Deaf people) but also information in Sign Language itself, is in very high demand, especially in contexts such as hospitals and train stations, where information is vital for functioning.

As the British Deaf Association reports, on "March 18th 2003 ... the British Government have taken the formal step of recognizing British Sign Language (BSL) as a language in its own right" [BDA, 2004].

This has affected many companies and organisations, however it has particularly affected many schools and their educational approach towards sign language. Organisations such as the RNID (Royal National Institute for Deaf people) [RNID, 2004] and the BDA (British Deaf Association) [BDA, 2004] have a unified interest in bilingual education for the Deaf, which accepts "linguistic, cultural and social identity" [BDA, 2004]

Many have commented that "There is a growing enthusiasm in this country and abroad for bilingual approach in the education of deaf children and the signs are that this enthusiasm will grow" [Lynas, 1994]

2.6.1 Problem

Not all children have access to special needs schools so that BSL can be taught properly, and it has been found that students will learn a form of signed English, which is not British Sign Language, but is a form which is regarded as being a mixture of English and sign language: “English and BSL are two languages, two separate languages. We should not confuse them, the grammar is different, the lexicon is different, non-manual features, intonation are all different and they work independently from each other” [Ackerman, 1994].

If parents want their children to learn sign language but the children have to go to mainstream schools, then sign language support can become very expensive for many schools to provide. There are often two choices: either an interpreter must be provided or sign language technology must be accessible. Sign language technology looks for ways to provide sign language support for individuals who require communication assistance in a varied environments.

The use of sign language when represented in digital forms is becoming increasingly popular and important to the deaf and hearing community. The reasons for this are the following: the cost of teaching sign language; the need for wide area communication, accessibility for people who don't read and only sign; and most importantly, the need for social inclusion so that the deaf feel involved in society [de Carvalho Cruz, 1997].

2.7 Sign Language Technology

To highlight the context of this research, the following sections provides a detailed analysis of previous and current sign language technology research. It is hoped that this analysis will highlight the main motivations of the research as well as the work that is, in varying degrees, related to it.

The remaining part of this chapter thus opens with a discussion of what sign language technology is and its impact on information delivery within the digital domain. The purpose of this discussion is not only to give the reader a sense of what is currently available, but also to highlight the benefits and drawbacks of current approaches. This shall indicate the unique dilemma of delivering sign language to the Deaf/HOH community within the digital domain.

Following this discussion the importance of sign language delivery and preservation within the digital domain will be highlighted. In particular, how the Deaf community responds to current developments in technology, what has been realised and may be realised in the future will be considered.

2.8 What is Sign Language Technology?

Sign language technology research [Marshall et al., 2004, Lincoln and Tryggvason, 2004, Bangham et al., 2004, Elliott et al., 2004, Cox et al., 2002, Verlinden et al., 2002, WISDOM, 2003, Petri et al., 2002, Scheffler, 2003, Huenerfauth, 2003, Dorr et al., 1998, Omlin and Glaser, 2001, d'Armond L. Speers, 2001] focuses on the needs of a specialist proportion of society, often excluded from the benefits and enhancements of the digital world. There are various forms of technology available, and they have varied functions. The following generic architecture aims to give an overall understanding of where these systems are in context of sign language technology.

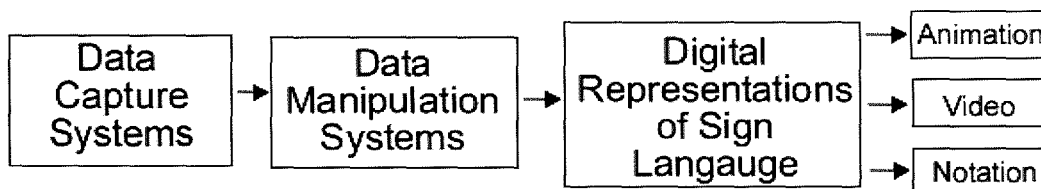


Figure 2.1: Generic architecture of sign language technology, assisting in categorising past, present and future technologies

The following sections aim to outline the typical characteristics of the components highlighted in the generic architecture, followed by examples of these types of systems.

2.8.1 Data Capture Methods of Sign Language Systems

The first component of the generic architecture is Data Capture, its typical characteristics and examples are listed as follows.

2.8.2 Typical Characteristics

Such a system component will capture information in a particular form in order to be manipulated into another form.

2.8.3 Examples

An example where neural networks have been applied in the context of sign language technology to capture data is the SLARTI (Sign Language Recognition System) [Vamplew, 1996] developed by the University of Tasmania. This system makes use of Neural Networks to recognise hand gestures in order to manipulate these into a textual output. The hardware used is a CyberGlove, which measures the hand with various sensors. This information is linguistically processed, classified and stored. The recognition and manipulation is done via the use of neural networks. So far this system recognises BSL and Auslan (Australian Sign Language), and creators are hoping to transfer this recognition to other sign languages and use this system as a teaching aid.

Another type of data capture system is speech recognition, where natural language is used in enabling applications [Nenad, 2003] to be manipulated for sign language technology. The University of Sheffield have a system that can understand natural language and process commands. There are three main components: speech recognition, speech synthesis and natural language understanding. The developers are hoping to expand this system into business applications in order to improve productivity for employees generally as well as replace employees in monotonous positions such as answering phones and returning information to a caller. This system has scope for capturing voice input to assist in the generation of sign language.

A different type of data capture system used in sign language technology is motion capture. This was used by the University of East Anglia [Bangham et al., 2000] to render a three-dimensional (3D) animation: an avatar (virtual human) called "Simon-the-Signer" and "TESSA" [Cox et al., 2002]. The motion was captured by using three pieces of hardware: cybergloves, magnetic sensors and a face tracker. This automatically generated "Simon-the-Signer". The system developers used this as the starting point for the European funded ViSiCAST project [Cox et al., 2002, Verlinden et al., 2002, RNID, 2004].

De la Salle University used motion capture data, to render 3D representations of sign language with an avatar. The synthesized avatar can be rendered (animated) from several different perspectives [Cadiz and Salvador, 2000]. The technology involves capturing an object's position and orientation in physical space, then recording that information in a computer usable form. The information that is recorded and is of interest are human bodies, facial expressions, camera or light positions and other elements in a scene. This information is stored in a data file, then the corresponding data is found and interpreted to sign. This system currently can generate an animated hand which can sign letters and some words. The system developers are hoping to develop an avatar which will exhibit facial expression such as happy, sad and excited, the creators are also working on investigating how to accomplish smooth transition between finger motion from one sign to the next. On a grander scale, they are proposing to make a Java system which will be made available over the Internet [Cadiz and Salvador, 2000].



Figure 2.2: Datacapture Method Used for “TESSA” the Avatar [Cox et al., 2002]



Figure 2.3: Data capture Method Used for “Simon-the-Signer” [Bangham et al., 2000]

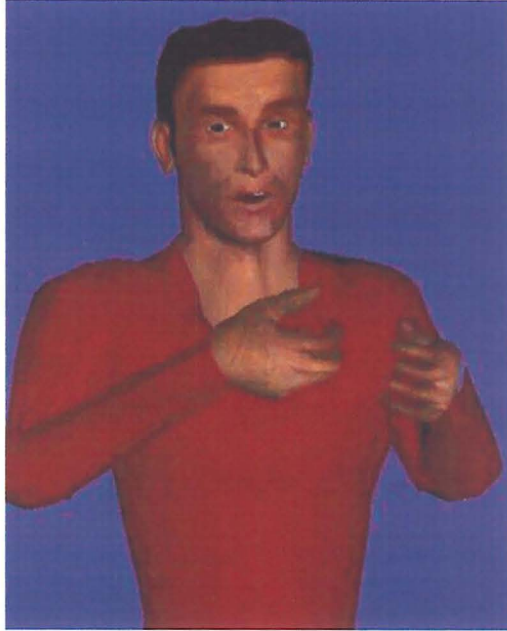


Figure 2.4: Example of an avatar which uses motion capture and replay [Bangham et al., 2000]

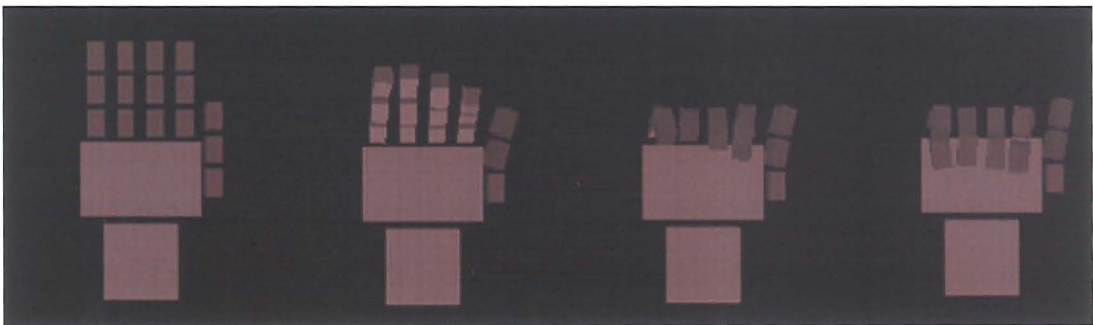


Figure 2.5: Example of animation made by the motion capture broken down into frames [Cadiz and Salvador, 2000]

Data capture can also be done via sensors on an expert signer [Eisenstein et al., 2001]. At the University of Southern California, a framework was developed to store and retrieve “moving sensors” data. The sensor information is broken down and stored in a database, whereas before it was found that sensor information was lost. This storage encourages the re-use of software, and the developers are hoping to develop an interface to the system.

Another type of data capture system made by Ryan Patterson in the 2002 Intel Science Talent Show [Intel, 2003] used a glove as an input device to generate text. The glove familiarised itself with the user and their hand movements to generate text words, the system is said to act as a translation device. Another version of such a system is Glove-Talk II [Fels and Hinton, 1995] where the system can take hand signs and translate them into English in real time. The system uses neural networks and maps sign language with control parameters. The users can generate sign and choose the flow of conversation, making the system unique. The developers are hoping to modify Glove-Talk II to make other sounds, therefore changing the system to translate to other languages.

A more mathematical approach to data capture was published [Malciu and Preteux, 2000a] where a model-based 3D head pose estimation is used in monocular and non calibrated video sequences. The system maps out the head with a mathematically designed mesh, which will synthesize the head from the video images. The designer’s are hoping to further develop analysis and synthesis of facial sequences in model based image coding.



Figure 2.6: Examples of images synthesized in a test sequence [Malciu and Preteux, 2000a, Malciu and Preteux, 2000b]

A statistical model called Hidden Markov Models (HMM) is also being used for data capture [Nefian and III, 1998, Starner and Pentland, 1996]. The system assumes that it is observing a Markov process (a simple stochastic process in which the distribution of future states depends only on the present state and not on how it arrived in the present) that has unknown parameters, and the challenge is to determine the hidden parameters from the observable parameters. The extracted model parameters can then be used to perform further analysis, for example pattern recognition [TheFreeDictionary.com, 2004]. HMM's can be used for speech, handwriting and now sign language gesture recognition. Currently systems [Starner and Pentland, 1996] can track hands when users are signing, provided the background and clothes are the same. To make the system more advanced they are currently developing a fingerspelling recognition model, which would require more intricate work.

A system by the Institute National des Telecommunications is able to track facial features in video sequences [Malciu and Preteux, 2000b]. This is done without the use of sensors, the system combines deformable template-based tracking of mouth and eyes in arbitrary video sequences. There are mathematical principles underlying the system which accurately map out the facial features of a model, and automatically generate the face symmetrically and realistically. The system developers are hoping to further develop this system in a MPEG-4 compliant framework [Preda et al., 1999] for signing avatars, this will allow for faster transmission of three-dimensional virtual characters over the Internet.

2.8.4 Data Manipulation for Sign Language Systems

The second component of the generic architecture is Data Manipulation, its typical characteristics and examples are listed as follows.

2.8.5 Typical Characteristics

Once data is captured the system uses that information to assist a process in a sign language system.

2.8.6 Example

An example of a system where captured data is manipulated is the CMU (Carnegie Mellon University) grammar parser [Marshall and Safar, 2002]. This system works on the syntactic stage first, the text is parsed by the CMU, then the most appropriate parse linkage is manually chosen and from this a Discourse Representation Structure(DRS) is generated. The DRS is fed as input to a Head Driven Phrase Structure Grammar(HPSG) (sign technology) to drive a virtual human via a Signing Gesture Markup Language(SiGML), the

SiGML is XML compliant and is based on the refined HamNoSys (Hamburg Notation System for Signs [Hanke, 2004] is a notation system for sign, assisting in grammatical analysis and even translation to a spoken language) sign language symbol notation [Hanke, 2004].

Fundamentally this system can parse text, to provide an input for an animation character. The system developers are hoping to further advance the features of the parser (breaks data into smaller elements, according to a set of rules that describe its structure).

Another parser is the “Grammar Writer’s Workbench for Lexical Functional Grammar” [Kaplan and Maxwell, 2004], the creators of this parser wanted to make a complete parsing system which can run on most operating systems. The system maps out the given input to check its grammar, currently there are no further plans for future development.

TEAM (Translation from English to ASL by Machine) [Zhao et al., 2001] is a system that can take in English text and outputs ASL in the form of an avatar, the project developers are hoping to tailor the system to different sign languages.

A system called Sign Stream [Neidle, 2004] designed at Boston University, is a database tool for analysis of linguistic sign language data captured on video. This tool is currently used for American Sign Language, however it can be applied to any sign language. The Sign Stream system has a database which consists of utterances (utterances in this circumstance are associated with sign movements), each utterance is associated with some video segment, so whenever the video is repeated and the utterance is therefore also repeated it is automatically associated and stored. The goal of the system developers is to advance the current system in order to have a large database which has every American Sign Language utterance recorded, which can then be manipulated for other use.

2.8.7 Digital Representations of Sign Language

The third component of the generic architecture is Digital Representations of Sign Language, its typical characteristics and examples are listed as follows.

2.8.8 Digital Representation of Sign

There are three main forms of digital representations of sign:

1. Notation Systems for Sign Language
2. Video Systems for Sign Language
3. Animation Systems for Sign Language



Figure 2.7: Example of a system which allows for linguistic analysis of signs [Neidle, 2004]

Representations of sign language in the digital domain have become increasingly available, and their benefits and drawbacks against each other are comparatively different.

2.8.9 Notation Systems for Sign Language

Notation systems are alphabets of graphical symbols used to write movements and hand shapes of sign languages, these systems are typically used to document signs or to document information. The following will explain their characteristics and provide examples of such systems.

2.8.10 Typical Characteristics of Notation Systems of Sign Language

Actual physical signs can be depicted into written images that can be later used to understand the sign used and, or its construction. The collection of images can explain information to the reader. These recordings are changeable and can be edited and manipulated to describe various pieces of signed information. It is possible to join various sentences from the same notation set together, as they will still flow and are readable. There are two branches of notation systems, one branch will document and depict sign language itself, with a combination of graphical characters written together to show the

construction of the sign. The other branch will use pictorial methods to explain a concept, instead of describing the sign for that concept such as a description of the word bus, being replaced by a picture of a bus.

2.8.11 Examples of Notation Systems of Sign Language

In 1979 Valerie Sutton [Sutton, 2004] modified a dance writing system to document sign language in a set of symbols. She stated "... because I respect ASL(American Sign Language) I want to write it and preserve it." [Collins, 1997].





d		one
		cry
oo		eleven

Figure 2.8: Examples of SignWriting Symbols [Sutton, 2004]

The system has left a lasting impression on the Internet community, and is not only documenting ASL, but is capable of documenting any sign language in the world. Her work has sparked much interest and admiration. Disability Compliance Alliance, for example has named her among esteemed company: "Alexander Graham Bell, Thomas Hopkins Gallaudet, and Valerie Sutton took different paths towards helping those who are deaf and hard of hearing" [disABILITY Compliance Alliance(DCA), 2001].

Another sign language notation system is Makaton [Walker, 1970], also available in signed form, it was initiated by Margaret Walker "for deaf adults with learning difficulties" using hospitals. The system was established to aid communication between the hard of hearing and hospital staff with the use of some basic signs and symbol set. It has since become a widely-used language in the United Kingdom. Systems have been made on the basis of the Makaton symbol set, such as Mak Messenger [Ohene-Djan et al., 2004] which is an instant messenger that uses the Mak Messenger symbol set.

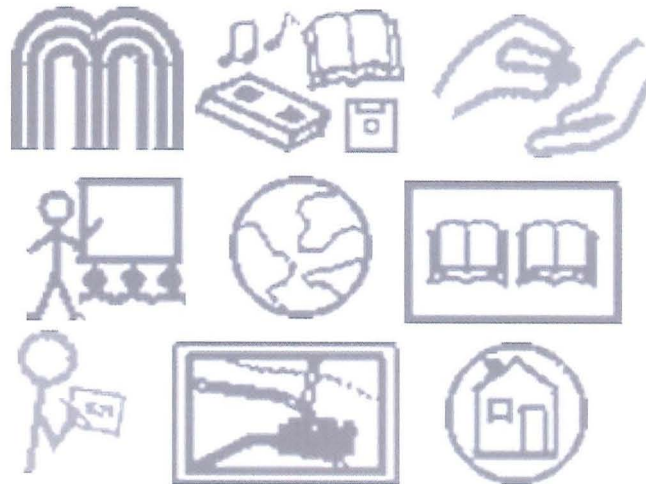


Figure 2.9: Examples of Makaton Symbols [Walker, 1970]

Sync Writer a system published in 1994-1995 [Hanke and Prillwits, 1995] by the University of Hamburg, was made to document sign language easily. The user can use this system to transcribe video with HamNoSys. The creators are hoping to develop this system so that it can accommodate any special needs. HamNoSys has been used as the backbone for an avatar system called eSign, where the HamNoSys is being translated into a signing avatar.

Sample U (Band)					
Timecode	09:12	09:39:18	09:40:18	09:41:17	09:42:05
Mirnik					
Glosse	FAX	SCHREIBEN	SCHICKEN- Eltern	MEIN	E
Gloss / Engl.	FAX	WRITE	SEND-parents	MY	P
Mundbild	fax	schreiben		mein	e
HamNoSys	[Handwritten HamNoSys symbols]				
Übersetzung	zu schreiben und meinen Eltern zu schicken.				
English transl	and to send it to my parents.				
	<input type="button" value="Play Scene"/>				

Figure 2.10: Example of the syncWRITER system [Hanke and Prillwits, 1995]

The Sigsymbol Dictionary [Cregan, 1982] made by Alisa Cregan, was launched in 1982. It demonstrates the analysis of signs, and how they can be drawn as symbols working on the same principle as SignWriter, Makaton and Sync Writer's HamNoSys.

The SignWriting system has received divided opinion, it presents a documented/written form of signing, however it was originally used to document dance and was not designed from the standpoint of documenting sign language, therefore it's representation although used by several communities is criticised for it's lack of detail and capturing of all the moving pieces for the actual construction of a sign itself.

Makaton although widely used is often misunderstood as a form of sign language, where in fact it acts more as a communication aid rather than a grammatically rich language. It's simplicity is tempting for system designers to implement into technologies where in fact it can further distance the Deaf signing community from technology, as yet again it is felt that sign language has been misunderstood or misrepresented.

It is important to note that HamNoSys is based on a German Sign Language (or Deutsche Gebrdensprache), and has been noted for it's lack of detail in notating facial expression. Using HamNoSys notation in Germany maybe appropriate due to the notation being based on the national sign language, however using the same notation for a British signing community (where the sign language is different) holds several risks of misrepresentation, and could explain the possible reasoning behind why this system has not been widely accepted by the British Deaf community. It's like using a different character set for a different language, you cannot write English in Chinese character set correctly.

Although sign languages can be notated symbolically (as shown by these systems), it is important to respect the language is structurally different therefore a more 3D understanding of the grammar needs to take place and a possible formalisation of this should be considered by the research community.

2.8.12 Video Systems for Sign Language

Video systems broadly consist of filmed sequences of signing used in a variety of contexts, such as television, internet or instructional videos. The following will explain their characteristics and provide examples of such systems.

2.8.13 Typical Characteristics of Video Systems of Sign Language

Actual physical signing is recorded in a video format, which can be played with the use of video recorders or computer based programs. These recordings can be used repeatedly and are static recordings of information. They can be edited and manipulated but a sequence can only be filmed in one shot. Joining sequences together will make them appear disjointed.

2.8.14 Examples of Video Systems of Sign Language

EuroBridge [EuroBridge, 2004] is a streaming video system that allows users to learn sign language via a dictionary. The system organises its information in a database, where users can make requests for different word files. There are currently no stated plans for the future development of the sign language training system. Another example of a similar system to Eurobridge is the ASL browser [Stewart et al., 2002] which is available online. It also has an online dictionary of American sign language terminology in the format of streaming video sequences which can be demonstrated upon user interaction with the system.

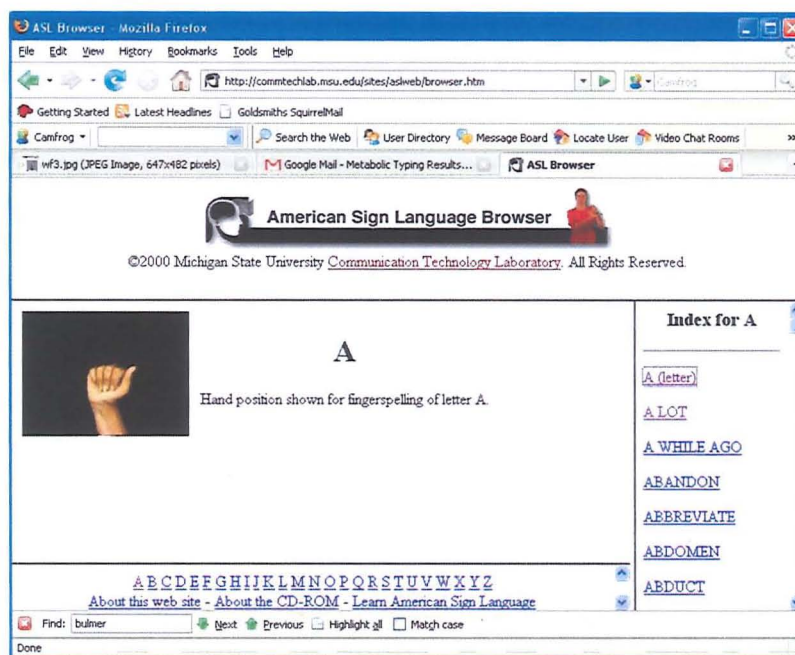


Figure 2.11: Example of a streaming video system available online [Stewart et al., 2002]

A teaching system developed by Goldsmiths College [Ohene-Djan et al., 2003, Naqvi, 2003] called KSO (Kids Sign Online) teaches children BSL and English online. The system uses numerous video clips embedded in tests, tutorial pages and signed fairy tales. The developers are hoping to advance on the content of the site, and add higher levels of BSL and English.

Another approach to learning sign through video was launched by the BDA, which “promotes learning sign through mail drive” [Booth, 2003].

Targeted at professionals via “Claritas Interactive’s Email Selector”, a signed video clip is emailed daily to the user. BDA’s head of fundraising comments: “...they can keep the email video on their system and learn at their leisure”.

Another type of video system that is used for sign language is the AT&T Video Relay System [AT&T, 2004]. The users log onto the AT&T site to connect to a web-cam service.

A user will sign a message to an interpreter, who will translate the message into text and send it to the recipient. When the recipient replies the interpreter will sign the message back to the user.

Signed video clips have been used in communication systems such as the iCommunicator [iCommunicator, 2003] which was launched in March 2000. The system reads text or uses speech recognition and changes it signing streaming video clips or synthesized voice, depending on which function the system is performing. The system is widely used and has gained vast publicity [Microsoft, 2004].

Online resources where pre-recorded video clips are hosted, provide excellent platforms for users to watch and communicate with each other and even learn/practise their signing skills. Video systems are consequently widely accepted in the d/Deaf or HOH community. However due to the flat two-dimensional (2D) view of the signing, it can become difficult to understand the signers space and the distance of the arms from the body when the signing is being produced. Additionally with video systems, practical difficulties arise when a video clip needs modification since, as noted below, extra signing cannot simply be filmed and then concatenated onto the beginning or end of a sequence. The entire clip often needs to be refilmed, edited and presented to the target audience, which can become a costly process.

AT&T is a very successful example of a live system, where the signers interact with each other in “real-time” therefore any natural signing errors that occur can be easily corrected during the natural flow of conversation, and there are no issues around re-filming of clips. The major issues that present themselves are around having enough trained signers to fulfill demand and also the cost implications of having signers on stand-by.

iCommunicator presents an example of how a pre-recorded real-time presentation of video clips can be used for communication, which reduces the cost issues previously noted with the AT&T system. However the biggest criticisms have come from the actual signing presentations of this system, as several clips are concatenated together, the presentation lacks the natural flow of signing, as signers literally raise and drop their hands after each word.

2.8.15 Animation Systems for Sign Language

Animation systems use signing avatars (virtual humans) to present a 3D version of signing, the system can be used in a variety of contexts, ranging from educational environments to public information services on the internet. The following will explain their characteristics and provide examples of such systems.

2.8.16 Typical Characteristics of Animation Systems of Sign Language

Actual physical signing is replicated with a 3D avatar, which can be played with the use of programs available on the Internet. These recordings can be repeated and are dynamic records of information that can be manipulated depending on the context in which they are used, individual sequences of signing can be joined together to appear like smoothly-signed pieces of information with the use of various programs and editing tools available with the avatar systems.

2.8.17 Examples of Animation Systems of Sign Language

Different countries have developed several different animation systems: Britain has developed systems for BSL [Cox et al., 2002, Verlinden et al., 2002], Japan for JSL(Japanese Sign Language) [?, Sagawa and Takeuchi, 2002], Australia for Auslan(Australian Sign Language) [QDS, 2004, Yeates et al., 2002], Poland for PSL(Polish Sign Language) [Harrington, 2004, Fabian and Francik, 2001, Suszczanska et al., 2005, Francik and Fabian, 2002], China for CSL(Chinese Sign Language) [Wilkinson, 2003, Gao et al., 2000] and America for ASL [Nakamura, 2002, Bureau, 2003]. However in evaluation these reports have noted many times that the clarity of the signs due to lack of mimicry, facial expressions and mouthing have lead to misinterpretations of the sequences displayed.

An ASL fingerspeller in VRML [Su, 1998] teaches fingerspelling online. The system takes text as an input and generates a 3-dimensional hand avatar which will sign the ASL letters back to the user. The system developers want to improve the accuracy of the signing and the smoothness of the movement. RNID [RNID, 2004] also have an animated fingerspelling system [RNID, 2004], which can take text and generate an animation of how the letters should be fingerspelt in BSL. This users can see the signing at three different speeds, depending on what they feel comfortable with. The designer's have also accounted for users who may have poor vision, allowing them to have the option of a larger view of the avatar hands [RNID, 2004].



Figure 2.12: Example of an ASL fingerspelling system made in a Virtual Reality Modelling Language [Su, 1998, Nakamura, 2002]

A detailed study by ViSiCAST (part of RNID [RNID, 2004, Safar and Marshall, 2001]) a European Union subsidised project, conducted two studies with Visia [Verlinden et al., 2002] and TESSA (Text and Sign Support Assistant) [Cox et al., 2002, RAD, 2001]. Visia was made to demonstrate weather reports and TESSA was made for use in postal offices. Visia aims for semi-automatic translation from text to sign language, the text is analysed and transposed into a sequence of signs, which are acted out. TESSA “recognises speech from the clerk and the system then synthesizes the appropriate sequence in BSL(British Sign Language)” [Cox et al., 2002]. With Visia, ViSiCAST found that the following areas were unclear: fingerspelling, mouthing, facial expression, movement, location, size and handshape. The ViSiCast team organised an experiment where participants will watch a weather report in broken down sections [Verlinden et al., 2002]. They found an average of 60% accuracy achieved, after further analysis, the experimentors found there was a learning effect, such that scores improved over a session. The quality of TESSA’s signing was measured in two ways [Cox et al., 2002]: intelligibility of signs, and acceptability of signs. In conclusion it was found that there was an accuracy of 61% for complete phrases and 81% for sign units.

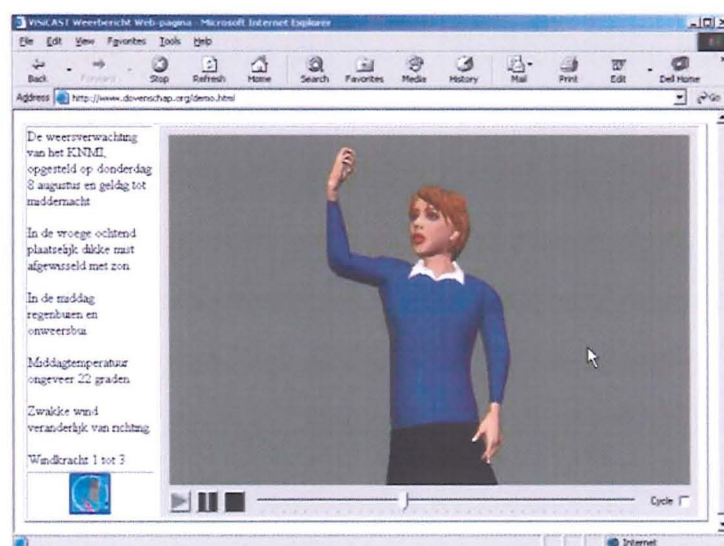


Figure 2.13: Example of Visia the avatar that signed the weather [Verlinden et al., 2002]

RNID is currently developing a more advanced avatar, called eSign (Essential Sign Language Information on Government Networks) [RNID, 2004]. It has been noted, from past avatar designs, that animation can sometimes be too slow which will therefore lead to misinterpreting correct sign movements for other words. The eSign system has a database design, storing the information required for the generation of the animation once it is made, which allows for faster access to signed words and phrases. Also the designer’s have made major new design decisions, for example they have made several heads for the avatar to make more accurate facial expressions. This technique is hoping to allow for sign language generation to be faster, more accessible for the Internet and generally more accurate. The system is currently under construction and evaluation. This provides a

technically interesting solution as TESSA was all pre-recorded, having an avatar that can work in real-time can provide many more applications, however the system designed is still in development, and the initial designs have not been received well. Several systems have been made with both approaches: prerecorded avatar movement, or database managed avatar that generates on demand.

The Synface project also hosted by RNID [RNID, 2004] is a project concerned with voice telephones for the deaf. When a hard of hearing person, has a conversation with someone who is hearing, the conversation relies on both hearing and lipreading. However when telephone conversations are made the hard of hearing person has to solely rely on what they can hear. This project aims to develop a synthetic face which simulates facial movement through audio stimuli in order to aid Hard of Hearing people with telephone calls so they can lip read as well as hear the conversation. Therefore when the individual receives a phone call the face will move, with particular focus on the lip movement. The lip movement will replicate the words that are being heard on the phone, which will inevitably aid the hard of hearing individual with the conversation. This system is still under construction and extensive evaluation.

Another approach to building an avatar is by making a skeleton first in order to make the movements more exact and realistic [Godenschweger and Strothotte, 1998]. The use of a "line drawing" allows the application to run with simple 3D models without loss of essential information, while achieving images which can be transferred very quickly over a network. The system works with the use of a fixed 3D model of a head onto which curves are mapped corresponding to facial features. The body is designed with a skeleton marking the main points, which construct signs and results in more accurate generation of the signs. The system designers are now focusing on assisting the needs of teaching and reference materials for the signing community.

DePaul University developed the signing avatar "Paula" [Fay, 1893], the goal of this project was to develop an automatic English to ASL [Nakamura, 2002] translator. Users can interact with the system; they can input signs by selecting sign parameters, handshapes, locations and movement, the sign is then animated by the software. The software is in continual development, making the signs more accurate and efficient. The project has received great recognition and awards [Fay, 1893].

An Auslan [QDS, 2004] teaching system [Yeates et al., 2002] looks at real-time 3D animation for teaching sign language in an educational and interactive environment. The human modelling system consists of three modules: the core human modelling module for model construction, manipulation and forwarding kinematics. The model rendering module for displaying model configuration visually uses OpenGL, and model interpolation module, for providing flexible partial-key frame Interpolation and animation control. The system designer's are aiming to improve the vocabulary of the system, adding display of facial expressions and lip movement, employing smarter interpolation schemes including

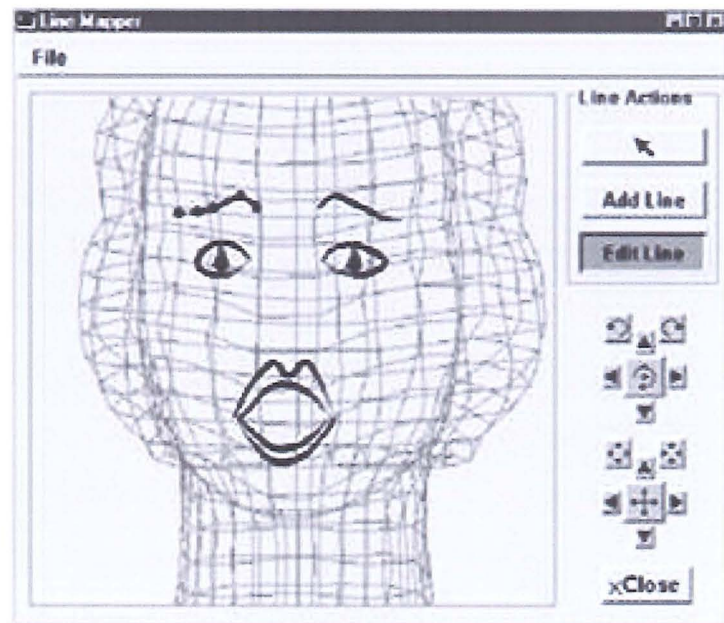


Figure 2.14: Modelling and Generating Sign Language as Animated Line Drawings [Godenschweger and Strothotte, 1998]

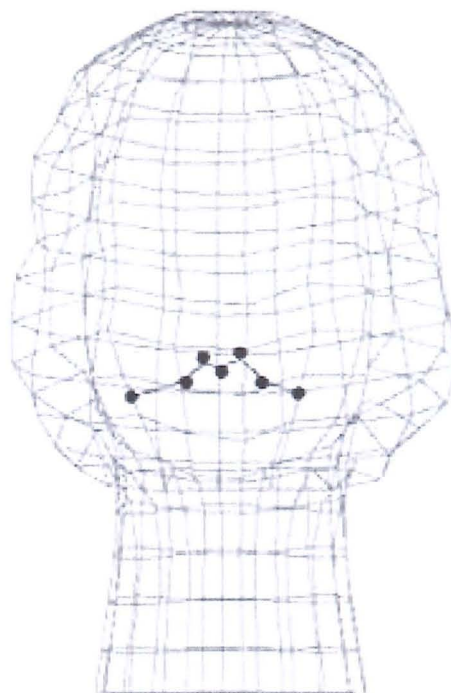


Figure 2.15: Modelling and Generating Sign Language as Animated Line Drawings [Godenschweger and Strothotte, 1998]

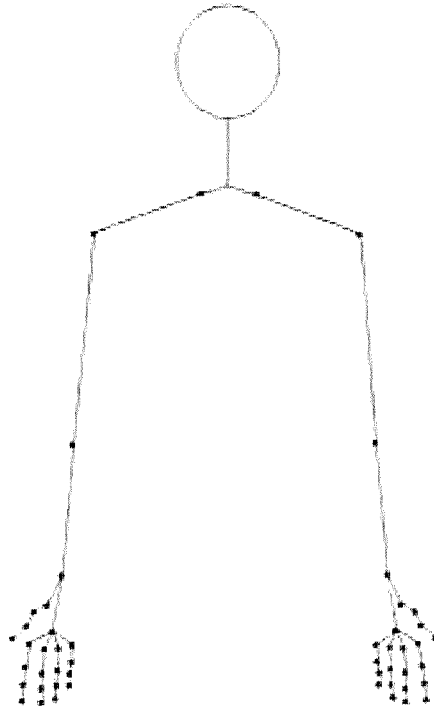


Figure 2.16: Modelling and Generating Sign Language as Animated Line Drawings [Godenschweger and Strothotte, 1998]

collision detection/obstacle avoidance, changing the rendering of the system so that the model is drawn with a smooth mesh, and including a parser designed to automatically translate English grammar to Auslan.

Another teaching system by Purdue University [Adamo-Villani and Beni, 2002a] was made to teach Mathematics to deaf children. The system uses a 3D virtual hand to explain maths problems to students to work out. The system designer's are hoping to further develop such a system so that it aids communication between the hearing and hard-of-hearing.

A project by students in the European Media Masters of Art (EMMA) designed software that could design and play 3D animation of sign language without expensive hardware or input devices. They developed a Virtual Signer (Vsign [EMMA, 2004]). The Vsign builder allows users to design new sign animations, which are stored in small text files. These can be played by the user, who can view the signs from different perspectives and speed. The system developers would like to develop other components to this system, such as a Vsign Composer where users can put different signs together and watch them animate in a smooth sentence. The Composer will offer different characters and the possibility to use this system for signing television content instead of human signing.

A system called "HandTalker" [Gao et al., 2000] made for CSL [Wilkinson, 2003] was designed to aid communication between the deaf/HOH and hearing. The system uses



Figure 2.17: Example of the signing avatar designed by DePaul University [Davidson, 2002]

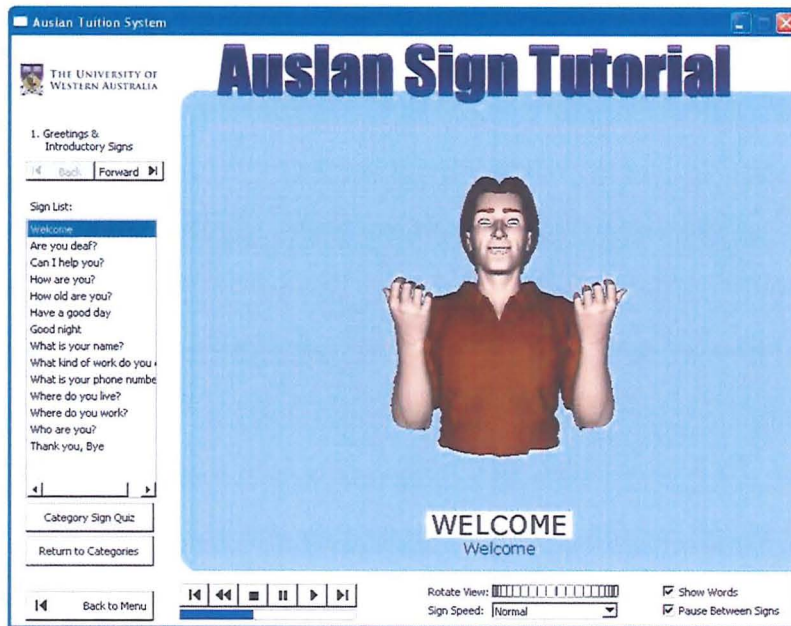


Figure 2.18: Avatar system to teach Auslan [QDS, 2004] demonstrating real-time 3D graphics for human modelling and teaching sign language [Yeates et al., 2002]

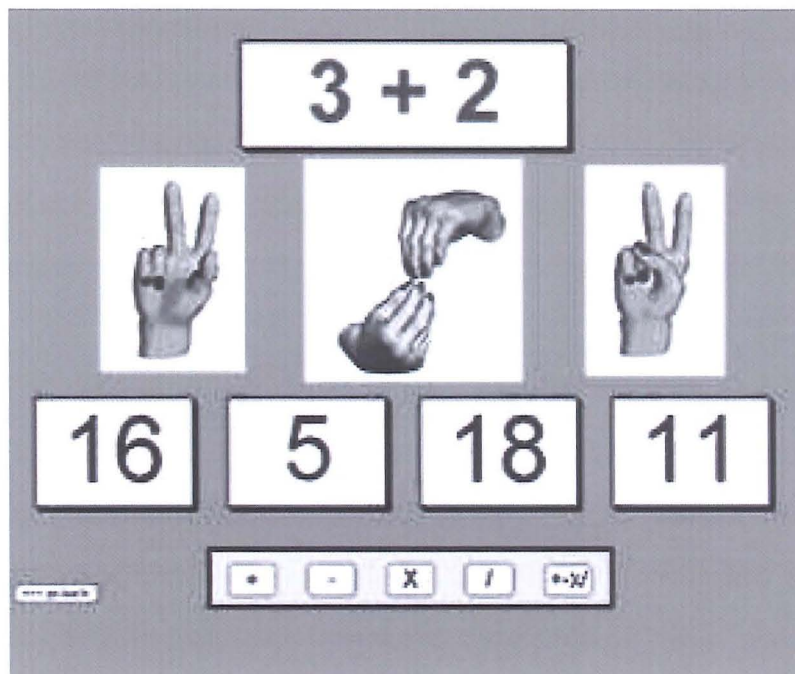


Figure 2.19: Example of an animated tutoring system for mathematics [Adamo-Villani and Beni, 2002a, Adamo-Villani and Beni, 2002b]



Figure 2.20: Example of an Avatar system where users can make sign animations [EMMA, 2004]

GTS (Gestures/Sign Language To Spoken Language) part of the STG (Spoken language To Gesture/Sign Language). GTS is based on sign language recognition technology, and STG is based on 3D virtual human synthesis. The system developers integrated sign language recognition with the 3D virtual human, the hard-of-hearing participants use a data-glove, camera and computer display, and the hearing participants use a microphone, keyboard and display. The system has been tested and evaluated, the designer's found that this system can support itself on any domain and continuously provides communication between deaf/HOH and hearing Chinese people.

The SignSynth project [Ipke Wachsmuth, 2002] is a system made to take text and translate it into sign language. The system takes text in ASCII-Stoke Notation [Mandel, 1993] and converts it into an internal feature tree (a linguistic understanding of what has been inputted into the system). The underlying linguistic representation is then converted into a 3D animation sequence in VRML or Web3D, which is automatically rendered by a Web3D browser. The system developers are investigating different features of the system for improvement, such as timing and the development of non-manual features. There is concern with how users will download plugins or should the system be built in a Java applet to avoid this problem.

Vcom3D [VCOM.3D, 2008, VCOM.3D, 2008] is an American company that is developing signing avatars. The avatars assist deaf children in learning how to read online, via translating text into Signed English [Schnieder, 2001]. The system developers are hoping to develop a machine translation system to use on websites with their avatar software to translate information into signing. The software allows the users to choose the view of their avatar, the signing speed, the character, and the background colour. An avatar called "Andy" has received great amounts of publicity from the National Science Foundation, as it was found that "Andy" had help boost deaf education for the children who were using



Figure 2.21: Example of sign language synthesis project in the University of New Mexico [Ipke Wachsmuth, 2002]

it [NSF, 2001].



Figure 2.22: Picture of Andy-the-Avatar [NSF, 2001]

Polish Sign Language [Harrington, 2004] systems [Suszczanska et al., 2005, Francik and Fabian, 2002, Fabian and Francik, 2001] are focusing on sign language generation in real time. The THETOS [Suszczanska et al., 2005] system takes Polish text, which is linguistically broken down and analysed, for morphological, syntactic and semantic structures. Then this information is translated into an animation output. The designer's of THETOS [Francik and Fabian, 2002, Fabian and Francik, 2001] are hoping to experiment with other avatars and animation techniques. They are also implementing a module for collision detection.

It has been argued that avatars lack realism [Thomas Rieger, 2003]. Rieger reports that with virtual signer's the signs are always done in the same way, almost like talking to someone with a monotone voice. Technologists are aiming to generate sign language in

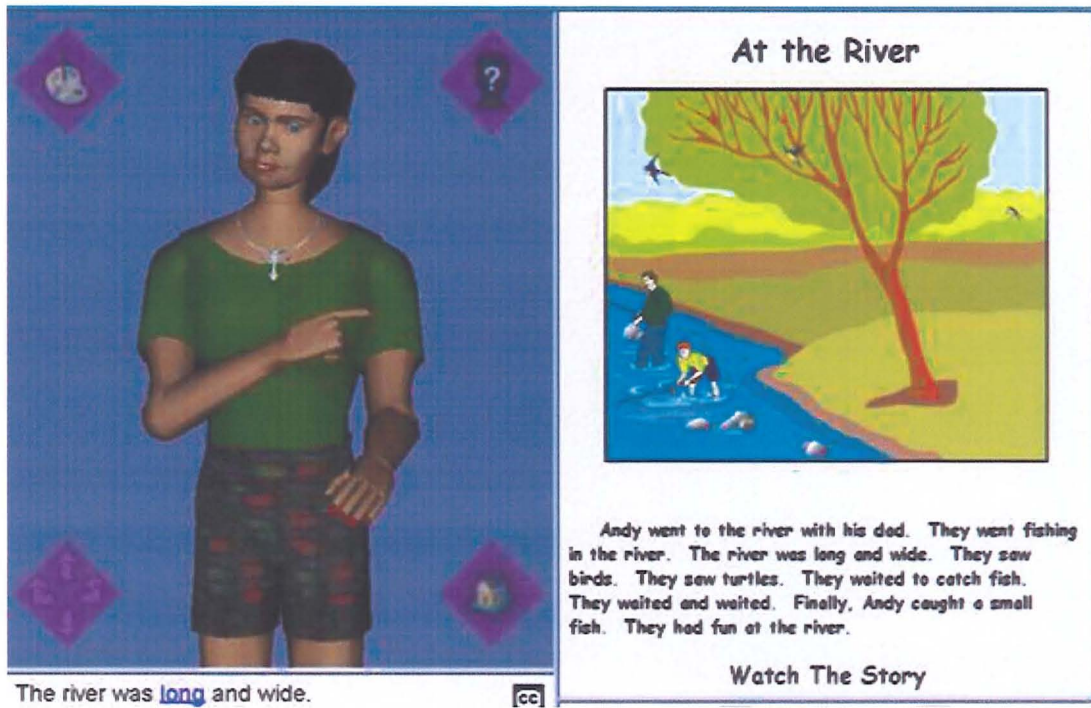


Figure 2.23: Example of a VCOM3D Avatar [NSF, 2001]



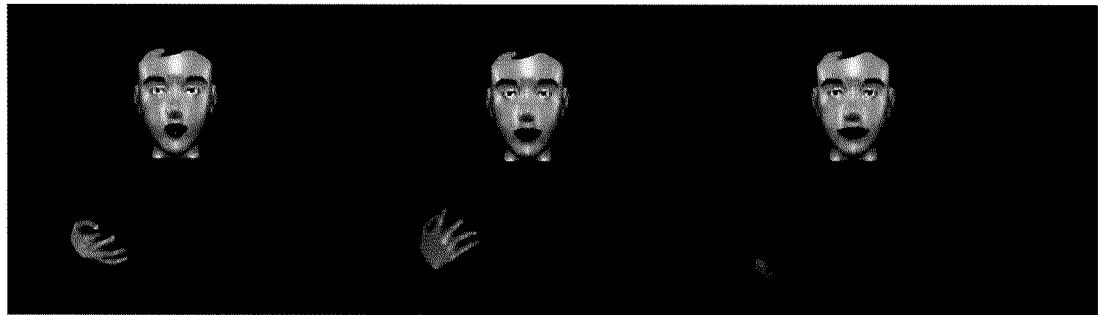
Figure 2.24: Example of a VCOM3D avatar



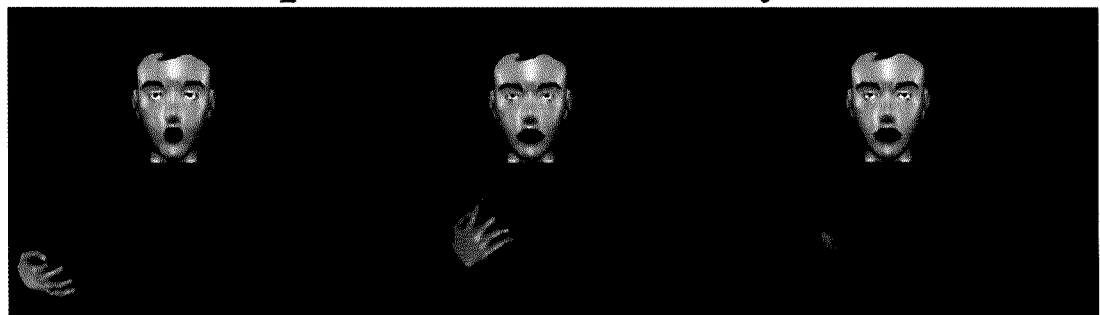
Figure 2.25: THETOS (Text into Sign Language Automatic Translator for Polish) Avatar animation in real time [Suszczanska et al., 2005, Francik and Fabian, 2002, Fabian and Francik, 2001]

real time, with changing facial expressions' for example emotional expression, dramaturgy etc. This system is called Narrative Extended Speech Acts (NESA), which allows for the generation of sign language and mouth motion in real time from text. They are hoping to advance gestures, expressions, and enhance graphical representations of the actor. Eventually a whole body realisation including arms and torso will be added to give the avatar a more human-like look.

Several avatar styled systems have been made, and although some such as the VRML fingerspelling system are interesting, in application there is limited use for such a system. Two major types of avatar design have been made, one where the avatar is generated from coding, and the other where the avatar is generated from pre-recorded clips. Questions arise around the evaluation of some of these systems, for instance the ViSiCAST system have been evaluated as over 60% accurate, although when asking the Deaf community what they thought of the system, it was severely criticised. Thus questions can be asked of the user evaluation process itself, for example, was the system tested on a target audience unfamiliar with avatar technology? Or was it tested on those already familiar with avatars? The presentation that the ViSiCAST system was explaining was a weather report, where the avatar signed and a map of the weather forecast with symbols were present. Therefore it needs to be asked whether the symbols assisted in the overall levels of comprehension and would the comprehension be different if the signing of the avatar was shown without the visual aid in the background? The general consensus amongst the Deaf community users consulted was that the avatar technology tends to degrade facial expression and thus degrades the quality of the signing. So how are these systems evaluated for the affectiveness outside of the research domain?



Above: Sign Language and facial expressions in a merry mood



Above: Sign Language and facial expressions in an angry mood

Figure 2.26: Example of the Narrative Use of Sign Language by a Virtual Character for the Hearing Impaired [Thomas Rieger, 2003]

Making a system so life-like opens it up to direct comparison to real-life signers, which is a problem as a digital system can never in fact replace a real person. This effects acceptance levels as the avatar may never be preferred to real human interaction. An example to consider is the WFD [Jokinen, 2009] avatar presentation of signing, where small children with button like eyes signed in a clip. The Deaf community have enjoyed this sequence and talk about its clear signing presentation. So could it be questioned, would more cartoon-like avatars be better received than life-like avatars? Could it also be that the WFD presentation was in a context of a playful introduction to WFD's conference, and that this is an acceptable platform to have an avatar? Maybe having avatars informing users of the news or weather is seen as inappropriate in the same way as it would be to have a synthesised voice presenting the news. There is a lot more that can be assessed and understood about avatars and although in some contexts they are doing well, we need to understand more about the ones that aren't doing well in order to improve them for the future.

2.8.18 Notation Systems vs Streaming Video Systems

Notation systems [Sutton, 2004, Walker, 1970, Hanke, 2004, Cregan, 1982] have shown their usefulness in the past. By having the ability to document all types of information and sign languages [Sutton, 2004], they keep with the visual theme of sign language giving pictorial associations to words, phrases and places [Walker, 1970]. Although they are graphical symbols and fully formed, almost like written pictorial sign alphabets and thus are a documented form of sign language, notational systems lack the natural flow of sign language itself. The nature of signing is that it does not rely on reading: it evolved through gestures and simple visual communication that became the natural and first language for a majority of the deaf/HOH community. Therefore a written form of signing seems against the nature of its origin. However they have shown their usefulness and almost act as an intermediate between signing and written languages. Notational systems are a cost effective way to document sign language, and provide the deaf/HOH community with written information, in a way that would not require the individual to be able to read the country's oral and written language (for example in the UK it would be English).

A more accurate way to document signing and its natural movement are video recordings [EuroBridge, 2004, Stewart et al., 2002, Naqvi, 2003, Booth, 2003, iCommunicator, 2003], as they accurately show the flow of signing. Watching video recordings, truly displays the nature of signing and its process of communication. There is a signing etiquette when individuals sign to each other, which becomes more evident when you see people in the act of signing to each other. Notation systems can depict sign, but re-creation of those signs solely through notation can be inaccurate and therefore dilutes the original sign, unless an actual signer from the community can be supplied to physically show and correct the

notational signing.

Notation systems have the ability to document signing and convey information. However it can be argued that they lack detail about the flow of signing, and the representation of a sign solely through documented signing can prove to be difficult and open to misinterpretation. However systems that use pictorial symbols to convey information can be useful in the context of providing facts to an individual whose English reading skills are poor, providing they have knowledge of how the notation system works. Video recordings are an ideal way to understand sign language in an information-delivery context as well as in an educational context of how sign language works and how signers communicate. The main advantage of notation systems over video systems would be that they are more cost effective ways of documenting sign language and providing information in a visually orientated format, whereas video requires various pieces of electrical equipment in order to view the recorded content. Video recordings in contrast give a more accurate visual demonstration of how signing works and flows; this is something notation systems cannot offer.

2.8.19 Notation Systems vs Animation Systems

Notation Systems [Sutton, 2004, Walker, 1970, Hanke, 2004, Cregan, 1982] and Animation Systems [Su, 1998, Suszczanska et al., 2005, Francik and Fabian, 2002, Fabian and Francik, 2001, Thomas Rieger, 2003, Verlinden et al., 2002, Cox et al., 2002, Godenschweger and Strothotte, 1998, Yeates et al., 2002, EMMA, 2004, Ipke Wachsmuth, 2002, RNID, 2004, Davidson, 2002, Adamo-Villani and Beni, 2002a, Gao et al., 2000, VCOM.3D, 2008] are on opposing poles of the domain of DRSLs: one documents sign in a set of symbols, the other gives a complete 3D view of how the sign is constructed. Notation systems need to be read symbol by symbol to understand the flow of the signs and how to use them. Even after detailed analysis, there is a great chance for error when reconstructing the sign. Notation systems are ideally for individuals with an understanding of sign language linguistics; a lay person will find understanding and interpreting such signs very difficult and most likely to make more mistakes. With Animation systems, you have a 3D view of an avatar, who as a surrogate “human”, demonstrates the sign from many views and angles. This can give a user a complete understanding of how the sign is formed, therefore not only a sign language linguist but the average lay person will understand how to model such signs.

Notation systems are less costly and require less hardware/software to work, they also have the ability to store information and details on sign construction more economically. Animation systems require both hardware and software which can be costly, but they can provide a more accurate demonstration of sign language.

2.8.20 Streaming Video Systems vs Animation Systems

Streaming video systems [EuroBridge, 2004, Stewart et al., 2002, Naqvi, 2003, Booth, 2003, iCommunicator, 2003] and Animation systems [Su, 1998, Suszczanska et al., 2005, Francik and Fabian, 2001, Fabian and Francik, 2001, Thomas Rieger, 2003, Verlinden et al., 2002, Cox et al., 2002, Godenschweger and Strothotte, 1998, Yeates et al., 2002, EMMA, 2004, Ipke Wachsmuth, 2002, RNID, 2004, Davidson, 2002, Adamo-Villani and Beni, 2002a, Gao et al., 2000, VCOM.3D, 2008] are very similar, but have some very different problems. With Video Systems, there is a 2D view of a sign from a front angle, which is useful. However understanding how far the hand or arm is from the body is much more difficult to grasp as there is only one view to work with. Animation systems give a 3D view so if a user requires an understanding of spatial positioning of the hands and arms, this is not difficult to achieve, as the user can simply see the avatar from different viewpoints. Animation does offer a 3D view, however the quality may not be very good. It has been noted in previous systems that animation can lack details such as lip movement, mimicry, facial expression and speed. If any one of these things is portrayed wrongly it can change the meaning of a sign or simply confuse the user. Video however has an exact copy of the sign from the original signer, and therefore can provide an accurate and timely demonstration of the sign. The problems with video occur when users want more phrases or sentences which may not be recorded in whole, therefore the editors may have to put video clips together and demonstrate a sentence in sign. This can be very disjointed and can also effect frame rates [Johnson and Caird, 1996] which can reduce the quality of the signing and the overall flow of sign language is lost. This was demonstrated with iCommunicator [iCommunicator, 2003]. It received very mixed reviews such as facilitating “smoother communication among co-workers” [Microsoft, 2004] and “sometimes cool technology alone doesn’t cut it” [Temin, 2003].

Animation however does not have this problem as several signs can be placed together and manipulated in the avatar software. Consequently the signs will be demonstrated in a smooth sentence and not disrupt the flow of sign language.

Overall the streaming video recordings can provide very accurate two-dimensional views of a signer, and the main problems are oriented around the inflexibility of the recordings. Usually a frontal view of the signer is provided but viewers may require an angle to understand the signed information more accurately. Also if the signing needs to have more information added, this can only be done by re-recording the sequence or concatenating another signed segment onto the recorded sequence, which can result in a disjointed presentation of signing therefore losing the flow of sign language. In contrast, animation can be easily manipulate to add more signed sequences and then edited with a program to smooth the two clips together. Avatars can also be viewed 3-dimensionally which can allow the user to manipulated the view of the avatar in order to understand the signed information more accurately. However the drawback with animation systems that has been continuously highlighted is their lack of facial expression, mimicry and lip movement.

Reduction in such detail can miscommunicate a sign to the viewer therefore confusing the information delivered or simply losing the viewers attention in relation to the signed sequence.

2.9 Roles of Digital Representations of Sign Language

Sign language representations for the digital domain aim to provide the d/Deaf and HOH audience with information in the native language of the d/Deaf community: sign language. There are as many forms of sign languages as there are spoken languages, and catering for such an audience can prove to be a challenging task. Many systems have been made, and they have received mixed criticisms; they have all shown that they can support a portion of the target market, however they have also shown how they are unable to satisfy the demands and needs of a large spectrum of the market. Therefore it raises these key questions: with all the digital sign language representations currently available, which ones work in which areas? How can we in the future understand what is most suitable for the context and environment we are developing a system for, and what is needed to make an effective DRSL?

The following diagram explains the three main categories of digital representations of sign language, and what types of systems there are in these categories.

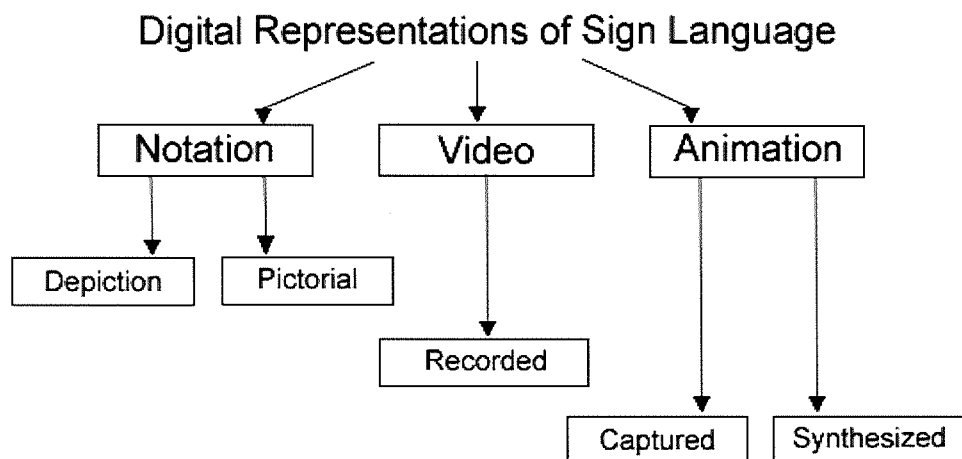


Figure 2.27: Types of digital representations of sign language, broken down further

2.9.1 Notation Systems: Depiction Style

This type of notation system depicts a sign and how it is constructed, an example of such a system is HamNoSys [Hanke, 2004]. The Hamburg Notation of Signs, has the ability to depict any sign movement in the world. It is a symbol notation set, where the user can

join several symbols together to write a symbol description of how a sign is constructed. Although this has transferrable qualities, and in the past it has proven to be successfully used in several countries, it lacks detail on facial expression, therefore the construction of the sign from the notation, without the assistance of a signer who may be familiar with the original sign being constructed, can create mistakes and therefore lose information. Also, as previously noted, the notation lacks the natural flow of signing. The system has been used and is still used today, however in order to understand the sign construction the user must be familiar with HamNoSys notation.

2.9.2 Notation Systems: Pictorial Style

Pictorial notation systems demonstrate words in graphical images. Such as the system developed by Margaret Walker; Makaton [Walker, 1970], where a word description is replaced with an image. For example, to repeat, an image of a bus replaces a written description of the word “bus”. This system does have rules for more detailed writing, such as hand shapes, and facial expressions. However overall the system keeps to a stronger visual style of presenting information. Whereas depiction systems are more appropriately used to document and record signs, pictorial notation systems deliver information to visual based language users. Again however the notation system has cost effective transferability, but lacks the natural flow of signing.

2.9.3 Video Systems: Filmed Content

There is only one type of video system, and this is filmed, either in real-time or pre-recorded. The sequences are recorded and then edited for presentation on a digital medium, for example Kids Sign Online [Naqvi, 2003] is an online tutorial system that uses such filmed video sequences. These generally provide a clear 2D representation of natural signing. They can show how the sign moves and is constructed, therefore it is applicable in an educational and information delivery context. However the main issue with filmed video is that clips cannot be joined together easily as they will appear disjointed and lose the natural flow of sign language. The only way to overcome this is by re-recording the sequence and re-editing it, which can become an expensive process, both in terms of time and money. Also the 2D frontality of the sign (in an educational context) can be difficult to fully understand the distance of the arms and hands from the body as this can be obscured in a frontal view. This loss of information, can confuse the signer, and therefore the sign could be re-constructed incorrectly thus confusing other signer’s. However these systems are cost-effective in terms of reproduction of recorded sequences and are widely accepted and used; they have the ability to demonstrate signing in its natural flow.

2.9.4 Animation Systems: Captured Generation

This approach uses sensor based data capture to gather information about a sign from an actual human signer, such as in Simon-the-Signer [Cox et al., 2002]. Here the signs were captured from a native signer with the use of hand gloves, body sensors, and facial sensors. The data was collected and stored, and then manipulated to render a 3D avatar. It was found that the signs were detected and recorded to a high standard and could be easily understood, however a problem similar to the filmed video sequences emerged where the sequences cannot be blended together easily. Although with animation systems there is still a way to blend signs together it requires many resources, and therefore is often regarded as not a cost effective approach. This system is more costly to produce than the filmed video, and has the same issues as the filmed video. The main advantage is that the avatar can be viewed 3D, and therefore the viewer could see both the sign and its production more clearly.

2.9.5 Animation Systems: Synthesised Generation

This type of animation is extensively programmed such as the eSign system [RNID, 2004]. It uses the HamNoSys notation, which demonstrates how a sign is constructed, and then this is translated into a programming language called SiGML. This is then translated into yet another intermediary named Animgen, which generates the avatars movements. This type of system can synthesise many sequences of sign language providing it has the right HamNoSys description. However it has been noted that these systems lack detail such as facial expression, mimicry and lip patterns. This can lead to confusion in interpreting the sign, and therefore loss of information. However the benefit of synthesised animation over captured animation is that sequences of signing can be blended together with greater ease.

2.10 Conclusion and Summary

Language philosophy looks at how we attach meaning to words and focuses on ways in which the formal systems of language are naturalised. J.L. Austin examined this concept in great deal and developed speech act theory [Austin, 1961] in which language statements are attributed constantative (descriptive) and performative utterance functions. Although Austin makes this division his contribution is principally to the performative in which the saying is also the doing; as in “I now declare you husband and wife”. In other words language structures the world or speech is itself a form of action. Austin further makes a distinction between authentic and inauthentic speech acts, where social and cultural conventions impact on the truth value of those speech acts. Words have effects that are social and linguistic and their usage within these cultural codes and conventions produces meaning affects that are dependent on social agreement. Sign languages therefore 3D

speech acts, where combinations of movements formulate words, and if the words are signed incorrectly or used out of context this can lead to error. Although Austin's focus was on spoken languages there is knowledge here that we can use when thinking of the development of sign language systems and the importance of comprehension as an act of meaning production. Sign language tallies with speech act theory in its focus on language as a active system in which users and language co-produce contexts of understanding.

This chapter has considered the concept of Deafness, the history and struggle towards recognition in society, the preservation, continuation of sign language and its technological development in this rapidly developing world: the question now that arises is what is currently happening in the area of sign language technology to assist the d/Deaf community in the modern world of information?

This chapter has described and organised chronologically many issues related to Deafness, big D and small d deaf, the Deaf community, Deaf culture, Deaf pride, Deaf education and sign language. As well as providing a broad understanding of sign language technology research, it has focused on the perceptions of the community towards digital representations of sign language. There is an increased demand to assist the d/Deaf community in the digital domain, therefore the quality of the digital representations of sign language needs to be assessed and studied in order to ensure that the language needs of the target audience are being met. Particular interest needs to be paid to the issues concerned with the artificial representation of sign language.

Sign language technology is a vast and expanding field. There are several systems available and are still being created to assist the d/Deaf and HOH community. The above analysis has provided an understanding of the range of areas in sign language technology research, and has also provided a generic architecture through which these systems can be placed into context. Some systems have more than one of the generic architecture's components, but they follow the same ordering as the architecture has shown, with capture systems first, followed by manipulation systems and finally finishing with digital representations of sign language.

In summary, there are many tools being made for the d/Deaf, in order to assist in daily life. Yet there is little understanding of why many systems are receiving such segregated views and if these systems are actually addressing the needs of the d/Deaf community, therefore many systems remain in research and development and are seldom used in the "real-world". There have been many historical moves towards mainstreaming the d/Deaf community and the community has opposed such moves. It is important to address the needs of the community with more attention and detail, without making the community feel patronised and defensive of their culture and language. This research aims to investigate such issues and is based around the d/Deaf and HOH user's view of interacting with digital representations of sign language.

In Chapter 3 will show some preliminary research conducted in the field of DRSLs in order to test possible differences in learning when presented with two different DRSLs, animation and video. This chapter will also provide some understanding into the experimental design for the Deaf, understanding and working with visual languages needs which helped inform the latter investigations.

Chapter 3

Preliminary Work for Research

3.1 Introduction

This chapter's study is informed by an awareness of the ever-increasing economic pressures on those providing sign language education. An issue has arisen of how to address the problem of supplying sign language education to remote areas where there may be a few to no sign language teachers present. Even more densely populated areas may not be able to provide enough teachers that can teach through signing. There is clearly a need for digital representations of sign languages to support education. Many are now available, as discussed in the preceding chapters, and range from sign notation systems, three-dimensional(3D) avatars (virtual human), multimedia web interfaces and digital video presentations. This study presents a set of experiments that test the hypothesis that within learning contexts, different digital representations of sign language result in different levels of sign language vocabulary recall by participants. This was conducted on hearing children who had no prior exposure to sign language so as to avoid biases in results.

This study motivated the large scale study into comparatively evaluating the differences between different digital representations of sign languages (chapter 4) with the deaf community, as it could be thought that different digital representations of sign languages work differently for varied information platforms. However in the process of designing the documentation for this research, it was noted that d/Deaf users found it difficult to comprehend and use the experimental document. In other words, traditional approaches to experimental design did not address the language needs of the participants. This problem assisted in a deeper understanding of the visual language needs of the Deaf within text-based documentation design, which impacted on the design of the major research within this thesis.

The chapter begins with an introduction and background, outlining the context of this study. Following this there will be a description of the experiment stating the hypothesis, methodology used and data collection methods employed. There will be a results section outlining the findings, discussion, the importance of this study, and a conclusion for future developments. This chapter will also go through the researchers experience of experimental design for the Deaf and what needs to be considered for further studies within this thesis.

3.2 Introduction to Testing the Effectiveness of Digital Representations of Sign Language Content

Representations of sign language in the digital domain have become increasingly available. Many users have been exposed to these systems and are now actively using them. There are many forms of digital representations of sign languages. These include sign notation systems [Sutton, 2004, Hanke, 2004, Walker, 1970], 3D avatars [RNID, 2004, Cox et al., 2002] and digital video [iCommunicator, 2003]. Although many systems have been improved, redeveloped and evaluated, their comparative effectiveness in delivering sign language content (to my knowledge) has not yet been investigated in the context of learning. This thesis provides the first study comparing two digital representations of sign language (Avatar and Streaming Video) in an educational context with a target audience that has no prior knowledge of sign language.

The chapter has four parts. First, it reviews the literature relevant to this study. Then, the research methodology is presented. Next the findings are discussed and summarized, and the chapter concludes with a discussion of theoretical implications and directions for further research.

3.2.1 Background

The need to demonstrate sign languages in a method other than an actual person signing has brought about the development and use of several different digital representations of sign language. These representations include video systems that broadly consist of filmed sequences of signing. These sequences are often used on television [C4, 2005], in internet dictionaries [BritishSignLanguage.com, 2005] or tutorial systems [Ohene-Djan et al., 2003] and in various communication software such as iCommunicator [iCommunicator, 2003].

Notation systems are alphabets of graphical symbols used to write movements and hand shapes of sign languages. Examples of these systems are Makaton [Walker, 1970], SignWriting [Sutton, 2004] and HamNoSys [Hanke, 2004]. Software has been developed that makes use of these notation sets, such as MakMessenger, Finger Chat [Ohene-Djan et al., 2004] and eSign [RNID, 2004, Cox et al., 2002].

More recently Avatar (Virtual Human) systems, have been used to replicate signing by a human. There are two types of avatars, the first uses sensors attached to different parts of a persons body and face [Lee et al., 2002], such as TESSA [Cox et al., 2002], which as noted was used in a post office to communicate with Deaf/Hard of Hearing customers. The second type of avatar synthesizes signing with the aid of extensive programming for example the synface project [RNID, 2004] which simulates facial movement through audio stimuli in order to aid Hard of Hearing people with telephone calls so they can lip read as

well as lightly hear conversation. Other synthesized systems, such as eSign [RNID, 2004], are based on existing notation systems [Hanke, 2004].

These systems have opened many avenues of communication, and have assisted in delivering information closer to the visual nature of sign language. They have been extensively evaluated, and through the evaluation and investigations various improvements have been identified that further enhance the quality of the software. Educational tools are available online that use these digital representations of sign language, for example BSL Dictionary [Multimedia, 2006] uses avatars to teach signs to children. There are also online tutorial systems such as Kids Sign Online [Ohene-Djan et al., 2003] that use video in an interactive learning environment to teach sign language, and Signwriter [Sutton, 2004] that uses a story and sign writing generator to teach children sign language notations. However it can be noted that (to my knowledge) different digital educational representations have not been compared. A comparison will test which system delivers sign language more effectively.

3.2.2 Experimental Methodology

This section describes the experiment conducted by outlining the hypothesis and methodology. Following this the materials and procedure undertaken will be described. Finally the approach to data collection and measurement are outlined and the results are presented.

Hypothesis

The type of media chosen to digitally represent the signer will determine a child's sign language vocabulary recall levels and will ultimately determine the levels of efficiency and effectiveness of the learning process experienced. The hypothesis at issue is that there is a learning effect between two different digital representations of sign language. Details about these will be provided below.

Sampling

The participants were taught the London regional dialect of British Sign Language (BSL). Sampling took place in and around the London (UK) area and the target population were children seven to eleven years of age. In order to determine the recall rate of the signs the children had seen, the participants selected were hearing to greatly reduce the likelihood of previous knowledge of BSL, and were screened to ensure that there was no previous exposure to the signs used in the experiment. Two groups were formed, one of which was shown streaming video, and the other was shown the Avatar.

After-school activity groups (in the UK there are Brownies and Cubs groups, being younger-age equivalents of girl and boy scouts, as also adopted in the USA) that tend

to have clusters of ten - fifteen children were used as the sample population. A list was compiled of all London boroughs, and from these two boroughs were randomly selected giving a sample of 31 groups within these boroughs. Due to previous exposure to sign language, five groups were eliminated, and the remainder (26) acted as the sample.

From the 26 remaining groups, fifteen were randomly selected and asked to participate in the research. Twelve groups agreed, giving an estimated participant sample of 124. As some participants were dropped due to prior knowledge of sign language, and some were unable to attend on the day of the experiment, the final realized sample was 81, representing a 65% response rate.

This initial sample size was considered to be large enough to give statistically significant results, however if, subsequently, there was no statistically significant difference in results obtained (i.e. major results with large effect sizes but insufficient power) then the experiment would have been repeated with an increased sample size.

Incentives and Procedure

Each participant took part in a single session, at the end of which they received a CD of signs, and a lollipop.

The following steps were implemented:

1. Introduction: The participants were called in one at a time and given general information, including clarification that the experiment was not a test and that respondents should not worry about who achieved the highest score. At the request of the Brownies and Cubs' groups organizers the participants were given an ID number, so that results would be anonymous. The participants were told who was involved in the research.
2. Familiarization: The experiment was explained to the participants and examples shown.
3. Presentation: Participants in the video group were shown on a computer four video clips each one introducing them to one sign, each clip was shown to them three times. Those in the avatar group were shown four separate computer animations of the same four words as the video group, again repeated three times; the clips and animations were of the same length and used the same signing style. The video clips were of a child signing and saying a particular word, each sign was presented by a different child, and were checked by BSL instructors to ensure a high standard of signing. The four avatar clips each showed a distinct child avatar signing and saying a word, and again were checked by BSL instructors for accuracy of signing. In each case participants could not hear what the child/avatar was saying.
4. Testing: Each participant was asked to leave and not to tell the rest of the group what

they had just seen; participants were called back individually after thirty minutes and asked to demonstrate their recall of the four signs.

5. Question and Answers: At the end of the session, participants were given the opportunity to ask questions and some information was given regarding the experiment and BSL

Data Collection Method Used

After the initial introductions, and before the presentation, participants were asked if they had seen any sign language before. Any participant confirming previous knowledge of sign language was not included in the results. Then the participant was presented with the clips; each sign was played three times. The participants were asked not to disclose the content seen to others. Thirty minutes after the viewing, the participants were filmed demonstrating their recall of the four signs seen earlier. This data was collected during October 2004 to February 2005.

Measurement

Each sign recalled by participants was evaluated using the following criteria, which was developed in conjunction with BSL Tutors:

1. Hand shape
2. Hand movement
3. Arm movement
4. Distance of the arm from the body
5. If the hand is facing the right way
6. If the hand is on the correct side of the body
7. Lip movement
8. Facial expression
9. Correct location of arm to body
10. Correct location of hand to body

After the filmed content was marked a random sample was second marked by a BSL instructor.

3.2.3 Results

Each sign was evaluated in terms of the above stated criteria. For each criterion the participants got correct they were given a mark of 0.1. Total marks received for correct sign recall was 1, and for correctly recalling all four signs, participants could achieve a total of 4 marks. The scores for the animation group and the video group were totalled, and then a *t*-test for unequal variances was conducted.

For the *t*-Test a null hypothesis and the alternative hypothesis was stated, the null hypothesis states that participants shown signs by video show no difference in sign language recall from those shown signs by avatars. $H_0: \mu V - \mu A = 0$ the H_0 (null hypothesis) implies that if the mean of V, (video group) is subtracted from the mean of A (animation group), the result will be 0, which means there is no difference in sign language recall.

The alternative hypothesis states that there is a difference in sign language recall. $H_1: \mu V - \mu A \neq 0$ the H_1 (alternative hypothesis) states that if the mean of V, and the mean of A were subtracted the result will not be equal to 0. This suggests there is a difference between the two means, which can indicate that there is a difference in sign language recall.

The significance level $\alpha = 0.05$, the amount that you are willing to accept that the findings you have observed have occurred by chance. The p value is the probability of getting a value of the test statistic that is extreme as or more extreme than the observed value, by chance alone, given that the null hypothesis is true; it is the probability of rejecting the null hypothesis if it is in fact true.

A two tailed *t*-test of unequal variances was used. With this *t*-test, if $p < 0.05$ than we can reject the null hypothesis, and we can conclude that there was a difference in learning rates between the two mediums of delivery. It was found that participants learning sign language with the Avatar had a higher learning rate ($MA = 2.676$, $SDA = .489$) than video ($MV = 2.289$, $SDV = .768$), $t(40) = 2.40$, $p < 0.02$. This size of effect is substantial, the two means being over on half of a standard deviation apart (using even the smaller of the two standard deviations).

3.2.4 Discussion of Findings

This study investigated if there was a more pronounced learning effect between two different digital representations of sign language. To our knowledge it is the first study to investigate and compare two different digital representations of sign language in an educational context.

It may be useful to investigate if there is an age effect on learning with the use of avatars and streaming video, as it is possible that the better retention rate shown by children in

the avatar group would not carry over to an adult sample.

This study has highlighted how children with no prior knowledge of sign language can pick up signs to a fairly high level of accuracy via the use of avatars. This information can be very useful for first time learners of sign language, children who may have recently become Deaf/Hard of Hearing, and/or children who are being exposed to sign language education for the first time. The avatar was developed by using a child proficient in signing and, during development, was continuously checked and improved to ensure a high level of accuracy. It is possible that the use of a child avatar with children helped to remove barriers and assist learning. It can also be hypothesised that the similarities between the avatar and cartoons makes the system easier for a child to engage with, and the development of interactive learning tools using such an avatar could help children to learn signing more effectively.

The Avatar and Video clips used in this study reflected the ethnic diversity of people in the London area. However a limitation of the study was that the avatar clips and video clips were not completely comparable, for example the avatar clips have a dark green background, and the video clips have a white one, also the children in the video clips are not wearing the same clothes as the avatars. This may have caused a different learning effect, and therefore, if the study is replicated the digital representations of sign language should have more visual similarity to each other; these factors will be taken into account in future studies. However it should also be noted that both avatar and video clips used signer's of the same age range, were of the same signs, used the same signing style and were of the same length. All sign language clips were checked and verified by BSL instructors.

It would have been useful and interesting to also use notation systems for testing to see how they assist learning sign language; this would have given further insight into the third identified digital representation of sign language. Also this study could be replicated on Deaf/Hard of Hearing children to ensure validity. However it would be difficult to find a sample population that has no exposure to sign language as was the case with the hearing sample in this study. Therefore the investigation would have to be modified significantly in order to find meaningful results.

Due to time constraints, it was difficult to interview the participants further to ask them what they thought of the two systems, which they preferred, and if they liked one system more than the other, and if so, why they liked it more? This would have given further insight into perceptions of digital representations of sign language. This could be addressed in future studies. The fact that a particular system more readily fosters accurate recognition at the outset does not of course necessarily mean that the system is better in other ways or in the long term. Also, although the results should generalise across similar populations and more over the present population is a diverse one, they would not necessarily generalise across all populations even within the given age range. Both of these matters could readily be addressed in future research. Finally, further research with

still larger samples would provide sufficient power to see whether the findings are about equally strong across various demographic differences.

3.2.5 Conclusion of Study

Any well sighted child has full perception of this visual language (Sign Language) and can therefore learn this language in the same natural way as hearing children learn spoken language: by perception, imitation, interaction and repetition [Verlinden et al., 2002]

This study provides strong empirical support for the use of avatar systems, but it should also be taken into account that the signing of the avatar used was of a very high standard. It is notable that the avatar's lip movements were not clearly recognised by participants, many of whom asked what the avatar was saying when it signed.

Several possible limitations of the present study and ways that they might readily be addressed in future research are discussed above. The results of this study support the hypothesis that participants shown signs by video show a significant difference in sign language recall from those shown signs by an avatar, and it indicates that avatar systems are received well by seven to eleven year old hearing children.

In summary this study suggests that the potential of avatar DRSL in the context of educational tools for children could be very useful, this would however need much more detailed investigation. Taking this further it would be particularly useful to understand which DRSL adults might find more useful for particular information delivery contexts.

3.3 Experimental Research Design for the Deaf: Approaches for Obtaining Accurate End-User Feedback

From the first set of findings it became apparent that there could be a different learning affect when providing DRSLs in different information contexts, therefore further experiments were designed to assess the three systems against each other in the same types of information delivery tasks in order to identify the contexts in which these systems could work.

A key challenge facing researchers interested in Deaf issues is how to approach experimental design, in a manner that allows the highest level of communication and contextualisation. After the first run of experiments we conducted with Deaf adults it became apparent that traditional approaches to experimental design did not address many of the language needs of the Deaf participants. The following sections propose a framework for understanding the visual language needs of Deaf participants and presents a set of rules for "Deaf friendly"

experimental design.

3.3.1 Background

Traditional approaches to experimental design focus on two main areas of data collection, quantitative and qualitative data [Creswell, 1994]. Each type of data collection has its own properties and merits, which enable researchers to have an in-depth understanding of different subjects and areas of interest. Data collection can be undertaken in numerous ways including social surveys, interviews and group discussion, to name a few [Creswell, 1994]. Such activities are normally supported by paper based or electronic materials. Traditional approaches to experimental design have evolved to address the needs of different audiences and their ethical requirements. As such, materials used are often tailored to meet these needs. In our research conducted with different members of the Deaf community, we have found a need to tailor traditional experimental design materials in a manner that enables them to be more usable by Deaf participants. Such tailoring aimed to bridge the information visualisation gap that our Deaf participants felt. This gap is the result of a difficulty in making visual connections between written instructions found in experimental design materials and signing.

This chapter aims to contribute a framework and a set of rules on how researchers could approach on the design of written experimental materials for the Deaf. It proposes a middle ground between English and Sign Language in which “visual connection” is the dominant design criterion. It defines a set of rules that assist in a translation of materials in order to make them more “Deaf-friendly”. It hopes by using this framework, researchers are able to understand and identify the problem areas and can obtain greater and more meaningful participation by the Deaf community in their experiments.

When research is conducted with the Deaf community it is important to have good communication with participants in order to obtain accurate responses. In order to achieve this researchers must present their questions in a manner and format that can be communicated to the Deaf and takes into account the nuances of their primary mode of communication, namely sign language. Through a series of recent experiments that were conducted with Deaf adults it became apparent that traditional approaches to experimental document design lowered participants’ levels of confidence and willingness to participate. Issues around literacy dominated the experimental setting and made the process very difficult [Power and Leigh, 2000].

The present set of experiments were concerned with perceptions of different digital representations of sign language in the digital domain [Walker, 1970, RNID, 2004, Sutton, 2004] and illustrated the following concerns. The level of reading involved in understanding the experiment questions determined levels of willingness regarding participation in experiments [Fischer and Lane, 1993]. Increased textual content saw willingness decline in

participants who, prior to seeing the documentation, had an interest in the research. This was the case even when interpreters were provided. Furthermore, when some participants who agreed to conduct experiments were told there would be questions they would have to work through on paper, they refused to participate citing reading and comprehending questions as a real issue, although it was clearly stated that an interpreter would be provided.

These concerns regarding participation led to further enquiry, and it was found that the documents presented to participants were making individuals uncomfortable. It was purely text and participants did not “visually connect” with the questions they were being presented with, although when translated into sign language they could understand what was being asked. After consulting with Deaf support specialists from deaf organisations in London and various members of the Deaf community, it was found that although the questions were in plain English and clearly phrased, there were a number of things that would make Deaf individuals uncomfortable when reading. A lack of a visual connection between questions and possible answers and the positioning and size of the text on paper were identified as possible causes.

3.3.2 Framework and Experimental Document Design Rules

Traditional approaches to experimental design focus on data collection via the use of qualitative and quantitative experimental practices. There is a layer of tailoring required to increase understanding for Deaf participants. The experimental design framework shown in Figure 4.1, outlines the proposal for document design. Notably it extends traditional approaches for Deaf communication to experimental design, with a set of visual language support rules.

This framework presents the Visual Language Translation Rules which provide the basis of changing textual documents to a Deaf-friendly design. The rules for allowing greater information access to the Deaf in experimental conditions involves the importance of addressing interpretational needs of the deaf in textual documents and not only in sign language. Consideration must be given to visually connecting textual information to several concepts in order to improve the clarity of any given investigation topic. It is important to note that interpreters should always be provided in experimental conditions.

3.3.3 Visual Language Translation Rules

The following rules were identified and developed by three Deaf professionals for the use of textual translation, these rules are given with explanation. Many of these could, at least in spirit, be sensible guidelines for communicators and for those who program communications to use in compiling presentations for almost any population.

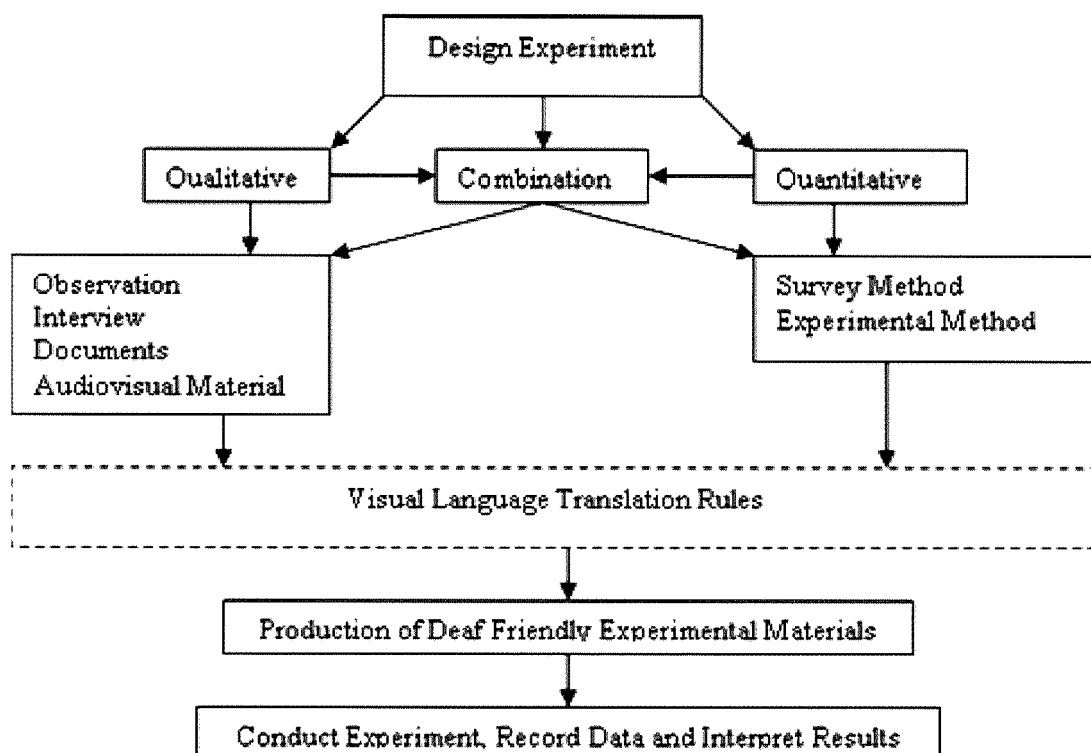


Figure 3.1: Framework of Experimental Design for the Deaf

1. Use pictorial associations in sentences, so that users can connect various subjects and concepts together easily.
2. Instead of explaining instructions it is better to demonstrate them; for example, use role play between the experimenter and interpreter so that it is clear what is expected from the participant if they wish to participate in the experiment. If the experiment is looking at behavioural exercises this can become more complicated as it is important not to influence behavior, therefore keep instructions brief and simple.
3. When using scales (such as Likert, or yes/no options) use images to explain potential answers.
4. Aim to keep a concept on one page, do not separate it over several pages, or if the concept is too large, clearly break it down with leading connections between the different pages.
5. Do not overload the page with textual information as this can become difficult to look at and absorb, it is advised to keep text well spaced and limited.
6. Use sign English (in the UK that would be BSL English) or plain English as it is easier to understand. Simplify English but do not make it dry or patronising.
7. Avoid repeating questions in different word orders, when translated into a sign language it often looks like repetitive information, which either confuses or irritates

participants

8. Try to keep layout of questions and information simple and self-contained. So that when participants are answering a question to a particular subject, they are able to view and answer the questions at the same time.
9. If the participant is no longer allowed to see the subject matter in question, take a snap shot of the subject in order to provide some visual association and place it besides the question.
10. Break questions down, do not ask multiple questions in one: rather break a question down to its constituent parts so that participants can understand each point clearly and answer each point clearly.

3.3.4 How to use these rules

These rules would be applied in the following way (the following examples have been successfully used in experimental conditions):

1. Question (a) is without a picture, question (b) is with a picture (the images will be explained in the Figure 2 description below) by applying rule 1

a. Did you prefer the animation system or the notation system?

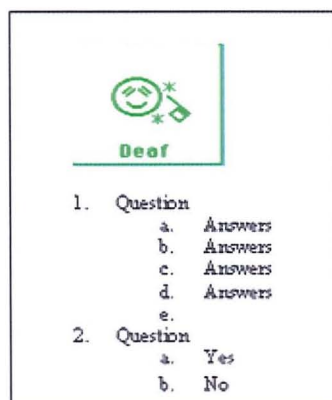
b. Did you prefer the  or the  ?

Figure 3.2: Example of Implementation of Rule One of Experimental Design for the Deaf

2. An example of the application of rule 2 cannot be provided in this chapter, however before an experiment was conducted the role-play was rehearsed between the experimenter and the interpreter, and was then demonstrated to the participant. It was found participants were more comfortable with the experimental conditions after this demonstration.

- rule 5:
- (a) Double line spacing
 - (b) Simple layout
 - (c) Ariel font
 - (d) Text size 14
6. The following is a BSL English example of a question, the first is an example question and the second is how it would be changed to match the requirements of rule six:
- (a) Are you the only Deaf person in your family?
 - (b) Family-You only Deaf?
7. Question 1 and 2 were the same questions just asked differently, they were changed to (c) in order to make them clearer by applying rule 7:
- (a) Was the presenter/notation clear?
 - (b) Did the presenter/notation explain the message clearly?
 - (c) Do you like the presentation?
8. A concept should be clearly explained on one page, or if there is a need for more than one page, each page should be clearly connected visually, with either an image or a page number. This is to give participants not only an indication of context but timing as well. This is done by applying rule 8. The following examples show how to demonstrate a self contained document and how to demonstrate a multiple page document.

Self Contained Document



Multiple Page Documents

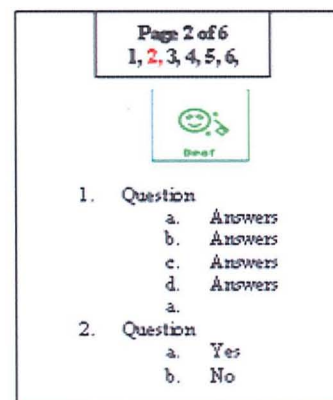


Figure 3.5: Example of Implementation of Rule Eight of Experimental Design for the Deaf

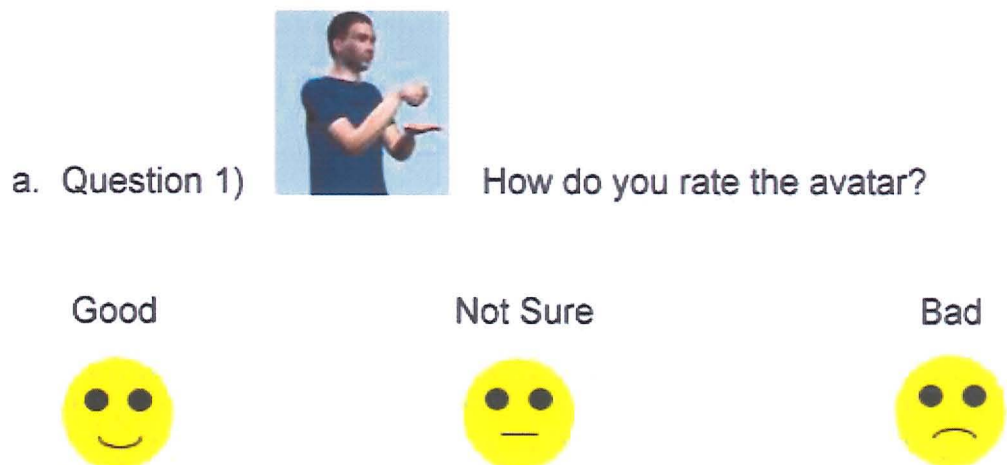


Figure 3.6: Example of Implementation of Rule Nine of Experimental Design for the Deaf

9. In this example an avatar sequence was shown in an experiment, later the participants had to rate the avatar on their first impression, the following is the application of rule 9:
10. In this example we break down question one into two parts, questions two and three; the following is an application of rule 10:
 - (a) Are you the only deaf person in the family? If not who else is Deaf in the family?
 - (b) Are you the only deaf person in the family?
 - (c) Who else is deaf in the family, for example mother, father, brother, sister, cousin?

This will allow participants to feel more included in the research by increased comprehension of the documentation, also it was found that participants were more willing to participate because of increased comprehension, and participants who previously found the experiment uncomfortable, were now more willing to participate in the research.

3.3.5 Implications

These rules were developed while working with a specialist Deaf support worker who has regularly used these principles to make text documents more accessible to the Deaf. These rules aim to enrich the experimental process for Deaf individuals by not only providing an interpreter during experimental conditions, but ensuring that textual documents provided are also accessible to the Deaf. This allows for an increase in confidence for participants when involved in research.

These visual language translation rules were applied to several experiments conducted during this research, and it was found that participants were able to understand the questions more clearly, and also had an increased level of confidence when interpreters were communicating with the aid of the document. Participants commented on the increased clarity and ease of comprehension of the research, which made participants feel more involved as users and not merely as test subjects in the research environment. These rules aided in the experimental documentation design when conducting research with the Deaf. However it is still essential that each participant is provided with an interpreter during an experiment if the experimenter cannot sign. The main purpose of this research is to provide participants the right, option and opportunity to be able to understand written documents more clearly and also indicate by themselves what the answers are. It is hoped that such an outline of rules will facilitate further research and discussion into experimental design methodologies used with Deaf individuals.

3.3.6 Conclusion and Summary

This finding has been of consequence to the work of this research: the importance of the users feeling comfortable with the experimental conditions cannot be emphasised more strongly. The feedback provided here greatly altered the approach of the experiments with the Deaf community and provided for richer participation as will be shown in the following chapters of work.

Chapter 4 describes how the rules were applied on the experimental documents to ensure higher levels of comfort and participation of the individuals involved. It was found that a wider range of audiences constituted of varied backgrounds of literacy could participate in the experiment. A summary document of these rules can be found in appendix A.

Chapter 4

Investigation: Comparative Evaluation of Digital Representations of Sign Language for Different Information Delivery Contexts

4.1 Introduction

There are different digital representations of sign language available. They have been widely used and adapted to a variety of different systems [Bureau, 2003, Hanke, 2004, Verlinden et al., 2002, Elliott et al., 2004]. Although the systems have been continuously refined and adapted [Elliott et al., 2000, Elliott et al., 2004], it has been noted that they all receive very mixed reviews, and some receive low acceptance rates [Abrahams, 2008]. This highlights two possible issues, either the content of the DRSL presented to the target audience was inappropriate or the DRSL itself was unable to transmit the information correctly to a Deaf audience.

The information that will be gathered will examine how d/Deaf people feel about different DRSLs and how the different systems are rated in terms of usability, likability, acceptability, sign language composition and overall preference. The investigation will examine if age, gender or personality effect the DRSLs' perception and how confident d/Deaf people feel about the communication offered by varied media presentations.

This study will compare different DRSLs in order to highlight and understand the different properties, problems and potential uses of the three main types of DRSLs. This study will first have a background detailing what has been previously noted with DRSL systems. Then the hypothesis of this study will be stated in order to define the area of research clearly, this will then justify and lead to the methodologies used and a section explaining the participant selection for this experiment. There will be details about the pilot studies conducted, what was found, and how the experimental design was adjusted

to be appropriate for the needs of the target audience.

4.2 Background

This section provides a detailed analysis of the research that will be analysing digital representations of sign language. Each digital representation of sign language (DRSL) has its own benefits and drawbacks. However, as previously suggested, their comparative effectiveness against each other is a new area of research, and this analysis aims to promote a deeper understanding of the perceptions of DRSLs in real-world applications. This research attempts to place into context the future of digital representations of sign language, providing technologists and organisations with a framework and guidelines when developing systems for d/Deaf and HOH users. This is intended as the major contribution of this research.

Many systems have been made, developed and used worldwide (chapter 2). There are different outlooks to methods of presenting information to the Deaf and in their native sign languages. The language requirements of the Deaf are vast, they range from oralists to signer's with varying degrees of the two extremes in the middle (as noted in chapter 2). The documentation of sign language and its movement in a digital form has led to many versions of such systems: some systems allow and permit users to transfer information in printed form (such as notation systems), while others record signing and are able to retransmit it in a two-dimensional form such as video recordings. Although less transferrable these are widely used on television, video and the internet. A third and more recent method is animation, where a virtual human signer can three-dimensionally(3D) sign information.

The difficulty is that the community feels divided about the different systems and there is no universally accepted DRSL. DRSL range from varied types of animation, notation and video systems. Each type of system has its own benefits and drawbacks such animation systems [Verlinden et al., 2002, Sagawa and Takeuchi, 2002, Yeates et al., 2002, Suszczanska et al., 2005, Gao et al., 2000] that use signing avatars (virtual humans) to present a 3D image of sign language. These can be used in a variety of contexts, ranging from educational environments to public information services on the internet [Cox et al., 2002]. Although the software is still developing and probably will have a real-world application in the future, currently there are a number of drawbacks that do not allow overall acceptance of the system. The system has the ability to smoothly join different sequences together which gives it a unique application advantage of real-time sign language delivery [RNID, 2004]. However its poor facial expression gives the system poor feedback, and is heavily criticised for this within the Deaf community [Elliott et al., 2000, Elliott et al., 2004].

Video systems [EuroBridge, 2004, RNID, 2004, Naqvi, 2003, Booth, 2003, iCommunicator, 2003] broadly consist of filmed sequences of signing. They are the most commonly accepted form

of DRSL and are used in a variety of contexts, such as television, internet and educational videos/CD-ROMS to name a few. Video gives an exact replication of sign language as it is filmed. If filmed correctly this will be of a very high quality, as facial expression and movement can be recorded very clearly. This form of DRSL is widely used in all areas of communication with the Deaf. However the major drawback of such a DRSL is that it is unable to join other video sequences together smoothly. They will appear disjointed and therefore goes against the natural flow of sign language.

Notation systems [Sutton, 2004, Walker, 1970, Cregan, 1982, Hanke, 2004] allow for the depiction of sign language movement into a series of symbols that represent shape, movement and location. The collection of images can explain signs, and sets of sign notations can explain information in a written form of sign. This DRSL is able to cover a lot of linguistic detail in its notations and can easily join signs together. However it is written and it is not actual movement, which many Deaf/HOH people feel uncomfortable accepting as it seems like a completely different language and is difficult to grasp. Although there are members of the Deaf community that feel it is visual enough and could have a good potential use in the future, it would need to be introduced a lot earlier in the education system so that individuals familiarise themselves with it and feel comfortable with the notations.

4.2.1 Which Types of Information Require Translation into Sign Language?

All types of information may require sign language translation. These systems are all very different to their approaches, benefits, problems and real-world applications, however in order to investigate and understand where these systems can be used in terms of information delivery, the following categories have been used to define information.

1. Real-time information: examples are train delays, news reports and airport announcements.
2. Static information: examples are soap operas, manuals and films.
3. Real-time and Static information: examples can be news reports that are showing live coverage and while they are waiting for a reporter, the producers may show an old pre-recorded sequence, or another example is a radio transmission which is playing songs.

In the investigations, digital sign language presentations will be categorised into the above information categories. In order to identify any relationships of system preferences between the different information types. The presentations will be tailored to demonstrate examples of such information delivery.

4.2.2 Are Combinations of Digital Representations of Sign Language More Effective for Information Delivery?

Different digital representations of sign language present different facets of sign language, for example animation can provide a 3-dimensional smooth flowing view of signing, whereas a pictorial notation system can provide information in a written printable style. By looking at the two systems together it might provide users with a more thorough understanding of the information delivered. It may be that combinations of digital representations of sign language support each other in information delivery better than on their own. If such a suggestion is true, which combinations are most useful, in which information context and why?

The combinations of sign language presentations will be as follows:

1. Video and Animation
2. Video and Notation
3. Animation and Notation
4. Video, Notation and Animation

It may also be that combinations of systems need to be shown together, or one after the other. It may be that together they support each other, or become too visually confusing, and it may be that showing them one after the other can help confirm what has just been explained or it may become a very long presentation and therefore frustrating to watch. If there is a preference to see one after the other, which one do users like to see first or second, and why? The users will also have the ability to manipulate the time of play, order of play and positioning of the different parts of their presentation. This will be done to observe any possible trends in users preferences.

4.2.3 What is Good Quality Signing and How can this be Represented on the Digital Domain?

In order to present sign language in the digital domain, it is important to understand the visual nature of signing [Schein and Stewart, 1995] and what is representative of high quality signing. Signing is primarily visually based [Stokoe, 2005], with deaf-blind people it becomes tactile [Heubner, 1995], with the hearing community, the primary form of communication is auditory [Heidegger, 1962], and communication is vitally important in each community. Often the complexity of translating from auditory communication to visual communication is misunderstood [White, 2000]. signer's are able to teach non-signer's the art of visual communication, correcting the speed and flow

of signing, and this learning process is not clearly documented, it takes time to perfect [Kyle and Woll, 1985, BritishSignLanguage.com, 2005]. Yet when d/Deaf people are asked about a hearing person who may appear to be a fluent signer, whether or not they are deaf, the d/Deaf person will be able to tell straight away that they are hearing, unless they are CODA's (children of deaf adults) where their first language is sign language [Preston, 1994].

So what is it that demonstrates the hearing community's lack of understanding of signing? A recent study on eye tracking [Agrafiotis et al., 2003] found that native d/Deaf signer's watch signing differently to how it has been traditionally perceived. It has been suggested that native signer's have peripheral vision, where the main focus of signing is around the face, however if the signing moves location, the eyes keep focused on the face and new location. So if for example the main signing is around the face, the signing in this region will be more intricate and detailed [Farnell, 1995, Johnston and Schembri, 2007], however the further out of the facial region, the handshapes become plainer and more simple. This study has potentially demonstrated how d/Deaf people visually collect information, and how this is different to hearing people [Sutton-Spence and Woll, 1999, Gary Morgan, 2007, Kyle and Woll, 1985]. This could possibly explain why digital representations of sign language such as avatars, are unable to communicate information clearly, because the primary peripheral (the face) often communicates poorly [Verlinden et al., 2002, Lee et al., 2002, NSF, 2001, Ben Salem, 2000, Selvarajah and Richards, 2005, Damer et al., 1997].

If sign language is to be translated into the digital domain, then it needs to be understood on more levels than just practical application. It needs to be made clear, which characteristics contribute to high quality signing: flow, speed, facial expression, signing style or how the signer is dressed, the background. Once all this is understood it can be clearly understood how previous systems have worked [EuroBridge, 2004, RNID, 2004, Foggitt, 2006] and if they have worked correctly in accordance with standards of high quality signing. For this individuals will be interviewed and asked questions about what they expect from a human signer, and what they expect digital representations of sign language to include.

Each of these systems have a variety of benefits and drawbacks, and it may be that their application in different contexts would be more appropriate and more acceptable to users as opposed to their current application areas.

4.2.4 Why Choose these Systems for this Research?

The animation, video and notation information systems selected needed to have the following characteristics to be comparable:

1. Use the same version of British Sign Language(BSL)

2. Use the same dialect of BSL
3. Use the same sentence structure, vocabulary, pace and order
4. Use the same signs or represent the same sign correctly and consistently

The information systems will be visually different, as they will present signing in their programmed form. However it is their ability to communicate with the target audience for whom they have been designed that will be examined.

The animation system selected is currently the only system of its kind in London [Verlinden et al., 2002], which can create both real-time and static presentations of BSL in the London dialect, and would be classified as a synthetic avatar generation system (as defined chapter 2). It fulfilled the above stated criteria and thus determined the selection of the video and notation systems. The video information system was produced for this assessment, following the exact structure, vocabulary, pace and order of the animation system. Thus it also fulfilled the above stated criteria. The animation system has the ability to produce sequences that can be organised and polished, in order to store into a database system for later retrieval. When the avatar signs it calls a preprogrammed code to generate the avatar's movements and signing sequence [RNID, 2004]. This is much like the ability of video sequences, where the lighting and location can be made appropriate for filming and the filming takes place. This sequence can be stored and recalled as and when necessary within an information system. With the real-time generation of sequences within the animation system, the program had prerecorded and stored vocabulary, which were generated on demand i.e. a request was made to the program and the program made the sequence. This does not appear disjointed but as it is generated on demand, it is not as polished as the static sequence. This was mirrored in the video sequence design, where pre-recorded vocabulary, was recorded i.e. stored. Then called on demand to generate a sequence. Therefore the presentation would show a signing sequence that had a series of vocabulary clips put together. Unlike the animation system this does not present a smooth sequence; it is a series of clips joined together and will appear more disjointed. However it provides a real-time signing alternative to animation, based on the same principles as how the animation is generated. With the notation system, there was a wide range of systems available, covering mainly two branches, pictorial or depicted. The pictorial systems [Walker, 1970] do not have the ability to provide detailed descriptions of a sentence as in BSL, it can provide an overall view of how this can be written, which can alter upon opinion. It was therefore more appropriate to use a notational system that depicted BSL in its actual form. There were still a range of systems available. Different systems provided different notation methods, however it was important to use a notation method such that someone who has limited to no understanding of notations could grasp the meaning of what is presented. The one notation system that was used in several educational contexts and is still actively used today to teach sign languages is the signwriting system, developed by Valerie Sutton [Sutton, 2004]. In order to develop the correct notation

for the BSL sequences in real-time and static delivery contexts, the assistance of Sutton was sought. From this it was established that signwriting is written from top to bottom, and the symbols can be depicted through different colours. This later proved to be very useful as participants could distinguish the signs easier. The real-time presentation was made similar to both the video and animation real-time presentations, where vocabulary is already established and called up to present a sentence. This was also done from top to bottom of a screen. Both the video and notation systems were a mock-up of what the real system may have looked like. In figure 4.1 shows the video system used in the experiment, figure 4.2 [RNID, 2004] shows the animation system used, and figure 4.3 [Foggitt, 2006] shows the notation system used in the experiment.



Figure 4.1: Video System Used in the Experiment



Figure 4.2: Animation System Used in the Experiment

4.3 Experimental Methodology

This section describes the experiment conducted by outlining the hypothesis and methodology. Following this the materials and procedure undertaken will be described. Finally

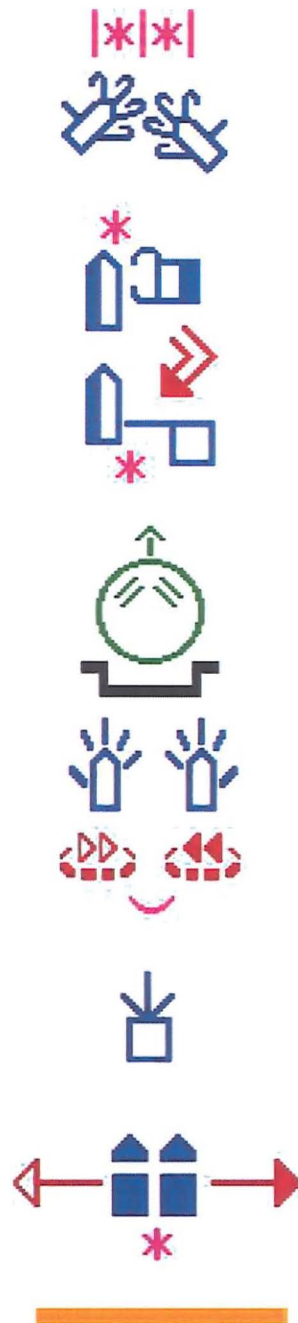


Figure 4.3: Notation System Used in the Experiment

the approach to data collection and measurement are outlined and the results are presented.

Hypothesis

The type of digital representation of sign language (i.e. avatar, video and notation systems) used in different information contexts (i.e. static, real-time and combination, which is static and real-time combined) will determine higher acceptance rates of the systems and ultimately the efficiency and effectiveness of the information delivery. The hypothesis that there is a difference in the perception of DRSL in different information delivery contexts will be tested.

Sampling

All organisations, schools, education centers and professional bodies working with Deaf adults were contacted to ask for participation in the research. In addition to this others who were not part of such organisations but were interested in the work contacted myself. A list was formed of all the potential participants, of which fifty people were randomly selected. Twenty-three agreed to participate and on the days of the experiments three participants were unable to attend. Bringing the total sample size to twenty.

The participants demonstrated the London regional dialect of British Sign Language (BSL). Therefore sampling took place in and around the London (UK) area and the target population were adults. In order to understand what the deaf community thinks of the systems, BSL and SSE users were invited for participation in this research. The participants selected were deaf and hard of hearing(HOH).

This initial sample size is considered to be large enough to give statistically significant results, however if, subsequently, there was no significant difference in results obtained then the experiment will be repeated with an increased sample size.

Incentives and Procedure

Each participant had been offered reimbursement for travel if needed. The following steps were implemented:

1. Introduction: the participants were called in one at a time and given general information, including clarification that the experiment was not a test of any kind, it was simply a comparison of different DRSLs that are currently available. Respondents were told that they should not worry about the organisations involved, and that this was an independent study using different technologies. They were also informed that they may stop the experiment at any time, and that if they wished they may remain anonymous in this research. Before the participants began the experiment, they were asked their age, gender and contact information.

2. Familiarization: the experiment was explained to the participants, they were then asked to fill in a questionnaire for some basic details before the sample sequences were shown.
3. Presentation: participants was shown three presentations that fitted the three information contexts. Each information context showed three DRSLs (video, avatar, and notation). Each DRSL sequence was shown twice, and the participants were asked if they would like to see it repeated once more. The presentations were shown in different orders to avoid primacy effects.
4. Information gathering: each participant was asked questions regarding the presentations they saw. They were asked if they understood what was said and asked to rate the presentation. After seeing all three DRSLs for a particular information context the participants were asked for their thoughts on the three presentations, and how they rated them. After all the demonstrations, participants were required to fill in another questionnaire which examined the participants personality types. Finally they were asked for feedback and information about their thoughts about such digitisation of sign language. This feedback has proved very significant.
5. Question and Answers: At the end of the session, participants were given the opportunity to ask questions. They were also asked if they had seen these systems before and where and what they thought about them at that stage.

Data Collection Method Used

The participants were given a form to complete which gathered information such as age, gender and contact information, if they are deaf or hard of hearing and whether they regard themselves as culturally Deaf or deaf. Other questions included their primary mode of communication, and other demographic information. They then saw various presentations of static, real-time and combination presentations which were evaluated. The experiment finished with a personality questionnaire and a question and answer session. The participant group will also partake in some sub studies in which they will be presented with different combinations of DRSLs in order to evaluate their effectiveness in sign language delivery. They then saw various presentations which they individually rated. At the end of the session they were interviewed and asked to complete a personality questionnaire.

When people viewed the presentations they were asked to rate the systems individually and instead of ranking them against each other. This is because if a user liked more than one presentation the same amount, and they had to choose, they may arbitrarily have chosen one system over the other, therefore giving inaccurate results. Also the actual ratings represent important information which should not be lost, as this can provide organisations, researchers and technologists with choices and alternatives in designing systems.

The experiment examined acceptability in terms of how much users liked a particular system in terms of its speed and accuracy measures. It will be useful to understand if the presentations given are acceptable for the target audience and what the threshold for inaccuracy is.

The experiment aimed to investigate how much people really understand over how much people perceive to understand and to use this information to determine if the system meets some acceptability standard.

Materials

The user was presented with three information category presentations, these information categories were:

1. Static: which is information that is standard and not often changed, such as a user manual, regular train times and a food recipe.
2. Real-time: this type of information is subject to change, such as a news or weather report, bus delays and traffic updates.
3. Combined: this information type combines both static and real-time information, this can be something like an announcement of a train time table, with a sudden break as the train has been cancelled, or a live interview with a celebrity during which the shows producers show some footage of an old film they may have starred in.

The presentations within these categories were

1. Static:
 - (a) Avatar: pre-recorded sequence, which will play an avatar clip.
 - (b) Video: pre-recorded sequence, which will play a streaming video clip.
 - (c) Notation: Pre-recorded sequence, which will display pre-recorded notation graphics.
2. Real-time:
 - (a) Avatar: which will be played from the software spontaneously.
 - (b) Video: which will be a series of video clips concatenated with each other.
 - (c) Notation: a set of graphics that will be organised spontaneously.
3. Combined:
 - (a) Avatar: which will show the pre-recorded and software generated sequence together.

- (b) Video: which will show pre-recorded video sequence, with the joined video sequences together.
- (c) Notation: which will show the pre-organised and spontaneous graphics together.

The users saw the presentations in their information categories, however the information categories were mixed up, and the sequences within the categories were mixed up in order to avoid primacy effects.

The BSL sequences demonstrated the following sentences:

1. Real-time sentence one: "Presentation start half-hour late. Where? [Room] number 20".
2. Real-time sentence two: "Train going to London. 10 minutes late".
3. Static sentence one: "Technology department where? Third floor".
4. Static sentence two: "Train going to London, [platform] number two".

As it can be noted the English structure is different, but this is done so that the sentences reflect the correct structure of BSL.

Participants were also presented with combinations of DRSLs in order to evaluate and understand if different DRSLs support each other better when presented together.

1. Static:
 - (a) Avatar and Notation: pre-recorded sequence of animation played alongside notation.
 - (b) Video and Notation: pre-recorded sequence of streaming video played alongside notation.
2. Real-time:
 - (a) Avatar and Notation: the avatar sequence was played from the software spontaneously alongside a presentation of the notation.
 - (b) Video and Notation: the video clips were played alongside the notation graphics.
3. Combined:
 - (a) Static Avatar and Real-time Video: the pre-recorded avatar clip was shown followed by the real-time video clip sequence (in which several video sequences were joined together).

- (b) Static Video and Real-time Avatar: the pre-recorded video sequence was shown followed by the avatar sequence which was spontaneously generated from the software
- (c) Static Avatar, Real-time Video and Notation: while the avatar and video sequences were shown the notation was shown below it
- (d) Static Video, Real-time Avatar and Notation: while the video and avatar sequences were shown the notation was shown below it

Testing the various combinations of DRSLs was not the main focus of this study, but this was tested on some participants in order check for some preferential differences.

Participants were asked if they would like to see the Avatar and Video sequences with or without the Notations.

The users saw the presentations in their information categories, however the information categories were mixed up, and the sequences within the categories will be mixed up in order to avoid primacy effects.

The data was collected through questionnaires, and video filming which was analysed after the experiments.

There is no experimental or control group in this study as its a comparative investigation.

4.4 Pilot Study One

In the initial run two Deaf participants were used. The problems encountered were as follows:

1. The English used in the experiment was too complex.
2. There were too many presentations and it became confusing.
3. Participants wanted to talk about their experiences but the experiment's design did not foresee this nor could its time structure allow for this kind of discussion to happen. The problem arose in time keeping as it became difficult to plan for how long a presentation ran. However the kind of feedback offered by participants was still valuable and stopping them from sharing meant losing this information.
4. Participants were confused with the notation, and therefore could not answer the questions that followed, as they felt they did not apply.

The English was modified with the assistance of the Plain English Campaign [Maher, 2006]. The extra-sub investigations such as combining different DRSLs for the presentation of

sign language information was removed as this was not the focus of the study and could have potentially damaged the overall experimental focus. Therefore the number of presentations shown was reduced. Participants were given more time after each presentation to discuss what they noticed and found, and they also had the opportunity to talk at the end of the complete set of presentations in order to give an overall review of what they have seen and what they think.

The notation sequences were explained to the participants and they were then asked to evaluate them. This allowed the participants to answer the questions in more detail, also helping participants feel more comfortable in the experiment. It was also noted that participants did not concentrate on the personality questionnaires, it could be because they were more engaged with the feedback of the systems and were disinterested in the this part of the data collection. Therefore the personality questionnaires were removed in order to not dilute the main focus of this study.

4.5 Pilot Study Two

During this trial it was found that participants initially understood the three information categories clearly. However it was found that during the presentations they could not work out which category was being shown - real-time, static or combination. Consequently, which combination was being put forward, what it meant and why it was shown was also in question.

Therefore again the main focus of this study was to see how DRSL's are perceived in real-time and static information contexts. The study also considered whether combined sequences of DRSL's (for example, combining video, animation and real-time information systems) would improve the comprehension of the information delivered as it would provide the strengths of particular DRSLs and support weaknesses of others. Thus all information would become clear. However this made the study very complicated and difficult to follow. The combined DRSL presentations were removed from the investigation making the final design simpler and more effective to manage.

4.6 Pilot Study Three

This trial was quick and simple to begin and focused in on the problems faced during the actual experimental questioning. It was found that participants realised a pattern in the ordering of the questions for each presentation, therefore started to circle very similar results in order to speed up the process. Although the participants knew that the investigations would take approximately 45 minutes, the participant ran through the investigation in 20 minutes, which clearly indicated that the participant had rushed through

the investigation and was not thinking about the answers.

Therefore the question ordering for every presentation was changed in a random fashion in order to avoid any patterns forming.

4.7 Pilot Study Four

Participants were also asked to evaluate the DRSLs in terms of British Sign Language (BSL) linguistic components such as handshape, facial expression etc. Although everyone could answer these, it was noted that not all signer's have a deep understanding of BSL linguistics, which was something that was not taken into account.

Therefore participants were asked questions before the investigation such as if they had undertaken any BSL language courses, BSL linguistics and BSL grammar courses. They were also asked how long they had been using BSL, and if they saw themselves as fluent users of BSL.

The final design of the experiment can be found in appendix B.

4.8 Results

This section provides the analysis of the results that were found in the study. It will compare the effectiveness and perception of different digital representations of sign language (DRSL) in order to recognise and understand the benefits and drawbacks of these systems, and also to establish a deeper understanding of the target audience, what they prefer and why.

4.8.1 Static vs Real-time

Digital representations for sign language can be developed and used for different information delivery contexts. For clarity purposes these information delivery contexts have been divided into two groups static (pre-recorded and edited sequences) and real-time (sequences made on demand). These two modes are available in all three digital representations of sign language. It was investigated that if each digital representation of sign language could be used to represent real-time or static presentations, which of the two would rate better and why? Also the significance of in the difference in their ratings was examined.

Static and real-time presentations were tested against each other and questions were asked about how the presentations were perceived. The categories of assessment were established

in the previous study in chapter 3, which was further confirmed with wider reading about BSL linguistics. The linguistic criteria have been slightly modified to cater for this study. Another element of systems that needed to be understood for the research is the overall acceptance of a system. It could be that a system may be very usable but is disliked, and a system may be comprehensible but simply not accepted because of another reason. Therefore questions were designed to assess the acceptability, usability, likeability and comprehension of the systems. Having only one question per criterion would not suffice as it does not give an overall understanding. Therefore a series of questions were asked, for which ratings could be given. These ratings could then be averaged to provide a score for each criterion outlined. The linguistic criteria have been verified with BSL practitioners, teachers and linguists within the BSL using community:

1. Acceptability

- (a) When assessing this criterion a series of questions were asked and their scores were averaged together to form the acceptability score. Questions asked were:
 - i. Did you understand the presentation?
 - ii. Did you find it easy to understand?
 - iii. Was the (animation/video/notation) presentation clear?
 - iv. Did the (animation/video/notation) presentation explain the message clearly?

2. Usability

- (a) When assessing this criterion a different series of questions were asked and their scores were averaged together to form the usability score. Questions asked were:
 - i. Is this system easy to use?
 - ii. Would you learn by this system?
 - iii. Would you recommend this system?
 - iv. Would you use a system like this?

3. Likability

- (a) When assessing this criterion a series of questions were asked and their scores were averaged together to form the likability score. Questions asked were:
 - i. Did you like the system?
 - ii. Did you like the way the information is presented?
 - iii. Did you like the (animation/video/notation) presentation?
 - iv. Did you like watching the presentation?
 - v. Do you like: (1 = all of it, 5 = none of it), please state which elements you liked or disliked?

4. Comprehension

- (a) When assessing this criterion a series of questions were asked and their scores were averaged together to form the comprehension score. Questions asked were:
 - i. Did you find facial expressions easy to understand?
 - ii. Was the movement of the sign clear to understand?
 - iii. Was it easy to see what the handshapes were?
 - iv. Did you understand the information being delivered?
5. Linguistics (which was identified by various readings and consultations with teachers who are Deaf and teach British Sign Language. It was agreed that this would be broken down into)
- (a) Hand shape [Morgan et al., 2003, Sutton-Spence and Woll, 1999]
 - i. Handshapes provide vocabulary in BSL, alongside the other linguistic characteristics, such as the face and body movement, this can alter the meaning of the sign presented.
 - (b) Morphology [Sutton-Spence and Woll, 1999, Kyle and Woll, 1985, Brennan, 90]
 - i. Morphemes are units of meaning in BSL which create the meaning of words, signs and structure.
 - (c) Distance of the arm from the body [Sutton-Spence and Woll, 1999, Kyle and Woll, 1985]
 - i. As sign language is three-dimensional in nature, the signer's space in front and around the signer is used to communicate. The way in which the arm movement is conducted can alter the spatial orientation, the significance and the emotional meaning of a given sentence.
 - (d) Lip movement [Sutton-Spence and Woll, 1999, Kyle and Woll, 1985, Elliott et al., 2007]
 - i. Lip patterns are essential for clarity of meaning in BSL vocabulary. They are a vital part of facial expression.
 - (e) Facial expression [Sutton-Spence and Woll, 1999, Kyle and Woll, 1985]
 - i. Emotionally enriches the information that is being signed. The facial expression can be compared to the intonation of speech.
 - (f) Correct sentence BSL structure [Sutton-Spence and Woll, 1999, Kyle and Woll, 1985]
 - i. BSL is a language in its own right and has its own grammatical structure. It is not the same as English, which is a common misconception amongst non-signer's.
 - (g) Correct placement [Sutton-Spence and Woll, 1999, Kyle and Woll, 1985]
 - i. Placement is used to provide a layout of a story/discussion/description of a conversation. The signer designates a location in their signing space, which can be referred to throughout the signing of the story/discussion/description of a conversation. This gives clarity and structure to the signing and is essential with complex topics and long signing sequences.

- (h) Correct signing context [Sutton-Spence and Woll, 1999, Kyle and Woll, 1985]
- i. The appropriateness of the sign within a particular context is very important in communication. A good example is compound words, where two different words are brought together to form a new word, unrelated to its original context, such as dustpan, doormat and hairdryer. In BSL these all have their own signs, similar to English if broken down into their component parts, their signs would become different.

4.8.2 Descriptive Statistics for Static Presentations

All 20 participants were involved in the experiment; they all had the opportunity to view the different digital representations of British Sign Language and rate them according to the above stated criteria. The tables below (4.1, 4.2, 4.3, 4.4, 4.5, 4.6) show the average scores of each system in terms of its usability, likeability, acceptability, comprehension and linguistics.

Averages of each Category	N	Min	Max	Mean	SD
Notation Likeability	20	2.20	5.00	4.21	.92
Notation Usability	20	1.75	5.00	4.03	.94
Notation Acceptability	20	2.00	5.00	4.10	.95
Notation Comprehension	19	1.75	5.00	4.30	.89
Notation Linguistics Overall	19	2.25	5.00	4.17	.93
Valid N (listwise)	19				

Table 4.1: **Descriptive Statistics of Notation Systems Static Presentation in the Categories of Usability, Likeability, Acceptability, Comprehension and Linguistic Ability** NOTE: Min represents minimum values, Max represents maximum values and SD represents Standard Deviations. The above scale is 1 for Excellent to 5 for Poor ratings. The above table presents descriptive statistics for the notation system in static presentation mode. Data summarised here provides the basic features of the data in this study. The sample group was a total of 20 participants, and we are able to establish from the data there was a strong dislike of the system that was presented.

From the descriptive statistics of static presentations we can clearly see that video averaged better in terms of digital sign language representations overall. The second best system was animation and the third was notation. In real-time mode we had the following results.

From the descriptive statistics of real-time presentations we can see that video averaged better in terms of digital sign language representations overall the same as the static results. The second best system was animation and the third was notation.

4.8.3 Inferential Statistics

Further inferential analyses [Box et al., 2005] were conducted in terms of *t*-tests. We noted that the only result that showed statistical significance was in the animation digital

Averages of each Category	N	Min	Max	Mean	SD
Animation Likability	20	1.60	5.00	3.8	1.12951
Animation Usability	20	1.75	5.00	3.6625	1.09807
Animation Acceptability	20	1.75	5.00	3.8125	1.00615
Animation Comprehension	20	1.50	5.00	3.9500	.95834
Animation Linguistics Overall	20	1.75	5.00	3.5563	.91180
Valid N (listwise)	20				

Table 4.2: **Descriptive Statistics of Animation Systems in Static Presentation in the Categories of Usability, Likeability, Acceptability, Comprehension and Linguistic Ability** NOTE: Min represents minimum values, Max represents maximum values and SD represents Standard Deviations. The above scale is 1 for Excellent to 5 for Poor ratings. This table also presents descriptive statistics, but for the animation system in static presentation mode. Data summarised here provides the basic features of the data in this study. The sample group was a total of 20 participants, and we are able to establish from the data there was a dislike of the system that was presented, but it was rated better than the notation system.

Averages of each Category	N	Min	Max	Mean	SD
Video Likeability	20	1.00	4.60	2.0600	1.02618
Video Usability	20	1.00	4.75	2.0500	1.02148
Video Acceptability	20	1.00	4.00	2.0375	.95033
Video Comprehension	20	1.00	4.00	2.1375	.96816
Video Linguistics	20	1.00	3.00	2.0313	.69995
Valid N (listwise)	20				

Table 4.3: **Descriptive Statistics of Video systems in Static Presentation in the Categories of Usability, Likeability, Acceptability, Comprehension and Linguistic Ability** NOTE: Min represents minimum values, Max represents maximum values and SD represents Standard Deviations. The above scale is 1 for Excellent to 5 for Poor ratings. This final table, presents descriptive statistics, but for the video system in static presentation mode. Data summarised here provides the basic features of the data in this study. The sample group was a total of 20 participants, and we are able to establish from the data that participants liked this presentation the best out of the three systems in static mode.

Averages of each Category	N	Min	Max	Mean	SD
Notation Likeability	20	1.60	5.00	4.3000	1.03110
Notation Usability	20	1.75	5.00	4.0750	1.08852
Notation Acceptability	19	1.75	5.00	4.1974	.95226
Notation Comprehension	20	1.75	5.00	4.2625	.88286
Notation Linguistics	19	2.00	5.00	4.2500	1.00347
Valid N (listwise) 19					

Table 4.4: **Descriptive Statistics of Notation Systems in Real-time Presentation in the Categories of Usability, Likeability, Acceptability, Comprehension and Linguistic Ability** NOTE: Min represents minimum values, Max represents maximum values and SD represents Standard Deviations. The above scale is 1 for Excellent to 5 for Poor ratings. The above table presents descriptive statistics for the notation system in real-time presentation mode. Data summarised here provides the basic features of the data in this study. The sample group was a total of 20 participants, and we are able to establish from the data there was a dislike of the system, similar to the results found in the static presentation in table 4.2.

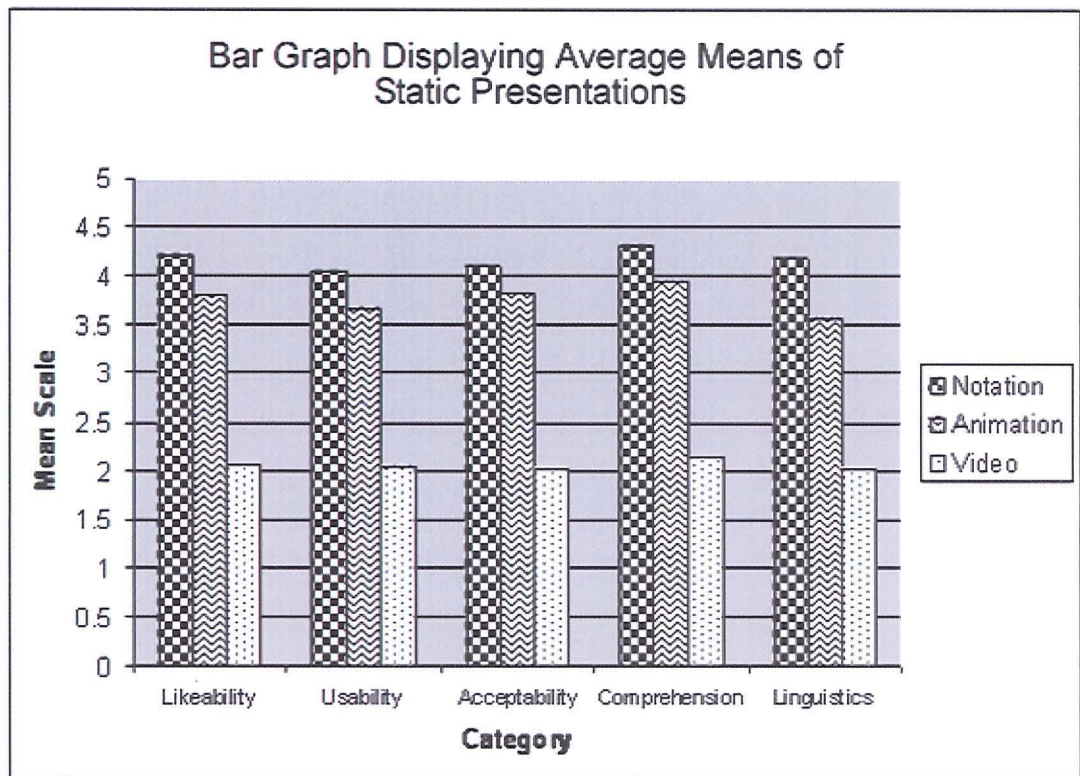


Figure 4.4: A bar graph displaying descriptive statistics for static presentations. The above scale is 1 for Excellent to 5 for Poor ratings

Averages of each Category	N	Min	Max	Mean	SD
Animation Likeability	20	1.40	5.00	3.3900	1.12479
Animation Usability	20	1.75	5.00	3.2375	1.10166
Animation Acceptability	20	1.00	5.00	3.5000	1.07911
Animation Comprehension	20	1.00	5.00	3.4125	1.15643
Animation Linguistics	20	1.50	5.00	3.3875	1.01137
Valid N (listwise)	20				

Table 4.5: Descriptive Statistics of Animation Systems in Real-time Presentation in the Categories of Usability, Likeability, Acceptability, Comprehension and Linguistic Ability NOTE: Min represents minimum values, Max represents maximum values and SD represents Standard Deviations. The above scale is 1 for Excellent to 5 for Poor ratings. The above table presents descriptive statistics for the animation system in real-time presentation mode. Data summarised here provides the basic features of the data in this study. The sample group was a total of 20 participants, and we are able to establish from the data there was a strong dislike of the system that was presented and the results were not much different from the static data set presented in table 4.1.

Averages of each Category	N	Min	Max	Mean	SD
Video Likeability	20	1.00	4.20	2.4500	1.10477
Video Usability	20	1.00	5.00	2.3625	1.17394
Video Acceptability	20	1.00	4.00	2.0875	.94338
Video Comprehension	20	1.00	4.25	2.3000	.90902
Video Linguistics	20	1.38	4.38	2.3250	.78995
Valid N (listwise) 20					

Table 4.6: **Descriptive Statistics of Video Systems in Real-time Presentation in the Categories of Usability, Likeability, Acceptability, Comprehension and Linguistic Ability** NOTE: Min represents minimum values, Max represents maximum values and SD represents Standard Deviations. The above scale is 1 for Excellent to 5 for Poor ratings. The above table presents descriptive statistics for the video system in real-time presentation mode. Data summarised here provides the basic features of the data in this study. The sample group was a total of 20 participants, and we are able to establish from the data there was a liking of the system, similar to the results found in the static presentation in table 4.3. As noted from the three above tables they are very similar to the descriptive statistics shown in the three tables for static presentation.

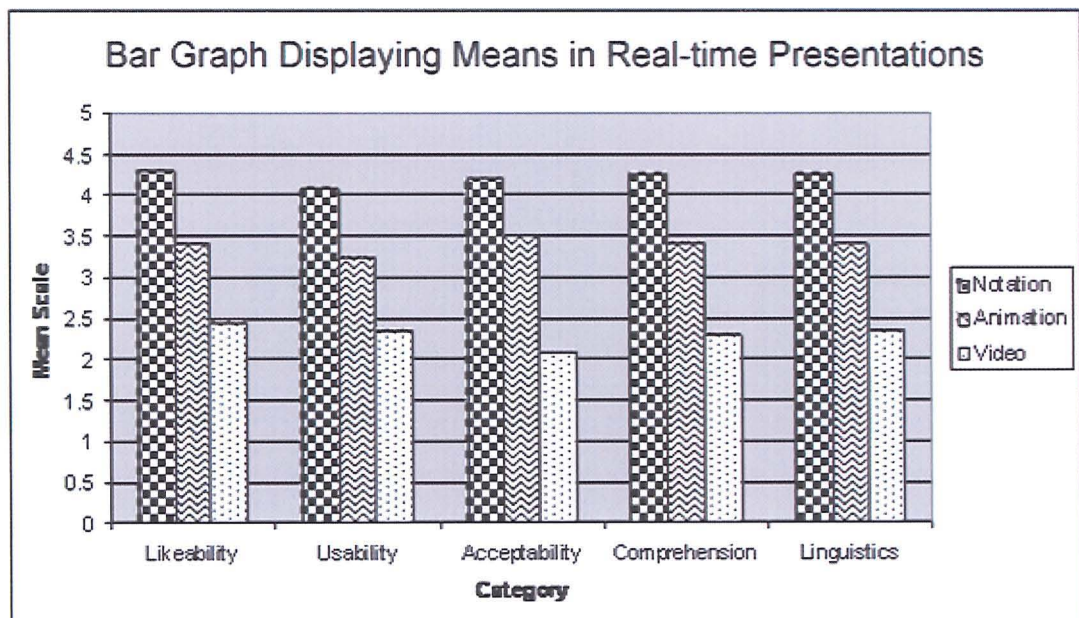


Figure 4.5: A bar graph displaying descriptive statistics for real-time presentations. The above scale is 1 for Excellent to 5 for Poor ratings

representation of sign language, under the linguistic category of hand shape. It was noted that the overall means were statistically significant; the mean for the static presentation of animation was 3.2 and the mean for the real-time presentation was 3.8, $t(19) = 2.11$, $p < 0.05$. This was on a scale where 1 was rated excellent and 5 was rated as poor. It can be suggested by the means that the static presentation was rated better than the real-time presentation.

It was observed that although the digital representations of sign language were different in appearance in static and real-time mode, there was no statistical difference in terms of their perception via the target audience. Instead it was found that static and real-time presentations had significantly high correlations. In the digital representation of animation, when static and real-time presentations were shown, the following categories had significant correlations: likeability $r = .75$, usability $r = .67$, linguistics $r = .60$. Under linguistics, the following were observed: morphology $r = .61$, lip movement $r = .59$, facial expression $r = .39$, correct sentence BSL structure $r = .44$. In the digital representation of Notation the following correlations were noted: likeability $r = .75$, acceptability $r = .72$, comprehension $r = .817$, linguistics $r = .70$. Under linguistics, the following were observed: hand shape $r = .61$, morphology $r = .73$, distance of the body from the arm $r = .43$, lip movement $r = .70$, facial expression $r = .70$, correct sentence BSL structure $r = .47$.

There were several high correlations between the variables used in the paired sample t-tests between static and real-time presentations of each digital representation of sign language. These results have been listed in the table below. As can be seen from the average means, the systems were rated quite poorly on the scale, where 1 was excellent and 5 was poor. In other words, for animation and notation, not only were the static and real-time means similar for a given category (as manifest within the rows of table 4.7) but the participants who gave higher (or lower) ratings for static presentations also tended to give higher (or lower) ratings to real-time presentations, as manifest in the generally high correlations.

The following table (4.9 and 4.9) will examine inferential statistics from the data found in the study. A one-way ANOVA was conducted to test the differences between the three systems (Video, Animation and Notation) in respect of their usability, acceptability, likeability and linguistics. Linguistics will be broken down into its respective components which are hand shape, morphology, distance of the arm from the body, lip movement, facial expression, correct sentence BSL structure, correct placement and correct signing context. Further t-tests were conducted between the systems to test if there was a difference between the groups. This was conducted on the data found on the same sample group of 20 participants within this study.

It was notable that irrespective of real-time or static presentations, the systems acceptability in terms of usability, acceptability, comprehension and likability was greatly influenced by its ability to linguistically represent British Sign Language in an artificial form and by

Presentation Mode	Category	<i>r</i>	Sig	Average Mean
Animation	Morphology	.611	0.004	(3.4+3.6)/2 = 3.5
Animation	Lip Movement	.583	0.007	(4.3+4.1)/2 =4.25
Animation	Facial Expression	.384	0.095	(4.2+4.1)/2 =4.2
Animation	Correct sentence BSL structure	.436	0.054	(3+3.2)/2 =3.05
Animation	Likeability	.747	0.000	(3.4+3.8)/2 =3.6
Animation	Usability	.668	0.001	(3.2+3.7)/2 =3.45
Animation	Linguistics	.601	0.005	(3.4+3.6)/2 =3.5
Notation	Handshape	.606	0.006	(4.3+4.1)/2 =4.2
Notation	Morphology	.732	0.000	(4.1+4)/2 =4.05
Notation	Distance of the arm from the body	.430	0.066	(4.3+4.3)/2 =4.3
Notation	Lip movement	.692	0.004	(4.4+4.4)/2 =4.4
Notation	Facial Expression	.704	0.001	(4.2+4.5)/2 =4.35
Notation	Correct sentence BSL structure	.466	0.002	(4.3+4)/2 =4.15
Notation	Likeability	.747	0.000	(4.3+4.2)/2 =4.25
Notation	Acceptability	.717	0.001	(4.2+4)/2 =4.1
Notation	Comprehension	.817	0.000	(4.2+4.3)/2 =4.25
Notation	Linguistics	.699	0.001	(4.3+4.2)/2 =4.25

Table 4.7: **Correlations Between Static and Real-time Presentations of Digital Representations of Sign Languages for the Respective Variables** NOTE: Sig represents Significance and column entries with 0.000 denote a value smaller than three decimal places. A statistical relationship between two variables (static and real-time) identified a few correlations of a high positive correlation. Means are shown in order to indicate that - the high correlations are not withstanding the variables were generally high (poor understanding). The main significant differences and correlations were found only in animation and notation, video did not show any statistical significance in terms of difference or correlation. This was data found again on the same 20 participant sample group.

how the Deaf community views these systems' ability.

4.9 Discussion

For the *t*-test a null hypothesis and the alternative hypothesis were stated. The null hypothesis states that participants shown the real-time and static information system will show no difference in the perception of the digital representation of sign language. Thus the acceptability of the system is reliant on its ability to function in the most technologically optimal solution for that given information delivery context. However the alternative hypothesis states that there is a difference in perception of the system when presented in different information delivery contexts. For example, avatars are promoted for their ability to present real-time sign language generation for any type of information. Video has limitations owing to its need to have the vocabulary/sentences prerecorded, thus joining various video clips together can appear awkward in its delivery as the signs do not connect like natural sign language. Avatars in contrast are able to connect vocabulary together without the awkwardness. It can therefore be assumed by practitioners in the field that avatars pose a more appropriate solution for real-time generation of information in sign language. This research tested the possibility of a video alternative to avatars for a real-time information delivery and presented by way of comparison, a video that contained the "awkward" connection of vocabulary. This was also done with notation systems. In the static presentation, video was prerecorded and had what would be seen as the most popular solution as it is most widely used. However avatars provided static presentations as well, but they have ability to be moved three-dimensionally and therefore, they can be viewed closer, further away, at another angle and any which way the avatar is moved, giving this technology a seeming advantage. So it can be asked how would this compare in the same information delivery context? Notations provided an alternative solution as they were like a written language, and can be manipulated much like subtitles, either recorded in advance and presented in demand, or presented in real-time.

Initially the hypothesis was testing whether the acceptance of a system was dependent on the information delivery context, that is, a real-time or static information delivery context. It was found from the data analysis (ANOVAs plus a series of *t*-tests checking for the difference of perception on the systems from both real-time and static delivery modes) that this was not in fact the case. It was identified that there was a strong difference in scores between the three systems, but that difference was not a manifestation of the information delivery context. Irrespective of the information delivery context, the linguistic criteria determined the system's level of acceptance.

Thus while the null hypothesis was supported, it was also established that the linguistic criteria rather than the information delivery context formed the basis of the systems' acceptance. This was supported by further analysis of the existing data. To further this

work it would be advisable not only to try additional participant settings, but possibly try different materials within the same context (Animation, Notation and Video), to try different participants from different areas within the UK (and elsewhere) but also to closely replicate the study, in order to establish that these findings are not only to chance.

The user-led approach to investigating this problem has assisted in understanding the difference between how technologists may identify the potential of a system and how they are actually received. Most essentially this has highlighted the “finite” criteria that are often missed by technologists in the thinking through of a system design, and has also highlighted the importance of the same “finite” criteria in terms of clear and effective communication for the Deaf. These findings have had a significant impact on the direction of the research and the proposed framework of design for information systems for the Deaf.

4.10 Conclusion and Summary

The hypothesis tested specified that the type of information delivered in different DRSLs would effect the system’s level of acceptance. This was not supported by the findings. Instead it was found that if the system demonstrated particular linguistics of BSL appropriately it would then receive higher acceptance from the Deaf community, irrespective of being in static or real-time mode. The main theme continuously mentioned by participants was “emotion”. The results show that regardless of technology the level of Emotional Representation is the key determinant to the systems’ level of success.

Sign Language technology has been fast developing into a popular area of research with many advances, tools, technology, hardware and software continuously being generated. It has spurred discussion amongst the d/Deaf and hearing community about the potential and real-world application of many of the systems that have been used and introduced. There have been many claims about the real-world application of various systems and their potential has and is being researched. However there has been skepticism among the d/Deaf and Hard of Hearing (HOH) as to whether DRSLs other than video have any potential to work within the Deaf community, and in many cases their criticism has been well justified.

This research’s aim was to understand more about DRSLs and whether particular DRSLs are more suited to particular information delivery contexts. However from the findings it was identified that irrespective of the information delivery context the DRSL itself held more importance, the central theme being can the DRSL communicate effectively? What was found was that it is not necessarily the system but more the “emotional characteristics” of a system that are needed for effective communication. It could be said that irrespective of the information system presented, if it holds true to the characteristics of sign language, such that it has particular linguistic elements present, it will receive a positive end-user response.

This research has provided an indepth understanding of the user perspective of the end-products that have been proposed for language support for Deaf people.

In order to establish the basis of the rules a further investigation was conducted with the Deaf community to establish the different areas that are important in the design of the rules. This study is described in chapter 5.

Test Criteria	ANOVA	<i>p</i> -value V and A	<i>p</i> -value V and N	<i>p</i> -value A and N
Acceptability	0.000	0.000	0.000	
Usability	0.000	0.000	0.009	0.006
Likeability	0.000	0.000	0.000	0.085
Comprehension	0.000	0.000	0.000	
Linguistics	0.000	0.000	0.000	
Linguistics - handshape	0.000	0.000	0.000	
Linguistics - morphology	0.000	0.000	0.000	
Linguistics - Distance of the Arm from the Body	0.000	0.000	0.000	
Linguistics - Lip Movement	0.000	0.000	0.000	
Linguistics - Facial Expression	0.000	0.000	0.000	
Linguistics - Correct Sentence BSL Structure	0.000	0.001	0.000	0.007
Linguistics - Correct Placement	0.000	0.000	0.000	0.006
Linguistics - Correct Signing Context	0.000		0.000	0.002

Table 4.8: Summary of Significance Levels of ANOVA’s Testing for the Differences Between the Three Systems (Animation, Notation and Video) in Static Presentation Modes in Respect of Varied Categories. Further post hoc analysis was conducted in the form of t-tests between the groups, and significantly relevant results are shown (*p*-values denote the results from varied *t*-tests. V represents video, A represents Animation and N represents Notation).

Test Criteria	ANOVA	<i>p</i> -value V and A	<i>p</i> -value V and N	<i>p</i> -value A and N
Acceptability	0.000	0.000	0.000	
Usability	0.000	0.000	0.000	
Likeability	0.000	0.004	0.000	0.003
Comprehension	0.000	0.001	0.000	0.003
Linguistics	0.000	0.001	0.000	0.003
Linguistics - handshape	0.000	0.000	0.000	
Linguistics - morphology	0.000	0.000	0.000	
Linguistics - Distance of the Arm from the Body	0.000	0.000	0.002	
Linguistics - Lip Movement	0.000	0.000	0.000	
Linguistics - Facial Expression	0.000	0.000	0.000	
Linguistics - Correct Sentence BSL Structure	0.000	0.000		0.002
Linguistics - Correct Placement	0.000	0.079	0.000	0.001
Linguistics - Correct Signing Context	0.000		0.000	0.002

Table 4.9: **Summary of Significance Levels of ANOVA’s Testing for the Differences Between the Three Systems (Animation, Notation and Video) in Real-time Presentation Modes in Respect of Varied Categories. Further post hoc analysis was conducted in the form of t-tests between the groups, and significantly relevant results are shown NOTE: (*p*-values denote the results from varied *t*-tests. V represents video, A represents Animation and N represents Notation.)**

Chapter 5

Investigation: Establishing the Rules of Emotional Software Design

5.1 Introduction

This study aimed to understand the Deaf user perspective on communication. To do so it was necessary to set up a way to analyse that perspective and how it operates to facilitate understanding that is, what areas of a signer are viewed when watching them sign and which areas are most important? This provides an interesting way to understand what, from a Deaf perspective, makes signing comprehensible, and to identify which are the most important areas of a signer.

This analysis will assist in the framework design, as the aim of the framework is to provide a translation between what technologists need to understand to create an effective information system and what deaf people understand about sign language communication.

To use an analogy in an auditory communication mode, this study is looking for the sounds in the word but not necessarily the letters that spell it, whereas the previous study has found the letters that can make different words. Phrased differently, this study is looking at the moving components of a signer that create comprehension of a sign but not necessarily the particular linguistic detailing that makes the sign itself.

This study will first detail a background into different communication modes in sign language. The hypothesis of this study will then be stated, followed by detailing of sampling, data collection, materials and procedures used. There will be details about the pilot studies conducted, what was found, and how the experimental design was adjusted to be appropriate to the needs of the target audience. The final design of the study is presented in this chapter with the findings and conclusions.

5.2 Background

When understanding BSL it is important to understand the transition of English to BSL and vice versa, in order to comprehend how different the two languages are, and the fact that they are very much languages in their own rights [Kyle and Woll, 1985]. English can have a written descriptive structure which is linear insofar as it is sequential. SSE is a method that uses signs in English word order and is also linear and sequential. Whereas BSL creates a descriptive structure within the multi-dimensional space in front of the signer (often referred to as the signer's space) [RNID, 2004]. BSL users do not follow the English word order and use signs accompanied by heavy use of facial expression and eye contact to demonstrate emotive responses to scenarios and conversations. In relation to English and SSE, BSL communication is a more visual embodied or enacted presentation of meaning.

The biggest and noticeable difference between SSE and BSL is that the number of English spoken words are significantly reduced in the latter and a greater transformation is noticeable in the way the language presents itself [Sutton-Spence and Woll, 1999, RNID, 2004]. BSL has it's own visual culture, which is absorbed and celebrated by the Deaf community. SSE users can still understand BSL users but BSL users find it more difficult to understand SSE users as they have vocabulary in their signing/lip patterns that are unfamiliar and confusing to follow in the context of BSL. This separates SSE from BSL, where SSE is more English language based and BSL is more visually based.

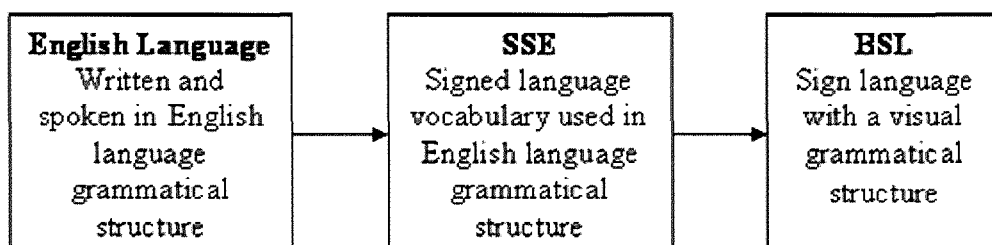


Figure 5.1: Example of difference between English, SSE and BSL

The rules presented in this thesis aim to work with the BSL user group, however they can also be used with SSE users. It is useful to note that though the visual nature of sign language is universal, differences arise through cultural influences which in turn alter the language structure. It was found in evaluation that the participants in the research continued to comment on a concept of “emotion” and how this needs to be presented in artificial representations of BSL. This “emotion” has been identified as particular linguistic components of BSL. However it is interesting to note that this “emotion” can also be expressed symbolically in a way that does not necessarily rely on a fluid signing sequence but on visual cues that can clarify the meaning of information.

The use of these rules will allow for higher levels of comprehension and acceptance of systems/materials that aim to communicate information to the Deaf community. The

motivation behind this study was to establish an order of importance of signers communication needs and how that fits with our results so far.

5.3 Experimental Methodology

From the investigations it had become apparent which linguistic components received the lowest and highest ratings in the sign language systems that were presented. This provided the basis of support behind the rules for system design. However when designing the rules for systems that communicated with the Deaf, it was important to decide how many rules to have, which rules supported which linguistic results from our previous study, and to establish the order of importance of these rules. Thus a consultation through interviews with the Deaf community was required regarding the design of these rules.

Hypothesis

Signer's can identify areas of importance in sign language communication as well as the order of what is important in such systems.

Sampling

All organisations, schools, education centres and professional bodies working with Deaf adults were contacted to ask for participation in the research. In addition to this others who were not part of such organisations but were interested in the work contacted myself. A list was formed of all the potential participants, of which fifty people were randomly selected. Ten agreed to participate and on the days of the experiments four participants were unable to attend. Bringing the total sample size to six.

The participants demonstrated the London regional dialect of British Sign Language (BSL). Therefore sampling took place in and around the London (UK) area and the target population were adults. In order to understand what the deaf community thinks of the systems, BSL and SSE users were invited for participation in this research. The participants selected were deaf and hard of hearing(HOH).

This initial sample size is considered to be large enough to give statistically significant results, however if, subsequently, there was no significant difference in results obtained then the experiment will be repeated with an increased sample size.

Incentives and Procedures

Each participant was offered reimbursement for travel if needed. The following steps were implemented:

1. Introduction: The participants were called in one at a time and given general infor-

mation, including clarification that the experiment is not a test of any kind, simply a way to understand in more detail what signers see as important areas of communication and what holds important information in Deaf communication. They were informed that they may stop the experiment at any time, and that if they wished they may remain anonymous in this research. Before the participants proceeded they were asked their age, gender and contact information.

2. Familiarization: They were shown the stick men so they were familiar with the diagrams that formed the record of the experiment.
3. Information gathering: Each participant was asked the question “In order of priority mark the areas of a signer that you watch the most when they sign/communicate”. They were provided with an interpreter to allow for clear communication.
4. Question and Answers: At the end of the session, participants were given the opportunity to ask questions. They were also asked if they had seen these systems before, where and what they thought about them.

Data Collection Methods Used

The participants were given a questionnaire with a picture of a stickman from a frontal and side view. They were asked the following: “In order of priority mark the areas of a signer that you watch the most when they sign?”

Materials

The user was presented with two stick men (one with a frontal and one with a side view), on which they could draw the areas they regarded as important, and then number their order of importance.

5.4 Pilot Study One

There were a total of four participants. Participants were asked on a one-to-one basis, they were provided with two stick men images (as shown in the figure).

Participants all marked:

1. Face as the most important part of the signer
2. The torso as the second most important
3. The hands as the third most important area

However, a few things were noted. Participants highlighted the face and then mentioned the features individually placing great importance on mouth patterns. When they spoke

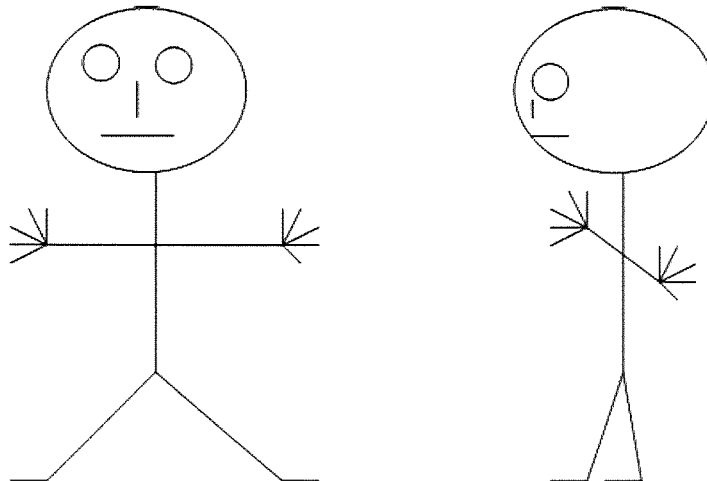


Figure 5.2: Stickmen Images used in Experiment

of the hands they mentioned a great deal about the handshape but also how they are used to “layout a story” as remarked by two of the BSL tutors. The final part was the torso and they mentioned how it described speed, feeling and expression. From this it was clear that there are three major parts and there is an order of importance. However more analysis needed to be done in order to understand about the face and hands as several comments were made about these areas.

5.5 Pilot study two

Therefore the study was revised and now included a stickman face, this was conducted on four participants.

Participants were shown the original stickmen figures (frontal and side view), once they mark the areas of these drawings, they were then presented with the face and asked “Can you please circle what parts of the face you think are important for a signer and also an order of preference”. This was done with a new group of participants.

They were also asked:

“What part holds descriptive information on the face? Please state which movements are used and what you think is expressed by these marked areas?”

The next part of the body that needed a deeper explanation/understanding was the importance of the torso. The participants were asked: “Please describe the importance of the torso and what that can represent in British Sign Language”

Finally the participants were also asked more about the hand shape. Their question read: “The handshape was also marked as important, can you please elaborate why?”

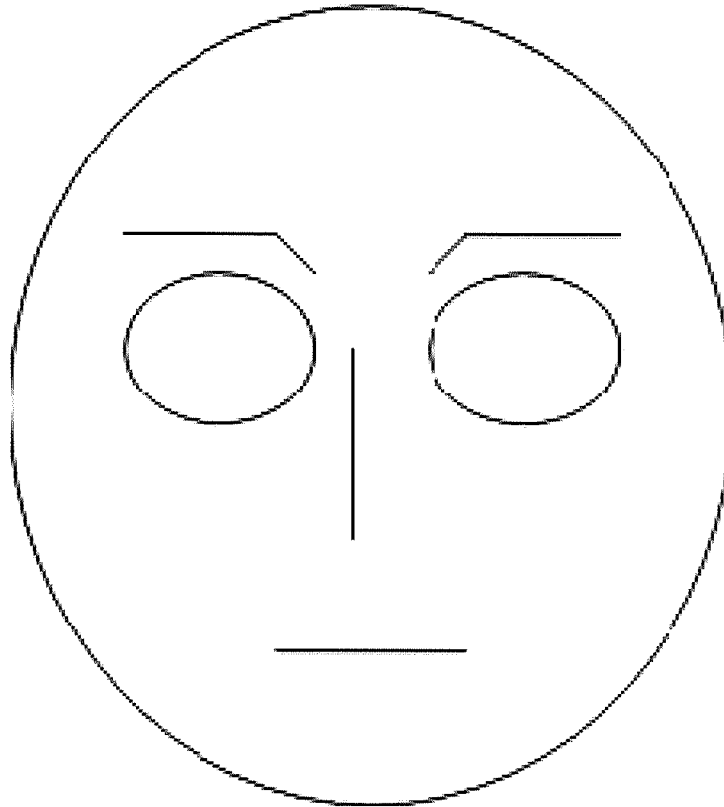


Figure 5.3: Stickmen Face Image used in Experiment

Participants again selected the same as in the first run:

1. Face as the most important part of the signer
2. The torso as the second
3. The hands as the third

When participants were asked about the face they clearly noted that the order of importance was

1. Lip patterns
2. Cheeks/forehead (two participants selected cheeks and two selected the forehead)

Participant A remarked that the forehead provides “feeling”, and participants B, C and D said that the forehead provides “questioning and feeling”. All four participants said that the cheeks described “pressure, weight and force” and the lips provided information through mimicry with the description of “sound, words, movement, pressure and questioning”.

When asked about the torso, participants responded that this part of the body provides respondents with clearer mime and provides scope for role play with clear shift of character,

speed, and more visual description, especially through the movement of the shoulders (and how they move). It was remarked that this is needed to make the communication more “natural”.

Finally when asked about the hands participants responded that they provided “shape, layout, direction, size, weight and story description”. Hands provide vocabulary but also need more space to express themselves and for this they work mainly in front of the signer. This explained why participants marked such a wide area around the hands of the stickman; they drew a larger circle around this area of the signer.

Finally participants were asked “From the areas marked on both images please place in order of importance which parts are most important and the least? One is first and five is last”.

From the pilots, the following areas were identified singularly and in this order by all participants:

1. Lip patterns
2. Facial expression
3. Torso
4. Hand shape
5. Signer’s space

After the study was conducted it was felt that participants could form a biased opinion when only viewing one type of image, a stickman. Therefore other images were introduced of faces and bodies, which varied in gender, ethnicity and age. Each participant was now shown a series of four different pictures each and the data was collected.

The final design of the experiment can be found in appendix D.

5.6 Results

In order to ensure that interpretation of the results was accurate, two British sign language instructors were consulted when the results were interpreted. The criteria under which they were sought included their sign language abilities, level of qualification and years of experience, and also if their deafness was from birth or acquired. It was important to have natural signers for this to ensure that the results were read correctly.

Teacher A has 10 years BSL teaching experience, is based in London and uses the British Sign Language dialect; is qualified up to Postgraduate Certificate in Education (PGCE)

level to teach BSL and works with deaf students. Teacher A was born Deaf and is a BSL user.

Teacher B has 12 years BSL teaching experience, has worked in different areas of the UK and has worked in London for 3 years. This individual has BSL qualifications up to level 4, and 10 years of training experience in BSL. Teacher B is currently completing a PGCE course. Teacher B was also born Deaf and is a BSL user.

We found that irrespective of the images shown and their differences in appearance, the choice of what was important in communication and its order of preference remained the same. The order of preference defined by the participants were:

1. Lip patterns
2. Facial expression
3. Torso
4. Hand shape
5. Signer's space

Not all participants marked the torso, but the first two that were marked were the face and the hands. If the participant marked the torso, it was marked third. (table 5.1)

When the participants were shown the face shots, again their opinions from each face were the same, irrespective of the gender, ethnicity or age of the people in the image. However there was a difference in opinion as to the second most important part of the face for communication and this varied from cheeks to face. Again not all participants marked a third most important part of the face (table 5.2).

On average eight people thought that the forehead was very important as the second most important part of communication of the face, and twelve people thought that the cheeks were the most important part of the face. In the category of third most important facial feature six people marked the forehead and eight participants marked the cheeks in addition six other participants did not mark a third region of the face.

5.7 Conclusion and Summary

This study assisted in identifying areas of a signer that are viewed by the Deaf community as separate vital parts of communication. The findings of the tests conducted with the target user group have been used to establish the hierarchy of those parts of a signer marked as important to facilitate effective communication. The analysis showed that an

Participant Number	Face Number One	Hands Number Two	Torso Number Three
1	4	4	4
2	4	4	4
3	4	4	3
4	4	4	4
5	4	4	
6	4	4	4
7	4	4	4
8	4	4	4
9	4	4	
10	4	4	
11	4	4	
12	4	4	4
13	4	4	4
14	4	4	4
15	4	4	4
16	4	4	
17	4	4	4
18	4	4	4
19	4	4	4
20	4	4	4

Table 5.1: Data from the Final run of the Feedback Session with members of the Deaf Community, Stating the most Important areas of Communication on a signer when Communicating NOTE: It can be noted that some participants did not mark a third area of importance on a signer.

Participant Number	Lips Number One	Forehead Number Two	Cheeks Number Two	Forehead Number Three	Cheeks Number Three
1	4	4			4
2	4	4			4
3	4	4			4
4	4		4		
5	4		4		
6	4		4		
7	4		4		
8	4		4		
9	4		4		
10	4	4			4
11	4	4			4
12	4	4			4
13	4	4			4
14	4		4	4	
15	4	4			4
16	4		4	4	
17	4		4	4	
18	4		4	4	
19	4		4	4	
20	4		4	4	

Table 5.2: Data from the Final run of the Feedback Session with members of the Deaf Community, Stating the most Important areas of Communication on a signer when Observing the Face NOTE: It can be noted that some cells are blank because participants either chose between the forehead or cheeks as the second most important area of the face, and also did not mark a third area of importance on a signer, therefore those cells are empty in the table

order has been established in terms of which linguistic criteria needs the greatest focus and improvement within DRSL system design. For each area identified the participants said that each of these parts held particular characteristics that needed to be expressed for clear communication. They were as follows:

1. Lip patterns assist with mouthing words, mimicking sounds, movement, pressure (explaining different extremes like “very heavy” or “very thin”), characters, questioning and expressing feeling.
2. Facial expression (which includes the forehead and cheeks) assists in expressing feeling, questioning, pressure, weight and size.
3. Torso provides users with clear mime and allows for role play shift between characters. The participants said that this part of the body made the communication more natural.
4. Hand shape provides descriptions of shape, direction, size, weight and vocabulary.
5. Signer’s space provides placement and clarity of information and layout.

These findings will be used in designing the rules for “emotionally aware” systems, where it is hoped that the Deaf perspective (of the parts) can be matched to the technologists’ perspective (of the information system) through analysis of essential language components (which are the linguistic characteristics). This will be explored in chapter 6.

Chapter 6

Emotional Engineering of Artificial Sign Languages

6.1 Introduction

This chapter will introduce the Emotional Engineering of Artificial Sign Languages, and the components which are key factors to a systems' level of success. (These were found through empirical testing and analysis).

Analysis and comparison of different Digital Representations of Sign Language (DRSLs) (presented in chapter 4) with Deaf users showed the most evident aspect of these systems to be a lack of emotional expression and the target audience involved in the study all raised this concern. Usability problems can be defined as aspects of a user interface that may not meet the needs of the target audience and thus fall out of favour with the end user. Usability is a fairly broad concept that refers to how easy it is for a user to learn a system, how efficiently they can use it once they have learned it, and how pleasant it is to use.

Systems that demonstrate Digital Representations of Sign Languages (DRSL) have developed different methods for technical transferability, such as streaming video recordings, notation images, and program generated avatars (artificial humans). However these systems have always received mixed reviews and high levels of rejection from various members of the Deaf communities. This thesis focused on the end-user needs of the British Deaf Community and the DRSL systems that have been developed. These systems were evaluated against each other in order to highlight, among available possibilities, what is working well and what is missing.

However alongside the quantitative analysis, various remarks were made and in particular the subject of emotion came into discussion regularly. Participants said that they could not emotionally relate to these systems. They said the system that worked best was video, although animation and notation showed potential scope for use in the future. However the criticisms around the lack of facial expression and lack of emotion kept providing a key link to what Deaf people think of as emotion and what technologists need to focus on in greater detail.

The fact that these systems (for the Deaf participants involved) did not express enough “emotion” manifested itself in different forms. The notation system received a low rating of user acceptance, owing to its primary focus on hand movements instead of facial description, which several participants remarked on. Similarly animation systems again lacked facial expression. The video systems’ criticisms were focused mainly around the lack of visual clarity of the signer. An interesting comment from a particular participant discussed how the linguistic characteristics of sign language can symbolically be represented and translated into a form other than an embodied signer. Another participant explained that for the future of DRSL systems there is a need for symbolic sign language to have emotional expression in textual information. He elaborated that if a system with plain text could explain what is meant out of a simple statement like “your home” in terms of emotional colours, such as red, black or blue, or by changing the font and its size, the system could convey the feeling of the concept “home” i.e. if it was angry, sinister or joyous place. However the associations with colour and font for emotional expression is still a vast field of research and would need extensive empirical research to understand in detail emotionally expressive systems. However the concept of emotional and symbolic expression could potentially effect the systems’ level of acceptability in terms of sign language representation. This strongly relates to the nature of sign language itself and how it conveys messages across to individuals.

The rules presented in this thesis aim to work with the BSL user group, however they can also be used with SSE users. It is useful to note that though the visual nature of sign language is universal, it differs due to cultural influence and its input into the language structure. This concept of “emotion” from the Deaf community is made up of particular linguistic components, which will be explained in the rules for design that will follow. But the character of these linguistic components can be presented in a symbolic representation, which contains the same “emotional” value that Deaf BSL users need in communication.

The use of these rules will allow for higher levels of comprehension and acceptance of systems/materials that aim to communicate information to the Deaf community. The same use of “emotion” in system design can be useful to work with non-deaf individuals who may have low literacy levels.

Emotional Representation in Sign Language is composed of many linguistic components of sign language itself, with particular focus around the face. However to understand this symbolically there is a need to understand the function of that linguistic component and its essential characteristic, thus providing a platform of alternative representations of the linguistic component. The following sections will explain these rules in more detail.

6.2 Rules

From the investigations it had become apparent which linguistic components received the lowest and highest ratings in the sign language systems that were presented. This provided the basis of support behind the rules for system design. After further consultation with the Deaf community (see chapter 5) the rules have been designed with consideration of the five areas of importance to a Deaf user. This thesis will present linguistic and symbolic rules for emotional system design. Rule one relates to several facets of lip patterns, rule two to facial expressions, rule three to torso, rule four to the hand shape and rule five to the signer's space. In this overall section on rules mentioned, there are corresponding illustrated figures throughout the chapter.

6.2.1 Rule One - Linguistic Emotional Representation in Lip Patterns

When using facial images add clear lip patterns to enhance language meaning, for example:

1. *Rule One: Mouthing Words Linguistically* - Is used to introduce new vocabulary, as some words may not always have particular signs associated with them. Therefore a particular handshape or fingerspelling can have multiple meanings, but alongside lip patterns, a clear meaning can be established.
2. *Rule One: Mimicking Sounds Linguistically* - Lip patterns are used to provide mimicking of sounds to objects/people. This provides a different level of emotional meaning: the sign for phone without lip patterns can simply mean phone, but with mouth patterns of ringing vibrations, means the phone is ringing.
3. *Rule One: Movement of Objects Linguistically* - When signing about the movement of objects, its weight and pressure can be enhanced with lip patterns. For example, when signing without the lip patterns the movement of the object will be signed as a simple movement. However with lip patterns the sign can mean that the object is heavy or light giving the movement a more emotional and contextualised meaning.
4. *Rule One: Characters Linguistically* - When explaining conversations or discussions between more than one person, character shift come into play and is a recognised sign language structure. With character shift different linguistic components in British Sign Language are used, one of them is lip patterns, which as part of facial expression, as they clarify the difference between characters.
5. *Rule One: Questioning Linguistically* - When signing questions, the pronunciation of some questions can start with lip patterns, such as the "wh" in what, where, who, when, why and "ow" in the how
6. *Rule One: Expressing Feeling Linguistically* - The lip patterns are involved in the facial expression of emotions and feelings. This is an essential part of the British

Sign Language communication as the emotion provides meaning to the language structure and almost the “intonation” of speech.

6.2.2 Rule One - Symbolic Emotional Representation in Lip Patterns

When you have an image, enhance its language meaning by adding

1. *Rule One: Mouthing Words Symbolically* - New vocabulary/Basic text - add new words to new topics to help with understanding and acquiring new vocabulary. Use alternative colours or fonts to denote a new word. This will provide a key code that viewers can become used to when viewing particular information systems or handouts.
2. *Rule One: Mimicking Sounds Symbolically* - When using objects or people that may be moving or speaking, give visual indications of sound movement; it provides more emotional context to topics. This can also be shown with the loudness or quietness of sound, i.e. a bigger or smaller symbol.
3. *Rule One: Movement of Objects Symbolically* - When showing moving objects, show their movement and direction through visual description, it provides emotional context and meaning.
4. *Rule One: Characters Symbolically* - When explaining topics from different speakers use their pictures or something that distinctly identifies that character, as this will allow for clarity as to who or what the discussion is about.
5. *Rule One: Questioning Symbolically* - In questions the question mark needs to be clearly and boldly added, so it is clear that a question is being asked.
6. *Rule One: Expressing Feeling Symbolically* - Use colour themes and images within the context of the information in order to provide emotional information.

6.2.3 Rule One - Explanation about the importance of Lip Patterns

A face with lip patterns adds more language meaning to concepts that need explanation; it also provides clarification of the meaning of some of the concepts that are being described. Lip patterns form part of non-manual features within sign languages. The importance of lip patterns is stressed in the use of Sign Language and these provide further language structure to BSL [Sutton-Spence and Woll, 1999].

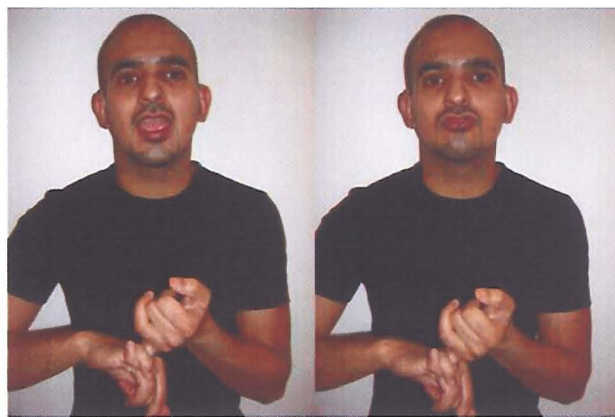
The following will provide examples of the above rule criteria as well as establish a scale of measure, through which you will be able to identify weak and strong representations within your information system DRSL.

6.2.4 Rule One - Linguistic Emotion Measure of Lip Patterns

The following images provide examples and also a way in which to measure what these descriptions within the rules mean. Example one is without lip patterns and example two is with lip patterns.



Example One



Example Two

Figure 6.1: *Rule One: Mouthing Words Linguistically* - An example of a signer with and without mouthing words. In example one the signer is signing, but without lip patterns, it appears as an “S”. If this motion is tapped twice it could then be interpreted as September. With example two the same sign with lip patterns has changed the meaning to a name. In this example the signer is signing “Sarah”, the word said while the “S” is signed.

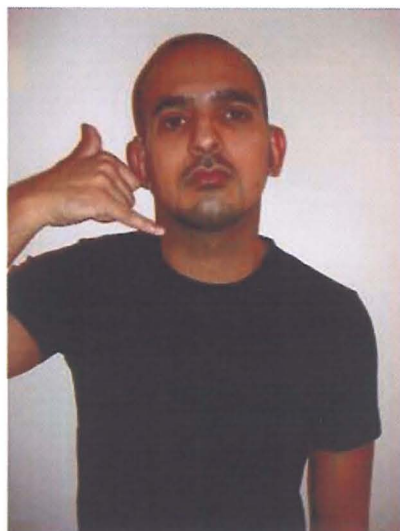
6.2.5 Rule One - Symbolic Emotion Measure of Lip Patterns

The following images provide examples and also a way in which to measure what these descriptions within the rules mean. Example one is without, and example two is with, emotional expression of symbolic representation.

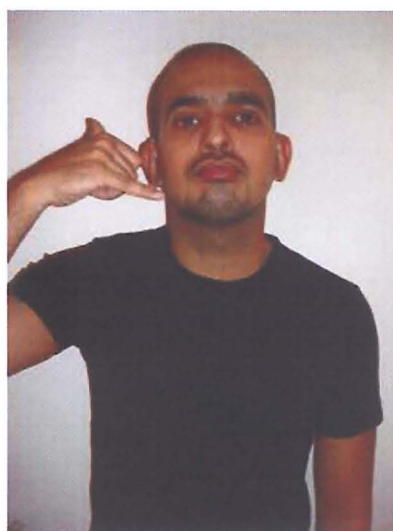
6.2.6 Rule Two - Linguistic Emotional Representation of Facial Expression

When you have a face, add facial expression for example, movement as follows:

1. *Rule Two: Forehead Linguistically* - Provides clarity to the meaning of signs as it is a part of several different signs in BSL. Two areas identified by users about where forehead movement is being used is in questioning and expressing feeling in different signs.
2. *Rule Two: Cheeks Linguistically* - The puffing and drawing in of cheeks provides emotional meaning and expressiveness of the weight and size of objects. This pro-



Example One



Example Two

Figure 6.2: *Rule One: Mimicking Sounds Linguistically* - An example of a signer with and without mimicking sounds. In example one the signer signs a phone. In example two the addition of the lip patterns indicates that the phone is ringing, which in a different context can have direct implications on what action is taken on communication of such information i.e. the phone needs to be answered.



Example One



Example Two

Figure 6.3: *Rule One: Movement of Objects Linguistically* - An example of a signer with and without lip patterns for the movement of objects. In example one we understand the signer is explaining that something is being carried; in example two we can understand that the signer explains that something heavy is being carried through the lowered puffing of his cheeks. This has direct implications for how a subject or conversation is understood by a viewer of signed information.

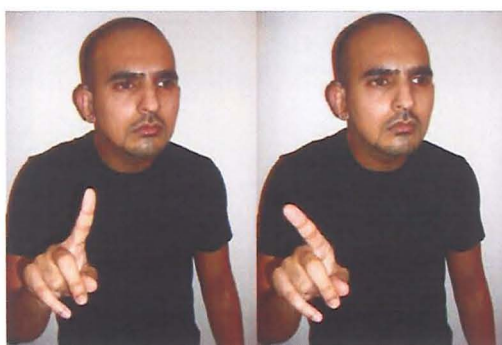


Example One

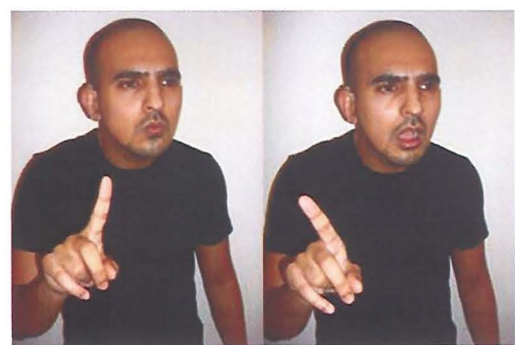


Example Two

Figure 6.4: *Rule One: Characters Linguistically* - An example of a signer with and without lip patterns when signing about characteristics. The first example shows the sign without lip patterns, although this can be understood it can be ambiguous. However with the second example the facial expression clarifies the meaning of the sign, which loosely translates to “prim and proper/reserved”. This is indicated by the facial expression, which include the lip patterns. Both of these are important to clarify the meaning of the sign. Facial expression in signing is almost analogous to tone and intonation of voice.



Example One

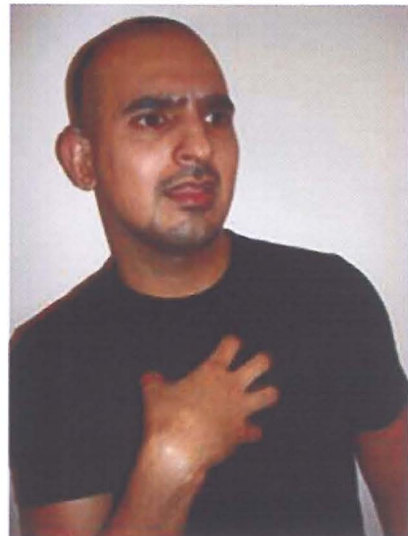


Example Two

Figure 6.5: *Rule One: Questioning Linguistically* - An example of a signer with and without lip patterns when questioning. Example one is when a signer is signing the word “what” without lip patterns. This is the incorrect way to sign this and holds no emotional meaning. However in example two the lip patterns that are part of the facial expression provide emotional meaning. These lip patterns can be lessened and exaggerated depending on the context/emotive mood in which the sign is being used.



Example One



Example Two

Figure 6.6: *Rule One: Expressing Feeling Linguistically* - An example of a signer with and without lip patterns when expressing feeling. Example one is an ambiguous sign and can mean intention or something related to the heart. With example two the facial expression clarifies the feeling as “shock”.

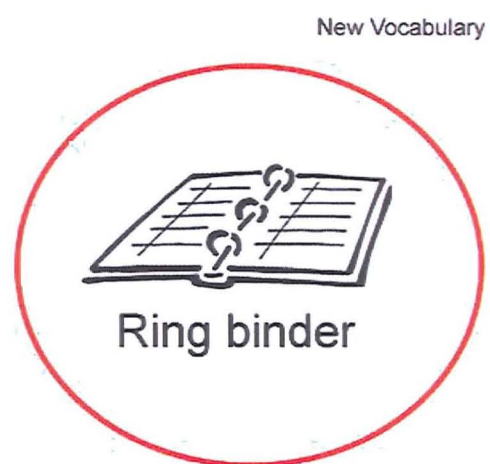


Figure 6.7: *Rule One: Mouthing Words Symbolically* - This presents two correct ways to use and introduce new vocabulary, as done linguistically in BSL lip patterns. One can be a text with the new word next to the image of the individual. This example shows an image of an individual/cartoon image of a character. This method can also be used with images of objects, locations or other things that may be unfamiliar to the target audience as shown in the second image, which has been circled in red. This red circle can then be used throughout the information system providing an indication to the viewer of new vocabulary.

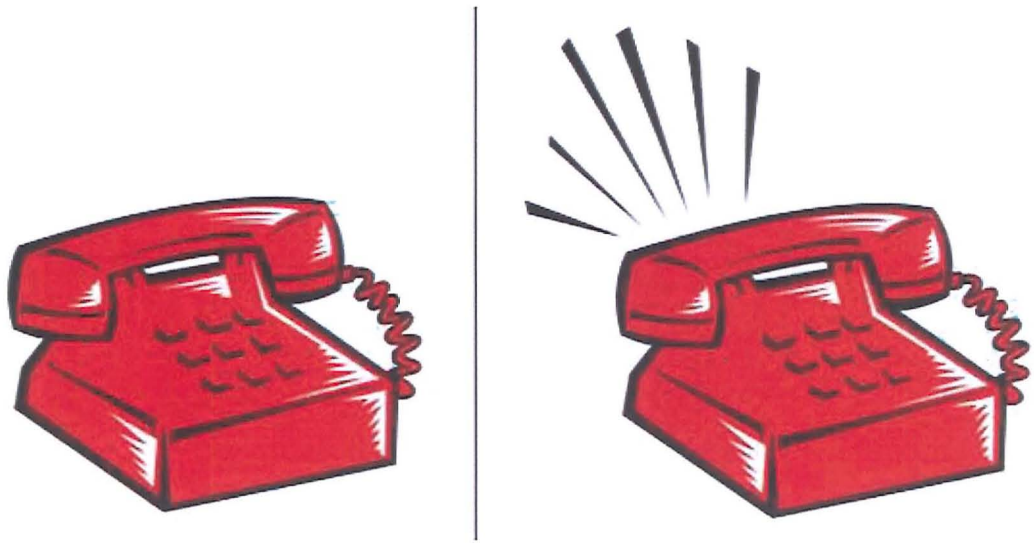


Figure 6.8: *Rule One: Mimicking Sounds Symbolically* - In the first image, there is a telephone but the second image shows that the telephone is ringing just by adding an indication of sound coming from the object itself. If there was a need to indicate the phone was ringing the second image would be correct use of this rule

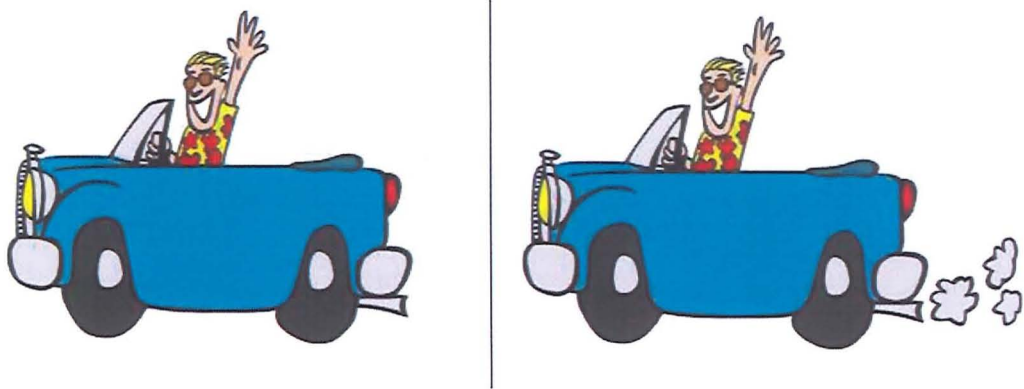


Figure 6.9: *Rule One: Movement of Objects Symbolically* - The first image shows the car with a driver inside. In the second image it becomes clear that the car is moving forward, due to the additional symbols of smoke behind the car's exhaust pipe. This gives the indication of movement. This symbol could be altered to indicate high speed or a slow moving vehicle. The second image is the correct use of this rule.

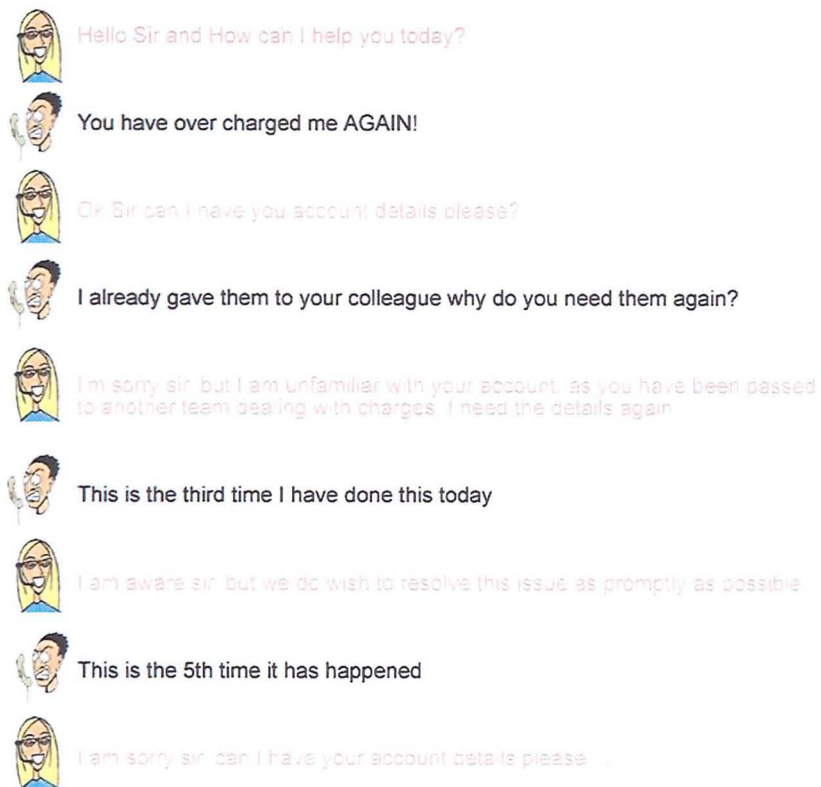


Figure 6.10: *Rule One: Characters Symbolically* - This example clearly shows the dialogue between two individuals. There is use of colour and images to label the text to specified individuals in the conversation. Thus allows for a clearer understanding of the character shift, but also indicates the emotion/tensions being presented by the characters in the conversation, being that one is calm and the other frustrated.

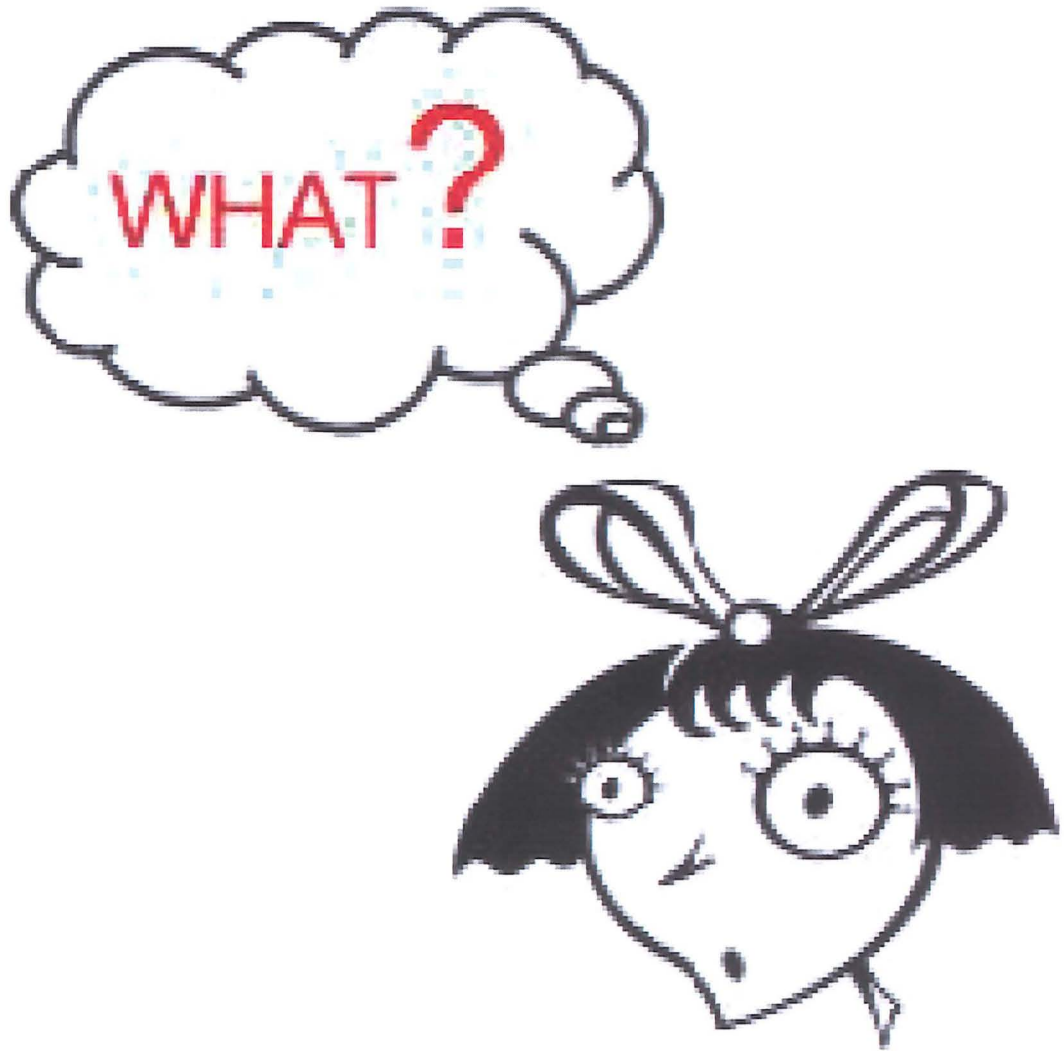


Figure 6.11: *Rule One: Questioning Symbolically* - An example of a symbolic way to present a question, where the character's face and the way the question has been written could imply that there is confusion around a given topic. This provides more information about a subject than plain written text, where we are able to establish that the character is confused and asks "what?"

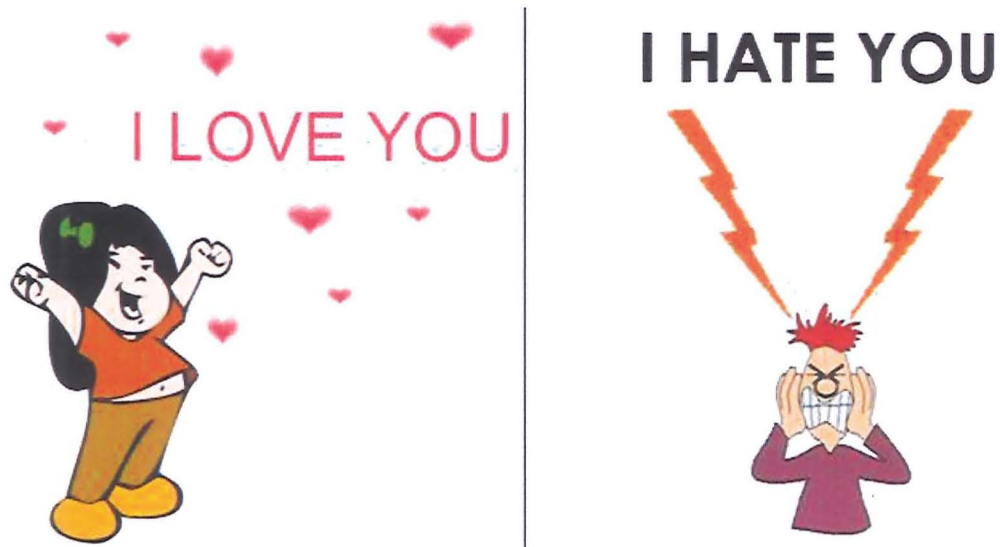


Figure 6.12: *Rule One: Expressing Feeling Symbolically* - In this example, using additional images allows for a clearer understanding of the emotion experienced. In image one it says “I love you” and in the second image, the additions say “I hate you”, two very clearly different feelings. The feelings have been exemplified with symbols, words and colours, which visually enhance their meaning.

vides meaning and clarity to the signs being used and the context in which they are being used.

6.2.7 Rule Two - Symbolic Emotional Representation of Facial Expression

When showing facial images, provide clear details including;

1. *Rule Two: Forehead Symbolically for Questioning* - This can represent questioning, which should be clear, in plain English and marked clearly by adding fonts or colours.
2. *Rule Two: Forehead Symbolically for Feeling* - By providing visual cues through using colour, images and icons different feelings can be expressed in an information system.
3. *Rule Two: Cheeks Symbolically* - This element of BSL structure provides details of weight and size. This can be shown symbolically in images where the alteration of the size of an image can indicate its size.

6.2.8 Rule Two - Explanation of the importance of Facial Expression

When assessing the three systems against each other it soon became apparent that the need for information around the face was very important for a signer and someone viewing

the signing in order to clarify details. Facial expression form part of non-manual features within sign languages. These details can be shown in British sign language but can also be shown symbolically as detailed above [Sutton-Spence and Woll, 1999].

6.2.9 Rule Two - Linguistic Emotion Measure of Facial Expression

The following images, provide examples and also a way in which to measure what these descriptions within the rules mean.



Example One



Example Two

Figure 6.13: *Rule Two: Forehead Linguistically* - Example one demonstrates the sign for “why?” but the emotion is not expressed in the face; with example two the forehead provides a clear sign of the word “why?” and also the emotional emphasis in the questioning. Thus provides clarity to the meaning of the sign.

6.2.10 Rule Two - Symbolic Emotion Measure of Facial Expression

The following images, provide examples and also a way in which to measure what these descriptions within the rules mean.

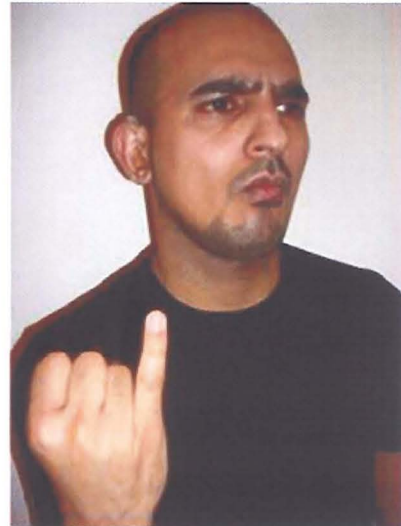
6.2.11 Rule Three - Linguistic Emotional Representation of Torso

The torso enhances information and provides visual clarity in larger movement, especially in the two areas listed below:

1. *Rule Three: Emphasis Linguistically* - The movement of the torso provides clarity in the signing. Some signs can become ambiguous without torso movement, such



Example One



Example Two

Figure 6.14: *Rule Two: Cheeks Linguistically* - Example one is an ambiguous sign, with example two it becomes clear that the sign is a description and it means someone is “very thin”, the cheeks drawn in are used to emphasise the thinness of the individual.

Why?

Example One

Why?

Example Two

Figure 6.15: *Rule Two: Forehead Symbolically for Questioning* - An example demonstrating that by changing the styling of the text, the emotional meaning has been established. Example one is without the emotional symbolic transformation, and example two is with the symbolic emotional translation.

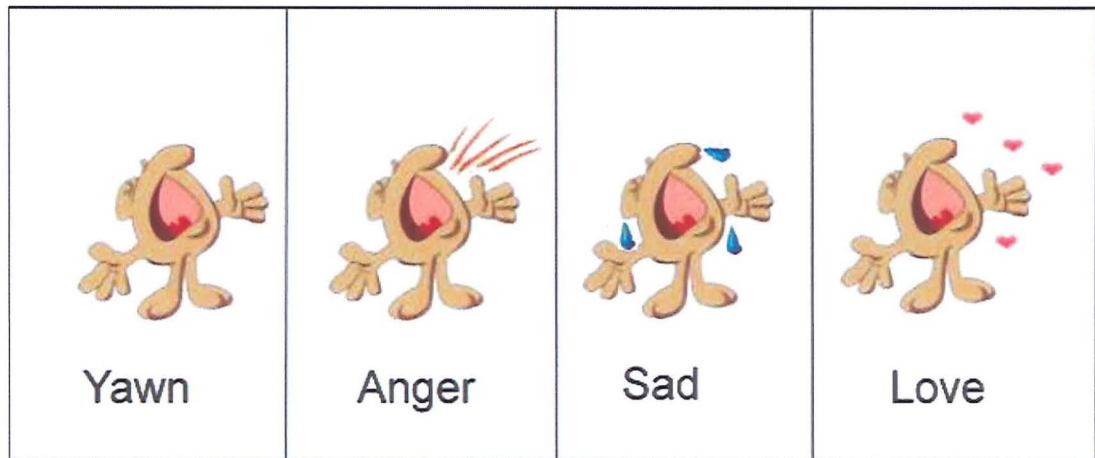


Figure 6.16: *Rule Two: Forehead Symbolically for Feeling* - In this example there is one character, with different symbols. The meaning of the same character is changed because of the input of the symbols.

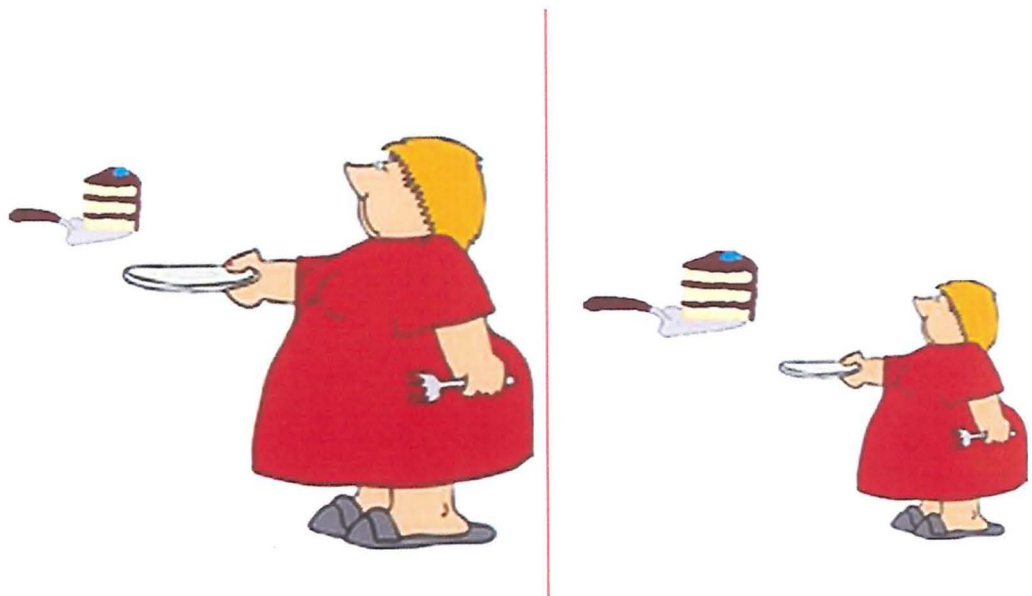


Figure 6.17: *Rule Two: Cheeks Symbolically* - An example of an image where the alteration of the person within the image changes the size of the cake. In image one the slice of cake would be considered smaller, as opposed to the second image

as emotions. Therefore the torso provides additional information to clarify what is being said.

2. *Rule Three: Character Shift Linguistically* - The torso is an important facet of character shift, especially if the characters are in a heated discussion, this can provide a clear distinction between characters.

6.2.12 Rule Three - Symbolic Emotional Representation of Torso

To provide emphasis and character shift symbolically, the following can be sought:

1. *Rule Three: Emphasis Symbolically* - Use boldness, or use one concept per viewable digital document in order to clarify and strengthen the importance of the point. However try to keep to a theme within the design as this shows information is connected.
2. *Rule Three: Character Shift Symbolically* - When describing different people, objects or locations use images, colour and or font, to associate different characters to different dialogue.

6.2.13 Rule Three - Explanation of the importance of the Torso

The torso allows for natural movement and additional information such as emphasis, which comes across in oral languages through intonation of speech. However in sign language this is done through a combination of movement of the hands, face, and torso which is important to express as it provides more emotional meaning to information [Sutton-Spence and Woll, 1999].

6.2.14 Rule Three - Linguistic Emotion Measure of Torso

The following images provide examples and also a way in which to measure what these descriptions within the rules mean.

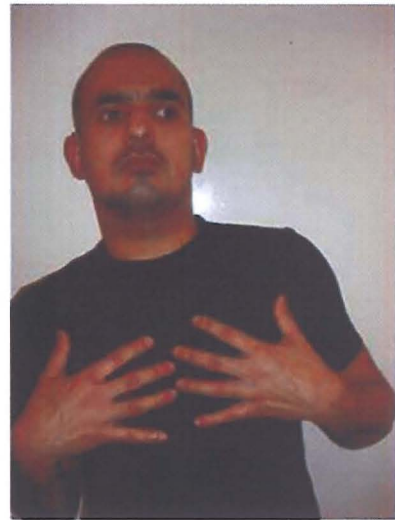
6.2.15 Rule Three - Symbolic Emotion Measure of the Torso

6.2.16 Rule Four - Linguistic Emotional Representation of Handshape

Use clear hand shapes to express as follows:



Example One

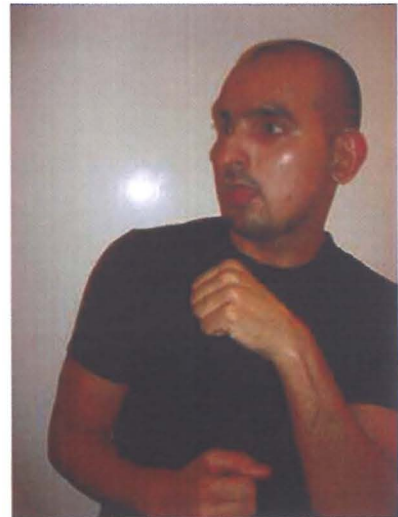


Example Two

Figure 6.18: *Rule Three: Emphasis Linguistically* - An example of a signer using his torso to bring emphasis to his signing.



Example One



Example Two

Figure 6.19: *Rule Three: Character Shift Linguistically* - An example of a signer using his torso to demonstrate character shift when describing a conversation.

"ARGH"
You
SCARED
me!!!



Figure 6.20: *Rule Three: Emphasis Symbolically* - In this example the same sentence has been symbolically represented in two possible ways. One with textual description and the other with image description. Both demonstrate how emphasis can be used within a symbolic representation of BSL.



Hello Dear, can you come down?

I'm busy

How long will you be?

I DON'T KNOW MOTHER!

Dinner's ready!!!

I don't KNOW MOTHER!!!!

Figure 6.21: *Rule Three: Character Shift Symbolically* - This image provides a symbolic way of presenting character shift, much like the example in *Rule One: Characters Symbolically*. When presenting character shift, several sign language linguistic components are used to make the signing accurate. As demonstrated here, this can overlap into different areas of emotional awareness in information system development.

1. *Rule Four: Size Linguistically* - The use of the hands can be formed and held in such a way that the size of an object can be shown. Such as how small or large something can be.
2. *Rule Four: Weight Linguistically* - Again by forming the hands differently a visual description can be shown of how heavy an object can be.
3. *Rule Four: Direction Linguistically* - Handshapes and movements can be used to give directions of how to get from one location to another.
4. *Rule Four: Shape Linguistically* - Handshapes and their movement can be used to show the shape of an object, such as a lamp, table or bowl.
5. *Rule Four: Vocabulary Linguistically* - Handshapes support and provide a wide range of vocabulary, through fingerspelling to handshapes.

6.2.17 Rule Four - Symbolic Emotional Representation of Handshape

Use clear and plain written English with visual cues

1. *Rule Four: Size Symbolically* - An image can be altered to show the size of an object in any given context. This is most effective when two or more symbols are used within an image as it allows for a standpoint of measure to indicate size.
2. *Rule Four: Weight Symbolically* - An image can be used to demonstrate the size of an object, again best shown with two or more symbols in an image as it provides a standpoint of measure to indicate size.
3. *Rule Four: Direction Symbolically* - Symbols and information maps can be used to provide clear directions symbolically.
4. *Rule Four: Shape Symbolically* - Shapes of objects are best shown through descriptive images.
5. *Rule Four: Vocabulary Symbolically* - Providing written text and images to clarify the meaning of new vocabulary, symbolically supports the building and maintaining of vocabulary. New vocabulary can be shown in different styling of colours and fonts as this can separate new information to ensure it is learnt and not brushed over.

6.2.18 Rule Four - Explanation of the importance of Handshape

Handshapes provide a great deal of information with a range of vocabulary to describe size, weight and shape. Hands can help clarify directions and also are used to provide layout of information, all very important details when understanding subjects. All of the

above have a symbolic alternative that is visual and can work with the Deaf community [Sutton-Spence and Woll, 1999].

6.2.19 Rule Four - Linguistic Emotion Measure of Handshape

The following images provide examples and also a way in which to measure what these descriptions within the rules mean.



Example One



Example Two

Figure 6.22: *Rule Four: Size Linguistically* - An example of a signer showing a small and large size object. Example one is the smaller size of the object and example two is larger size of the object.

6.2.20 Rule Four - Symbolic Emotion Measure of Handshape

The following images, provide examples and also a way in which to measure what these descriptions within the rules mean.

6.2.21 Rule Five - Linguistic Emotional Representation of Signer's Space

Use placement as it will provide:

1. *Rule Five: Layout of Story Linguistically* - Provides an understanding of order of events with use of reference to particular things within the signer's space.
2. *Rule Five: Structure Linguistically* - This allows for the dialogue to have structure and clarity.



Example One



Example Two

Figure 6.23: *Rule Four: Weight Linguistically* - An example of a signer showing a light and heavy object. Example one is the lighter object and example two is heavier object. Note also that facial expression has also changed, and this should highlight the overlapping and the interaction of the linguistic rules.



Example One



Example Two

Figure 6.24: *Rule Four: Direction Linguistically* - An example of a signer showing direction. Example one is showing the direction sign for right and example two is showing the direction sign for left, it should also be noted that there is a change in lip patterns to express this sign.



Example One



Example Two

Figure 6.25: *Rule Four: Shape Linguistically* - An example of a signer showing the shape of a box. Example one is the first part of the sign, and example two last part of the sign

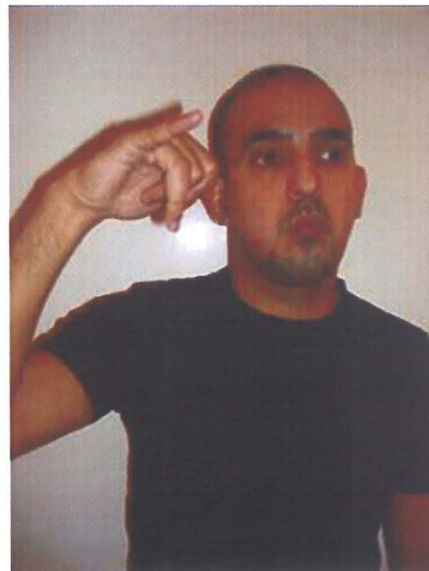


Figure 6.26: *Rule Four: Vocabulary Linguistically* An example of a signer showing the sign for aeroplane. This is an example of how hand shape can form vocabulary, the wrong handshape can make the sign ambiguous

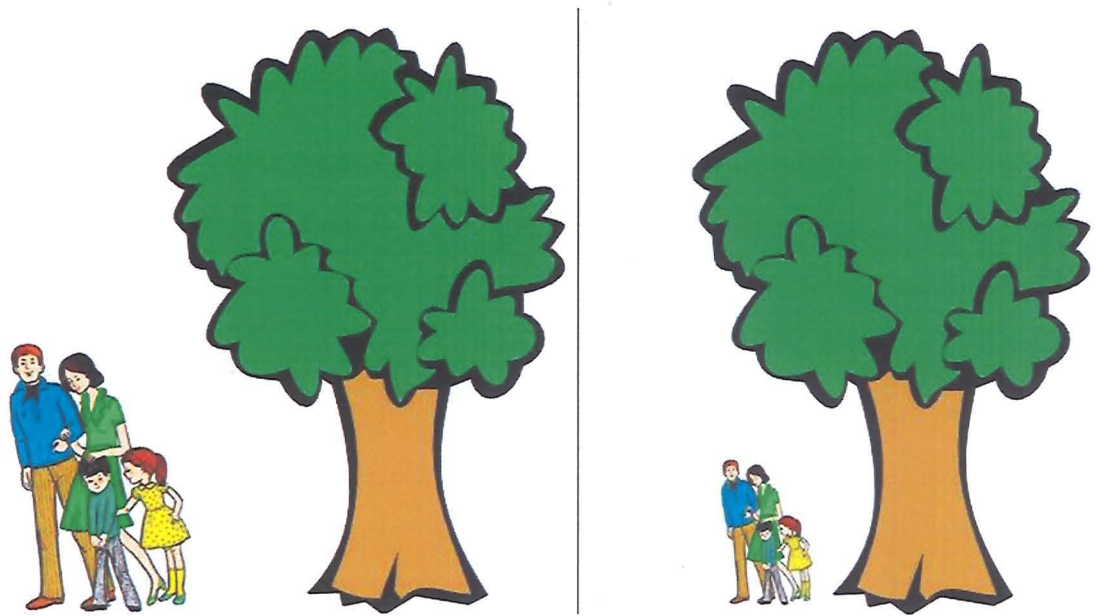


Figure 6.27: *Rule Four: Size Symbolically* - An example of how size can be demonstrated with different symbols within an image. Changing the proportions of the two symbols has altered the understanding of how large the tree is. Image one shows a smaller tree and image two shows a larger tree.

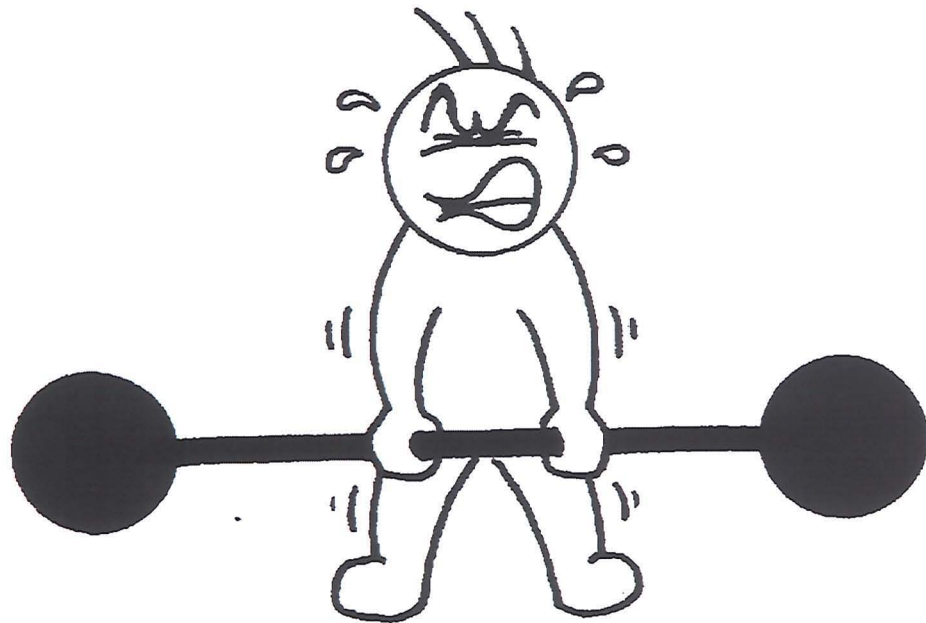


Figure 6.28: *Rule Four: Weight Symbolically* - An example of a man lifting a heavy object. The demonstration of feeling on the face and the size of the actual object that he is lifting demonstrates that he is lifting a heavy weight.

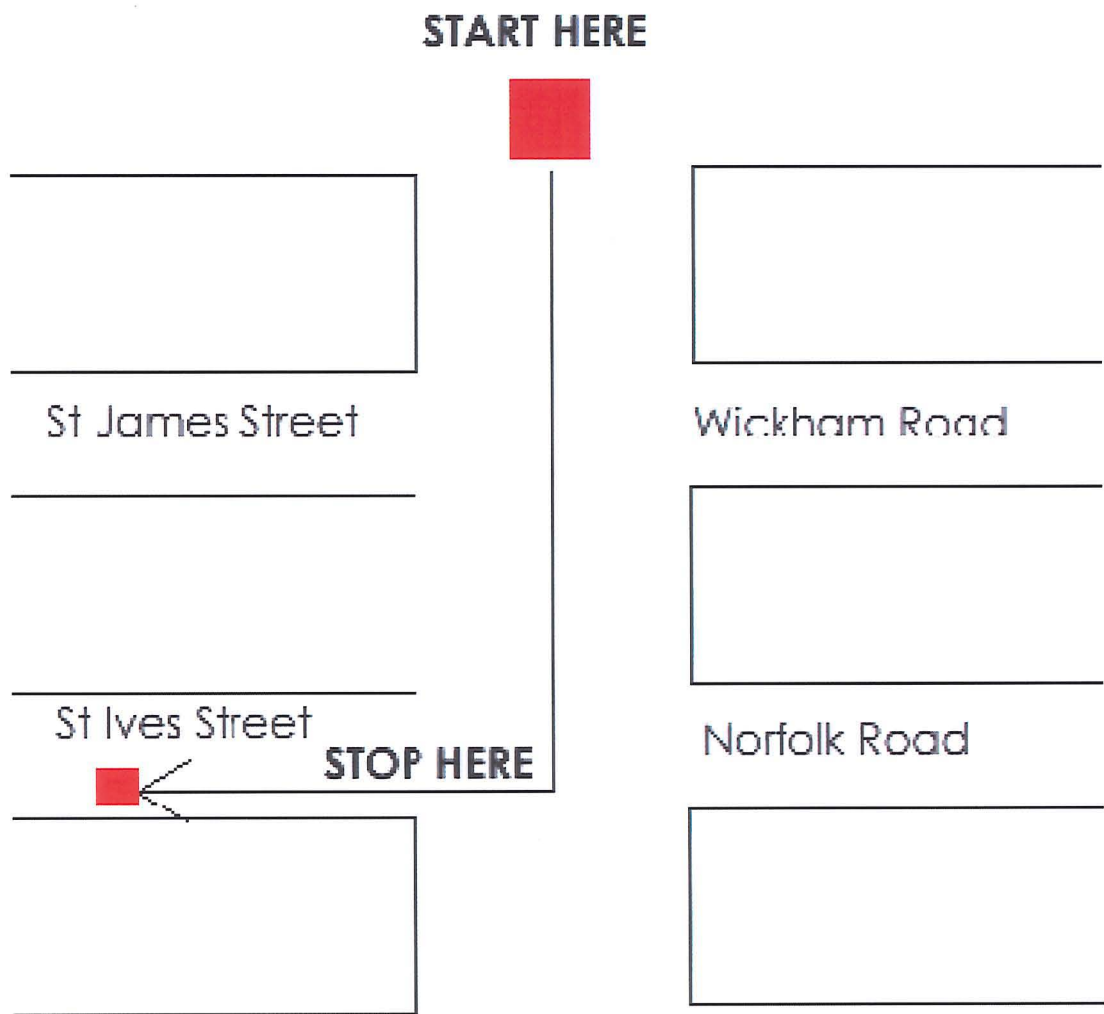


Figure 6.29: *Rule Four: Direction Symbolically* - An example of a map in this image is a clear way to provide directions and would be a symbolic way to represent directions in sign language.

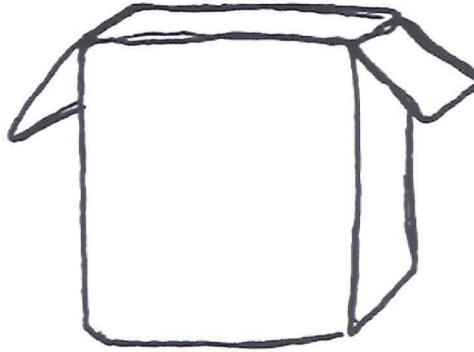


Figure 6.30: *Rule Four: Shape Symbolically* - When representing the shape of an object in symbolical form, it is best to show the object itself. In this example an image of a box is shown to describe the shape of a box. This can be done with any object/person, for example the person was tall and thin.

Aeroplane



Figure 6.31: *Rule Four: Vocabulary Symbolically* - In this example the word can either be shown as text or its image equivalent (as shown in the example above), depending on the target audience and their level of literacy. If the words are more complicated, it is better to introduce the image with the word, and as the users get used to the word, the image can be used to reference the word symbolically, or the text can be used, again depending on the user group of the information system.

6.2.22 Rule Five - Symbolic Emotional Representation of Signer's Space

When using complex story lines or vocabulary:

1. *Rule Five: Layout of Story Symbolically* - Use previous rules to explain the concept but iconise the concept so it becomes a reference image, which can be later used to revisit the topic of discussion.
2. *Rule Five: Structure Symbolically* - Chunk sections of the story clearly in order to provide structure but use a colour or theme that continues in order to provide a link between different chunks of information.

6.2.23 Rule Five - Explanation of the importance of Signer's Space

Placement provides layout of information, which allows for clarity of details. Placement associates details to different characters, locations and objects, which provides a fuller sense of what is being described [Sutton-Spence and Woll, 1999].

6.2.24 Rule Five - Linguistic Emotion Measure of Signer's Space

The following images provide examples and also a way in which to measure what these descriptions within the rules mean.

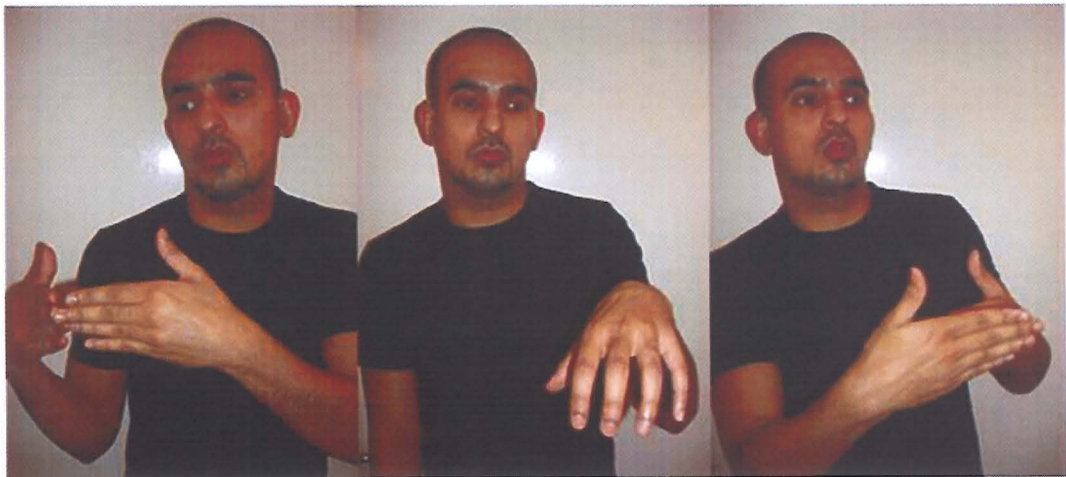


Figure 6.32: *Rule Four: Layout of Story and Structure Linguistically* - In this example the images used demonstrate how a signer would use his signing space to layout information. This provides a layout and structure to the information in the signing sentence.

6.2.25 Rule Five - Symbolic Emotion Measure of Signer's Space

The following images provide examples and also a way in which to measure what these descriptions within the rules mean.

6.3 User Interface Emotional Design Process Cycle

The following sections will assist in understanding the process cycle to design Emotionally Aware Software.

6.3.1 Establish Base Rules for the User Group

When designing the appropriate interface for the target audience, it is important to establish what type of information system it is. Two possible categories are

1. New information
2. Old information

New information is like a class lecture, news reports, new books or information that is, unfamiliar to the Deaf person. Old information can be information that a Deaf person is used to or has been introduced to in the past already, such as a train timetable, or a doorbell that has rung, or a description of a new room location in a building that is already familiar to the deaf person.

6.3.2 Breaking Down Information for Processing

Information needs to be broken down into its concepts/chunks. If a concept is too large, find smaller concepts within that in order help break it down to manageable chunks. These would be segments of information that are around a sentence long, or that explain one clear step or point or fact. Within that the emotional facets of information are built up to allow for a clearer understanding of the concept being explored.

6.3.3 User Centred Evaluation and Feedback on rule design

In order to understand whether the above rule criteria are fulfilled, the following steps need to be taken.

There were three friends



Peter



Jim



Stuart



Peter said to



Jim that he wanted to go and see



Stuart.



Stuart said he is "not available",



but Jim said he saw him at the park only 5 minutes ago.



Peter was very confused.

Figure 6.33: *Rule Four: Layout of Story and Structure Symbolically* - In this example, the information is laid out. Firstly it identifies the three main characters within the dialogue, and then uses those images within the text to clarify who was speaking. This allows for clarity of what is being said and by whom. This could also be used with locations, objects or other significant elements to a conversation/discussion/dialogue.

6.3.4 System Development Steps

1. Step One, Separate Concepts: To aid translation
2. Step Two, Focus On Concept: Start to work with first/next concept for translation
 - (a) Step One, Translate: Involve a sign language expert and translate the information into BSL. For example native signers
 - i. English Sentence: How was your trip to school today?
 - ii. BSL Sentence: School trip, good?
 - (b) Step Two, Identify: Although the BSL example has been written in English, there is a great deal of information held in the face. Upon assessment the following two characteristics need to be closely assessed to ensure they are present in the linguistic representation of the system. These are
 - i. Questioning: because of the “How” in the sentence.
 - ii. Expressing feeling: because of the “Good” in the sentence.
 - (c) Step Three, Convert: - Linguistics. Ensure that these two elements are demonstrated in the sentence that is being expressed (more elements will be covered with the same sentence and the application of the other rules will follow. Work with one rule at a time, but ensure all five rules are checked before moving to the next concept)
 - (d) Step Three, Convert: - Symbolic. Ensure that these two elements are demonstrated in the information presented (other elements of this sentence will be demonstrated in the implementation of the other rules)
 - (e) Step Four, Assessment: Check if these criteria are in the Linguistic/Symbolic Emotion Presentation of the sentence. Questioning should follow the following format:
 - i. **Comprehension**: “What does this sentence say?”
 - ii. **Accuracy of Meaning**: “Are the lip patterns clear?” (use alternative questions for the different rules)
 - iii. **Area of Improvement, if any**: “What can be improved with the lip patterns?” (use alternative questions for the different rules)
 - (f) Step Five, Improvement: If the answers provide area of improvement, it is advised to improve the system on the basis of the feedback of the user group and re-assess with Step Three if needed.
 - (g) Step Six, Finish: End of procedure
3. Step Three, Repeat: Go back to step two until all concepts are complete, then continue to Step Four.
4. Step Four, Connect Concepts: Connect the concepts together and run final feedback of **Comprehension**, **Accuracy of Meaning** and **Areas of Improvement on**

entire information system. When connecting linguistic concepts use the same signer; when connecting symbolic concepts, keep the same visual theme, for example the colour schemes.

5. Step Five, Finish: Process is complete. If, however, circumstances justify doing so, try out the complete output with a different but equivalent group of users and incorporate any revisions for which the need has emerged.

6.4 Architectural Model

The following diagram presents an architectural model of how the system design process will work when designing an emotionally aware system for the Deaf.

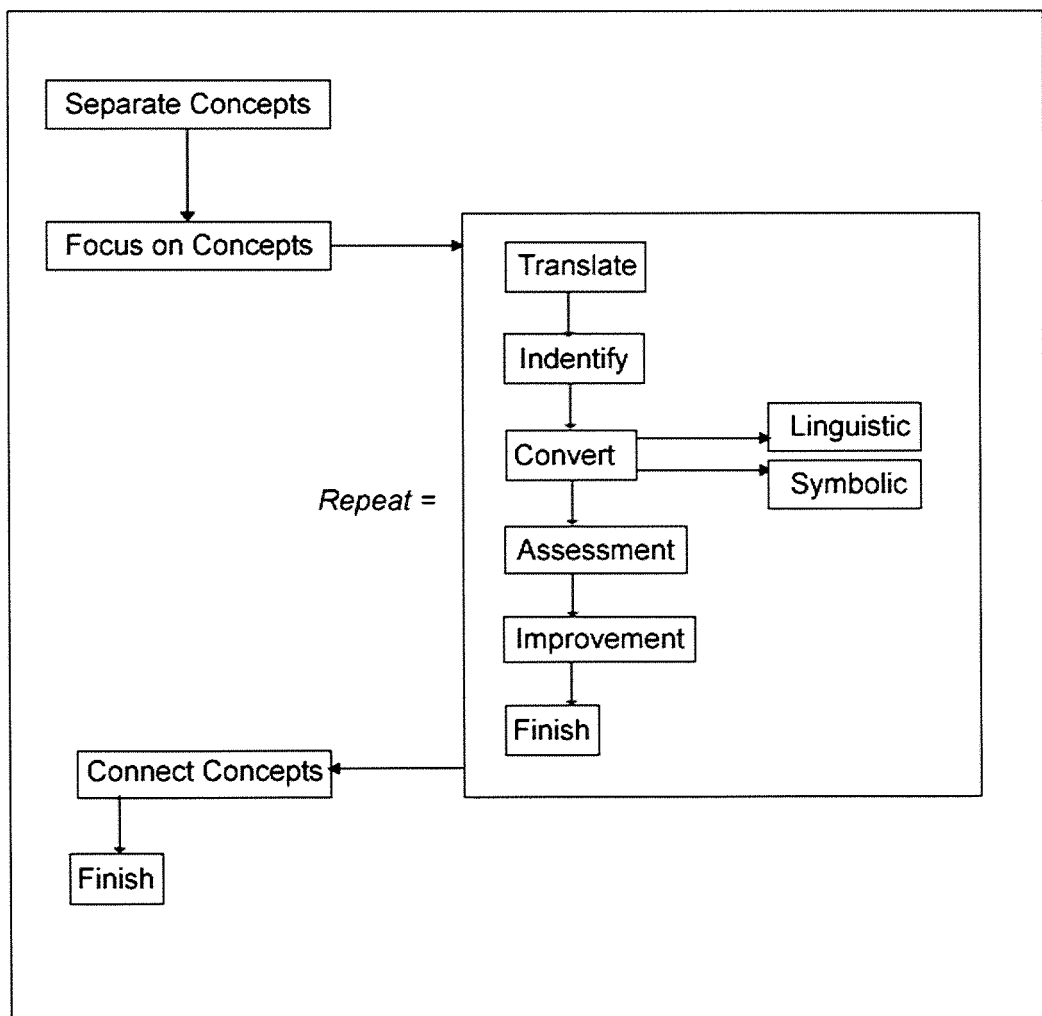


Figure 6.34: Emotional System Design

6.5 Conclusion and Summary

There are a number of well established heuristics within the field of Human Computer Interaction (HCI) [Nielsen, 1994, Shneiderman, 1998], that successfully assist designers on how to design systems for varied users. The emotional engineering presented in this chapter was initiated due to the lack of understanding of the language needs of the Deaf, and this framework was constructed to assist in the development of future systems.

Although these rules and framework present themselves from a different perspective to that of Shneiderman and Nielsen, where the emotional engineering approach focuses on the need for essential linguistic characteristics of British Sign Language. Shneiderman and Nielsen cover more of the holistic approach to overall systems interfaces, the emotional engineering rules (i.e. the emphasis and importance of sign language linguistics and Deaf systems design) sit within these established rules and have application within mainstream HCI.

These have been presented within appendix F and appendix G you will find the ten usability heuristics by Nielsen and the eight golden rules by Shneiderman. Within these rules there is reference to the rules of design, architecture, process steps of emotional engineering presented in this chapter and principles of design presented in chapter 8.

A central problem that this dissertation responds to is the gap between technologists of DRSLs and the users experiences of DRSLs. This chapter aims to bridge this gap, through establishing which detailed criteria for clear communication correspond to the parts identified by signer's as constituting clear communication. Because this research is based on the signer's perspective it isolates key components of DRSLs to convey a more nuanced style of communication, as these rules are inextricably bound to the nature of BSL itself.

The rules provide the guidelines for the translation process through which content is turned into a user-oriented information system, thus providing a clearer understanding of what is needed by technologists and users when approaching the task of developing a system for this user group.

This chapter has also presented a process cycle for clear identifiable steps towards system development, and an architectural overview of the process of system development.

The summary of the rules, system development steps and architectural model can be found in appendix E.

In order to assess if these rules work, the results have been tested in chapter 7.

Chapter 7

Investigation: Linguistic and Symbolic Rules Assessment

7.1 Introduction

In order to understand digital representations of sign language; studies have been conducted that are primarily motivated by system designer's [Damer et al., 1997, Elliott et al., 2007]. However this thesis has presented the first study of its kind to compare digital representation of sign language in order to find what the Deaf community regard as both necessary and important in order to understand and use information in the communication system. The design of this assessment is based on the rules provided in chapter 6. This forms the basis of the criteria for assessment for future system designer's who work for or within the deaf community.

The information gathered aims to validate the linguistic and symbolic rules outlined in chapter 6 and their applicability within system design for the deaf community. This study outlined here will be comparing different DRSL presentations using the rules identified in chapter 6 as its guiding criteria. Samples will be shown without the application of particular rules to see if this alters understanding of the information presented. This chapter presents a background that details what has been previously noted with DRSL systems. Then the hypothesis of this study is stated in order to define the area of research clearly, this will then justify and lead to the methodologies used and a section explaining the participant selection for this experiment. There will be details about the pilot studies conducted, what was found and a summary of the conclusions made.

7.2 Background - Traditional Approach to Accessible Design with the Deaf Community

With traditional approaches to accessible design, rules and guidelines have been established in order to ensure that systems technologies are accessible to special interest groups, such as disabled communities. Deaf communities are often regarded as disabled and placed within the same category, although the Deaf community that proudly uses sign language

as its main mode of communication often strongly opposes being classified as disabled. One of the central problems to traditional approaches to accessible information systems for the Deaf is that they have not completely considered the intricacies of BSL. This research has aimed to understand the technologist's perspective and the user perspective, then developed a middle ground where they can both meet. The rules presented in chapter 6 can not only help develop systems but can also act as an assessment criterion for existing systems, in order to present suggestions for improvement.

For the purpose of this thesis and in order to explain how the rules from chapter 6 can be used as assessment criteria for assistive information systems technologies, it is important to understand the assistive technology movement. Its alternative perspective may provide a deeper understanding of what makes the difference in a system's level of acceptance, comprehension, usability and likeability. Further, it will help to reinforce the criteria for emotional system design which must be met to ensure it matches the needs of the Deaf community.

As the intended users of assistive technologies are disabled people, it is important to understand the definition of the intended user of such technologies. Therefore before considering definitions of assistive technology, the different models of disability will be presented. The two main approaches are: the medical and social model.

The medical model draws on terms set out by the World Health Organisation (WHO) in 1980 [WHO, 1980] in particular the definitions of the terms "impairment", "disability" and "handicap" (sometimes referred to as the ICDH (International Classification of Functioning, Disability and Health) model). The WHO defined "impairment" as "any loss or abnormality of psychological, physical or anatomical structure or function". A "disability" then occurs when the impairment prevents a person from being able to "perform an activity in the manner or within the range considered normal for a human being". Hence a "handicap" results when the person with a disability is unable to fulfil their normal role in society and the community at large. Thus the medical model focuses on the person's impairment(s) as the cause of disadvantage leading to the approaches of occupational therapy and rehabilitation. It should be noted that organisations of disabled people dislike the term "handicap" and it should not be used.

The social model of disability gives emphasis to the physical and social barriers experienced by disabled people [Swain et al., 2004] rather than their impairments and considers the problem to be in society rather than the disabled person. It is compatible with the empowerment of disabled people and user-centred and participative design approaches [Damodaran, 2001, Bearne et al., 1994, Rowley, 1998]. The social model was first developed by the Union of the Physically Impaired Against Segregation [UPIAS, 2008] and then modified by the Disabled Peoples International (DPI) [Barnes, 1991]. The model is based on the two concepts of impairment and disability. "Impairment" is defined as the functional limitation caused by physical, sensory or mental impairments. "Disability" is

then defined as the loss or reduction of opportunities to take part in the normal life of the community on an equal level with others due to physical, environmental or social barriers.

To illustrate the difference in focus of the two models, the medical model identifies the disability of a hard of hearing or profoundly Deaf person as related to their inability to hear clearly and thus limiting their spoken language acquisition. The social model identifies their disability as a consequence of the fact that, for instance, only some information is tailored to suit the language needs of the Deaf. Or, more simply, in the social model it is the steps that are the problem not the wheelchair. Organisations of disabled and Deaf people influenced by the social model of disability have had an important role in changing attitudes towards disabled and Deaf people, with a great push and increase in accessibility in the community and securing new services and rights for disabled and Deaf people. There is still a need for a great deal of work to ensure full rights for the disabled and Deaf community as professionals are still largely influenced by the medical model, and many services and facilities are being provided within a rehabilitation framework.

The social model influenced the WHO to change those definitions initially created using the medical model so in the new version (usually referred to as the ICIHD2) the terms “impairment, disability and handicap” were replaced by “disability, activity and participation” [WHO, 2001]. This revised model considers disablement to be a consequence of the interaction between an individual’s health and contextual factors. Nevertheless, it is still the individual’s condition rather than external factors that drives the classification. This departs from the social model in which impairment is considered simply to be part of human diversity, and that disability and its isolation are more factors created by social and community environments that have been designed without taking the needs of disabled people into account.

The social model provides a more equal and empowering footing for disabled and Deaf people and this is the appropriate model to use when developing research, design, development and implementation of assistive technologies. Understanding this will not only enhance the process but will allow for more liberating dialogue between designer’s and end users, thus resulting in a more acceptable and usable product. On the same note it is important and useful to be aware of physical effects of impairments in the context of diversity and equality. This means people working with disabled and Deaf end-users need to recognise physical and other differences. It reinforces awareness that everyone is entitled to equal rights and equal opportunities and that there is no particular normal way of ‘being human’ but that the full range of diversity is equally valid and valuable in society.

7.2.1 Working with Deaf End-Users

Much of assistive technology research is about the design of new products, processes and devices for d/Deaf people. Carrying out this design process effectively requires the involvement of end-users, who are generally deaf people. This is important because only (potential) users of a particular product, process, device or service:

1. Understand what is needed in the end product.
2. Can test and explain what will and won't work in practice.
3. Will accept or reject the finished product/service.
4. Can determine whether the product is acceptable from all view points, as deaf individuals will have an alternative insight into a product/service in comparison to a hearing person.

To have effective system development, end-users should be involved from the start of the research design process. Changes introduced at a later stage may be both considerably less effective and more expensive. However, the problem is that many scientists and engineers find it difficult to work with end-users and will therefore not involve them at all or only involve them at the final stage of testing a finished product. Though better than nothing, this is often much too late and the community will lose confidence very early on in the product/service.

There are three main possibilities for bringing end-users into the research, design and development process:

1. Participation in which end-users (generally representing particular organisations / communities / language groups / backgrounds are involved in the decision making processes and will be thought of as part of the research team(s).
2. Consultation in which advice is sought from end-users at different stages of development, including testing prototypes and evaluating finished devices.
3. Involvement of end-users as research 'participants' acting as focus groups, interviewee respondents and in system testing with feedback.

The same or different (groups of) end users may be involved in all three roles. However it is important to note that working with special interest groups, there may be particular communication needs that you may need to be aware of such as (in the present context):

1. Sign Language communication,
2. The use of clear spoken language in order to allow for lip reading,

3. Visually friendly design of questions (chapter 3.)
4. T-loop systems.

As society becomes more widely educated in Deaf awareness, adjustments are being made to different working atmospheres in order to accommodate the communication needs of Deaf people, such as a visual fire alarm that lights up or sends tactile signals when activated, or telephone devices which allow for communication through sign language or text. Some pre-lingually Deaf people do not always seek devices that will help them to hear better as their Deaf identity is very strong.

However people who become hard of hearing later on in life due to ageing or exposure to noise usually have a different view. They generally do not know sign language and want devices that will enhance their hearing. They frequently want these devices to be subtle so it is not obvious that they have a hearing impairment. However this distinction between attitudes of people who were born deaf and those who became hearing impaired later on in life cannot be automatically assumed.

Particular care should be taken to treat d/Deaf end-users who are involved in research, design or development as experts or consultants rather than objects of the research. As noted in the investigations, many participants who refused to take part in the work remarked that they are “fed-up of being used to evaluate things such as new ways to simulate sign language”. This includes, but is not restricted to:

1. Recognising that d/Deaf people are not defined by their deafness.
2. Only asking for information that is relevant to the research and not pressurising respondents to divulge personal information, even when this is relevant.
3. Not asking intrusive, personal questions.
4. Not staring at or avoiding looking at a d/Deaf person. When using an interpreter it is important to look at the d/Deaf subject/expert and not the interpreter while communicating, as the interpreter is purely a communication tool but is not the contributor to the work.
5. When talking do not cover your mouth with your hand or with your hair or if you have a moustache keep it clear of your mouth. If you have a deaf person who may rely on lip reading as a means of communication it is important to ensure you are allowing them to lip read with ease. Do not shout, as this over emphasises the lip patterns and becomes unnatural which is not easy to read.

7.2.2 Deaf Awareness Training

It is advisable that individuals designing assistive technologies for the Deaf community should partake in Deaf awareness training. This will be very valuable not only in providing insight but also demystifying any preconceived ideas about the community as a whole.

7.2.3 Communication Issues

The involvement of (lay) Deaf people in research and project development presents two types of communication issues:

1. The use of jargon, scientific and engineering terms.
2. Different ways or styles of communicating.

The first issue is relevant to the co-operation of all mixed groups, involving engineering and scientific “experts” and the lay population, whether or not they are d/Deaf. For instance a glossary of terms would be useful for interpreters and communicators to ensure consistency, and no misinterpretation. If the sign for a word is slightly taken out of context, its meaning can change, such as the positive or negative emphasis on the subject in question. Also with Deaf people, the design of the documentation needs to be less wordy and more visually digestible (as stated in chapter 3). Deaf people have different reading levels and a lot of this is related to schooling experiences of young Deaf people and how they may have been taught English.

The second issue is specific to the participation of Deaf people. For instance the group may involve:

1. Deaf people who use sign language.
2. Deaf people using sign supported English.
3. Deaf people using lip reading.
4. Deaf people using home signing (more gesture based communication created through the need to communicate in the home when there maybe one deaf person present and the others may be hearing).

These issues are part of the wider context of accessibility. It will often be necessary to provide

1. Sign language interpreters [RNID, 2004].
2. Interpreters who know sign supported English [RNID, 2004].

3. Lip speakers [RNID, 2004].
4. Relay interpreters (who are Deaf and can adapt and modify communication with home signer's more easily than in comparison to hearing interpreters) [RNID, 2004].

It should be the responsibility of all participants especially the ones who are non-disabled to ensure that the communication needs of disabled participants are met. Communication needs should be discussed in advance, so that as far as possible, disabled participants can communicate in their preferred form.

Sufficient time should be allowed for interpretation and the participation of people who communicate slowly on account of disabilities. Therefore a longer time period may be required for meetings and interviews and this should be allowed for in planning. It is also important to clarify the way in which technical and other special terms are being communicated by interpreters to prevent misunderstandings or differing interpretations.

7.2.4 The Problem

Systems are designed for general accessibility for the "disabled" community. However with the Deaf community, it is more a case that sign language assistive solutions do not always reflect the full nature, style or structure of sign languages. Sign languages use the space in front, above and on the sides of the signer to express conversations and discussions. It is a complete language in its own right and many Deaf people view themselves as a linguistic minority instead of hearing impaired. The needs of this particular community are based around visual communication and this thesis aims to address how to design a system that visually matches and provides for the needs of this linguistic minority group.

7.3 Experimental Methodology

Hypothesis

When an information system is designed holding either symbolic or linguistic emotional representation it will achieve higher levels of acceptance by the Deaf community.

Sampling

Many organisations, schools, education centres and professionals have been contacted to ask for participation in the research. People who were not contacted but were interested in the research have contacted myself. A list was formed of the participants that came forward, and then participants were selected for the pilot studies. A further twelve were selected for the final investigation. All participants were randomly selected for participation

in the research. These participants were enough to test each of the different presentation scenarios.

The participants were selected from London and used the London regional dialect of British Sign Language (BSL), as the rules have been designed for this target audience. Therefore sampling took place in and around the London (UK) area and the target population was adult. In order to understand what the deaf community thinks of the systems, BSL users were invited for participation in this research. The participants selected were Deaf and HOH(Hard of Hearing).

Incentives and Procedures

Each participant was offered reimbursement for travel if needed. The following steps were implemented:

1. Introduction: The participants were called in one at a time and given general information, including clarification that the experiment is not a test of any kind, it is simply a comparison of different DRSLs that are currently available. They were informed that they may stop this experiment at any time, and that if they wished they may remain anonymous in this research. Before the participants proceeded they were asked their age, gender and contact information.
2. Familiarization: The experiment was explained to the participants, they then filled in a questionnaire for some basic details, before the sample presentations were shown.
3. Presentation: Participants were shown two presentations and were asked:
 - (a) What do you think this means?
 - (b) (after being shown the original sentence, were then asked) How accurate is this to the original sentence?
 - (c) What was unclear?
4. Information gathering: All information was documented on a questionnaire by the participant and experimenter. There was an interpreter present to aid communication.
5. Question and Answers: At the end of the session, participants were given the opportunity to ask questions.

Data Collection Methods Used

The participants were shown a series of different information systems presentations that fulfil and do not fulfil the linguistic or symbolic emotional representations of sign language and were asked:

1. What do you think this means?
2. How accurate is this to the original sentence?
3. What was unclear?

After participants explained what they thought the DRSL presentation meant, they were shown the original sentence and asked further questions.

The data was collected by having a questionnaire filled by the experimenter and a video recording was made in order to check over and assess accuracy later. When participants were asked "How accurate is this to the original sentence?" they were asked to rate from 1 to 5, where 1 was the lowest score and 5 was the highest. The data was collected through questionnaires, and video filming which was analysed after the experiments. There were no control groups in this study.

Materials

There were a set of symbolic and linguistic representations presented to participants, however the sequences shown demonstrated their ability with particular rules missing (identified in the emotional engineering of systems in chapter 6).

Each participant was shown one linguistic and one symbolic presentation and provided feedback. The following explains the differences between the various presentations that were shown.

1. Linguistic representation correct sequence
2. Linguistic representation sequence minus rule one
3. Linguistic representation sequence minus rule two
4. Linguistic representation sequence minus rule three
5. Linguistic representation sequence minus rule four
6. Linguistic representation sequence minus rule five
7. Symbolic representation correct sequence
8. Symbolic representation sequence minus rule one
9. Symbolic representation sequence minus rule two
10. Symbolic representation sequence minus rule three
11. Symbolic representation sequence minus rule four
12. Symbolic representation sequence minus rule five

The sentence to be presented is:

The weather today was sunny, but later it will become cloudy and you can expect thunder and rain

In BSL the sentence holds more detail with facial expression, and the following words presented themselves as various handshapes for the sentence structure. Such that:

sunny now later cloudy rain thunder will

Participants were shown two presentations, one linguistic and one symbolic, the presentations shown to the participant were randomly allocated so that all presentations could be viewed.

7.4 Pilot Study One

In the initial run of the experiment, it became clear the question that I was asking was ambiguous. Therefore to clarify the meaning and make it more appropriate in BSL, the participants were asked “What is the message in this?” That made it clear to the participants what the experiment was asking.

7.5 Pilot Study Two

The re-run worked clearly and the experiment was conducted.

7.6 Results: Categories, Comparison and Differentiation

The following is a breakdown of results in correspondence to the test categories designed.

The participants involved had the opportunity to view the presentations and mark them out of 5. 1 is the lowest score, and 5 being the highest.

No inferential statistics test was used in evaluating the data displayed in the bar graph, the fact that both participants in every condition gave identical scores (or, in a minority of instances, scores that were only 1 point apart) instills confidence in the reliability of the results.

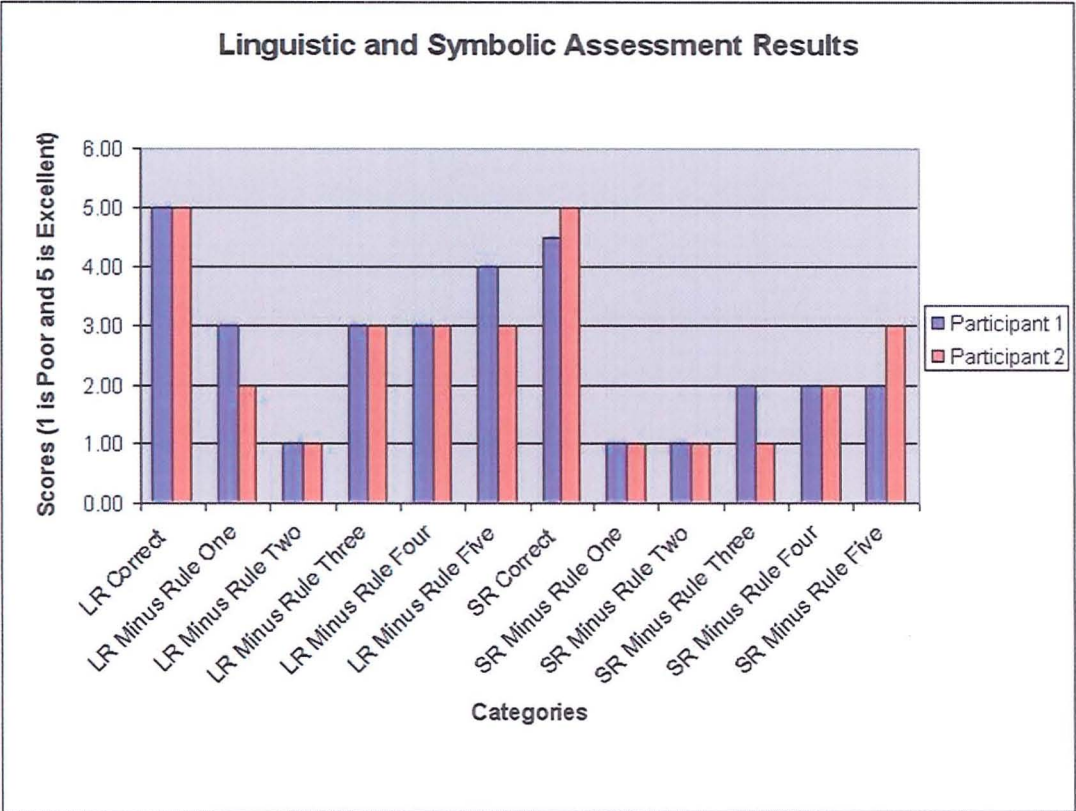


Figure 7.1: A bar graph displaying descriptive statistics for the assessment of varied Symbolic and Linguistic representations of information systems.

7.6.1 Linguistic Representation of Correct Sequence

Participant one stated that the sentence meant “It is sunny now, later there will be cloud, rain and thunder”, whereas participant two said “Sunny now, later cloud and rain and thunder”. The differences in interpretation of sentence depended greatly on individual literacy skills. When the actual sentence was presented to the participants they both felt that their sentences were very similar to the original sentence. The ratings for both linguistic representations by the participants were 5 (which was the highest score possible) and they didn’t identify any areas of improvement. Although one participant remarked that she prefers the weather being told by a female as opposed to a male.

7.6.2 Linguistic Representation of Sequence Minus Rule One

Participant one stated that the sentence meant “sunny now, where (but handshapes are wrong way round) rain and thunder”, whereas participant two said “Sunny, with rain and thunder”. The differences in interpretation of sentence demonstrated that signs became ambiguous and also participants could not absorb all the signs that were presented to them. When the actual sentence was presented to the participants, they both felt that their sentences were unclear in the presentation. The ratings for both linguistic representations by the participants were 3 and 2 (where 1 was the lowest and 5 was the highest score). Both participants criticised the lack of lip patterns and one criticised the handshape as unclear as it became confusing to follow.

7.6.3 Linguistic Representation of Sequence Minus Rule Two

Participant one stated that the sentence meant “sunny (something...) rain and thunder”, whereas participant two said “This is not sign language and I do not understand”. The lack of facial expression caused one participant only to understand two words in the sequence but without real meaning of why they were being used, which meant there was no sense of context. The second participant did not attempt to try and understand this as she felt that the signing was not correct. When the actual sentence was presented to the participants, they both felt that their sentences were unclear in the presentation. The ratings for both linguistic representations by the participants were both 1 (where 1 was the lowest and 5 was the highest score). Both participants criticised the lack of facial expression and referred to the lack of “emotion” a previously discussed concept in chapter 4.

7.6.4 Linguistic Representation of Sequence Minus Rule Three

Both participants understood the sequence, but both participants said the signer was unnatural and didn’t move like a native signer. One participant said that the signer

looked stiff and would be difficult to watch over long sequences. When the actual sentence was presented to the participants, both participants felt they got a good grasp of what was said, but both felt the signer unnatural. The ratings for both linguistic representations by the participants were 4 and 3 (where 1 was the lowest and 5 was the highest score). Both participants criticised the stiffness of the signer.

7.6.5 Linguistic Representation of Sequence Minus Rule Four

Participant one stated that the sentence meant “bump, later (something) rain”, whereas participant two said “(first sign unclear) later rain”. The participants were unable to identify the sign with the incorrect handshape, but also it had a level of negative impact on the overall comprehension of the sequence. When the actual sentence was presented to the participants, one participant commented on how “easy it is to become unclear, even though the other signs were present”. The other participant laughed and said “I see the similarity now, but I didn’t realise the mistake would affect the next few signs I saw, very interesting”. The ratings for both linguistic representations by the participants were both 3 (where 1 was the lowest and 5 was the highest score). Both participants criticised the poor handshapes and were surprised at how it affected the overall comprehension of the sentence.

7.6.6 Linguistic Representation of Sequence Minus Rule Five

Participant one stated that the sentence meant “sunny now, later rain and panic”, whereas participant two said “sunny now, later rain, panic and thunder”. The participants found that the word thunder, as it moved too close to the signer’s space it became unclear and both participants thought it meant panic. It was notable that one participant after viewing the sequence practiced the sequence on himself before giving an answer, almost to identify what the sign was. When the actual sentence was presented to the participants, both participants saw the similarity, but complained that the signer was signing too close to his body, and it became difficult to understand his signs. The ratings for both linguistic representations by the participants were both 3 (where 1 was the lowest and 5 was the highest score). Both participants criticised the poor use of “natural signing space”.

7.6.7 Symbolic Representation of Correct Sequence

Participant one stated that the sentence meant “Sunny morning, evening cloud, rain, thunder”, whereas participant two said “Sunny daytime, afternoon cloud, thunder rain”. There was a difference in interpretation of the symbolic presentation however; when participants were shown the original sentence they felt that particular words were missing, but the general “understanding” was there, and the symbolic image was very helpful.

One participant remarked that with “the information like the weather, the symbols are so easy to understand as they are part of our knowledge already because of the news, that grasping concepts can be done easily as it is very visual.” The ratings for the symbolic representations by the participants were 4.5 and 5 respectively (1 being the lowest and 5 being the highest) and participants said that although particular words were missing, the concept was very clear and visual, and did not identify areas of improvement.

7.6.8 Symbolic Representation of Sequence Minus Rule One

In this representation the symbolic understanding of the role of lip patterns was removed, therefore the timing of when the weather took place was gone (for example now, and later). Participant one stated that the sentence meant “The sunshine was shining, with clouds of rain”, whereas participant two said “This is describing different weather symbols and what they mean, such as the sun is shining, the rain is pouring, the thunder is cracking”. The participants were unable to grasp the concept of the image; however, when shown the original sentence, they said that the image was ambiguous, as it did not clarify the context of the weather. One participant remarked that “the images are clear but they need a context”. The ratings for the symbolic representations by both of the participants were 1 (1 being the lowest and 5 being the highest).

7.6.9 Symbolic Representation of Sequence Minus Rule Two

In this representation the symbolic understanding of the role of facial expression, therefore the strength of the sunshine, the levels of rainfall and the loudness of the thunder were removed. The symbolic representation demonstrated the same images but the emphasis of the weather types was removed. Participant one stated that the sentence meant “This shows that there will be some sun and then some rain today”, whereas participant two said “that after sun comes light rain”. The participants were unable to grasp the concept in the image, however when shown the original sentence, they said that the image was unclear, it did not clarify the meaning in terms of times and intensity of the weather. One participant remarked that “the information was very unclear, the symbols were great, but what they mean was completely unclear”. The ratings for the symbolic representations by both of the participants were 1 (1 being the lowest and 5 being the highest).

7.6.10 Symbolic Representation of Sequence Minus Rule Three

For this presentation the same presentation was used as in the correct sequence but the ordering was adjusted by placing the rain, thunder and lighting weather symbols before the sunshine symbols. The symbolic representation altered the ordering and the emphasis of the weather types. Participant one stated that the sentence meant “there later today

is rain, cloud and thunder but now there is sunshine”, whereas participant two said “that there is rain now and later there will be sunshine”. This was interesting as the first participant still gathered that the rain will happen later, however one participant thought it was the other way round, making the information ambiguous. The ratings for the symbolic representations by the participants was 2 and 3 respectively (1 being the lowest and 5 being the highest).

7.6.11 Symbolic Representation of Sequence Minus Rule Four

For this presentation the same presentation was used as in the correct sequence but the ordering, emphasis and wording was removed, by placing the rain, thunder and lighting weather symbols before the sunshine symbols, taking away how severe the weather may be and also by removing the words “later” and “now”. Participant one stated that the sentence meant “rain and sunshine will be at the same time”, whereas participant two said “rainy sunshine is the weather”. This was interesting as the participants gathered that the image was around the weather but thought the weather conditions will overlap. The ratings for the symbolic representations by the participants was 2 and 1 respectively (1 being the lowest and 5 being the highest).

7.6.12 Symbolic Representation of Sequence Minus Rule Five

Again the same presentation was used as in the correct sequence but chunks of the sentence, as in the “sunshine now” and “rain later” were spaced out disjointedly, therefore separating the link between the two. Participants viewed the concepts separately, both participants said that one image meant “sunshine now” and “rain later”. The ratings for the symbolic representations by both of the participants were 2. (1 being the lowest and 5 being the highest).

7.7 Conclusion and Summary

This study has demonstrated that the absence of particular rules can effect overall acceptance and clarity of information in a DRSL. There is also an indication minor disruptions can have a major impact on the overall comprehension of a DRSL.

It would be interesting to see that if errors in sequences were presented at different intervals of the sequence, depending on where the errors where shown (for example, near the face, or in the outer peripherals of a signer), if it would still effect overall comprehension of a sequence. This may help identify where accuracy is most vital in a signer’s space and where there can be a percentage of error and what that percentage might be? For post-doctoral research this study could well be repeated with different sentences processed through

emotional engineering techniques presented in chapter 6, to further assess the generality of the present findings.

This study has helped support the rules within the Emotional Engineering of Artificial Sign Languages, and emphasised the importance of sustained consultation with the Deaf community. This chapter, through empirical investigation, provided support for the work in this thesis but has also highlighted areas for future work within the DRSL domain.

The findings of this thesis will be explored further in chapter 8.

Chapter 8

Discussion and Summary of Contributions

8.1 Introduction

Several approaches have been developed towards designing for people with impairments. One common approach is to design specific solutions for people with a specific well defined need. This approach has been termed rehabilitation design [Keates et al., 2000] and it has been claimed that resultant products are not meeting the needs of particular individuals with additional needs and this is reflected in poor uptake of such systems [Mahoney, 1997]. Design by story-telling [Keates et al., 2000] is a broadly similar approach with a four stage structure geared towards inclusion of older age groups in design, however this can be modified to understand an approach to deafness. The stages are:

1. Understanding what it is like to be old, can be adapted to understand what it is like to be deaf (this can be done by mixing with the Deaf community, partaking in Deaf awareness training and understanding the history of the community);
2. Observing coping strategies adopted by other deaf people;
3. Visualising a scenario free from technical constraint;
4. and then evaluating a product for the intended users.

This approach has a methodology that is a function of deafness, rather than ability or disability. It is very difficult for people to understand Deafness if they are not deaf themselves. Thus the importance of mixing and working closely with the Deaf community is stressed. Understanding and analysing the effects of being deaf would be more achievable and less prone to subjective differences. It is the implications of impairments that are relevant in design, not the cause of the impairments.

The design approaches described above consider the specifics of deaf people as special interest groups that are distinct and apart, thus leading to specialised products which suffer from being labelled as such and can be harshly criticised as they are not always able to meet the needs of the deaf community. It is not good practice to set apart portions of

the customer base where it is at all avoidable: it is far more acceptable to produce products that are for use by both “able-bodied” and those with impairments. The research presented in this thesis has the potential to work with foreign language, autistic, lower literacy groups and also perhaps the general population, as the concepts of symbolic emotional representation can be clear to grasp. Such design can be helpful with developing initial understandings of new concepts, from which knowledge bases grow, such as language development.

Universal design [Keates et al., 2000] aims to maximise the number of people for whom a product is accessible and usable, but it is questionable as to how inclusive “universal” really is. There is also the user pyramid design approach, which categorises target user capabilities as a basis for the design process [Benktzon, 1993].

It does this through creating a correspondence between a pyramid design and user capabilities, in which the lowest band corresponds to the majority population group i.e. able-bodied. Subsequent bands decrease in size according to levels of impairment: middle band are those who have reduced strength and mobility and the apex of the pyramid comprises of the more severely impaired.

The authors at Engineering Design Centre at the University of Cambridge have developed a design model known as The Inclusive Design Cube (IDC) [Magrab, 1997], which relates capability level, population profile and design approach. This idea of a relation between user groups and impairments extends the pyramid approach into three-dimensionality. This creates an inclusive space in which different users can be represented along axes of levels of mobility, cognition and sensory impairment. Therefore members of the population who may be severely immobile with sensory impairments but with high levels of cognition have a more complex and better representation in the cube space than in the pyramid design approach. “User-aware” design thus dominates the cube approach and corresponds to the principles of universal design which result in products accessible to a wide portion of the population. Special purpose design relates to developing products for more severely impaired users and may involve adopting the rehabilitation design approach of designing distinct products for specific users. Intermediate between these two approaches there is modular or rapid/mass customisable design which takes a base unit designed using the user-aware design principles, but with a changeable interface that is either adaptable or can be swapped for one of a series of modular designs.

Emotional engineering of artificial sign languages offers both a special purpose solution and a mass purpose approach. Its user-aware focus provides a system purely for the Deaf community whose main mode of communication is BSL, and its linguistic design focus is on the constructs of the language itself. Its mass purpose application does not follow the linguistic representation of BSL but rather the symbolic translation of the linguistic understanding of BSL focus systems. This makes it accessible not only for the Deaf community but also, because of its visual style, it allows access to a wider audience such

as those who are of foreign language or low literacy groups and need to be accommodated differently.

The approaches outlined so far look very clearly at the impairment and possible design solutions, however with the Deaf community (and very possibly with some other communities) design must take other cultural, social and political factors into account. That is, many Deaf people do not see themselves as disabled, but rather as a member of a cultural and linguistic minority and as such, are empowered differently. Their uniqueness is seen as a politically strong identity rather than as an impairment in mainstream population.

8.1.1 How does the Deaf Community feel about the Digitisation of Sign Language

The preservation of sign language has been a primary issue for the Deaf community. It was felt that owing to the Milan Conference of 1880, sign language was almost lost. Therefore the conservation of the language for the community has become a very important concern, Deaf culture and its language heritage is strongly promoted. Therefore carrying this language into a domain unfamiliar to its visual, natural and sometimes tactile style is a very delicate issue, one which needs to be handled with care. The Deaf community strongly defends the language and does not wish to see it diluted in any form, therefore the objections towards digitised signing and why they are being made need to be understood and addressed in order to ensure the promotion and usability of future systems. It would be useful and interesting to hold an open discussion about the digitisation of sign language, and what the community feels about this issue. This may highlight several issues that need to be taken into consideration for future system design.

8.1.2 Marginalisation of Deaf Society from Mainstream Culture, Communication and Education

The hearing community is attempting to address the needs of a portion of society often marginalised from mainstream culture, communication and education. However as it is in its early stages, the parameters in which they should be developing systems needs to be understood in greater depth. This vague approach to developing digital representations of sign language for the d/Deaf community is not and will not encompass mainstream life in the foreseeable future unless drastic changes are made to the approach of technological development in consultation with the d/Deaf community.

System developers need to stop thinking from a writing perspective and start thinking from a seeing perspective. An example of such an approach is a system that was made to assist d/Deaf education, named MAGPie [for Accessibly Media NCAM, 2003]. The students have classroom activities where they learn some historical information and then

write a report or statement from the perspective of those historical figures that they have been taught about. The activity aims to develop historical understanding of society and English writing skills. Traditionally children either read or watch a video and then perform the classroom activity. The MAGPie software shows students the video sequence, and allows them to go back and forth through the sequence to add notes and other textual information, almost like making notes in a hand held book. The system was tried and tested and the developers received promising results. The students wrote more in this style of teaching as opposed to the traditional approach; they also found some students wanted to write more but ran out of time. The writing produced by the students was creative and used much factual information that was gathered from the video sequence. Tutors noted that previously the students missed many facts from the video presentation, but with MAGPie they were able to recall and write them down, mainly because they had a point of reference and could go back to it. The instructors generally noticed an improvement in students' writing abilities, self-confidence and motivation to write more.

The system's strong visual approach helped connect to the students, whose language is visually based, and therefore assisted in the classroom activity. As a hearing community we have a tendency to approach most concepts in different cultures with the same approach as we are used to. This however can work for most auditory-based language communities but since this is a visual-based community, it needs to be addressed visually. This simple but effective system allows students to view this visual information and edit through video as opposed to working in textual format, which is readily available for the hearing community. With hearing people the understanding of language is a lot clearer; when reading a book you can go back and forth in order to make notes. We slowly and bit by bit develop a deeper understanding of the subject. This is a well-used and traditional learning approach, where small chunks of information are learnt, re-worked and absorbed. One might provide d/Deaf students with large amounts of visual information and expect them to process it; but it can become too heavy to digest. So just as we read through and make notes in a book, Deaf people need such an option in a visual medium, which allows for ease of absorption. Over time we have learnt that more effective learning approaches are through reading smaller amounts of data, understanding that data, processing it and then developing our own thoughts and work from that data. This basic educational approach when applied to the d/Deaf community needs to be more visually oriented. This is not to suggest that d/Deaf and HOH people cannot use text books and read, but it is to note that approaching education in the first and natural language of the d/Deaf and HOH community will allow for faster and more improved rates of learning and educational development. Simply providing visual presentations of information is not enough; it needs to be taken further and considered together with manageability of information, so that users can manipulate the rate and flow of information being received. This is not unfamiliar to the hearing community; we simply apply this principle to how we manipulate auditory data. We control sound, volume, speech. With reading too, we all have an individual pace and style of reading with which we are comfortable. This step and further understanding

of manageability of information can help link technological development with the needs of the d/Deaf community.

The visual concept of signing needs to be translated into the digital domain, and needs to be thought about not only from a practical perspective but from a communication perspective. Although English is rich, it is two-dimensional in the way in which it is written, in that it has an ordered and sequential approach, we can systematically read through text and understand it clearly, information is systematically delivered. Sign language is three-dimensional, one movement can encompass several pieces of information. As sign language communication is visually oriented, communication is faster and each movement can explain several words of a sentence in a combination of movements. The language may look simple, but it is more comprehensive in how it delivers information. For example a sentence such as “The plane moves rapidly through the air, crashing towards the ground”, in sign a signer would use the handshape of a plane, starting high and rapidly moving down, across the front of the signer. The signer will also use lip movement and facial expression in order to convey its speed. The hand would move fast to demonstrate the swiftness of what is happening. This would take less time than reading the sentence above. The three-dimensional nature of sign where several components (the hand, arms, body, face and lip movement) are used simultaneously convey information clearly and fast, whereas in English text, this would be described in several ways with the use of several words. This transfer of 3D to 2D is not clearly understood. Sign language is a complex and layered language, which simultaneously uses several moving parts, whereas English uses several words to make a lengthy sentence which explains only linearly and sequentially what is happening.

When learning sign language, the origins of the words are easily understood and therefore easily recalled, this could partly be linked to our natural ability to visually connect information, this is also evident in our non-auditory communication such as body language and facial expression. Now that the World Wide Web (WWW) can support several types of media, such as video, imagery and animation, the exploration into signing and how it can be visually supported on the digital domain has brought about several attempts for visual communication support via the Internet. However its effectiveness is questionable, on the basis that the community this media is supposed to support is still separated in its view towards digital representations of sign language and its needs are not considered in the process of digitisation itself.

In political terms, the situation at issue can be framed as follows: the majority of the population is hearing, and has imposed its methods and techniques of communication and lifestyle on the minority. However the minority (in this case the d/Deaf and HOH community) either accepts the majority’s standards (the hearing community), which results in forcing a method of learning which is unnatural to the d/Deaf and HOH or the community revolts and stands against the mainstream. The d/Deaf and HOH community feel that the current standards provided by mainstream society need to be improved and

tailored to the needs of the target group. We know this because the community remains divided over several issues such as facilities, communication support and acceptance in mainstream society. This division is reflected in all facets of the community, especially in the language. There are oralists and there are signer's, and they both have strong views about communication, acceptance and if they are or are not conforming to society. There are several documents, articles and forum discussions surrounding the subject.

Technologists that are catering for the Deaf community are aiming to provide sign language support to individuals who are predominantly Deaf with a capital D, and whose first language is not English, and need communication support on the WWW. Technologists need to return to their visual understanding of their environment where the representation of a concept is more closely related to it's actual form. This needs to be conveyed in technology and will help accelerate acceptance of digital representations of sign language by its d/Deaf audience.

8.2 Principles of Design

The previous chapters have outlined and explained the studies, findings and emotional engineering proposed for effective system design for the Deaf community. However the rules are not enough to completely understand and support systems development with the Deaf community. The following design principles have been developed through the experience of this research and will assist technologists when approaching this field of work. They are listed as follows:

1. When designing an information system for the Deaf, start with the details around the face first as these are regarded as highly emotional and important to communication with Deaf people.
2. Ensure that all five rules are used as this will allow for higher levels of acceptance of information system. An interesting aspect of BSL grammar is multi-channel signs; these are special signs where both manual (i.e. using your hands) and non-manual (e.g. facial expressions, lip patterns etc) actions are combined to form a single sign.
3. These rules can be used to assess an existing DRSL, in order to identify essential language criteria for effective communication. This can also provide a basis for a more focused design strategy to improve the identified areas. Please note that when evaluating a system for missing rules, always assess the rule against all five rules. They are heavily linked and are dependent on each other for clear communication.
4. When designing an information system for the Deaf community, it is advised to provide an actual signing solution that meets the linguistic criteria outlined in the emotional engineering of artificial sign languages. However if this is not possible

due to platform constraints, it is advised to use the symbolic rules for translation. Platform constraints can include an image or information paper based handout which does not have the capability to provide a clear signing solution.

5. The symbolic method of design rules can also be used to add additional information support in the linguistic method of design.
6. Keep the design theme consistent, e.g. colour schemes, signer's, symbols, icons etc.
7. When designing a system, always view the information in it's constituent parts and not as a whole, deal with each constituent one at a time as this will be easier to manage. One does then need to consider the whole system with a complete overview.
8. Always translate information into the signer's English and observe the signer to identify the areas of emotion in the sentence and which words carry the most emotional information, as this will need to be present in the system to appeal and work with a wider Deaf audience.
9. Have Deaf people involved through all the stages, especially at the beginning. The individuals involved will be aware of the system and may inform the community and can provide their feedback as it is developed at each stage.
10. A highly complex system does not mean it has high levels of emotional representation within it e.g. road signs are information systems that are simple and very clear to understand.
11. Images and/or Signing work better than text.
12. Do not make the interface too busy, keep it simple, clear and well connected to different concepts being presented in the information, through colour schemes and layout.
13. The marketing of the final system needs to be in an assistive stance and not a replacement for the communities' language needs.
14. High linguistic or symbolic emotional representation can create a positive user experience.
15. Low linguistic or symbolic emotional representation can create a negative user experience.

The above empirically derived principles need to be kept under review and periodically re-assessed using a representative sample of the target populations. The above rules further assist in acknowledging the vast area of user interface design for special interest groups, with particular focus on design strategies for populations with particular disability issues or more so specific communication needs. This has also helped in providing an understanding of where this research fits, with the overall approach and this very focused

user-led approach to system design. The research experience highlights issues around the marginalisation of the Deaf community and its fight for the preservation of sign language in the structure of BSL and how to translate this into the digital domain. Understanding this complex dynamic can assist not only in designing for this community but also in approaching this community to participate in the future development of DRSLs. Design principles have been introduced to further assist the information systems development within this community and to further assist technologists on understanding the more particular needs of Deaf people. The summary of the emotional engineering rules, system development steps, architectural model and principles of design can be found in appendix E.

8.3 A Summary of Research Contributions

The summary of research contributions, future directions of work and research conclusions will be elaborated in the following sections. This concludes this dissertation by summarising the research contributions made, indicating possible future directions for extending this research and highlighting conclusions that may be drawn from the approach taken to the Emotional Engineering of Artificial Sign Languages.

The major contribution is the Emotional Engineering of Artificial Sign Languages within the information system domain. This approach has been developed by a novel way of comparing and understanding existing systems in order to identify the ultimate elements of a complete user-led design process that incorporates the necessary characteristics of the language needs of the Deaf community. This highly focused thesis looks purely at the relationship between the user and the end-product, and this aims to provide a design cycle that will encourage higher acceptance of the final information system.

8.3.1 Motivation Revisited

The initial motivation outlined in the introduction chapter examined the notion of research into digital representations of sign languages (DRSLs) and was motivated by the need (both scientific and commercial) to increase the effectiveness of DRSLs as a platform for information delivery within the digital domain for users who have different information goals and histories. From this standpoint the first approach was to work on a well accepted form of a DRSL, however through research it was found that there was no universally accepted form of DRSL, but varied opinions about different systems that have been proposed as a means to communicate with Deaf people. It became apparent that there was a divided opinion around what makes an effective information system for the Deaf, where the technologists kept creating and the Deaf community kept a reserved view about the potential progress of such systems within Deaf communication.

8.3.2 Challenges Revisited

The challenge in this research was not so much to create a DRSL information delivery platform, but to go further back in the creation process and understand, what is the essential characteristic that will allow a system to be accepted by the Deaf/HOH community?

It became apparent that a consensus on what constitutes an agreeable system needed to be created through empirical research with the intended user group. Therefore a user-led investigation was conducted, to comparatively evaluate the effectiveness of information delivery by recognised forms of DRSLs. It was found that it was not necessarily the DRSL that was effective but more so the characteristics within that DRSL that determined its level of acceptance by the Deaf community

These characteristics then formed the basis of the Emotional Engineering of Artificial Sign Languages and became the criteria that systems need to reach in order to ensure higher levels of user approval by the target audience.

8.3.3 Summary of Contributions

Through this research it was realised that not only was there limited understanding about the DRSL movement within and for the Deaf community, but also there was limited understanding about research design approaches for the Deaf community. In chapter 3 there is an experimental design approach that aims for comfortable participation of Deaf people who have limited literacy skills but also to assist in obtaining accurate end-user feedback. The next major contribution was the comparative study in chapter 4. The research findings assisted in developing and moulding the design rules presented in chapter 6 which formed the main contribution of this thesis. From these findings it could be said that irrespective of the final output, if particular characteristics are clearly presented in an information system that clear delivery of information is still possible. To conclude and validate the findings further an investigation was conducted in chapter 7 which supported the work and provided an initial outline of future directions of research. This research has designed a set of heuristics for Deaf people, it has provided a new methodology of systems development and has found that the rules are useful for individuals who are not only Deaf but have different visual learning needs and are from low literacy backgrounds. This research is unique in its approach and has provided an insightful solution to a reoccurring problem of design.

8.4 Application of Research and Future Directions

The following sections will outline future directions of research from this thesis:

8.4.1 Application of Research

This research applies predominantly with the Deaf community, however with the symbolic rules of emotional engineering there is potential scope to use this with other minority special interest language groups, such as application to support low literacy and foreign language individuals. The major emphasis on the design is the need of “emotion” to clarify meaning within communication, such an approach to language could also potentially work with populations of people with autism, where the emotional context of language is not always understood, this could provide an insightful area for future directions of research.

8.4.2 Applicability to other Sign Languages

It would be of particular interest to assess whether these rules could be adapted to apply to other sign languages for a more universal design strategy, however the question arises, as to whether by taking such an approach would it dilute the strength of this current system for British Sign Language users.

8.4.3 Originality, Impact and Timeliness of the Research

The methodological procedure presented helps isolate the key factors that establish why users may prefer one DRSL over another in different information contexts. The system design methodology that is proposed helps to identify such characteristics when designing and implementing future systems. This is both novel in its approach and unique in its opportunities.

For sign language systems to be deployed in several environments, it is important to understand success rates and estimate the potential for possible systems, while still in design mode. This will inevitably reduce cost factors, such as time, money and work-force allocation. Hopefully this will encourage a wider acceptance of such technology. These findings will be made available to research and commercial institutes in order to assist in building future sign language systems [Ohene-Djan et al., 2003, Naqvi et al., 2005, Naqvi, 2006, Naqvi et al., 2006, Spiegel et al., 2007, Naqvi, 2007a, Ali et al., 2007, Ali and Naqvi, 2008, Naqvi, 2008].

8.4.4 Relevance to Beneficiaries

The key beneficiaries of the research will be academic and commercial organisations that wish to understand their target audience better. This research will give a system design methodology to deaf technologists who wish to develop new systems for deaf users. This will allow for a closer understanding of the market, and therefore higher levels of acceptance

of systems that are being developed.

The most obvious beneficiaries will be the d/Deaf community, as such research could influence organisations and companies to understand the market better. Commercial applications of such research is vast, and will allow d/Deaf users to find something more satisfactory on the assistive technology front, hopefully attempting to bridge the gap between the hearing and d/Deaf with more acceptable communication technology.

Such research can allow technologists to understand how DRSLs could be designed for varied contexts, such as train stations to news channels. Schools could benefit from such research, as this could aid in the communication between teachers and students, leading to better support and learning environments in classrooms. Hospitals could benefit from such research as they can help disseminate more vital health information easily to the d/Deaf individuals whose first and dominant language is sign. With general ease of communication by improving sign language facilities, d/Deaf individuals can benefit and can contribute more affectively to the common good.

Non-commercial applications for this research include E-learning, chat-room applications, emailing a friend a message which is digitally signed, can prove to be an interesting area of research, and many other Internet resources could be tailored to the d/Deaf more appropriately.

8.5 A Summary of Research Conclusions

This research has a primary application for the Deaf community in how information system development is undertaken. The thesis presents an initial standpoint of how to examine the complex language structures from the technologist's perspective, the community's perspective of what makes sign language essentially work and the overall impact of developing systems in a community whose history is based around the pride, use and preservation of its language. It is important to identify the need for this community to be involved within the technology domain, and to avoid providing solutions that have had limited contribution from the community and are more focused on Deafness as an impairment than opposed to a recognised language in its own right. It is vital that when technologists approach working with this target population that an understanding of the language structure and deaf awareness should be sought.

It is hoped this research presents an alternative angle and approach to understanding a community that is in large part isolated from mainstream information dissemination in a format that is not always agreeable for clear comprehension and that the native language needs of the Deaf have not been aptly accommodated. If they were, it would not only provide an information learning system for the Deaf but the symbolic representation can potentially work with a wider range of audiences.

There is a need to support the community's transition to widespread access of information via information systems but technologists need to consider not just the technical solutions available but also the cultural and social factors involved when working with minority groups.

Appendix A

Experimental Research Design for the Deaf

This appendix contains a framework for understanding the visual language needs of Deaf participants in research, alongside rules for assisting such documentation development.

The following sections will show the framework, the visual translation rules and examples of how to implement these rules for reference purposes (presented in more detail in chapter 3).

A.1 Framework and Experimental Document Design Rules

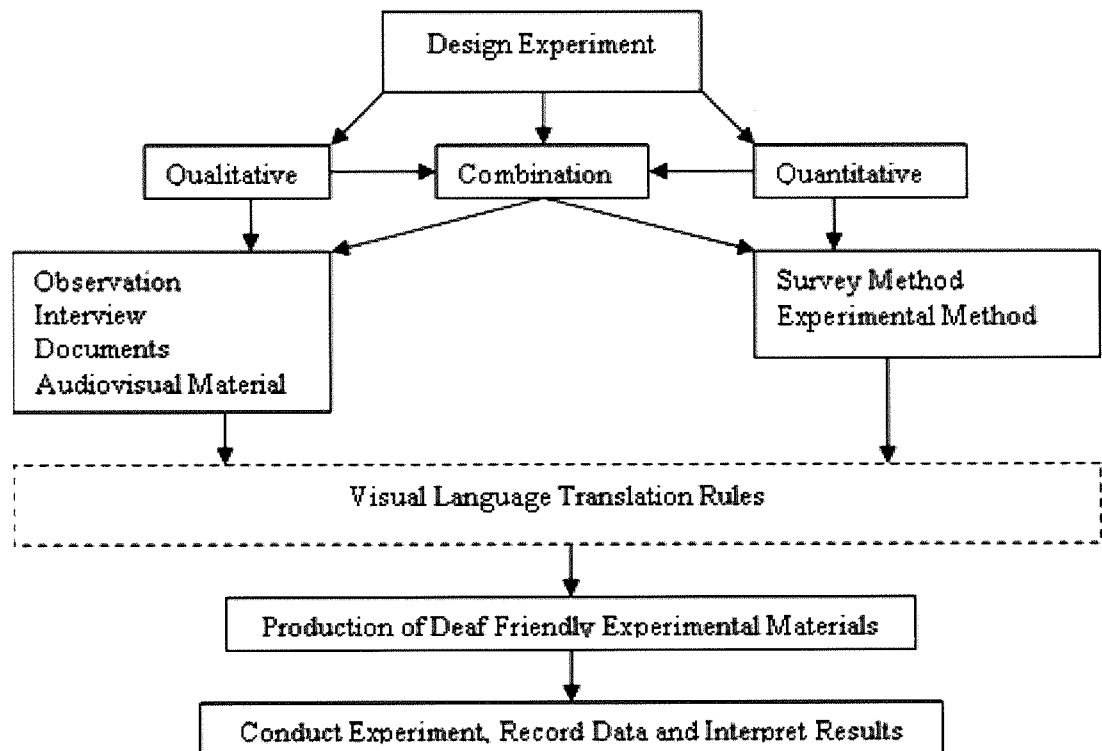


Figure A.1: Framework of Experimental Design for the Deaf

This framework presents the Visual Language Translation Rules which provide the basis of changing textual documents to a Deaf-friendly design. The rules for allowing greater

information access to the Deaf in experimental conditions involves the importance of addressing interpretational needs of the deaf in textual documents and not only in sign language. Consideration must be given to visually connecting textual information to several concepts in order to improve the clarity of any given investigation topic. It is important to note that interpreters should always be provided in experimental conditions.

A.2 Visual Language Translation Rules

The following rules were identified and developed by three Deaf professionals for the use of textual translation, these rules are given with explanation. Many of these could, at least in spirit, be sensible guidelines for communicators and for those who program communications to use in compiling presentations for almost any population.

1. Use pictorial associations in sentences, so that users can connect various subjects and concepts together easily.
2. Instead of explaining instructions it is better to demonstrate them; for example, use role play between the experimenter and interpreter so that it is clear what is expected from the participant if they wish to participate in the experiment. If the experiment is looking at behavioural exercises this can become more complicated as it is important not to influence behavior, therefore keep instructions brief and simple.
3. When using scales (such as Likert, or yes/no options) use images to explain potential answers.
4. Aim to keep a concept on one page, do not separate it over several pages, or if the concept is too large, clearly break it down with leading connections between the different pages.
5. Do not overload the page with textual information as this can become difficult to look at and absorb, it is advised to keep text well spaced and limited.
6. Use sign English (in the UK that would be BSL English) or plain English as it is easier to understand. Simplify English but do not make it dry or patronising.
7. Avoid repeating questions in different word orders, when translated into a sign language it often looks like repetitive information, which either confuses or irritates participants
8. Try to keep layout of questions and information simple and self-contained. So that when participants are answering a question to a particular subject, they are able to view and answer the questions at the same time.

9. If the participant is no longer allowed to see the subject matter in question, take a snap shot of the subject in order to provide some visual association and place it besides the question.
10. Break questions down, do not ask multiple questions in one: rather break a question down to its constituent parts so that participants can understand each point clearly and answer each point clearly.

Appendix B

Final Design of Investigation: Comparative Evaluation of Digital Representations of Sign Language for Different Information Delivery Contexts

This appendix contains the final design of the experiment in chapter 4, and is as follows:

B.1 Experimental Methodology

The participants were given a form to complete, which gathered all the same information but included details about their understanding of BSL and asked if they had completed levels one, two or three. If they had completed BSL linguistics and grammar courses, they were asked how long they have been using BSL for and if they saw themselves as fluent BSL users.

Participants were then shown presentations of real-time and static animation, notation and video sequences, and were then asked to rate each presentation. The DRSLs showed two sets of information, one was about trains and the other was about meetings at an office.

B.2 Hypothesis

The type of digital representation of sign language (i.e. avatar, video and notation systems) used in different information contexts (i.e. static, real-time) determines higher acceptance rates of the systems and ultimately the efficiency and effectiveness of the information delivery. The aim was to test the hypothesis that there is a difference in the perception of DRSL in different information delivery contexts.

B.3 Sampling

All organisations, schools, education centers and professional bodies working with Deaf adults were contacted to ask for participation in the research. In addition to this others who were not part of such organisations but were interested in the work contacted myself. A list was formed of all the potential participants, of which fifty people were randomly selected. Twenty-three agreed to participate and on the days of the experiments three participants were unable to attend. Bringing the total sample size to twenty.

The participants demonstrated the London regional dialect of British Sign Language (BSL). Therefore sampling took place in and around the London (UK) area and the target population were adults. In order to understand what the deaf community thinks of the systems, BSL and SSE users were invited for participation in this research. The participants selected were deaf and hard of hearing(HOH).

This initial sample size is considered to be large enough to give statistically significant results, however if, subsequently, there was no significant difference in results obtained then the experiment will be repeated with an increased sample size.

B.4 Incentives and Procedures

Each participant had been offered reimbursement for travel if needed. The following steps were implemented:

The following steps were implemented:

1. Introduction: The participants were called in one at a time and given general information, including clarification that the experiment was not a test of any kind, but simply a comparison of different DRSLs that are currently available. Respondents were assured this was an independent study using different technologies. They were also informed that they may stop the experiment at any time, and that if they wished they may remain anonymous in this research. Before the participants proceeded they were asked their age, gender and contact information.
2. Familiarization: The experiment was explained to the participants, who then filled in a questionnaire on some basic details before the sample sequences were shown.
3. Presentation: Participants were shown three presentations that fitted the two information contexts. Each information context showed three DRSLs (video, avatar, and notation). Each DRSL sequence was screened as many times as needed, until the participant was ready to evaluate the presentation. The presentations were shown in different orders to avoid primacy effects.

4. Information gathering: Each participant was asked questions regarding the presentations they saw. They were asked if they understood what was said, and how they rated the presentation. After seeing all three DRSLs for a particular information context the participants were asked what they thought of the three presentations, and rate them. After all the demonstrations, participants were asked to fill in another questionnaire which examined the participants personality types. Finally they were asked questions regarding their views and how they feel about such digitisation of sign language.
5. Question and Answers: At the end of the session, participants were given the opportunity to ask questions. They were also asked if they had seen these systems before, where and what they thought about them.

B.5 Data Collection Method Used

The participants were given a form to complete which gathered information such as age, gender and contact information, if they are deaf or hard of hearing and whether they regard themselves as culturally Deaf or deaf. Other questions included their primary mode of communication, and other demographic information. They then saw various presentations of static, real-time and combination presentations which were evaluated. The experiment finished with a personality questionnaire and a question and answer session. The participant group will also partake in some sub studies in which they will be presented with different combinations of DRSLs in order to evaluate their effectiveness in sign language delivery. They then saw various presentations which they individually rated. At the end of the session they were interviewed and asked to complete a personality questionnaire.

When people viewed the presentations they were asked to rate the systems individually and instead of ranking them against each other. This is because if a user liked more than one presentation the same amount, and they had to choose, they may arbitrarily have chosen one system over the other, therefore giving inaccurate results. Also the actual ratings represent important information which should not be lost, as this can provide organisations, researchers and technologists with choices and alternatives in designing systems.

The experiment examined acceptability in terms of how much users liked a particular system in terms of its speed and accuracy measures. It will be useful to understand if the presentations given are acceptable for the target audience and what the threshold for inaccuracy is.

The experiment aimed to investigate how much people really understand over how much people perceive to understand and to use this information to determine if the system meets some acceptability standard. The data was collected with questionnaires and interviews.

B.6 Materials

The user was presented with two information category presentations, these information categories are:

1. Static: this is information that is standard and not often changed, such as a user manual, regular train times and a food recipe.
2. Real-time: this type of information is subject to change, such as a news or weather report, bus delays and traffic updates.

The presentations within these categories are

1. Static:
 - (a) Avatar: Pre-recorded sequence, which played an avatar clip.
 - (b) Video: Pre-recorded sequence, which played a streaming video clip.
 - (c) Notation: Pre-recorded sequence, which displayed pre-arranged notation graphics.
2. Real-time:
 - (a) Avatar: which played from the software.
 - (b) Video: a series of video clips concatenated together.
 - (c) Notation: a set of graphics presented on demand.

Appendix C

Detailed Descriptions of the ANOVAs and *t*-tests Conducted on the Static and Real-time Presentations of the Artificial Representations of Sign Language

This appendix contains the detailed data descriptions of the ANOVAs and *t*-tests conducted on the three systems (animation, video and notation), where the summary of that data was presented in table 4.8 and table 4.9. This is provided as an alternative for the reader who wishes to view the statistics in a more descriptive form.

The following sections will examine inferential statistics from the data found in the study. A one-way ANOVA was conducted to test the differences between the three independent groups (Video, Animation and Notation). Further *t*-tests were conducted between the groups to test if there was a difference within pairs of the groups. Further detail can be found in chapter 4.

C.0.1 Levels of Acceptability in Video, Animation and Notation in Static Mode

The one-way ANOVA test for the three different groups, checking the systems' level of acceptability in the static information delivery style, showed a significance level of 0.000 (i.e., $p < 0.001$). Therefore further post hoc analysis was conducted in the form of three *t*-tests. Significance in difference between particular presentations was present. Notation (mean 4.2) and video (mean 2.1) where $p = 0.000$, and also with animation (mean 3.5) and video (mean 2.0) where $p = 0.000$. Note that the difference between notation and animation is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.0), secondly - animation (mean 3.5) and thirdly - notation (mean 4.2), but where the difference between the last two was not statistically significant.

C.0.2 Levels of Acceptability in Video, Animation and Notation in Real-time Mode

The one-way ANOVA test for the three different groups, checking the systems' level of acceptability in the real-time information delivery style, showed a significance level of 0.000. Therefore further post hoc analysis was conducted in the form of three t-test. Significance in difference between particular presentations was present. Notation (mean 4.1) and video (mean 2.0) where $p = 0.000$, and also with animation (mean 3.8) and video (mean 2.0) where $p = 0.000$. Note that the difference between notation and animation is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.0), secondly - animation (mean 3.8) and thirdly - notation (mean 4.1).

C.0.3 Levels of Usability in Video, Animation and Notation in Static Mode

The one-way ANOVA test for the three different groups, checking the systems' level of usability in the static information delivery style, showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.0) and animation (mean 3.0) where $p = 0.006$, and also with notation (mean 4.0) and video (mean 2.0) where $p = 0.000$. Finally with animation (mean 3.0) and video (mean 2.0) $p = 0.009$. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.0), secondly - animation (mean 3.0) and thirdly - notation (mean 4.0).

C.0.4 Levels of Usability in Video, Animation and Notation in Real-time Mode

The one-way ANOVA test for the three different groups, checking the systems' level of acceptability in the real-time information delivery style, showed a significance level of 0.000 (table in appendices 4). Therefore further post hoc analysis was conducted in the form of three t-test. Significance in difference between particular presentations was present. Notation (mean 4.1) and video (mean 2.0) where $p = 0.000$, and also with animation (mean 3.8) and video (mean 2.0) where $p = 0.000$. Note that the difference between notation and animation is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.0), secondly - animation (mean 3.8) and thirdly - notation (mean 4.1).

C.0.5 Levels of Likeability in Video, Animation and Notation in Static Mode

The one-way ANOVA test for the three different groups, checking the systems' level of likeability in the static information delivery style, showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.2) and animation (mean 3.8) where $p = 0.085$, and also with notation (mean 4.2) and video (mean 2.0) where $p = 0.000$. Finally with animation (mean 3.8) and video (mean 2.0) where $p = 0.000$. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.0), secondly - animation (mean 3.8) and thirdly - notation (mean 4.2).

C.0.6 Levels of Likeability in Video, Animation and Notation in Real-time Mode

The one-way ANOVA test for the three different groups, checking the systems' level of likability in the real-time information delivery style, showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.3) and animation (mean 3.4) where $p = 0.003$, and also with notation (mean 4.3) and video (mean 2.5) where $p = 0.000$. Finally with animation (mean 3.4) and video (mean 2.5) where $p = 0.004$. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.5), secondly - animation (mean 3.4) and thirdly - notation (mean 4.3).

C.0.7 Levels of Comprehension in Video, Animation and Notation in Static Mode

The one-way ANOVA test for the three different groups, checking the systems' level of comprehension in the static information delivery style, showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.3) and video (mean 2.1) where $p = 0.000$, and also with animation (mean 3.9) and video (mean 2.1) where $p = 0.000$. Note that the difference between notation and animation is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.1), secondly - animation (mean 3.9) and thirdly - notation (mean 4.3).

C.0.8 Levels of Comprehension in Video, Animation and Notation in Real-time Mode

The one-way ANOVA test for the three different groups, checking the systems' level of comprehension in the real-time information delivery style, showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.3) and animation (mean 3.4) where $p = 0.003$, and also with notation (mean 4.3) and video (mean 2.3) where $p = 0.000$. Finally animation (mean 3.4) and video (mean 2.3) where $p = 0.001$. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.3), secondly - animation (mean 3.4) and thirdly - notation (mean 4.3).

C.0.9 Levels of Linguistics in Video, Animation and Notation in Static Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistics overall in the static information delivery style, showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.2) and video (mean 2.0) where $p = 0.000$, and also with animation (mean 3.5) and video (mean 2.0) where $p = 0.000$. Note that the difference between notation and animation is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.0), secondly - animation (mean 3.5) and thirdly - notation (mean 4.2).

C.0.10 Levels of Linguistics in Video, Animation and Notation in Real-time Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistics overall in the real-time information delivery style, showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.3) and animation (mean 3.4) where $p = 0.003$, and also with notation (mean 4.3) and video (mean 2.3) where $p = 0.000$. Finally animation (mean 3.4) and video (mean 2.4) where $p = 0.001$. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.3), secondly - animation (mean 3.4) and thirdly - notation (mean 4.3).

C.0.11 Levels of Linguistic Rating with Handshapes in Video, Animation and Notation in Static Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistic capability, were broken down to further categories. The hand shape rating in real-time information delivery style, showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.0) and video (mean 1.9) where $p = 0.000$, and also with animation (mean 3.8) and video (mean 1.9) where $p = 0.000$. Note that the difference between notation and animation is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 1.9), secondly - animation (mean 3.8) and thirdly - notation (mean 4.0).

C.0.12 Levels of Linguistic Rating with Handshapes in Video, Animation and Notation in Real-time Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistic capability, were broken down to further categories. The hand shape rating in static information delivery style showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.3) and video (mean 1.9) where $p = 0.000$, and also with animation (mean 3.2) and video (mean 1.9) where $p = 0.000$. Note that the difference between notation and animation is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 1.9), secondly - animation (mean 3.2) and thirdly - notation (mean 4.3).

C.0.13 Levels of Linguistic Rating with Morphology in Video, Animation and Notation in Static Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistic capability, were broken down to further categories. The morphology rating in static information delivery style showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.0) and video (mean 1.9) where $p = 0.000$, and also with animation (mean 3.6) and video (mean 1.9) where $p = 0.000$. Note that the difference between notation and animation is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 1.9), secondly - animation (mean 3.6) and

thirdly - notation (mean 4.0).

C.0.14 Levels of Linguistic Rating with Morphology in Video, Animation and Notation in Real-time Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistic capability, were broken down to further categories. The morphology rating in real-time information delivery style showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.2) and video (mean 2.1) where $p = 0.000$, and also with animation (mean 3.4) and video (mean 2.2) where $p = 0.000$. Note that the difference between notation and animation is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.2), secondly - animation (mean 3.4) and thirdly - notation (mean 4.2).

C.0.15 Levels of Linguistic Rating with the Distance of the Arm from the Body in Video, Animation and Notation in Static Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistic capability, were broken down to further categories. The distance of the arm from the body rating in static information delivery style showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.3) and video (mean 2.1) where $p = 0.000$, and also with animation (mean 3.3) and video (mean 2.1) where $p = 0.000$. Note that the difference between notation and animation is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.1), secondly - animation (mean 3.3) and thirdly - notation (mean 4.3).

C.0.16 Levels of Linguistic Rating with the Distance of the Arm from the Body in Video, Animation and Notation in Real-time Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistic capability, were broken down to further categories. The distance of the arm from the body rating in real-time information delivery style showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.3) and video (mean 2.1) where $p = 0.002$, and also with animation (mean 3.2) and video (mean 2.4) where $p = 0.000$. Note that the difference between notation

and animation is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.4), secondly - animation (mean 3.2) and thirdly - notation (mean 4.3).

C.0.17 Levels of Linguistic Rating with Lip Movement in Video, Animation and Notation in Static Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistic capability, were broken down to further categories. The lip movement rating in static information delivery style showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.4) and video (mean 2.2) where $p = 0.000$, and also with animation (mean 4.0) and video (mean 2.2) where $p = 0.000$. Note that the difference between notation and animation is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.2), secondly - animation (mean 4.0) and thirdly - notation (mean 4.4).

C.0.18 Levels of Linguistic Rating with Lip Movement in Video, Animation and Notation in Real-time Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistic capability, were broken down to further categories. The lip movement rating in real-time information delivery style showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.4) and video (mean 2.7) where $p = 0.000$, and also with animation (mean 4.3) and video (mean 2.7) where $p = 0.000$. Note that the difference between notation and animation is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.6), secondly - animation (mean 4.3) and thirdly - notation (mean 4.4).

C.0.19 Levels of Linguistic Rating with Facial Expression in Video, Animation and Notation in Static Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistic capability, were broken down to further categories. The facial expression rating in static information delivery style showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean

4.5) and video (mean 1.9) where $p = 0.000$, and also with animation (mean 4.1) and video (mean 1.9) where $p = 0.000$. Note that the difference between notation and animation is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 1.9), secondly - animation (mean 4.1) and thirdly - notation (mean 4.5).

C.0.20 Levels of Linguistic Rating with Facial Expression in Video, Animation and Notation in Real-time Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistic capability, were broken down to further categories. The facial expression rating in real-time information delivery style showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.21) and video (mean 2.2) where $p = 0.000$, and also with animation (mean 4.15) and video (mean 2.3) where $p = 0.000$. Note that the difference between notation and animation is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.25), secondly - animation (mean 4.15) and thirdly - notation (mean 4.21).

C.0.21 Levels of Linguistic Rating with the Correct Sentence BSL Structure in Video, Animation and Notation in Static Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistic capability, were broken down to further categories. The correct sentence BSL structure rating in static information delivery style showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 2.9) and animation (mean 3.1) where $p = 0.007$, and also with notation (mean 3.9) and video (mean 2.1) where $p = 0.000$. Finally with animation (mean 3.2) and video (mean 2.1) where $p = 0.001$. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.1), secondly - animation (mean 3.25) and thirdly - notation (mean 3.9).

C.0.22 Levels of Linguistic Rating with the Correct Sentence BSL Structure in Video, Animation and Notation in Real-time Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistic capability, were broken down to further categories. The correct sentence BSL structure

rating in real-time information delivery style showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.3) and animation (mean 3) where $p = 0.002$, and also with animation (mean 4.2) and video (mean 2.2) where $p = 0.000$. Note that the difference between notation and video is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means average = 2.2), secondly - animation (mean average 3.6) and thirdly - notation (mean 4.3).

C.0.23 Levels of Linguistic Rating with the Correct Placement in Video, Animation and Notation in Static Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistic capability, were broken down to further categories. The correct placement in static information delivery style showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.1) and animation (mean 3.2) where $p = 0.006$, and also with notation (mean 4.1) and video (mean 2.2) where $p = 0.000$. Finally with animation (mean 3.5) and video (mean 2.1) where $p = 0.000$. By observing the means we can determine the order of preference of the systems, firstly - video (means 2.2), secondly - animation (mean average 3.5) and thirdly - notation (mean 4.1).

C.0.24 Levels of Linguistic Rating with the Correct Placement in Video, Animation and Notation in Real-time Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistic capability, were broken down to further categories. The correct placement in real-time information delivery style showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.2) and animation (mean 3.0) where $p = 0.001$, and also with notation (mean 4.2) and video (mean 2.3) where $p = 0.000$. Finally with animation (mean 3.0) and video (mean 2.4) where $p = 0.079$. By observing the means we can determine the order of preference of the systems, firstly - video (means 2.3), secondly - animation (mean 3.0) and thirdly - notation (mean 4.2).

C.0.25 Levels of Linguistic Rating with the Correct Signing Context in Video, Animation and Notation in Static Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistic capability, were broken down to further categories. The correct signing context in static information delivery style showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.0) and animation (mean 3.0) where $p = 0.002$, and also with notation (mean 4.0) and video (mean 1.9) where $p = 0.000$. Note that the difference between notation and video is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means 1.9), secondly - animation (mean 3.0) and thirdly - notation (mean 4.0).

C.0.26 Levels of Linguistic Rating with the Correct Signing Context in Video, Animation and Notation in Real-time Mode

The one-way ANOVA test for the three different groups, checking the systems' linguistic capability were broken down to further categories. The correct signing context in real-time information delivery style showed a significance level of 0.000. Therefore a further three t-tests were done to check what is happening between the different sets of data. It was found that there was significance in difference between the presentations. Notation (mean 4.2) and animation (mean 3.0) where $p = 0.002$, and also with notation (mean 4.2) and video (mean 2.3) where $p = 0.000$. Note that the difference between notation and video is not statistically significant. By observing the means we can determine the order of preference of the systems, firstly - video (means 2.3), secondly - animation (mean 3.0) and thirdly - notation (mean 4.2).

Appendix D

Final Design of Investigation: Establishing the Rules of Emotional Software Design

This appendix contains the final design of the experiment in chapter 5, and is as follows:

D.1 Experimental Methodology

From the investigations it had become apparent which linguistic components received the lowest and highest ratings in the sign language systems that were presented. This provided the basis of support behind the rules for system design. However when designing the rules for systems that communicated with the Deaf, it was important to decide how many rules to have, which rules supported which linguistic results from our previous study, and to establish the order of importance of these rules. Thus a consultation through interviews with the Deaf community was required regarding the design of these rules.

D.2 Hypothesis

Signer's can identify areas of importance in sign language communication as well as the order of what is important in such systems.

D.3 Sampling

Twenty participants were selected. The participants were shown presentations in BSL using its London dialect to match the participants involved in the study. Therefore sampling took place in and around the London (UK) area and the target population were adults. In order to understand what the deaf community thinks of the systems, BSL and SSE users were invited for participation in this research. The participants selected were deaf and hard of hearing(HOH).

All organisations, schools, education centres and professional bodies working with Deaf adults were contacted to ask for participation in the research. In addition to this others who were not part of such organisations but were interested in the work contacted myself. A list was formed of all the potential participants, of which fifty people were randomly selected. Thirty-four agreed to participate and on the days of the experiments fourteen participants were unable to attend. Bringing the total sample size to twenty.

This initial sample size is considered to be large enough to give statistically significant results, however if, subsequently, there was no significant difference in results obtained then the experiment will be repeated with an increased sample size.

D.4 Incentives and Procedure

Each participant was offered reimbursement for travel if needed. The following steps were implemented:

1. Introduction: The participants were called in one at a time and given general information, including clarification that the experiment is not a test of any kind, simply a way to understand in more detail what signer's see as important areas of communication and what holds important information for them in communication. They were informed that they may stop the experiment at any time, and that if they wished they may remain anonymous in this research. Before the participants proceeded they were asked their age, gender and contact information.
2. Familiarisation: They were shown an example of a full image and a face image and were walked through how they can mark the images for areas of communication importance
3. Information gathering: Each participant was shown four full shot images, and four face images and asked:
 - (a) "In order of priority mark the areas of a signer that you watch the most when they sign/communicate"
 - (b) "In order of priority mark the areas of a signer that you watch the most when they sign?"
 - (c) "Can you please circle what parts of the face you think are important for a signer and also an order of preference"
 - (d) "What part holds descriptive information on the face? Please state which movements are used and what you think is expressed by these marked areas?"
 - (e) "Please describe the importance of the torso and what that can represent in British Sign Language"

(f) “The handshape was also marked as important, can you please elaborate why?”

They were provided with an interpreter to allow for clear communication.

4. Question and Answers: At the end of the session, participants were given the opportunity to ask questions. They were also asked if they had seen these systems before, where and what they thought about them.

D.5 Data Collection Methods Used

The participants were given a questionnaire that asked them: “In order of priority mark the areas of a signer that you watch the most when they sign/communicate”. Once this was done, this should highlight different areas of importance to signer’s and also the order of importance. Data was collected on the images, and also notes were made on the respondents’ comments to enhance the understanding of what was found.

D.6 Materials

The user was presented with four images of full shots of people and four images of faces. Each face and full shot of a person was different, showing both front and side angles. The order of presentation was varied to avoid primacy affects.

Appendix E

Linguistic and Symbolic Rules, System Development Steps, Architectural Model and Principles of Design of Emotional Engineering of Artificial Sign Languages

This appendix contains the rules of emotional engineering of artificial sign languages, to assist the reader for ease of reference of materials. This appendices contains the rules, development steps, architectural model and principles of design. Further details of this can be found in chapter chapter 6 and chapter 8.

E.1 Rules

From the investigations it had become apparent which linguistic components received the lowest and highest ratings in the sign language systems that were presented. This provided the basis of support behind the rules for system design. After further consultation with the Deaf community (see chapter 5) the rules have been designed with consideration of the five areas of importance to a Deaf user. This thesis will present linguistic and symbolic rules for emotional system design. Rule one relates to several facets of lip patterns, rule two to facial expressions, rule three to torso, rule four to the hand shape and rule five to the signer's space. In this overall section on rules mentioned, there are corresponding illustrated figures throughout the chapter.

E.1.1 Rule One - Linguistic Emotional Representation in Lip Patterns

When using facial images add clear lip patterns to enhance language meaning, for example:

1. *Rule One: Mouthing Words Linguistically* - Is used to introduce new vocabulary, as some words may not always have particular signs associated with them. Therefore a particular handshape or fingerspelling can have multiple meanings, but alongside lip patterns, a clear meaning can be established.
2. *Rule One: Mimicking Sounds Linguistically* - Lip patterns are used to provide mimicking of sounds to objects/people. This provides a different level of emotional meaning: the sign for phone without lip patterns can simply mean phone, but with mouth patterns of ringing vibrations, means the phone is ringing.
3. *Rule One: Movement of Objects Linguistically* - When signing about the movement of objects, its weight and pressure can be enhanced with lip patterns. For example, when signing without the lip patterns the movement of the object will be signed as a simple movement. However with lip patterns the sign can mean that the object is heavy or light giving the movement a more emotional and contextualised meaning.
4. *Rule One: Characters Linguistically* - When explaining conversations or discussions between more than one person, character shift come into play and is a recognised sign language structure. With character shift different linguistic components in British Sign Language are used, one of them is lip patterns, which as part of facial expression, as they clarify the difference between characters.
5. *Rule One: Questioning Linguistically* - When signing questions, the pronunciation of some questions can start with lip patterns, such as the “wh” in what, where, who, when, why and “ow” in the how
6. *Rule One: Expressing Feeling Linguistically* - The lip patterns are involved in the facial expression of emotions and feelings. This is an essential part of the British Sign Language communication as the emotion provides meaning to the language structure and almost the “intonation” of speech.

E.1.2 Rule One - Symbolic Emotional Representation in Lip Patterns

When you have an image, enhance its language meaning by adding

1. *Rule One: Mouthing Words Symbolically* - New vocabulary/Basic text - add new words to new topics to help with understanding and acquiring new vocabulary. Use alternative colours or fonts to denote a new word. This will provide a key code that viewers can become used to when viewing particular information systems or handouts.
2. *Rule One: Mimicking Sounds Symbolically* - When using objects or people that may be moving or speaking, give visual indications of sound movement; it provides more

emotional context to topics. This can also be shown with the loudness or quietness of sound, i.e. a bigger or smaller symbol.

3. *Rule One: Movement of Objects Symbolically* - When showing moving objects, show their movement and direction through visual description, it provides emotional context and meaning.
4. *Rule One: Characters Symbolically* - When explaining topics from different speakers use their pictures or something that distinctly identifies that character, as this will allow for clarity as to who or what the discussion is about.
5. *Rule One: Questioning Symbolically* - In questions the question mark needs to be clearly and boldly added, so it is clear that a question is being asked.
6. *Rule One: Expressing Feeling Symbolically* - Use colour themes and images within the context of the information in order to provide emotional information.

E.1.3 Rule Two - Linguistic Emotional Representation of Facial Expression

When you have a face, add facial expression for example, movement as follows:

1. *Rule Two: Forehead Linguistically* - Provides clarity to the meaning of signs as it is a part of several different signs in BSL. Two areas identified by users about where forehead movement is being used is in questioning and expressing feeling in different signs.
2. *Rule Two: Cheeks Linguistically* - The puffing and drawing in of cheeks provides emotional meaning and expressiveness of the weight and size of objects. This provides meaning and clarity to the signs being used and the context in which they are being used.

E.1.4 Rule Two - Symbolic Emotional Representation of Facial Expression

When showing facial images, provide clear details including;

1. *Rule Two: Forehead Symbolically for Questioning* - This can represent questioning, which should be clear, in plain English and marked clearly by adding fonts or colours.
2. *Rule Two: Forehead Symbolically for Feeling* - By providing visual cues through using colour, images and icons different feelings can be expressed in an information system.

3. *Rule Two: Cheeks Symbolically* - This element of BSL structure provides details of weight and size. This can be shown symbolically in images where the alteration of the size of an image can indicate its size.

E.1.5 Rule Three - Linguistic Emotional Representation of Torso

The torso enhances information and provides visual clarity in larger movement, especially in the two areas listed below:

1. *Rule Three: Emphasis Linguistically* - The movement of the torso provides clarity in the signing. Some signs can become ambiguous without torso movement, such as emotions. Therefore the torso provides additional information to clarify what is being said.
2. *Rule Three: Character Shift Linguistically* - The torso is an important facet of character shift, especially if the characters are in a heated discussion, this can provide a clear distinction between characters.

E.1.6 Rule Three - Symbolic Emotional Representation of Torso

To provide emphasis and character shift symbolically, the following can be sought:

1. *Rule Three: Emphasis Symbolically* - Use boldness, or use one concept per viewable digital document in order to clarify and strengthen the importance of the point. However try to keep to a theme within the design as this shows information is connected.
2. *Rule Three: Character Shift Symbolically* - When describing different people, objects or locations use images, colour and or font, to associate different characters to different dialogue.

E.1.7 Rule Four - Linguistic Emotional Representation of Handshape

Use clear hand shapes to express as follows:

1. *Rule Four: Size Linguistically* - The use of the hands can be formed and held in such a way that the size of an object can be shown. Such as how small or large something can be.
2. *Rule Four: Weight Linguistically* - Again by forming the hands differently a visual description can be shown of how heavy an object can be.

3. *Rule Four: Direction Linguistically* - Handshapes and movements can be used to give directions of how to get from one location to another.
4. *Rule Four: Shape Linguistically* - Handshapes and their movement can be used to show the shape of an object, such as a lamp, table or bowl.
5. *Rule Four: Vocabulary Linguistically* - Handshapes support and provide a wide range of vocabulary, through fingerspelling to handshapes.

E.1.8 Rule Four - Symbolic Emotional Representation of Handshape

Use clear and plain written English with visual cues

1. *Rule Four: Size Symbolically* - An image can be altered to show the size of an object in any given context. This is most effective when two or more symbols are used within an image as it allows for a standpoint of measure to indicate size.
2. *Rule Four: Weight Symbolically* - An image can be used to demonstrate the size of an object, again best shown with two or more symbols in an image as it provides a standpoint of measure to indicate size.
3. *Rule Four: Direction Symbolically* - Symbols and information maps can be used to provide clear directions symbolically.
4. *Rule Four: Shape Symbolically* - Shapes of objects are best shown through descriptive images.
5. *Rule Four: Vocabulary Symbolically* - Providing written text and images to clarify the meaning of new vocabulary, symbolically supports the building and maintaining of vocabulary. New vocabulary can be shown in different styling of colours and fonts as this can separate new information to ensure it is learnt and not brushed over.

E.1.9 Rule Five - Linguistic Emotional Representation of Signer's Space

Use placement as it will provide:

1. *Rule Five: Layout of Story Linguistically* - Provides an understanding of order of events with use of reference to particular things within the signer's space.
2. *Rule Five: Structure Linguistically* - This allows for the dialogue to have structure and clarity.

E.1.10 Rule Five - Symbolic Emotional Representation of Signer's Space

When using complex story lines or vocabulary:

1. *Rule Five: Layout of Story Symbolically* - Use previous rules to explain the concept but iconise the concept so it becomes a reference image, which can be later used to revisit the topic of discussion.
2. *Rule Five: Structure Symbolically* - Chunk sections of the story clearly in order to provide structure but use a colour or theme that continues in order to provide a link between different chunks of information.

E.2 System Development Steps

1. Step One, Separate Concepts: To aid translation
2. Step Two, Focus On Concept: Start to work with first/next concept for translation
 - (a) Step One, Translate: Involve a sign language expert and translate the information into BSL. For example native signers
 - i. English Sentence: How was your trip to school today?
 - ii. BSL Sentence: School trip, good?
 - (b) Step Two, Identify: Although the BSL example has been written in English, there is a great deal of information held in the face. Upon assessment the following two characteristics need to be closely assessed to ensure they are present in the linguistic representation of the system. These are
 - i. Questioning: because of the "How" in the sentence.
 - ii. Expressing feeling: because of the "Good" in the sentence.
 - (c) Step Three, Convert: - Linguistics. Ensure that these two elements are demonstrated in the sentence that is being expressed (more elements will be covered with the same sentence and the application of the other rules will follow. Work with one rule at a time, but ensure all five rules are checked before moving to the next concept)
 - (d) Step Three, Convert: - Symbolic. Ensure that these two elements are demonstrated in the information presented (other elements of this sentence will be demonstrated in the implementation of the other rules)
 - (e) Step Four, Assessment: Check if these criteria are in the Linguistic/Symbolic Emotion Presentation of the sentence. Questioning should follow the following format:
 - i. *Comprehension*: "What does this sentence say?"

- ii. **Accuracy of Meaning:** “Are the lip patterns clear?” (use alternative questions for the different rules)
 - iii. **Area of Improvement, if any:** “What can be improved with the lip patterns?” (use alternative questions for the different rules)
 - (f) Step Five, Improvement: If the answers provide area of improvement, it is advised to improve the system on the basis of the feedback of the user group and re-assess with Step Three if needed.
 - (g) Step Six, Finish: End of procedure
3. Step Three, Repeat: Go back to step two until all concepts are complete, then continue to Step Four.
 4. Step Four, Connect Concepts: Connect the concepts together and run final feedback of *Comprehension, Accuracy of Meaning* and *Areas of Improvement on entire information system*. When connecting linguistic concepts use the same signer; when connecting symbolic concepts, keep the same visual theme, for example the colour schemes.
 5. Step Five, Finish: Process is complete. If, however, circumstances justify doing so, try out the complete output with a different but equivalent group of users and incorporate any revisions for which the need has emerged.

E.3 Architectural Model

The following diagram presents an architectural model of how the system design process will work when designing an emotionally aware system for the Deaf.

E.4 Principles of Design

1. When designing an information system for the Deaf, start with the details around the face first as these are regarded as highly emotional and important to communication with Deaf people.
2. Ensure that all five rules are used as this will allow for higher levels of acceptance of information system. An interesting aspect of BSL grammar is multi-channel signs; these are special signs where both manual (i.e. using your hands) and non-manual (e.g. facial expressions, lip patterns etc) actions are combined to form a single sign.
3. These rules can be used to assess an existing DRSL, in order to identify essential language criteria for effective communication. This can also provide a basis for a more focused design strategy to improve the identified areas. Please note that when

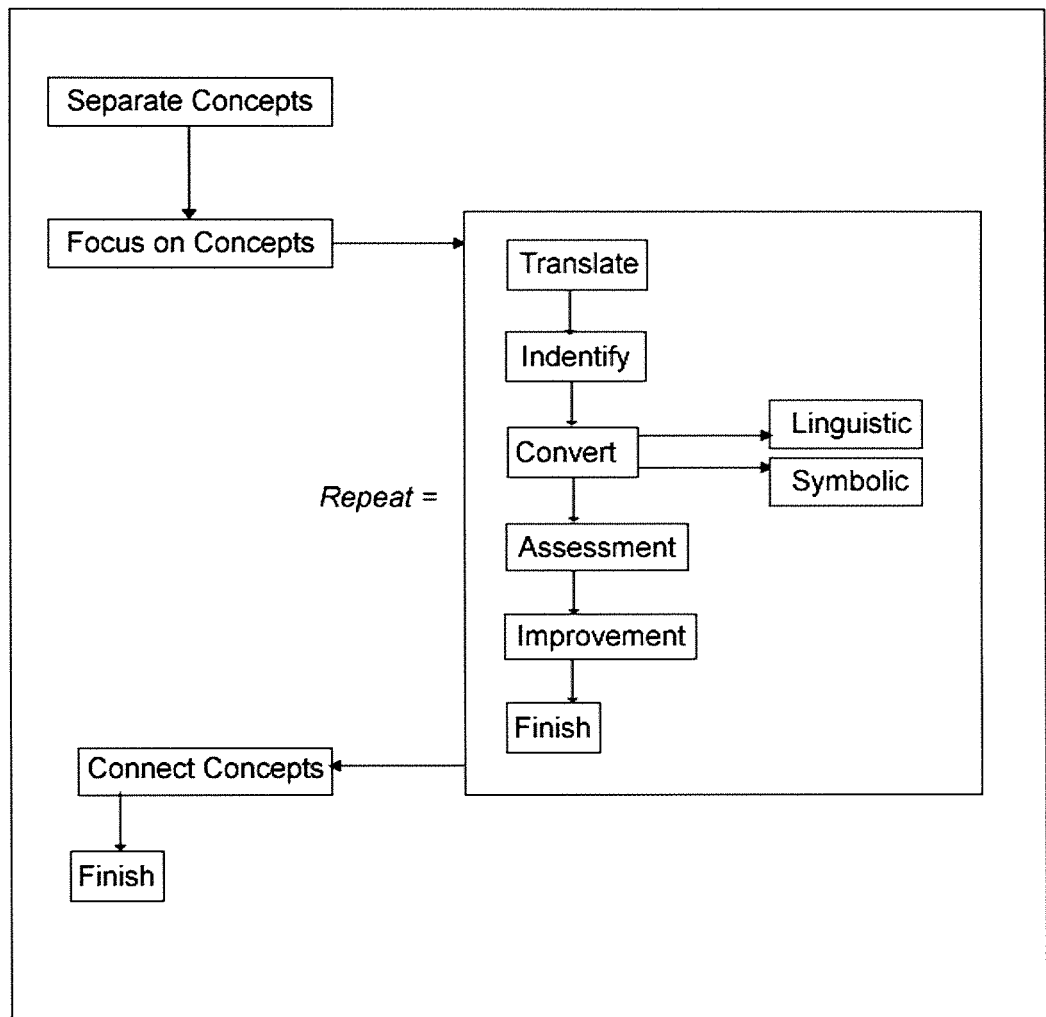


Figure E.1: Emotional System Design

evaluating a system for missing rules, always assess the rule against all five rules. They are heavily linked and are dependent on each other for clear communication.

4. When designing an information system for the Deaf community, it is advised to provide an actual signing solution that meets the linguistic criteria outlined in the emotional engineering of artificial sign languages. However if this is not possible due to platform constraints, it is advised to use the symbolic rules for translation. Platform constraints can include an image or information paper based handout which does not have the capability to provide a clear signing solution.
5. The symbolic method of design rules can also be used to add additional information support in the linguistic method of design.
6. Keep the design theme consistent, e.g. colour schemes, signer's, symbols, icons etc.
7. When designing a system, always view the information in it's constituent parts and not as a whole, deal with each constituent one at a time as this will be easier to manage. One does then need to consider the whole system with a complete overview.
8. Always translate information into the signer's English and observe the signer to identify the areas of emotion in the sentence and which words carry the most emotional information, as this will need to be present in the system to appeal and work with a wider Deaf audience.
9. Have Deaf people involved through all the stages, especially at the beginning. The individuals involved will be aware of the system and may inform the community and can provide their feedback as it is developed at each stage.
10. A highly complex system does not mean it has high levels of emotional representation within it e.g. road signs are information systems that are simple and very clear to understand.
11. Images and/or Signing work better than text.
12. Do not make the interface too busy, keep it simple, clear and well connected to different concepts being presented in the information, through colour schemes and layout.
13. The marketing of the final system needs to be in an assistive stance and not a replacement for the communities' language needs.
14. High linguistic or symbolic emotional representation can create a positive user experience.
15. Low linguistic or symbolic emotional representation can create a negative user experience.

Appendix F

Emotional Engineering within Nielsen's Usability Heuristics

This appendix shows how the principles of design for the emotional engineering of artificial representations of sign languages fits within the Usability Heuristics of Jakob Nielsen [Nielsen, 1994]. Nielsen's rule will be followed by the emotional engineering process formulated here which includes: Architecture of Design, Process Steps, Linguistic and Symbolic Rules and Principles of design.

Ten Usability Heuristics by Jakob Nielsen

Visibility of system status *The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.*

1. Activate the use of the Architecture
2. Principles of Design with Emotional Engineering
 - (a) Have Deaf people involved through all the stages, especially at the beginning. The individuals involved will be aware of the system and may inform the community and can provide their feedback as it is developed at each stage.

Match between system and the real world *The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.*

1. Activate the use of the Process Steps
2. Activate the use of the Rules
3. Principles of Design with Emotional Engineering:
 - (a) Ensure that all five rules are used as this will allow for higher levels of acceptance of information system. An interesting aspect of BSL grammar is multi-channel signs; these are special signs where both manual (i.e. using your hands) and

non-manual (e.g. facial expressions, lip patterns etc) actions are combined to form a single sign.

- (b) These rules can be used to assess an existing DRSL, in order to identify essential language criteria for effective communication. This can also provide a basis for a more focused design strategy to improve the identified areas. Please note that when evaluating a system for missing rules, always assess the rule against all five rules. They are heavily linked and are dependent on each other for clear communication.
- (c) When designing an information system for the Deaf community, it is advised to provide an actual signing solution that meets the linguistic criteria outlined in the emotional engineering of artificial sign languages. However if this is not possible due to platform constraints, it is advised to use the symbolic rules for translation. Platform constraints can include an image or information paper based handout which does not have the capability to provide a clear signing solution.
- (d) The symbolic method of design rules can also be used to add additional information support in the linguistic method of design.
- (e) When designing a system, always view the information in it's constituent parts and not as a whole, deal with each constituent one at a time as this will be easier to manage. One does then need to consider the whole system with a complete overview.
- (f) Always translate information into the signer's English and observe the signer to identify the areas of emotion in the sentence and which words carry the most emotional information, as this will need to be present in the system to appeal and work with a wider Deaf audience.
- (g) A highly complex system does not mean it has high levels of emotional representation within it e.g. road signs are information systems that are simple and very clear to understand.
- (h) Images and/or Signing work better than text.
- (i) The marketing of the final system needs to be in an assistive stance and not a replacement for the communities' language needs.
- (j) When designing an information system for the Deaf, start with the details around the face first as these are regarded as highly emotional and important to communication with Deaf people.

User control and freedom Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

1. Activate the use of the Process Steps

2. Activate the use of the Rules

3. Principles of Design with Emotional Engineering:

- (a) Do not make the interface too busy, keep it simple, clear and well connected to different concepts being presented in the information, through colour schemes and layout.
- (b) High linguistic or symbolic emotional representation can create a positive user experience.
- (c) Keep the design theme consistent, e.g. colour schemes, signifier's, symbols, icons etc.
- (d) Low linguistic or symbolic emotional representation can create a negative user experience.

Consistency and standards Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

1. Activate the use of the Process Steps

2. Activate the use of the Rules

3. Principles of Design with Emotional Engineering:

- (a) Keep the design theme consistent, e.g. colour schemes, signifier's, symbols, icons etc.

Error prevention Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

Recognition rather than recall Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

Flexibility and efficiency of use

Accelerators – unseen by the novice user – may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

Aesthetic and minimalist design

Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

Help users recognize, diagnose, and recover from errors *Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.*

Help and documentation *Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.*

Appendix G

Emotional Engineering within Shneiderman's Eight Golden Rules

This appendix shows how the principles of design for the emotional engineering of artificial representations of sign languages fits within the Eight Golden Rules of Interface Design by Shneiderman. Shneiderman's rule will be followed by the emotional engineering process formulated here which includes: Architecture of Design, Process Steps, Linguistic and Symbolic Rules and Principles of design.

Eight Golden Rules of Interface Design by Shneiderman

Shneiderman [Shneiderman, 1998] proposed this collection of principles that are derived heuristically from experience and applicable in most interactive systems after being properly refined, extended, and interpreted.

Strive for consistency. *Consistent sequences of actions should be required in similar situations; identical terminology should be used in prompts, menus, and help screens; and consistent commands should be employed throughout.*

1. Activate the use of the Architecture
2. Principles of Design with Emotional Engineering
 - (a) Keep the design theme consistent, e.g. colour schemes, signifier's, symbols, icons etc.

Enable frequent users to use shortcuts. *As the frequency of use increases, so do the user's desires to reduce the number of interactions and to increase the pace of interaction. Abbreviations, function keys, hidden commands, and macro facilities are very helpful to an expert user.*

Offer informative feedback. *For every operator action, there should be some system feedback. For frequent and minor actions, the response can be modest, while for infrequent and major actions, the response should be more substantial.*

Design dialog to yield closure. *Sequences of actions should be organized into groups with a beginning, middle, and end. The informative feedback at the completion of a group*

of actions gives the operators the satisfaction of accomplishment, a sense of relief, the signal to drop contingency plans and options from their minds, and an indication that the way is clear to prepare for the next group of actions.

1. Activate the use of the Process Steps
2. Activate the use of the Rules
3. Principles of Design with Emotional Engineering:
 - (a) Ensure that all five rules are used as this will allow for higher levels of acceptance of information system. An interesting aspect of BSL grammar is multi-channel signs; these are special signs where both manual (i.e. using your hands) and non-manual (e.g. facial expressions, lip patterns etc) actions are combined to form a single sign.
 - (b) These rules can be used to assess an existing DRSL, in order to identify essential language criteria for effective communication. This can also provide a basis for a more focused design strategy to improve the identified areas. Please note that when evaluating a system for missing rules, always assess the rule against all five rules. They are heavily linked and are dependent on each other for clear communication.
 - (c) When designing an information system for the Deaf community, it is advised to provide an actual signing solution that meets the linguistic criteria outlined in the emotional engineering of artificial sign languages. However if this is not possible due to platform constraints, it is advised to use the symbolic rules for translation. Platform constraints can include an image or information paper based handout which does not have the capability to provide a clear signing solution.
 - (d) The symbolic method of design rules can also be used to add additional information support in the linguistic method of design.
 - (e) When designing a system, always view the information in it's constituent parts and not as a whole, deal with each constituent one at a time as this will be easier to manage. One does then need to consider the whole system with a complete overview.
 - (f) Always translate information into the signer's English and observe the signer to identify the areas of emotion in the sentence and which words carry the most emotional information, as this will need to be present in the system to appeal and work with a wider Deaf audience.
 - (g) A highly complex system does not mean it has high levels of emotional representation within it e.g. road signs are information systems that are simple and very clear to understand.
 - (h) Images and/or Signing work better than text.

- (i) The marketing of the final system needs to be in an assistive stance and not a replacement for the communities' language needs.
- (j) When designing an information system for the Deaf, start with the details around the face first as these are regarded as highly emotional and important to communication with Deaf people.

Offer simple error handling. *As much as possible, design the system so the user cannot make a serious error. If an error is made, the system should be able to detect the error and offer simple, comprehensible mechanisms for handling the error.*

1. Activate the use of the Process Steps

Permit easy reversal of actions. *This feature relieves anxiety, since the user knows that errors can be undone; it thus encourages exploration of unfamiliar options. The units of reversibility may be a single action, a data entry, or a complete group of actions.*

Support internal locus of control. *Experienced operators strongly desire the sense that they are in charge of the system and that the system responds to their actions. Design the system to make users the initiators of actions rather than the responders.*

1. Activate the use of the Process Steps
2. Activate the use of the Rules
3. Principles of Design with Emotional Engineering:

- (a) Have Deaf people involved through all the stages, especially at the beginning. The individuals involved will be aware of the system and may inform the community and can provide their feedback as it is developed at each stage.

Reduce short-term memory load. *The limitation of human information processing in short-term memory requires that displays be kept simple, multiple page displays be consolidated, window-motion frequency be reduced, and sufficient training time be allotted for codes, mnemonics, and sequences of actions.*

1. Activate the use of the Process Steps
2. Activate the use of the Rules
3. Principles of Design with Emotional Engineering:

- (a) Do not make the interface too busy, keep it simple, clear and well connected to different concepts being presented in the information, through colour schemes and layout.

- (b) High linguistic or symbolic emotional representation can create a positive user experience.
- (c) Keep the design theme consistent, e.g. colour schemes, signifier's, symbols, icons etc.
- (d) Low linguistic or symbolic emotional representation can create a negative user experience.

Bibliography

- [Abrahams, 2008] Abrahams, P. (2008). What is the use of a signing avatar? Practice Leader, Accessibility and Usability, Bloor Research.
- [Achiba et al., 2002] Achiba, M., Alred, G., Byram, M., and Fleming, M. (2002). *Intercultural Experience and Education*. Multilingual Matters.
- [Ackerman, 1994] Ackerman, J. (1994). *Bilingualism for Deaf Children with Deaf parents: some issues*. University of Bristol: Centre of Deaf Studies.
- [Adamo-Villani and Beni, 2002a] Adamo-Villani, N. and Beni, G. (2002a). Teaching mathematics in sign language by 3d computer animation. In *Information Society and Education: Monitoring a Revolution*, volume 2, pages 918–924, Spain. International Conference on Information and Communication Technologies.
- [Adamo-Villani and Beni, 2002b] Adamo-Villani, N. and Beni, G. (2002b). Teaching mathematics in sign language by 3d computer animation. International Conference on Information and Communication Technologies, Spain.
- [Adams and Rohring, 2004] Adams, J. W. and Rohring, P. S. (2004). *Handbook to Service the Deaf and Hard of Hearing*. Emerald Group Publishing.
- [Agrafiotis et al., 2003] Agrafiotis, D., Canagarajah, N., Bull, D. R., Dye, M., Twyford, H., Kyle, J., and How, J. C. (2003). Optimized sign language video coding based on eye-tracking analysis. In Ebrahimi, T. and Sikora, T., editors, *VCIP*, volume 5150, pages 1244–1252. SPIE.
- [Akkerman and Vanderjagt, 1988] Akkerman, F. and Vanderjagt, A. J. (1988). *Rudolphus Agricola Phrisius, 1444-1485: Proceedings*. BRILL.
- [Ali and Naqvi, 2008] Ali, S. and Naqvi, S. (2008). Adapting learning materials to support the language acquisition of black minority ethnic deaf individuals. In *An International Symposium Instructional Technology and Education of the Deaf*, Rochester, New York.
- [Ali et al., 2007] Ali, S., Naqvi, S., and Cater, K. (2007). The need to develop deaf friendly materials for black ethnic minority deaf experiencing identity issues. In *Conference and Workshop on Assistive Technologies for Vision and Hearing Impairment*, Granada, Spain.
- [Amman, 1692] Amman, J. C. (1692). *Surdus loquens - The Talking Deaf Man, A Method Proposed, Whereby He Who is Born Deaf, May Learn to Speak*. publisher not known.

- [Amman, 1965] Amman, J. C. (1965). *A Dissertation on Speech*. North-Holland Pub. Co.
- [ASD, 1915] ASD (1915). *American Annals of the Deaf*. Executive Committee of the Convention of American Instructors of the Deaf.
- [AT&T, 2004] AT&T (2004). How to make a video relay call: what is AT&T video relay service.
- [Austin, 1961] Austin, J. L. (1961). The meaning of a word. *Philosophical papers*.
- [Baker-Shenk et al., 1991] Baker-Shenk, D., Baker-Shenk, C., and Cokely, B. (1991). *American Sign Language*. Gallaudet University Press.
- [Bangham et al., 2004] Bangham, A., Cawley, G., and Theobald, B.-J. (2004). Visual speech synthesis.
- [Bangham et al., 2000] Bangham, A., Cox, S., Lincoln, M., and Marshall, I. (2000). Signing for the deaf using virtual humans. Technical report, University of East Anglia, <http://www.visicast.sys.uea.ac.uk/Papers/iee2000-04PaperAFinal.pdf>.
- [Barnes, 1991] Barnes, C. (1991). *Disabled People in Britain and Discrimination: A Case for Anti-Discrimination Legislation*. Hurst & Co.
- [Bearne et al., 1994] Bearne, M., Jones, S., and Sapsford-Francis, J. (1994). Towards usability guidelines for multimedia systems. In *MULTIMEDIA '94: Proceedings of the second ACM international conference on Multimedia*, pages 105–110, New York, NY, USA. ACM.
- [Ben Salem, 2000] Ben Salem, N. E. (2000). Designing a non-verbal language for expressive avatars. In *CVE '00: Proceedings of the third international conference on Collaborative virtual environments*, pages 93–101, New York, NY, USA. ACM.
- [Benktzon, 1993] Benktzon, M. (1993). Designing for our future selves: the swedish experience. In *Applied Ergonomics*, pages 19–27.
- [Bloomer et al., 2005] Bloomer, A., Griffiths, P., Merrison, A., and Merrison, A. J. (2005). *Introducing Language in Use*. Routledge.
- [Bonet, 1620] Bonet, J. P. (1620). *Simplification of the Letters of the Alphabet and Method of Teaching Deaf-Mutes to Speak*. not known.
- [Booth, 2003] Booth, E. (2003). BDA promotes learning to sign through email drive. <http://www.brandrepublic.com/Revolution/News/193179/BDA-promotes-learning-sign-email-drive/>.
- [Box et al., 2005] Box, G., Hunter, S., and Hunter, W. (2005). *Statistics for Experimenters: Design, Innovation, and Discovery (Wiley Series in probability and Statistics)*. WileyBlackwell, 2nd edition edition.

- [Brennan, 90] Brennan, M. (90). Productive morphology in british sign language. focus on the role of metaphors. In Siegmund Prillwitz, T. V., editor, *Current Trends in European Sign Language Research. Proceedings of the 3rd European Congress on Sign Language Research*, volume 9, pages 205–228, Hamburg. Signum.
- [BritishSignLanguage.com, 2005] BritishSignLanguage.com (2005). Britishsignlanguage.com. <http://www.britishsignlanguage.com/>.
- [Bulwer, 1648] Bulwer, J. (1648). *The Deaf and Dumb Man's Friend*.
- [Bulwer and Cleary, 1974] Bulwer, J. and Cleary, J. W. (1974). *The Natural Language of the Hand*. Southern Illinois University Press.
- [Bureau, 2003] Bureau, D. N. (2003). Cti's sign language project wins award. <http://newslines.depaul.edu/newslinesadmin/anmviewer.asp?a=163>.
- [Byram, 1994] Byram, M. (1994). *The Context of Bilingualism at Home and at School*. Bristol: Centre for Deaf Studies.
- [C4, 2005] C4 (2005). Vee tv. <http://www.channel4.com/life/microsites/V/vee-tv/>.
- [Cadiz and Salvador, 2000] Cadiz, M. M. and Salvador, F. (2000). Sign language using motion capture based animation. In *Proceedings of the Philippine Computing Science Congress (PCSC) 2000*.
- [Carroll and Lane, 1991] Carroll, C. and Lane, H. (1991). *Laurent Clerc: The Story of His Early Years*. Gallaudet University Press.
- [Carter, 2006] Carter, K. (2006). Deafax. <http://www.deafax.org/>.
- [Collins, 1997] Collins, B. (1997). Sign writing and american sign language.
- [Cox et al., 2002] Cox, S., Lincoln, M., Tryggvason, J., Nakisa, M., Wells, M., Tutt, M., and Abbott, S. (2002). Tessa a system to aid communication with deaf people. In *Communication Technologies*, pages 205–212.
- [Cregan, 1982] Cregan, A. (1982). *Sigsymbol Dictionary*. Cambridge, LDA.
- [Creswell, 1994] Creswell, J. (1994). *Research Design: Qualitative and Quantitative Approaches*. Sage Publications.
- [Dalgarno et al., 2001] Dalgarno, G., Cram, D., and Maat, J. (2001). *The Deaf and Dumb Man's Friend*. Oxford University Press.
- [Damer et al., 1997] Damer, B., DiPaola, S., Paniaras, J., Parsons, K., Roel, B., and Ma, M. (1997). Putting a human face on cyberspace (panel): designing avatars and the virtual worlds they live in. In *SIGGRAPH '97: Proceedings of the 24th annual conference on Computer graphics and interactive techniques*, pages 462–464, New York, NY, USA. ACM Press/Addison-Wesley Publishing Co.

- [Damodaran, 2001] Damodaran, A. (2001). *Investment Valuation: Tools and Techniques for*. John Wiley and Sons, 2 edition.
- [d'Armond L. Speers, 2001] d'Armond L. Speers (2001). *Representation of American Sign Language for Machine Translation*. PhD thesis, Graduate School of Arts and Sciences of Georgetown University, <http://higbee.cots.net/holtej/dspeers-diss.pdf>.
- [Davidson, 2002] Davidson, M. (2002). Depaul demo asl. <http://asl.cs.depaul.edu/demo.html>.
- [de Carvalho Cruz, 1997] de Carvalho Cruz, A. L. (1997). Music for the deaf: A qualitative approach. In *18th Annual Conference on Interdisciplinary Qualitative Studies*. Qualitative Interest Group.
- [Deaf and Information, 2005] Deaf and Information, H. C. (2005). Deaf history. <http://www.geocities.com/gsgoda/aslhistory.htm>.
- [Deafblindness, 2005] Deafblindness (2005). The two-handed manual alphabet used by many sighted deaf people. <http://www.deafblind.com/deafsign.html>.
- [Deffman, 2005] Deffman, M. (2005). Signing/writing may sometimes be better than speech.
- [disABILITY Compliance Alliance(DCA), 2001] disABILITY Compliance Alliance(DCA) (2001). Accessibility for everyone.
- [Door, 2003] Door, S. (2003). Deafness. <http://www.surgerydoor.co.uk/>.
- [Dorr et al., 1998] Dorr, B., Jordan, P., and Benoit, J. (1998). A survey of current paradigms in machine translation. Technical report, University of Maryland, University of Pittsburgh, Artificial Intelligence Center.
- [DPN, 1997] DPN (1997). A brief history of gallaudet. Technical report, Gallaudet University Public Relations Office. <http://pr.gallaudet.edu/dpn/issues/HISTORY/newhistory3.html>.
- [Drolsbaugh, 1996] Drolsbaugh, M. D. (1996). What is deaf pride? <http://www.ldpride.net/deafpride.htm>.
- [Eisenstein et al., 2001] Eisenstein, J., Ghandeharizadeh, S., Shahabi, C., Shanbhag, G., and Zimmermann, R. (2001). Alternative representations and abstractions for moving sensors databases.
- [Elliott et al., 2004] Elliott, R., Glauert, J., and Kennaway, R. (2004). Synthetic real-time animation of humanoids. <http://www.cmp.uea.ac.uk/web/research/showproject.jsp>.
- [Elliott et al., 2000] Elliott, R., Glauert, J., Kennaway, R., and Marshall, I. (2000). The development of language processing support for the visicast project. In *Assets '00: Proceedings of the fourth international ACM conference on Assistive technologies*, pages 101–108, New York, NY, USA. ACM.

- [Elliott et al., 2007] Elliott, R., Glauert, J., Kennaway, R., Marshall, I., and Safar, E. (2007). *Linguistic Modelling and Language-processing Technologies for Avatar-based sign Language Presentation*, pages 375–391. Springer Berlin/Heidelberg.
- [EMMA, 2004] EMMA (2004). Vsign: Virtual signs by the european media masters of arts (emma). <http://www.vsign.nl/EN/vsignEN.htm>.
- [EuroBridge, 2004] EuroBridge (2004). The sign language training system. Technical report, Finland University.
- [Fabian and Francik, 2001] Fabian, P. and Francik, J. (2001). Synthesis and presentation of the polish sign language gestures.
- [Farnell, 1995] Farnell, B. (1995). *Do you see what I mean?: Plains Indian Sign Talk and the Embodiment of Action*. University of Texas Press, 1st edition edition.
- [Fay, 1893] Fay, V. B. E. A. (1893). *Histories of American Schools for the Deaf, 1817-1893*. The Volta Bureau.
- [Fels and Hinton, 1995] Fels, S. and Hinton, G. (1995). Glove-talkii: An adaptive desture-to-formant interface. In *CHI '95 Proceedings*.
- [Fischer and Lane, 1993] Fischer, R. and Lane, H. (1993). *Looking Back: A Reader on the History of Deaf Communities and Their Sign Langauges (International Studies on Sign Language & Communication of Deaf)*. Gallaudet University Press.
- [Fischer and Vollhaber, 1996] Fischer, R. and Vollhaber, T., editors (1996). *The role of the manual alphabet in deaf education in the 16th/17th centuries*, volume 33. Hamburg, Poppdruck, Langenhagen.
- [Foggitt, 2006] Foggitt, I. (2006). Signwriting in south africa. <http://www.signwriting.org/africa/africa.html>.
- [for Accessibly Media NCAM, 2003] for Accessibly Media NCAM, N. C. (2003). Media access generator (magpie). <http://ncam.wgbh.org/webaccess/magpie/>.
- [Francik and Fabian, 2002] Francik, J. and Fabian, P. (2002). Animating sign language in real time. In *Applied Informatics AI 2002, Innsbruck*, pages 276–281, Austria. 20th IASTED International Multi-Conference.
- [Gallaudet, 2006] Gallaudet, E. M. (2006). *Life of Thomas Hopkins Gallaudet: Founder of Deaf-mute*. H. Holt and Co.
- [Gao et al., 2000] Gao, W., Ma, Y., Shan, S., Chen, X., Zheng, W., Zhang, H., Yan, J., and Wu, J. (2000). Handtalker: A multimodal dialog system using sign language and 3-d virtual human. In *Advances in Multimodal Interfaces - ICMI 2000: Third International Conference, Beijing, China, October 2000. Proceedings*, volume 1948/2000, page 564. Springer-Verlag Heidelberg.

- [Gary Morgan, 2007] Gary Morgan, Sarah Barrett-Jones, H. S. (2007). The first signs of language: Phonological development in british sign language. In Press, C. U., editor, *Applied Psycholinguistics*, volume 28, pages 3–22.
- [Godenschweger and Strothotte, 1998] Godenschweger, F. and Strothotte, T. (1998). Modeling and generating sign language as animated line drawings. published on a website by the department of simulation and graphics.
- [Hanke, 2004] Hanke, T. (2004). Sign language notation system: Hamnosys. Technical report, University of Hamburg.
- [Hanke and Prillwits, 1995] Hanke, T. and Prillwits, S. (1995). syncwriter. <http://www.sign-lang.uni-hamburg.de/Artikel/1/Muenchen.html>.
- [Harrington, 2004] Harrington, T. (2004). Sign languages of the world by country. <http://library.gallaudet.edu/dr/faq-world-sl-country.html>.
- [Heidegger, 1962] Heidegger, M. (1962). *Being and Time*. Blackwell Publishing.
- [Heinicke et al., 1968] Heinicke, S., de L’Epe, C.-M., Christopher, and Garnett, B. (1968). *The Theory of Signs (Theorie des Signes)*. Vantage Press.
- [Heubner, 1995] Heubner, K. M. (1995). *Hand in Hand: Essentials of Communication and Orientation and Mobility for Rehabilitation*. American Foundation for the Blind, U.S.
- [Howe et al., 1909] Howe, S. G., Richards, L. E. H., and Sanborn, F. B. (1909). *Letters and Journals of Samuel Gridley Howe*. Lee D. Estes.
- [Huenerfauth, 2003] Huenerfauth, M. (2003). A survey and critique of american sign language natural language generation and machine translation systems: Written preliminary examination ii computer science. Technical report, University of Pennsylvania.
- [iCommunicator, 2003] iCommunicator (2003). Communication in sign language simply by speaking. <http://www.mycommunicator.com>.
- [Intel, 2003] Intel (2003). Intel sts winner-high school senior invents sign language translator. Intel Website.
- [Ipke Wachsmuth, 2002] Ipke Wachsmuth, T. S., editor (2002). *SignSynth: A Sign Language Synthesis Application Using Web3D and Perl*, volume 2298 of *Lecture Notes in Computer Science*, London. Springer.
- [Johnson and Caird, 1996] Johnson, B. and Caird, J. (1996). The effect of frame rate and video information redundancy on the perceptual learning of american sign language gestures. In *Conference Companion on Human Factors in Computing Systems*, pages 121–122. ACM Press.

- [Johnston and Schembri, 2007] Johnston, T. and Schembri, A. (2007). *Australian Sign Language (Auslan): An Introduction to Sign Language Linguistics*. Cambridge University Press.
- [Jokinen, 2009] Jokinen, M. (2009). World federation of the deaf. <http://www.wfdeaf.org/>.
- [Kaplan and Maxwell, 2004] Kaplan, R. and Maxwell, J. (2004). Grammar writer's workbench for lexical functional grammar.
- [Keates et al., 2000] Keates, S., Clarkson, J., Harrison, L.-A., and Robinson, P. (2000). Towards a practical inclusive design approach. In *CUU '00: Proceedings on the 2000 conference on Universal Usability*, pages 45–52, New York, NY, USA. ACM.
- [Keller, 1970] Keller, H. (1970). *Helen Keller: the Story of My Life*. Airmont Pub Co., reissue edition edition.
- [Kiddle and Schem, 1876] Kiddle, H. and Schem, A. J. (1876). *The Cyclopdia of Education*. Trbner & Co.
- [Killion and Fikret-Pasa, 1993] Killion, M. C. and Fikret-Pasa, S. (1993). The 3 types of sensorineural hearing loss: Loudness and intelligibility considerations. *The Hearing Journal*, 46:31–36.
- [Knight and Swanwick, 1999] Knight, P. and Swanwick, R. (1999). *The Care and Education of Deaf Children*. Multilingual Matters.
- [Kyle, 1987] Kyle, J. (1987). *Sign and School: Using Signs in Deaf*. Multilingual Matters.
- [Kyle and Woll, 1985] Kyle, J. and Woll, B. (1985). *Sign Language: The Study of Deaf People*. Cambridge University Press.
- [Lane, 1994] Lane, H. (1994). *Parallel Views: Education and Access for Deaf People in France and the United States*. Gallaudet University Press.
- [Lauri, 2005] Lauri (2005). History of sign language. <http://members.aol.com/>.
- [Lee et al., 2002] Lee, J., Chai, J., Reitsma, P., Hodgins, J., and Pollard, N. (2002). Interactive control of avatars animated with human motion data. In *SIGGRAPH '02: Proceedings of the 29th annual conference on Computer graphics and interactive techniques*, pages 491–500, New York, NY, USA. ACM Press.
- [Lee, 2004] Lee, R. (2004). *A beginner's introduction to deaf history*. Feltham : BDHS Publications.
- [Lincoln and Tryggvason, 2004] Lincoln, M. and Tryggvason, J. (2004). Gesture and sign recognition.
- [Lockwood, 2005] Lockwood, L. (2005). *Beethoven: the Music and the Life*. W. W. Norton & Co., reprint edition edition.

- [Lynas, 1994] Lynas, W. (1994). *Total Communication: Current Status and Research Evidence*. University of Manchester.
- [MacKenzie, 2003] MacKenzie, C. (2003). *Alexander Graham Bell: The Man who Contracted Space*. Kessinger Publishing.
- [Magrab, 1997] Magrab, E. B. (1997). *Integrated Product and Process Design and Development: The Product Realization Process (Environmental and Energy Engineering) (Hardcover)*. CRC Press.
- [Maher, 2006] Maher, C. (2006). Plain english campaign. <http://www.plainenglish.co.uk/>.
- [Mahoney, 1997] Mahoney, R. (1997). Robotic products for rehabilitation: Status and strategy. In *ICORR'97*, pages 12–22.
- [Malciu and Preteux, 2000a] Malciu, M. and Preteux, F. (2000a). A robust model-based approach for 3d head tracking in video sequences. In *Fourth IEEE International Conference on Automatic Face and Gesture Recognition*.
- [Malciu and Preteux, 2000b] Malciu, M. and Preteux, F. (2000b). Tracking facial features in video sequences using a deformable model-based approach. In *SPIE Conference on Mathematical Modeling, Estimation and Imaging, San Diego*, volume Vol. 4121.
- [Mandel, 1993] Mandel, M. (1993). Ascii-stokoe notation: A computer-writable transliteration system for stokoe notation of american sign language. Technical report, Dragon Systems Incorporated.
- [Mann and Mann, 2007] Mann, M. T. P. and Mann, M. (2007). *Life of Horace Mann*. Lee and Shepard.
- [Marschark and Spencer, 2003] Marschark, M. and Spencer, P. E. (2003). *Deaf Studies-Language and Education*. Oxford University Press US.
- [Marshall et al., 2004] Marshall, I., Dionisio, N., and Safar, E. (2004). English to sign language.
- [Marshall and Safar, 2002] Marshall, I. and Safar, E. (2002). Extraction of semantic representations from syntactic cmu link grammar linkages. In *ViSiCAST publications*.
- [Microsoft, 2004] Microsoft (2004). icommunicator aids communication for perrigo employee with hearing impairment. Technical report, Perrigo.
- [Monaghan et al., 2003] Monaghan, L. F., Monaghan, L., Nakamura, K., Schmaling, C., and Turner, G. H. (2003). *Many Ways to be Deaf*. Gallaudet University Press.
- [Moore, 2005] Moore, D. R. (2005). Exploring gender effects on the spatial probability measure. In *ICALT '05: Proceedings of the Fifth IEEE International Conference on Advanced Learning Technologies*, pages 435–436, Washington, DC, USA. IEEE Computer Society.

- [Morgan et al., 2003] Morgan, G., Barriere, I., and Woll, B. (2003). First verbs in british sign language development. In *In Working Papers in Language and Communications Scienc*. City University London.
- [Morley, 1854] Morley, H. (1854). *Jerome Cardan: The Life of Girolamo Cardano, of Milan*. Chapman and Hall.
- [Multimedia, 2006] Multimedia, D. (2006). Dunedin multimedia - bsl dictionary. <http://www.learnbsl.org/>.
- [Nakamura, 2002] Nakamura, K. (2002). About american sign language. <http://www.deaflibrary.org/asl.html>.
- [Naqvi, 2003] Naqvi, S. (2003). Kso: Kids sign online. Technical report, Goldsmiths College - University of London, <http://www.mcs.gold.ac.uk/ma001sn/index.php>.
- [Naqvi, 2005] Naqvi, S. (2005). An interview with edward j. richards.
- [Naqvi, 2006] Naqvi, S. (2006). Experimental research design for the deaf: Approaches for obtaining accurate end-user feedback. In *Conference and Workshop on Assistive Technologies for Vision and Hearing Impairment*, Kufstein, Austria.
- [Naqvi, 2007a] Naqvi, S. (2007a). End-user involvement in assistive technology design for the deaf - are artificial forms of sign language meeting the needs of the target audience? In *Conference and Workshop on Assistive Technologies for Vision and Hearing Impairment*, Granada, Spain.
- [Naqvi, 2007b] Naqvi, S. (2007b). An interview with sadaqat ali.
- [Naqvi, 2008] Naqvi, S. (2008). Artificial representations of sign language to access information: How affective are they? In *An International Symposium Instructional Technology and Education of the Deaf*, Rochester, New York.
- [Naqvi et al., 2005] Naqvi, S., Ohene-Djan, J., and Spiegel, R. (2005). Testing the effectiveness of digital representations of sign language with children. In *An International Symposium Instructional Technology and Education of the Deaf Supporting Learners*, Rochester, New York.
- [Naqvi et al., 2006] Naqvi, S., Spiegel, R., Ohene-Djan, J., Moore, D., and Hsiao, E. (2006). Measuring sign language comprehension through spatial response. In *Conference and Workshop on Assistive Technologies for Vision and Hearing Impairment*, Kufstein, Austria.
- [Nefian and III, 1998] Nefian, A. and III, M. H. (1998). Hidden markov models for face recognition. In *IEEE International Conference on Acoustic, Speech and Signal processing*, volume vol. 5.
- [Neidle, 2004] Neidle, C. (2004). Sign stream. Technical report, Boston University, <http://www.bu.edu/asllrp/SignStream/>.

- [Nenad, 2003] Nenad, P. (2003). Natural language processing and speech enabled applications. Technical report, Affiliated Institution of University of Sheffield.
- [Nielsen, 1994] Nielsen, J. (1994). Ten usability heuristics.
- [NSF, 2001] NSF (2001). Animated 3-d boosts deaf education. <http://www.nsf.gov/od/lpa/news/press/01/pr0120.htm>.
- [Ohene-Djan et al., 2004] Ohene-Djan, J., Zimmer, R., Bassett-Cross, J., Mould, A., and Cosh, B. (2004). Mak-messenger and finger-chat, communications technologies to assist in the teaching of signed languages to the deaf and hearing. In *ICALT '04: Proceedings of the IEEE International Conference on Advanced Learning Technologies (ICALT'04)*, pages 744–746, Washington, DC, USA. IEEE Computer Society.
- [Ohene-Djan et al., 2003] Ohene-Djan, J., Zimmer, R., Gorle, M., and Naqvi, S. (2003). A personalisable electronic book for video-based sign language education. In *Educational Technology and Society*, pages 86–99. IEEE.
- [Omlin and Glaser, 2001] Omlin, C. and Glaser, M. (2001). Integration of verbal and signed communications: Real-time sign language translation. Technical report, University of Western Cape, University of Cape Town, <http://www.cs.uwc.ac.za/com-lin/sasl.html>.
- [Padden and Humphries, 1988] Padden, C. and Humphries, T. (1988). *Deaf in America: Voices from a Culture*. Harvard University Press.
- [Petri et al., 2002] Petri, H., Fisher, W., Depuydt, S., Pyhers, L., Weber, G., Gladstone, K., and Rundle, C. (2002). Report on developments in state of the art in multimedia and ebook technologies. Technical report, City University-London, Katholieke Universiteit-Leuven, Royal National Institute of the Blind, Multimedia Camput-Kiel.
- [Power and Leigh, 2000] Power, D. and Leigh, G. (2000). Principles and practices of literacy development for deaf learners: A historical overview. *Journal of Deaf Studies Deaf Education*, 5(1):3–8.
- [Preda et al., 1999] Preda, M., Zaharia, T., and Prteux, F. (1999). 3d body animation and coding within a mpeg-4 compliant framework. In *International Workshop on Synthetic-Natural Hybrid Coding and THree Dimensional Imaging*.
- [Preston, 1994] Preston, P. (1994). *Mother father deaf. Living Between Sound and Silence*. Cambridge.
- [QDS, 2004] QDS (2004). Auslan. <http://www.qds.org.au/auslan.php>.
- [RAD, 2001] RAD (2001). Royal association for deaf people - prototype virtual signing system. <http://www.royaldeaf.org.uk/vsign.htm>.
- [Renate Fischer, 1996] Renate Fischer, T. V., editor (1996). *Facets of Deaf History*, volume 33. Orebro, Poppdruck, Langenhagen.

- [Ripley and Dana, 2006] Ripley, G. and Dana, C. A. (2006). *The New American Cyclopaedia: The Popular Dictionary of General Knowledge*. D. Appleton and Company.
- [RNID, 2004] RNID (2004). Royal National Institute for Deaf People. <http://www.rnid.org/>.
- [Rowley, 1998] Rowley, J. (1998). *Towards a Methodology for the Design of Multimedia Public Access Interfaces*. Journal of Information Science.
- [Safar and Marshall, 2001] Safar, E. and Marshall, I. (2001). The architecture of an english-text-to-sign-language translation system. In et Al (ed), G. A., editor, *Recent Advances in Natural Language Processing (RANLP)*, pages 223–228.
- [Sagawa and Takeuchi, 2002] Sagawa, H. and Takeuchi, M. (2002). A teaching system of japanese sign language using sign language recognition and generation. In *Proceedings of the tenth ACM international conference on Multimedia*, pages 137–145. ACM Press.
- [Scheffler, 2003] Scheffler, K. (2003). Konrad scheffler computer science department university of western cape, current projects. Technical report, University of Western Cape, <http://www.cs.uwc.ac.za/kschef/projects.html>.
- [Schein and Stewart, 1995] Schein, J. and Stewart, D. (1995). *Language in Motion*. Gallaudet University Press.
- [Schnieder, 2001] Schnieder, E. E. (2001). American sign language (asl) vs signed english(se). <http://www.lesstutor.com/eesASLIntro.html>.
- [Selvarajah and Richards, 2005] Selvarajah, K. and Richards, D. (2005). The use of emotions to create believable agents in a virtual environment. In *AAMAS '05: Proceedings of the fourth international joint conference on Autonomous agents and multiagent systems*, pages 13–20, New York, NY, USA. ACM.
- [Shneiderman, 1998] Shneiderman, B. (1998). *Designing the User Interface*. Addison Wesley.
- [Sicard, 1818] Sicard, A. R. (1818). *The Theory of Signs (Theorie des Signes)*. not known.
- [Spiegel et al., 2007] Spiegel, R., Naqvi, S., Ohene-Djan, J., Moore, D. R., and Hsiao, E. (2007). A neuropsychological perspective on measuring sign language learning and comprehension. In *International Journal of Emerging Technologies in Learning*, volume 2.
- [Starner and Pentland, 1996] Starner, T. and Pentland, A. (1996). Real-time american sign language recognition from video using hidden markov models. In *IEEE*.
- [Stewart et al., 2002] Stewart, D., Dickson, P., Heeter, C., Russell, R., and Winn, B. (2002). American sign language browser.
- [Stokoe, 2005] Stokoe, W. (2005). Sign language structure: An outline of the visual communication systems of the american deaf. In *Journal of Deaf Studies and Deaf Education*, volume 10, pages 3–37. Oxford University Press.

- [Su, 1998] Su, A. (1998). Asl fingerspelling in vrml. Technical report, Texas A&M University, <http://www.csdl.tamu.edu/su/asl/>.
- [Suszczanska et al., 2005] Suszczanska, N., Szmaj, P., and Kulikow, S. (2005). Continuous text translation using text modelling in the thetos system. In *International Journal of Computational Intelligence*.
- [Sutton, 2004] Sutton, V. (1996-2004). The sign language training system. Technical report, Sign Writing.
- [Sutton-Spence and Woll, 1999] Sutton-Spence, R. and Woll, B. (1999). *The Linguistics of British Sign Language*. Cambridge University Press.
- [Swain et al., 2004] Swain, J., French, S., Barnes, C., and Thomas, C. (2004). Controversial issues disabling society. In Press, O. U., editor, *Disabling Barriers Enabling Environments*.
- [Temin, 2003] Temin, T. (2003). Pure technology not the only answer to accessibility. Technical report, Washington Technology Review.
- [BDA, 2004] BDA (2004). British Deaf Association. <http://www.bda.org/>.
- [TheFreeDictionary.com, 2004] TheFreeDictionary.com (2004). Hidden markov models.
- [Thomas Rieger, 2003] Thomas Rieger, N. B. (2003). Narrative use of sign language by a virtual character for the hearing impaired.
- [UPIAS, 2008] UPIAS (2008). Greater manchester coalition of disabled people (gmcdp). <http://www.gmcdp.com/UPIAS.html>.
- [Valentine and Skelton, 2003] Valentine, G. and Skelton, T. (2003). Living on the edge: the marginalisation and ‘resistance’ of d/deaf youth. *Environment and Planning*, 35:301–321.
- [Vamplew, 1996] Vamplew, P. (1996). Recognition of sign language gestures using neural networks. In *Virtual Reality and Association Technology*.
- [VCOM.3D, 2008] VCOM.3D (2008). “the forest” by jason stewart.
- [Verlinden et al., 2002] Verlinden, M., Tijsseling, C., and Frowein, H. (2002). *A Signing Avatar on the (WWW)*. Springer Link.
- [Walker, 1970] Walker, M. (1970). Makaton. <http://www.makaton.org/>.
- [Web, 2005] Web, H. L. (2005). assistive listening devices (alds) for people with hearing loss.
- [Weisel, 1998] Weisel, A. (1998). *Issues Unsolved: New Perspectives on Language and Deaf Education*. Gallaudet University Press.

- [White, 2000] White, J. (2000). *Envisioning Machine Translation in the Information*. Springer.
- [WHO, 1980] WHO (1980). World health organisation - international classification of impairments, disabilities and handicaps.
- [WHO, 2001] WHO (2001). World health organisation - international classification of impairments, disabilities and handicaps.
- [Wilkinson, 2003] Wilkinson, J. (2003). Csl: Chinese sign language. <http://library.thinkquest.org/11942/csl.htm?tqskip1=1>.
- [WISDOM, 2003] WISDOM (2003). University of bristol wisdom - a project for the deaf community.
- [Yeates et al., 2002] Yeates, S., Holden, E.-J., and Owens, R. (2002). Real-time 3d graphics for human modelling and teaching sign language. In Zakopane, editor, *ICCVG 2002 Proceedings*, Department of Computer Science and Software Engineering, The University of Western Australia, 35 Stirling Hwy, Crawley, WA 60009 Australia. International Conference on Computer Vision and Graphics, ICCVG.
- [Zhao et al., 2001] Zhao, L., Kipper, K., Schuler, W., Vogler, C., Badler, N., and Palmer, M. (2001). A machine translation system from english to american sign language.