BLINKING IN HUMAN COMMUNICATIVE BEHAVIOUR AND ITS REPRODUCTION IN ARTIFICIAL AGENTS

by

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A thesis submitted to the

PLYMOUTH UNIVERSITY, U.K.

in partial fulfilment for the degree of

DOCTOR OF PHILOSOPHY

September 2014

BLINKING IN HUMAN COMMUNICATIVE BEHAVIOUR AND ITS REPRODUCTION IN ARTIFICIAL AGENTS by CHRISTOPHER C. FORD

A significant year-on-year rise in the creation and sales of personal and domestic robotic systems and the development of online embodied communicative agents (ECAs) has in parallel seen an increase in end-users from the public domain interacting with these systems. A number of these robotic/ECA systems are defined as social, whereby they are physically designed to resemble the bodily structure of a human and behaviorally designed to exist within human social surroundings. Their behavioural design is especially important with respect to communication as it is commonly stated that for any social robotic/ECA system to be truly useful within its role, it will need to be able to effectively communicate with its human users. Currently however, the act of a human user instructing a social robotic/ECA system to perform a task highlights many areas of contention in human communication understanding. Commonly, social robotic/ECA systems are embedded with either non-human-like communication interfaces or deficient imitative human communication interfaces, neither of which reach the levels of communicative interaction expected by human users, leading to communication difficulties which in turn create negative association with the social robotic/ECA system in its users. These communication issues lead to a strong requirement for the development of more effective imitative human communication behaviours within these systems. This thesis presents findings from our research into human non-verbal facial behaviour in communication. The objective of the work was to improve communication grounding between social robotic/ECA systems and their human users through the conceptual design of a computational system of human non-verbal facial behaviour (which in human-human communicative behaviour is shown to carry in the range of 55% of the intended semantic meaning of a transferred message) and the development of a highly accurate computational model of human blink behaviour and a computational model of physiological saccadic eye movement in human-human communication, enriching the human-like properties of the facial non-verbal communicative feedback expressed by the social robotic/ECA system. An enhanced level of interaction would likely be achieved, leading to increased empathic response from the user and an improved chance of a satisfactory communicative conclusion to a user's task requirement instructions. The initial focus of the work was in the capture, transcription and analysis of common human non-verbal facial behavioural traits within human-human communication, linked to the expression of mental communicative states of understanding, uncertainty, misunderstanding and thought. Facial Non-Verbal behaviour data was collected and transcribed from twelve participants (six female) through a dialogue-based communicative interaction. A further focus was the analysis of blink co-occurrence with other traits of human-human communicative non-verbal facial behaviour and the capture of saccadic eye movement at common proxemic distances. From these data analysis tasks, the computational models of human blink behaviour and saccadic eye movement behaviour whilst listening / speaking within human-human communication were designed and then implemented within the LightHead social robotic system. Human-based studies on the perception of naïve users of the imitative probabilistic computational blink model performance on the LightHead robotic system are presented and the results discussed. The thesis concludes on the impact of the work along with suggestions for further studies towards the improvement of the important task of achieving seamless interactive communication between social robotic/ECA systems and their human users.

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ACKNOWLEDGEMENTS

This research was carried out at the Centre for Robotics and Intelligent Systems (CRNS) at Plymouth University, U.K. This project was running from 2008–2013 and was funded by a Plymouth University Graduate School - Faculty of Technology Scholarship.

Dr. Guido Bugmann was the Director of Studies of this thesis and I thank him greatly for his kindness, advice and invaluable guidance throughout this study. Also, I would like to thank Dr. Phil Culverhouse for his help and guidance in seeing me through this study, in his role as 2nd Supervisor. Both gave generously of their time and invaluable knowledge, both professionally and in everyday life and for this I am eternally grateful.

I would like to thank members of the robotics research lab, Samantha Adams, Ali Ali, Peter Gibbons, Simon Oliver (RIP), George Terzakis and Julian Tilbury for their kind moral support and the exchange of many insightful and inspiring ideas throughout the duration of this study.

I would like to send great thanks to my co-collaborator on my final experiment and the designer of the LightHead social robotic system, Frederic DeLaunay, whose untiring effort and unswerving belief in this work has been both inspiring and humbling in equal measure.

Finally, I would like to send my love to both my wife, Supattra, and my mother, Christine, whose unending wisdom, support and love have been instrumental in the completion of this PhD. Words alone cannot express my gratitude for all you have done to aid me through the sine wave of emotion that depicts the PhD journey. Thank you both from the bottom of my heart.

Plymouth, September 2014

Christopher. C. Ford.

AUTHOR'S DECLARATION

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Graduate Committee.

Work submitted for this research degree at the Plymouth University has not formed part of any other degree either at Plymouth University or at another establishment.

This study was financed with the aid of a Plymouth University Graduate School - Faculty of Technology scholarship.

A programme of advanced study was undertaken, which included the extensive reading of literature relevant to the research project and attendance at international conferences on Robotics and Human-Robot Interaction. Paper Review work was also undertaken at both International Conference (HRI, HCI, ICSR and IROS) and Scientific Journal (IJSR) levels.

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1. International Journal of Humanoid Robotics (IJHR): Published April 10th 2013 Ref: Ford, C., G. Bugmann & P. Culverhouse (2013). "Modeling the human blink: a computational model for use within human-robot interaction" International Journal of Humanoid Robotics, World Scientific Publishing Company.

and has submitted papers in the following peer-reviewed international journal:

2. International Journal of Humanoid Robotics (IJHR): Submitted Sept 12th 2014 Ref: Ford, C., G. Bugmann & P. Culverhouse (2013). "User-perception evaluation of a computational human blink model, implemented on a social robotic/ECA system utilising back-projected facial animation" International Journal of Humanoid Robotics, World Scientific Publishing Company.

and has presented papers and posters in the following international and national conferences:

3. Ford, C., Bugmann, G. & Culverhouse, P. (2010) Eye Movement & Facial Expression in Human-Robot Communication. *KEER 2010*. Arts et Metiers, Paris, France: March 2nd – 4th 2010. Publisher: JSKE / Art et Métiers ParisTech.
4. Ford, C., Bugmann, G. & Culverhouse, P. (2010) A Model of Human Blinking for Human-Robot Interaction. *PCCAT 2010*. Exeter University, UK: June 9th 2010.
5. Ford, C., G. Bugmann, et al. (2012). "Modeling the human blink: a computational model for use within human-robot interaction". Workshop - "Dynamics of Conversational Engagement: An Interdisciplinary Perspective". 20th September 2012, Cognition Institute, Plymouth University, UK
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Word count of main body of thesis: 29,518

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"Communication is not only the essence of being human,
but also a vital property of life."

John. A. Piece.

PART I

HUMAN-HUMAN COMMUNICATION

The Key to Unlocking Human-Robot Interaction?

1. Introduction

This chapter gives an overview of and discusses the relevant background and literature from Psychology, Human-Robot Interaction and Embodied Communicative Agents (ECA) research domains. In particular human-human communication is investigated, and therein a presentation of the state of play of humanlike communication with social robotics and ECAs is presented to gain an insight into the background and motivation for this PhD work.

1.1 Looking to the Future: Social Communication in Robots/ECAs

As humanity moves ever deeper into the technological age, the possibility of the creation of a social cognitive robotic/ECA system (i.e. a system which resembles the bodily structure of a human, can communicate effectively utilising human socio-communication metaphors, and still comfortably exist in human social surroundings) becomes increasingly attainable. This has sparked a global increase in research into the creation of social robotic/ECA systems (André & Pelachaud, 2010; Dautenhahn, 2007a), encapsulating disciplines of Psychology, Sociology, Electrical/Mechanical Engineering, Physics, Cognitive Science, Artificial Intelligence, Mathematics and Computing, making it a truly multi-disciplinary research area.

The requirement for these social robotic/ECA systems stems largely from countries such as Japan and Korea. Japanese researchers started work in this area to create social robotic/ECA systems to perform two main tasks. The first: care for the elderly and the second: to perform job roles within human social environments. These requirements arose due to future societal issues whereby approximately one third of Japans population will be retiring from work between 2006 and 2055 at which point those aged over 65 will have doubled in size to 40.5% of the overall population (News, 2006). Furthermore, a lack of procreation within Japanese society means that to date, younger

generations have not had a birth rate large enough to repopulate this loss to any major degree, thus the idea was formulated that robotic/ECA systems could aid their economy through caring for the elderly (thus leaving their children to continue working) and by filling many of the vacated job roles.

According to a survey from World_Robotics (2012), sales of service robots for personal and domestic use increased by 19% in 2011 to 2.5 million units, with projections for 2012-2015 showing increases in domestic, entertainment, leisure and handicap assistance robotics to 15.6 million units overall. A study by Shukla and Shukla (2012) looks at the growth of robotics since the start of the 21st Century to the conclusion of 2011 and shows that personal and domestic service robotics growth has increased by 74%, through the sale of 13.4 million systems in this period. A further study has revealed much about the predicted global market growth specifically within the area of social robotics (with market predictions moving from $600 million in 2002 to greater than $52 billion by the year 2025 (Robotics_Trends, 2009)). These figures display a trend, which, if it continued as expected, will see social robotic systems become ever more common in daily life.

Many of these social robotic systems are being developed for use most commonly in the areas of medical care, education and entertainment as these allow us to create useful robotic devices within the current breadth of robotic knowledge. These areas however are somewhat in contrast to the most common public requested tasks of these social robotic systems, those of food preparation, general household cleaning and helping with a child's homework (Bugmann & Copleston, 2011). Also, as social robotic/ECA systems become more common in daily life, a significant rise in end-users from the public domain utilising and interacting with these systems will be seen. These points highlight that the market for social robotic systems is currently driven only partially by

user requirements, but more commonly by what we as robotic developers can actually create due to the significant challenges inherent in the design and implementation of robots that serve human needs and hence require human interaction with which to function. Thus we can see that research into social robotic/Embodied Cognitive Agent (ECA) systems is still within its infancy and thus numerous problems still require solving before truly social robots/ECAs appear (Bugmann, 2005), that can exist on a level with humans within their social environment and thus gain human (social) acceptance (Breazeal, 2002; Dautenhahn, 2007b; Oestreicher, 2007a; Oestreicher, 2007b; Oestreicher & Eklundh, 2006). This displays an industry in the early part of its creation, but none-the-less one with huge potential in both economic growth and human benefit, if research in this area is ever more closely tied and driven towards actual user requirements and improvements in communicative functionality.

The motivation behind this research focuses on Human-Robot Interaction (HRI) and ECAs (within Human-Computer Interaction (HCI)), two fields of research which are dedicated to the understanding, design and evaluation of robotic/ECA systems that interact and communicate with humans (Figure 1-1). For an introduction to HRI see (Breazeal, 2002; Breazeal & Scassellati, 2002; Dautenhahn, 2007a; Dautenhahn, 2007b; Goodrich & Schultz, 2007; Kanda et al., 2003; Kanda, Ishiguro & Ishida, 2001; Ramey, 2005; Sidner et al., 2004). For an introduction to HCI with ECAs see (André & Pelachaud, 2010; Bickmore & Cassell, 2005; Cassell, 2000; Cassell, 2001; Cassell et al., 1994; Foster, 2007; Gratch et al., 2002; Ochs et al., 2005; Ochs & Pelachaud, 2013; Poggi & Pelachaud, 2002)

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Figure 1-1 The Process of Human-Robot Interaction (Lee & Kim, 2006)

The aim of this PhD is to contribute to knowledge in the field of HRI/HCI through the improvement of communication and social behaviour of social robots/ECAs through deep understanding of human-human facial communicative non-verbal behaviour and from the findings therein, the design and development of a highly accurate humanlike computational blink model for implementation within any social robotic/ECA system, to better aid communication and empathy with human users. The motivation for creating a computational blink model for use in social robotic/ECA systems was borne from our initial research of human communicative non-verbal facial behaviour (Section 3) wherein blinks were shown to be commonly co-occurring with other non-verbal facial behaviours way beyond levels of chance (Section 3.5), suggesting that blinks likely play a role within human-human communication. This concept has since been backed up through neurological research by Brefczynski-Lewis et al. (2011) which concludes that *"small and task-irrelevant facial movements such as blinks are measurably registered by the observers brain. This finding is suggestive of the potential social significance of blinks…"*

The project itself mixes the research paradigms expressed by Bartneck (2004) wherein a computational model of human blink behaviour in communication is created and then tested with participants through the perception of their interaction with a social robotic system within which the computational blink model has been implemented.

Developing improved social communication skills within social robotic/ECA systems would seem a high priority, not least if, as projected, they continue to become ever more common and their public domain user base grows, as this will lead to the requirement of these social robotic/ECA systems to be simple to use and instruct. Public domain users will likely have little to no training in robotic control / interaction and it is well understood that for any social robotic/ECA system to be truly useful within its role, it will need to effectively communicate with its users (Badler et al., 2002; Breazeal & Scassellati, 1999; Breazeal & Scassellati, 2002; Cassell *et al.*, 1994; Oestreicher, 2007b; Oestreicher & Eklundh, 2006; Peters et al., 2005; Sakamoto et al., 2005). Awareness of this fact is highly important in the sense that, for seamless instruction by human users, the use of manuals, complex menu interfaces or esoteric instruction based rule sets, essentially expecting users to learn new and specific communication skills to interact with and set tasks for these systems, will likely lead many users to great frustration and eventually non-interaction with the robotic/ECA system(s) in question.

Further, humanoid social robotic/ECA systems designed to imitate the look, movement and behaviour of humans could also cause confusion in a user if their appearance or behaviour are significantly different to that of an actual human (Coradeschi et al., 2006; Dautenhahn, 2004; Nishio, Ishiguro & Hagita, 2007). This development of humanlike social robots/ECAs is an important task however, as it has been shown that specific brain activity in viewers does not occur when actions are performed by non-humanlike agents (Han et al., 2005; Longo & Bertenthal, 2009; Perani et al., 2001), and as such,

these humanlike social robotic/ECA systems will require the development of increasingly complex cognitive, perceptive and social capabilities to balance their level of human appearance and thus alleviate the possibility of this user confusion arising (Coradeschi *et al.*, 2006).

Humans are experts in social interaction, spending on average 70% of their waking hours in some form of communication (Mortensen, 2008) and as such, human expectation of any communicative interaction will be extremely high. This expectation places greater emphasis on the quality and accuracy of the imitative human communicative behaviour expressed by a social robotic/ECA system within any social interaction with a human user.

The task of modelling any part of human communicative behaviour is in itself an enormous challenge, as communicative behaviour is complex and its rule sets elusive (Mortensen, 2008), utilising both verbal and non-verbal modes of communication, which include speech, auditory expression, facial expression, head motion, eye motion, gesture and pose with which to transmit (what can be subtle) communicative messages incorporating detailed semantic meaning (Knapp & Hall, 2010; Koneya & Barbour, 1976). The definition of a message in this case can be seen as an informational unit that links communicators together through their intentions within a communicative interaction. Within an interaction, multiple communicative acts take place requiring detailed translation through encoding and decoding processes to express and interpret the messages transmitted between interlocutors. It is important to note that the transmitted messages hold no significance until this translation function has occurred and so the control of these encoding / decoding processes is of primary importance in the continuity of human communication. The rules of the encoding / decoding within human communication are unknown and seemingly personal in their implementation

and as such, issues in communication understanding, where communicators misunderstand subtle behaviours (for example condescending behaviour), arise due to the level of complexity and personal understanding within these rules (Mortensen, 2008).

The sheer amount of variables affecting human-human communicative behaviour makes detailed understanding of communicative behaviour very elusive. Adding to the elusive nature of communicative behaviour is the concept of social perception, wherein humans analyse others with respect to their own goals, role identities and life experience within specified contexts and analyse how, through communication, they could positively affect these. This is poignant as this perception of others is based upon an image built from a chosen dataset (derived from a perceived fraction of the data available on the interlocutor in question and subject to strong personal bias), through which meanings and identities are attached which dramatically affect communicative behaviour (Simmons & McCall, 1979).

"'This quality of elusiveness makes the study of human communication particularly difficult. With so many variables working at once, it is often difficult to know what to look for and what to ignore." (Mortensen, 2008).

An age old problem for technologists, from the point of view of communication with technology, is formulated in the question "*How do we communicate with complex pieces of technology?*" This is as true for roboticists as it is for, ECA creators, video game designers and mobile phone application developers amongst others. Anywhere a real-time interface has to link a user to their technology, the same problem looms. Many previously tried to overcome this issue by designing their own user interfaces, hoping that (and in many cases making) users learn a new method of communication, however there is a slowly growing shift towards the incorporation of biologically-inspired

interfaces within technological systems, such as TVs, mobile phones and game consoles, allowing users to utilise already formulated methods of communicative behaviour (Zhang, 2012), but in the process running into the inherent complexity (and elusiveness in understanding) of the human communication process (Kotsia, Patras & Fotopoulos, 2012).

Currently, the act of a human user instructing a social robotic/ECA system to perform a task highlights many weaknesses in both human communication understanding and core development restrictions within HRI research (André & Pelachaud, 2010; Dautenhahn, 2007b). Commonly, social robotic/ECA systems are embedded with either non-humanlike communication interfaces or deficient imitative human communication interfaces, neither of which reach the levels of communicative interaction expected by human users, leading to communication difficulties which in turn create negative association with the social robotic/ECA system in its users (Bartneck et al., 2009). These communication issues point to the requirement for greater research into more humanlike communication methods within social robotic/ECA development. Another issue is that many research studies in the area of HRI are not easily reproducible, due in large part to the problem of not generalising to differing platforms and as such are unusable by many other researchers / developers (Dautenhahn, 2007a).

Lastly, during the creation of such a system, if greater knowledge in the understanding of any facet of human communication itself can be gained, this would clearly backup the strength and believability of such a system. This concept is nicely expressed by Barnland (1979) when he states that "*Any conceptual device that may give order to the many and volatile forces at work when people communicate deserves attention.*"

1.2 Current body of work in Human-Human Communication

Much research has already been performed in the understanding of human

communicative behaviour within the areas of Psychology / Sociology / Neuroscience / HRI / Human-Computer Interaction (HCI). Research herein has led to improvements in imitative human communicative systems (Kanda *et al.*, 2003; Lee & Kim, 2006; Mutlu et al., 2009; Trutoiu et al., 2011), but the problem of creating truly realistic human communicative behaviour that is indistinguishable by human users still exists (Bartneck *et al.*, 2009; Breazeal, 2002; Bruce, Nourbakhsh & Simmons, 2002; Dautenhahn, 2007b; Oestreicher, 2007b).

1.2.1 Human Social Interaction

One of the major features that take humans beyond all other animals on this planet in terms of development and as such, perceived intelligence, is the depth of our social interaction and the scale of co-operation that this brings within the confines of the rules of a society's social norms (i.e. standards of behaviour that are based on widely shared beliefs of how individual group members ought to behave in a given situation) within a culture (Elster, 1989; Fehr & Fischbacher, 2004; Henrich, 2003). Human communication is extremely complex (Knapp & Hall, 2010; Mortensen, 2008), in part to deal with these detailed social norms that human society and sub-societies (e.g. families, work peers, friends etc...) have created within them.

Culture also has a huge impact on the development of social norms and on the language and gestures (verbal and non-verbal output) used in communication by the people therein.

According to Lazear (1997)

> *"Culture is defined by anthropologists in a variety of ways. The definition usually includes some notion of shared values, beliefs, expectations, customs, jargon and rituals. Language is the set of common sounds and symbols by which individuals*

communicate"... "Both terms are somewhat ambiguous. Culture is the more amorphous of the two terms, but even language lends itself to somewhat blurred distinctions".

It is beyond the scope of this project to discuss in detail the creation and links between culture and language (Fitch, 2010), and as shown above, these terms can be translated in many ways. Suffice to say that our human social interaction is strongly affected by culture and together these drive the creation of specific languages and communicative behaviour, allowing the verbal, written and inherent non-verbal actions in the expression of societal norms within a defined cultural scope (Fitch, 2010).

The act of physical communication (that of delivering a message (i.e. semantics)) is split into two major types: verbal and non-verbal. Verbal communication is the auditory part of communication where the human vocal chords are used to create sounds; these sounds define the words of a cultures language as well as non-lexical conversation sounds for added communicative grounding (Section 1.2.2) and/or subtle message context alteration (e.g. "Ah" and "Umm" sounds can be expressed whilst in the mental communicative state of thought). (Smith, 2008) Non-verbal communication is described generally as "*communication effected by means other than words, assuming words are the verbal element*" (Knapp & Hall, 2010), which for the purposes of this work, can be further expressed as the gesture based part of communication where the position and movement between positions of the human body, specifically within facial features (such as facial expression, head movement (nodding / shaking), eye movement and blinking) express our prior defined mental communicative states and emotional state information as well as containing inherent communication grounding information (Kendon, 1967; Smith, 2008).

Interestingly, the vocalic information (i.e. loudness, pitch, rhythm, intonation and

cadence) of the verbal delivery are also considered to fall inside non-verbal communication. These are highly informative to the conversational interlocutor, dramatically adding to the overall semantic meaning conveyed within a verbal communication (Smith, 2008).

Studies into the impact that verbal and non-verbal communications have on the transfer of an intended message and its inherent detailed semantic meaning have shown a significant bias towards nonverbal information, with facial behaviours shown to have the strongest effect on semantic meaning transfer (Knapp & Hall, 2010; Koneya & Barbour, 1976), as expressed in Figure 1-2.

Figure has been removed due to Copyright restrictions

Figure 1-2 Semantic Impact upon Communication (Koneya & Barbour, 1976)

1.2.2 Communication Grounding

"Except for the simplest reflex behaviours, human beings seldom communicate without some kind of expectancy." (McLuhan, 1964).

Communication grounding is an essential part of human conversation for controlling the bidirectional flow of 1:1 or 1:many conversations (Argyle & Dean, 1965; Clark, 1992; Clark & Krych, 2004; Grosz & Sidner, 1986; Kendon, 1967; Kozima, Nakagawa & Yano, 2003; Walker & Whittaker, 1990). The processes involved include:

- Conversation Instigation/Completion
- Turn-Taking
- Bodily Distance Negotiation (i.e. Proxemics)
- Reaction Feedback
- Topic Change
- Joint Intention (including during object focus)

These communication grounding processes are not discussed in detail here as the papers cited explain them well, suffice to say that any models of human communication will require communication grounding processes to be wrapped around them so that a models expressed communicative behaviour functions in a grounded and socially acceptable manner. An overview of pertinent (Western) communication grounding information for this study follows.

Non-verbal head movement and eye gaze are strongly linked in gaze behaviour in human communication (Land & Tatler, 2009) and play a hugely important role in human communication grounding processes (Argyle, 1988; Argyle & Dean, 1965; Clark, 1992; Clark & Krych, 2004; Knapp & Hall, 2010; Land & Tatler, 2009). Argyle and Dean (1965) specifically state that "*Research has shown that the average time that we gaze at an interlocutor in 1:1 communication amounts to 75% whilst listening and 40% when speaking, with mutual gaze (eye contact) occupying 30% overall. Average gaze timings are generally around 3sec, with mutual gaze being half this at 1.5sec. Generally, those who look more are seen as attentive whereas those who look less are seen as passive (or inattentive). Continuous gaze however is very distracting and uncomfortable and as such is occasionally used as part of a threatening state… It seems that other things being equal, the more people look at each other's faces the more positive and engaged the relationship, provided a subtly defined upper limit is not*

breached".

Of note, a recent study by Gullberg (2001) displayed the average time that we gaze at an interlocutor in 1:1 communication whilst listening as 96%, above the 75% average previously posited by Argyle (1988). The reasons for this difference could be numerous, however for this project; these values are none the less significant due to their grounding role within human communication.

As shown, facial contact and more specifically eye contact are strong elements in human recognition and also in human communication control and feedback (Argyle, 1988; Argyle & Dean, 1965; Land & Tatler, 2009) as both an instigator and as a grounding mechanism throughout conversation (Clark, 1992). Eye gaze itself produces such detailed communication grounding feedback (Kendon, 1967) that conversational dynamics are able to be changed in real-time through this information, allowing for subtle updates in communication, such as understanding/misunderstanding (Clark & Krych, 2004), mood, acceptance, hierarchy, noise level filtering, expressiveness and focus of attention (Bruce, Nourbakhsh & Simmons, 2002).

As a backup to this statement, with specific reference to the eyes, research has shown that random gaze does not improve communication, but that directed gaze, that reacts based upon the conversation dialogue, significantly improves attention and understanding over audio-only communication (Maia et al., 2001; Pelczer, Cabiedes & Gamboa, 2007; Vertegaal et al., 2001) giving evidence to the importance of gaze (a facet of overall non-verbal facial information) in communication grounding. Further, Raidt, Bailly and Elisei (2007) and Land and Tatler (2009) show that when taking the listener role in a human-human communication, visual focus is placed mainly on the face of the interlocutor and specifically at the triangle of the eyes and mouth. This visual focus can be expressed through viewing a complex picture of a face (Figure 1-3),

as displayed in Yarbus and Riggs (1967) seminal work Eye Movements and Vision, whose study backs up the effect of interlocutor focus on the face during communication through their finding that saccadic eye movements on a focussed object are task specific in nature.

Figure has been removed due to Copyright restrictions

Figure 1-3 Scan Path over Facial Image (Yarbus & Riggs, 1967)

This follows on from Koneya and Barbour (1976) statement that a significant amount of semantic information is transmitted non-verbally through the face and specifically the region around the eyes. However, higher focus is placed on the region of the mouth when listening, the concept of which is expressed as a process of lip reading, allowing for improved error control within message reception and decoding (Raidt, Bailly & Elisei, 2007), and has a major communicative role in high-noise environments; This can have a direct effect on the level of message information received by the interlocutor (Shannon & Weaver, 1948).

It was therefore deemed especially important to this project to look specifically at facial non-verbal behaviour during communication (incorporating head and eye movement behaviour) as this has proven to be the most expressive non-verbal behaviour in

carrying semantics within human communication (Koneya & Barbour, 1976).

Emotional state message content also figures heavily in communication grounding. Fischer (2004) has explored emotion with respect to pure language, finding emotional speech to pose many grounding problems if not responded to and correctly understood by the robotic/ECA system and further, that extreme emotive responses seem to require more face-to-face communication with deliberate eye contact to ascertain and acknowledge these detailed but subtle emotive cues.

Finally, no discussion of communication grounding would be complete without the mention of proxemics (Argyle & Dean, 1965) defined as the "social use of space in a communication situation" (Smith, 2008). This is based around the distance that people place themselves during communication, which is roughly defined in four areas of space:

1. Intimate space (0-46 centimetres)
2. Personal space or informal distance (46 centimetres to 1.2 metres)
3. Social space or formal distance (1.2 to 3.6 metres)
4. Public space or distance (beyond 3.6 metres)

This space generally changes during conversation to aid in communication grounding and the correct transfer of message semantics.

With the exceptional complexity of human communication it does indeed make sense to imbue a social cognitive robot with models that can imitate humans in communication to allow for seamless social human-robot interaction. Communication grounding therefore will be an important component in controlling any communication model to allow for the instigation and completion of any human-robot communication and the control of the message semantics transferred therein.

Recent studies have already seen the creation of a computational model of communication grounding with respect to enabling an ECA to control the instigation, maintenance and completion of a communication with a human user through gaze behaviour (Peters *et al.*, 2005) and a recent study of human-robot proxemics shows that proxemic communicative behaviour differs slightly to natural human-human proxemics with users that dislike a specific robotic design (Mumm & Mutlu, 2011). These models make important steps towards the creation of a complete system of human communicative behaviour for use within social robotic/ECA systems.

1.2.3 A Definition of Human Non-Verbal Facial Behaviour

For the requirements of this study, Human Non-Verbal Facial Behaviour is defined as all of the movements made by the head and face, excluding that of the lips through speech. This incorporates the following behaviours:

1. Eye Movement (incl. Gaze Direction and stare)
2. Head Movement (incl. Gaze Direction, shaking and nodding)
3. Blinks
4. Facial Expressions (e.g. smile, grimace, stare, down-turned mouth, frown etc...)

All of these movements allow humans to better ground communication, express mental and emotional communicative states, and heavily affect the semantic meaning of any transferred message (Koneya & Barbour, 1976), whether delivered purely non-verbally or with the inclusion of speech.

It is important to note that non-verbal behaviour is intimately linked to the act of speaking (Bavelas & Chovil, 2000; Kendon, 2004), utilising a distinct co-ordination which is driven by the aim of the speaker, modifying and/or elaborating the semantic meaning of the message being relayed (Kendon, 1983; Knapp & Hall, 2010; Koneya &

Barbour, 1976).

Additional non-verbal facial expression accentuation is exceptionally common, and accurate, at accentuating the semantic meaning of speech in many varied ways to alleviate confusion within message delivery (Knapp & Hall, 2010; Koneya & Barbour, 1976). This accuracy is impressive considering the level of difference within each person's physical facial features and the complexity of the facial expressions that the human face can portray (Rinn, 1984). It needs to be stressed however, that the requirement of context is extremely important herein, as is shown by Munn (1940) in a classic experiment which tested participants understanding of displayed static images of human facial expressions with background information removed vs. background information included along with verbal descriptions of the situation in which the communication took place. The latter variant, through its increase in contextual data, greatly improved participants accuracy in guessing the correct emotional state represented by the displayed facial expression. Of interest, there is some contention as to whether facial expressions are purely linked to the expression of emotional state, or whether they are naturally utilised for overall social communication purposes (Fridlund, 1997), the latter of which this study would concur, with respect to the expression of emotional states during human-human communication.

With regard to the definition/representation of human facial expressions linked to emotional states, the Facial Action Coding System (FACS) devised by Ekman et al. (1978) has become a commonly used representation for facial expressions at muscular level detail. The FACS system utilises 46 basic Action Units (AU), each of which represent areas of facial muscular movement (either contracting or relaxing) that, through activation, can reproduce a wide range of human facial expression. Beyond its use in characterising and expressing emotional states, this system has also been widely

used within film and game animation design to portray human facial behaviour in human and humanlike characters (for example, the King Kong character in the eponymously titled movie (Jackson, 2005). With regard to this study, the FACS system has been implemented within the LightHead robotic systems (Delaunay, De Greeff & Belpaeme, 2009) facial expression modelling and control modules (Section 2.5.1.1).

Referring back to Figure 1-2, the importance of non-verbal facial behaviour within human-human communication cannot be underestimated (Knapp & Hall, 2010; Koneya & Barbour, 1976; Land & Tatler, 2009). Therefore, this study tries to answer an important question… *Does blink behaviour have a role to play within human-human communication?*

1.2.4 Blink Behaviour in Human-Human Communication

The act of blinking in humans is an automatic and generally unnoticed behaviour (Burr, 2005). Blinking performs important physiological roles: cleaning, oxygenating and replenishing the tear film of the eye (Al-Abdulmunem & Briggs, 1999; Carney & Hill, 1982), however, much research also suggests that beyond these roles lies a deeper relationship between human blink behaviour and cognitive processing (Bentivoglio et al., 1997; Burr, 2005; Gordon, 1951; Hall, 1945; Ponder & Kennedy, 1927). This concept is strengthened through developmental research, which has shown that blink behaviour is almost non-existent at birth and increases in frequency during the formative years, reaching a peak blink rate in adulthood (Bentivoglio *et al.*, 1997; Karson, 1988; Ponder & Kennedy, 1927).

In normal adults, spontaneous eye blink rate (SEBR) is generally inhibited upon greater cognitive load (Al-Abdulmunem & Briggs, 1999), however, within communication the opposite is found to be true; Compared to SEBR when at rest (SEBR between 8.0 and 21.0 eye blinks/min), the rate increases during communication (SEBR between 10.5 and

32.5 eye blinks/min) and decreases during reading (SEBR between 1.4 and 14.4 eye blinks/min) (Doughty, 2001), suggesting that human blink behaviour could possibly have a role within human-human communication. A recent neurological study of human blink behaviour by Brefczynski-Lewis et al (2011) backs up this statement; through the analysis of event-related potentials elicited by observing non-task relevant blinks, eye closure, and eye gaze changes in a centrally presented natural face stimulus, this research draws the conclusion that *"small and task-irrelevant facial movements such as blinks are measurably registered by the observers brain. This finding is suggestive of the potential social significance of blinks…"* They further state that *"…this has implications for the study of social cognition and use of real-life social scenarios."*

Blinks have been found to co-occur at temporal points within communicative behaviours, for example Condon and Ogston (1967) note *"The eye blink has been found to occur during vocalization at the beginning of words or utterances, usually with the initial vowel of the word; at word medial syllabic change points; and precisely following the termination of a word. Thus, speed variations and eye blinks do not seem to occur randomly, but are also related to their on-going variations in the sense that if they occur, their point of occurrence may be relatively specifiable"* and Peters (2010) suggests that human blink behaviour is closely related to gaze behaviour.

In two studies parallel to our own, similar findings were observed in human blink behaviour: Cummins (2011) recently reported on co-occurrences between gaze, start of own speech and blinks wherein he suggests that blinks and gaze are inseparably linked in a way that defines individual communicative style. Nakano and Kitizawa (2010) observed blink co-occurrence at the end and during pauses of speech in participants conversing with an interlocutor displayed via video clips with sound, however blink co-occurrence did not occur when the sound was removed from the video clips leading

them to suggest that the observed blink co-occurrence reflects smooth communication between interactants. Our findings concur with these conclusions and helped to motivate the creation of a computational model of human blink behaviour to aid communication between a human user and a social robotic/ECA system.

Blinks also add a visual behaviour, as with the rise and fall of the chest when breathing, that express life (Thomas & Johnston, 1981). Blinks are a constant of human behaviour and are noted by their absence. Such is the resolution by which blink behaviour is subconsciously monitored within human-human communication that SEBR either slower or faster than natural human communicative blink behaviour produces a strong negative response in the interlocutor (Lee & Kim, 2006).

This body of research strongly suggests that blinks have additional roles within human-human communication that have yet to be described. To express (and possibly describe) these roles was the motivation for this study and the creation of a computational model of blink behaviour for implementation within social robotic/ECA systems.

1.3 Human Blink Behaviour in HRI and HCI-ECA Research

A further question posed by this project was defined as *Can computationally modelled humanlike blink behaviour performed by a social robotic/ECA system be seen as acceptable to human users as a substitute for real human blink behaviour?*

Commonly, current humanlike social robotic/ECA systems are curtailed through the implementation of communicative models that are based on human communicative behaviour, but their overall performance is not expressed in an accurate humanlike manner (Ishiguro & Nishio, 2007; Kuratate, Pierce & Cheng, 2011), however, even unnatural characteristics in the imitation of human behaviour can receive positive responses from human users… Studies such as those performed by Breazeal et al (Breazeal, 2002;

Breazeal & Scassellati, 1999; Breazeal & Scassellati, 2000; Breazeal & Scassellati, 2002), Lee and Kim (2006), Dautenhahn (2007b) and Ishiguro and Nishio (2007) have shown that over time, social emotional behaviours are strongly elicited in users of anthropomorphic systems displaying semi-humanlike non-verbal expressive actions (Prendinger, Becker & Ishizuka, 2006).

With respect to the expression of blink behaviour for social robotic/ECA systems, a number of models have been created: Lee and Kim (2006) utilised isochronal blink behaviour to display the information for the scenario "I'm busy…" , imitating the role of a progress bar on a computer and thus, giving feedback to the user that the robot is busy processing data. This system utilised a 2D graphical representation of a robot on a computer screen, utilising a simple eyelid closed / open blink animation at differing isochronal speeds to test users patience and overall acceptability of this method of feedback)as opposed to no feedback) from the robot whilst it was processing information. Positive results were received from participants who found it easier to wait when they could see that the robot was blinking, and as such was still perceived as processing information. Further, natural blink timings were found to be more favourable overall, with fast blinks rushing the user and slow blinks making the user wait for an expected response, with both of these states found to frustrate the user. Lee et al (2002) have developed a seminal model of animated eye gaze for use with avatars that utilised the alterEGO facial animation system (Capin, Petajan & Ostermann, 2000) to produce animated blinks amongst other facial behaviours. They suggested, from their face tracking data, that eye blinks have a link to eye movement. Deng (2005) followed up on the concept of eye blinks triggered through eye movement behaviour. Their work stands out for its use of texture synthesis techniques (utilising motion capture of human communicative behaviour) to generate eye motion and blinking in avatars. Weissenfeld et al (2009) created a detailed probabilistic model of eye movement generation utilising actual image samples

of human eye behaviour and reflecting the experimental link between blink behaviour and eye movements (specifically the head movement made when looking at / away from the interlocutor during communication). The system synthesised specific image sets of eye behaviour (incl. blinks) that would be expressed in real-time dependant on the eye movement requirements from the speech to be performed by the avatar. The blink model implemented on the Mask-bot (Kuratate et al., 2011) (Figure 1-5) was coded by Prof Hiroyuki Mitsudo based on the model created by Hoshino (1996) utilising the Ornstein-Uhlenbeck function of Brownian Motion (Uhlenbeck & Ornstein, 1930). The blink model utilises the inter-blink interval (i.e. the time between blinks) from captured human communicative behaviour to define blink triggers. Utilising this data, variables for the Ornstein-Uhlenbeck function were set to closely fit the inter-blink interval timings. Each of the models above is based purely on physiological blink timings and not with blink behaviour linked to other human communicative behaviour. Our model intends to differentiate itself through this holistic analysis and will likely improve upon the current computational blink models in existence at this time.

Blink behaviour strongly expresses life in an anthropomorphic entity (Lee & Kim, 2006; Thomas & Johnston, 1981) and is now more commonly seen as having a role in the process of communication (Bavelas & Chovil, 2000; Brefczynski-Lewis *et al.*, 2011; Cummins, 2011; Kendon, 2004; Nakano & Kitazawa, 2010). Blink behaviour in animals greatly differs from human blink behaviour (Blount, 1927), however a recent study by Tada et al. (2013) of 71 species of primate shows that the primate blink rate increases as group size increases, leading them to state that "*Our results suggest that spontaneous eye blinks have acquired a role in social communication, similar to grooming, to adapt to complex social living during primate evolution.*" These findings suggest that the importance and benefits of accurately modelling human blink behaviour within a computational blink model cannot be understated, as this accuracy will likely increase the be-

lievability of the simulated human communicative behaviour through the expression of realistic social cues and through this, the acceptability of both the computational blink model and the overall social emotional behaviour elicited from users interacting with social robotic/ECA systems within which the computational blink model is embedded.

1.4 A Computational Model of Blink Behaviour in Human-Human Communication

To enable creation of an accurate computational model of human blink behaviour in communication, the process of human-human facial communication needed to be understood in detail. To aid this understanding, an initial prototype human communicative behaviour system was conceptually designed to express realistic human-human facial non-verbal communication, to define the data corpus to be collected and analysed in the creation of the computational blink model, and to understand where the computational blink model would reside within this system to enable accurate simulation of human communicative blink behaviour.

The concept of the mental communicative state, posited as a communicative behaviour driver in human-human communication in prior psychological, HRI and HCI research (Cassell, 2007; Cassell *et al.*, 1994; Clark & Krych, 2004; El Kaliouby & Robinson, 2005; McNeill, 1992) was utilised along with speech context as the driver for the human communicative behaviour systems conceptual design.

The human communicative behaviour system design (Figure 1-4) functions as follows: Semantic information is derived from a user's captured speech-based requests through natural language processing. This semantic information is analysed to create a list of possible speech responses. Dependant on the number of speech responses created through natural language processing, the mental communicative state (i.e. thought, understanding, uncertainty or misunderstanding) is derived. The dialogue manager

utilises the derived speech responses and mental communicative state to choose the actual speech response (held in the speech transcription). The chosen speech response and mental communicative state are then utilised by the behaviour complex model and the blink model to define and create the temporal non-verbal facial behaviour complex and blinks (held in the non-verbal behaviour transcription). The transcriptions are then merged to create a list of temporal communicative behaviour (i.e. speech and associated non-verbal facial behaviour complexes) which are then expressed by the social robotic/ECA system as a response to the users dialogue (speech).

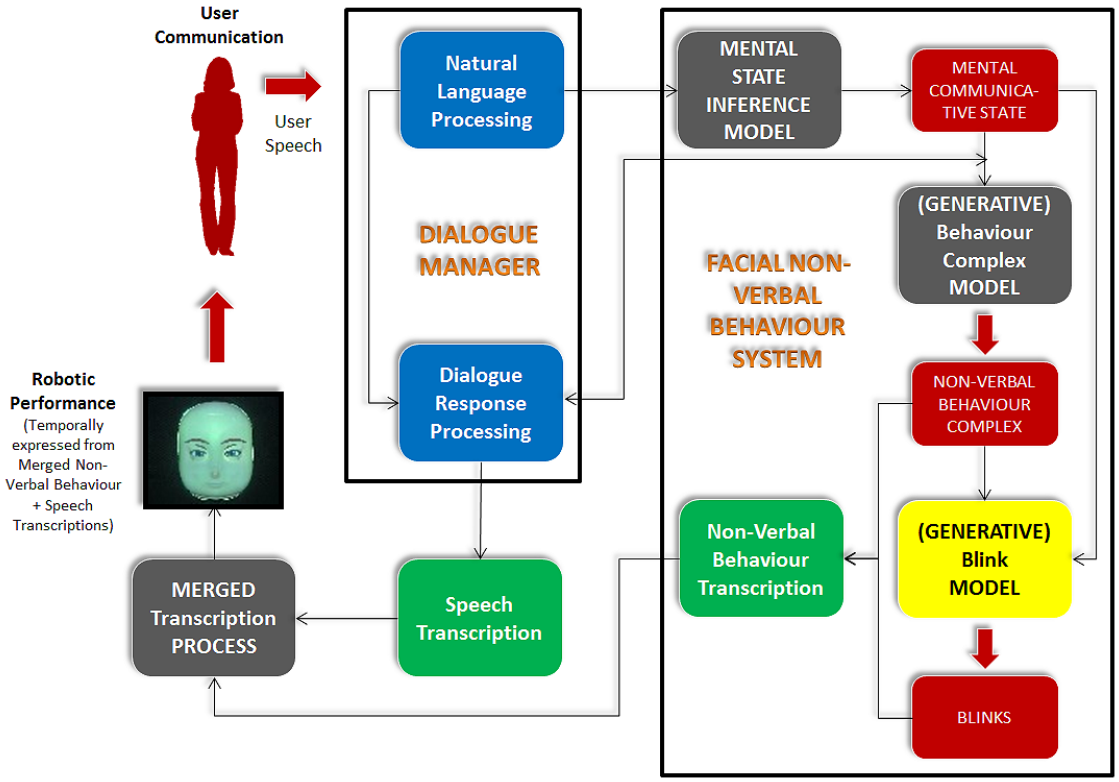


Figure 1-4 Human Communicative Behaviour System

To gather the data required for creation of the computational blink model and to observe behaviour relating to the system driver of mental communicative states, a prototype experiment was designed to elicit each defined mental communicative state from human-human communication through a pre-defined dialogue script (Section 2.3). The data transcription (Section 2.5) of fourteen participants non-verbal facial

communicative behaviour was processed through bespoke parsing software and further analysed/transcribed to temporally display and map the communicative behaviour of each mental communicative state (Section 0).

Through this process, it was observed that many blinks were commonly co-occurring with other non-verbal facial communicative behaviour primitives during the communicative process. This co-occurrence behaviour was then analysed (Section 3.5) and the results utilised to formulate the probabilistic blink trigger behaviour of the computational blink model (Section 4.2).

The computational blink model was then implemented within the LightHead robotic system (Delaunay, De Greeff & Belpaeme, 2009) (Figure 1-5) along with a model of saccadic eye movement within communication (Section 5.3.1.3), derived from research performed by Raidt, Bailly and Elisei (2007). A user-based testing experiment was then designed and performed to ascertain levels of human perception elicited by the computational blink model behaviour, versus actual human blink, isochronal blink and no blink behaviours (Section 6).

The design of a few recent social robotic systems have implemented back-projection systems which use a mini-projector with a fish-eye lens to display the face of the robot on a human head shaped translucent mask. Back-projection allows detailed graphical control of the movement of the projected face at musculature level (similar to the animation of an ECA) creating the possibility of imbuing the robotic system with realistic humanlike non-verbal facial behaviour.

Two of these social robotic systems, LightHead [1] (Delaunay & Belpaeme, 2012; Delaunay, De Greeff & Belpaeme, 2009) and Mask-bot[2] (Kuratate *et al.*, 2011; Kuratate, Pierce & Cheng, 2011) can be seen in Figure 1-5.

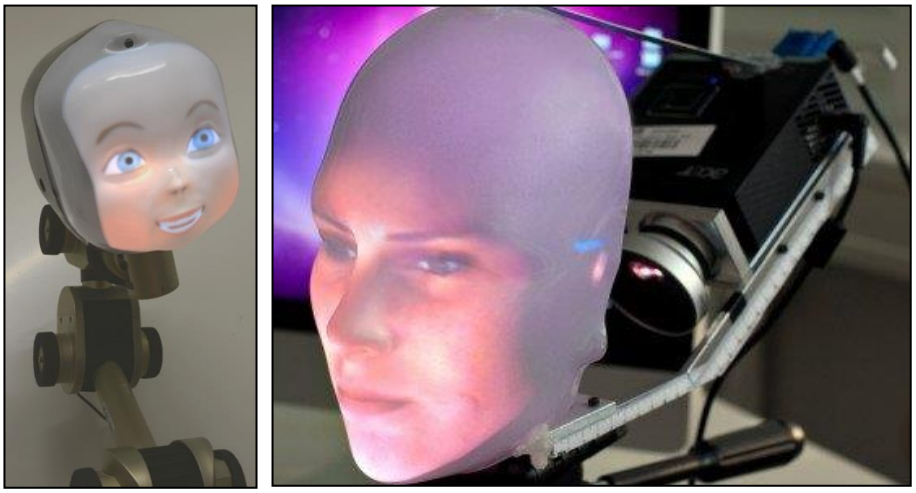


Figure 1-5 LightHead (Delaunay, De Greeff & Belpaeme, 2009) and Mask-bot (Kuratate et al., 2011) Social Robotic Systems

Both systems have their faces projected onto a 3D head-shaped translucent mask, adding the benefit of depth to the physiology of the face. Thus, standing to the side of these robots allows viewing of the lens of the eye and the protrusion of the nose as would be seen whilst standing to the side of a human interlocutor, thus allowing gaze direction to be more accurately assessed by the systems user (Al Moubayed et al., 2011). The graphical control of the face projection from these back-projection systems provides very subtle control of facial motion (as opposed to the use of mechanical hardware), allowing much greater accuracy in the creation/expression of realistic human facial movement (Delaunay & Belpaeme, 2012; Kuratate *et al.*, 2011). These benefits

[1] http://youtu.be/_KIhXaovnNg

[2] http://youtu.be/oFp1hpH25oI

of the back-projection system allow for a more realistic representation of the human head/face and improve the overall realism of the simulation of human communicative non-verbal facial behaviour.

These social robotic systems however are currently open book and await cognitive human behavioural models to be implemented within them. This study was situated in the same department in which the LightHead social robotic system was being developed, allowing for a mutually beneficial collaboration to be formed with the systems designer. The LightHead back-projection design had the granularity to allow us to express realistic humanlike communicative non-verbal facial behaviour and was therefore chosen for the implementation of our computational models of human blink and saccadic eye movement behaviour (Section 5). The LightHead social robotic system is described in more detail in Section 5.3.

1.5 Research Contributions

During this study, the following contributions to knowledge were made:

1. Categorisation of communicative non-verbal facial behaviour for the mental communicative states of Thought, Understanding, Uncertainty and Misunderstanding, wherein we also display statistical analysis for the proof that these mental communicative states can be differentiated through their behaviour characteristics (Ford, Bugmann & Culverhouse, 2013). The use and choice of mental communicative states as a driver of communicative behaviour was motivated through prior research studies which define and utilise mental states of thought, understanding and uncertainty in the design and control of communicative behaviour within social robotic/ECA systems (Cassell, 2007; Cassell *et al.*, 1994; Clark & Krych, 2004; El Kaliouby & Robinson, 2005; McNeill, 1992).

2. We state that blinks are directly related to human communicative behaviour and are not simply "physiological" (e.g. for cleaning/humidifying the eye) in nature (Ford, Bugmann & Culverhouse, 2010), prior to Cummins et al (2011) who concur strongly with our findings.

3. Creation of a computational blink model which reproduces human blink behaviour in communication to a level that is indiscriminate with actual human blink behaviour in communication. (Ford, Bugmann & Culverhouse, 2013)

4. Definition of new blink behaviour triggers of: Facial Expression Onset / Offset, Interlocutor Speech Onset and Mental Communicative State Change, including the newly investigated mental communicative state of misunderstanding. (Ford, Bugmann & Culverhouse, 2013)

5. Definition of gender-based differences for blink triggers in all the above newly defined communicative facial behaviour primitives. (Ford, Bugmann & Culverhouse, 2013)

6. A definition of the half blink type (where the upper eyelid only half covers the eye, but still covers the pupil, therefore inhibiting vision as would a standard blink). (Ford, Bugmann & Culverhouse, 2013)

7. Definitions of blink morphology and gender based differences in overall blink duration. (Ford, Bugmann & Culverhouse, 2013)

8. Formulation of the FaceML XML Schema to enable detailed transcription of human communicative facial behaviour. (Ford, Bugmann & Culverhouse, 2010)

Several parts of the research described in this thesis have already been published, or are currently submitted for publication in peer-reviewed journals. See the Authors

Declaration on pages 17-18 for details. Copies of the publications from this study can be found at *www.ccford.co.uk*.

1.6 Thesis Structure

The rest of the thesis is divided broadly into four parts. Part II (Chapters 2 to 4) presents details of the human-human communication experiments performed, results obtained for each stage of implementation and the computational models derived. Part III (Chapters 5 and 6) presents details of the blink model user testing experiments performed and the results obtained for each implementation stage. Part IV (Chapter 7) presents the final discussion, conclusions and future work.

"Electric communication will never be a substitute for the face of someone who with their soul encourages another person to be brave and true."

Charles Dickens, The Wreck of the Golden Mary, Page 10, Column 2, 1856.

PART II

OBSERVING HUMAN-HUMAN NON-VERBAL FACIAL COMMUNICATIVE BEHAVIOUR

Capturing the Complexity of Human Communication.

2 An Experimental Study of Human-Human Communication

This chapter presents an exploration into human-human non-verbal communicative behaviour in a one-to-one communication scenario to define the non-verbal communicative behaviour that is commonly expressed within the mental communicative states of understanding, uncertainty, misunderstanding and thought and to define common traits of human blink behaviour in communication. Analysis of this data will drive the development of the conceptual human-human communication model and the creation of a computational model of human blink behaviour in communication. The computational blink model, once implemented within a social robotic/ECA system, would likely aid a user's communication with the system in question through its improvement of attention (Lee & Kim, 2006) and its imitation of life (Thomas & Johnston, 1981) properties, improving the chances of a successful communicative interaction.

2.1 Definition of Mental Communicative States

The expression of mental communicative states is a foundational concept in the design of both the human communicative behaviour system (Figure 4-1) and the computational blink model (Figure 4-2). These states were derived from both human communicative behaviour, as expressed in prior HRI research (Lee, Badler & Badler, 2002; Ochs *et al.*, 2005; Ochs & Pelachaud, 2013) and from the functional concept of the Dialogue System (Figure 1-4), which itself is trying to imitate human communicative behaviour as part of an interactive system. Within the Dialogue System, mental communicative states are defined on-the-fly by both the currently running process and also the number of responses generated during the semantic processing stage from the embedded Natural Language Processing (NLP) module. This delineation follows:

- The **Thought (Listening)** state occurs whilst the users speech is being recorded and processed, ready for semantic analysis by the NLP module.

- The **Thought (Processing)** state occurs during the pause created by the NLP module whilst it is performing semantic processing on the recorded user speech.

- The **Misunderstanding** state occurs when the NLP module cannot make sense of the received speech and thus creates an error response from the semantic processing.

- The **Uncertainty** state occurs when the NLP modules semantic processing creates more than one response for the received user speech.

- The **Understanding** state occurs when the NLP modules semantic processing creates a single response from the received user speech.

These mental communicative states run concurrently throughout human-human communication and can therefore be judged to be important for HRI/HCI when considering the feedback required for a user to both interact with and to eventually complete a communication with a social robotic/embodied conversational agent (ECA).

The protocol for the human-human communication experiment was designed to elicit these mental communicative states from participants over time through defined dialogue scripts, allowing the transcription of the participants expressed communicative facial non-verbal behaviour primitives during each of these mental communicative states as they are triggered throughout the communicative process.

Communicative non-verbal facial behaviour was chosen specifically for this research project, pared back from full body behaviour (including bodily gestures and pose) for two reasons. The first reason was based on the decision that analysing full body human

communicative behaviour would be an exceptionally complex undertaking, beyond the scope of a single PhD study and thus some constraints in this overall complexity needed to be implemented. The second reason was due to the strength of non-verbal facial behaviour having the highest effect in conveying subtle semantic information during the communicative process (Knapp & Hall, 2010; Koneya & Barbour, 1976) and as such that the mental communicative states defined could be adequately expressed through non-verbal facial behaviour alone.

2.2 A Definition of Communicative Facial Behaviour

The complexity of human social interaction is explicitly shown within communicative non-verbal facial behaviour during human-human communication, with its intricate yet subtle interplay of movements adding greater semantic meaning to the context of any expressed message. To capture this intricate behaviour, a number of communicative non-verbal facial behaviour primitives were defined for analysis to be performed on the captured data at a resolution that would allow for accurate model creation.

Table 2-1 displays a list of the defined communicative behaviour primitives recorded from the participant's communication during the initial experiment along with their FaceML (Section 2.5.1) morphology coding schema:

Table 2-1 Communicative Behaviour Primitives (incl. morphology FaceML coding)

Coding Title (FaceML)	Description
sSpeech	**Interlocutor (Experimenter) Utterances** - Speech and filler words made throughout the duration of the communication with a participant. Interlocutor (Experimenter) Utterance FaceML morphology coding definition: • Start Time • End Time • Duration (Start Time – End Time + 1) • Utterance

pSpeech	**Participant Utterances** - Speech and filler words made throughout the duration of the communication with the interlocutor/experimenter. Participant Utterance Morphology FaceML schema: • Start Time • End Time • Duration (Start Time – End Time + 1) • Utterance
PEM	**Participant Eye Movement** – All participant eye movements. Eye Movement Morphology FaceML schema: • Start Time • End Time • Duration (Start Time – End Time + 1) • Direction (0 → 359^{o}) • Distance (0 (Pupil centred in eye) □ 1 (Pupil at far edge of eye))
PEG	**Participant Eye Gaze** – Looking at or away from the interlocutors face. Eye Gaze Morphology FaceML schema: • Start Time • End Time • Duration (Start Time – End Time + 1) • Looking (at (ATF), or away (AWF) from the interlocutors face).
PHG	**Participant Head Movement** – All participant head movements. Head Movement Morphology FaceML schema: • Start Time • End Time • Duration (Start Time – End Time + 1) • Direction (0 → 359^{o}) • Distance (0 (Head facing forward) → 1 (Head at furthest extension)) • End Angle (Slant of the head on shoulder (horizontal) axis). (NOTE: Head rotation is not a highly accurate measure when viewed and transcribed from video information, however, the transcription process has shown an acceptable level of error to enable this non-verbal behaviour to be displayed/categorised for non-verbal co-occurrence mapping and also for imitating realistic head movement within a social robotic/ECA system / ECA through use of the FACS model (Ekman *et al.*, 1978).
PBL	**Participant Eye Blink** – All eye blink activations. Eye Blink Morphology FaceML schema: • Start Time • End Time • Duration (Start Time – End Time + 1) • Closure Type (Half or Full) • Attack (eyelid closing motion) • Sustain (eyelid closed)

	• Decay (eyelid re-opening motion)
PFE	**Participant Facial Expression** - Communicative expressions made using the face/head. Facial expressions found within our data analysis process: smile, pursed lips, squint, furrowed brow(s), raised brow(s) and down-turned mouth. Facial Expression Morphology FaceML schema: • Start Time • End Time • Duration (Start Time – End Time + 1) • Expression Type
cState	**Participant Mental Communicative State** – Cognitive communicative state changes expressed throughout the communication with the interlocutor/experimenter. Mental Communicative State definitions: • Thought ○ Sub-Types: Thought (Listening) and Thought (Processing) • Understanding • Uncertainty • Misunderstanding These states are derived from the temporal expression of participants verbal and all other non-verbal facial behaviour primitives throughout the communication, as recorded by the experimenter. Eye Blink Morphology FaceML schema: • Start Time • End Time • Duration (Start Time – End Time + 1) • State Type (PCO-T(L/P), PCO-U, PCO-UU and PCO-M)
PST	**Participant Stare** - Suspended saccadic eye movement/scene processing, as though the participant is looking through the interlocutor/experimenter. Stare Morphology FaceML schema: • Start Time • End Time • Duration (Start Time – End Time + 1)

2.3 Experimental Dialogue Design

To elicit the mental communicative states and their associated non-verbal facial behaviour primitives over time, an interlocutor (experimenter) engaged with participants in a one-to-one communication utilising four separate pre-defined dialogue scripts (Appendix II). Each script incorporated specific sentence/word delays, noise (e.g.

made-up words within a sentence), and errors (e.g. incorrect or misplaced words within a sentence) (Table 2-2) at points within its structure, creating transitions between mental communicative states throughout the communication process.

Table 2-2 Dialogue Stimuli

Dialogue #	Description
1	This is a strongly conversational script which derives heightened emotional links from the participant towards the interlocutor through emotion based question content. Dialogue errors are blocked together at the end of the script such that misunderstanding is less likely to occur through the bulk of the conversational interaction.
2	This is a knowledge question based script that is intended to heighten the differences in eye movement behaviour between immediate thought → understanding and longer term thought → misunderstanding → understanding responses. Errors in the dialogue are blocked together at the beginning of the script such that misunderstanding is likely to occur more frequently throughout the main bulk of the conversational interaction.
3 / 4	These are a mixture of emotive and knowledge based question content. Script #4 is also performed with visual denial of speaker to elicit any differences in behaviour pertaining to verbal only communication.

An example section of dialogue #1 follows (with the expected mental communicative state transitions for each participant response shown inside brackets):

Interlocutor: ***Do you know which star sign you are?***

Participant: ~SPEECH RESPONSE~ (*Thought to Understanding or Uncertainty*)

Interlocutor: ***I was born in mid-November. Do you know which star sign I am?***

Participant: ~ SPEECH RESPONSE~ (*Thought to Understanding or Uncertainty*)

Interlocutor: ***I'm not sure I believe in the information gleaned from star signs, do you?***

Participant: ~ SPEECH RESPONSE~ (*Thought to Understanding or Uncertainty*)

Interlocutor: ***Hmm. That's interesting. So, why do you believe this?***

Participant: ~ SPEECH RESPONSE~ (*Thought to Understanding*)

The transitions between mental communicative states varied greatly between participants, however this was both expected (due to the differences in knowledge, age, gender, mood etc... of each participant) and acceptable within the context of the project requirements.

2.4 Experiment Set-Up and Methodology

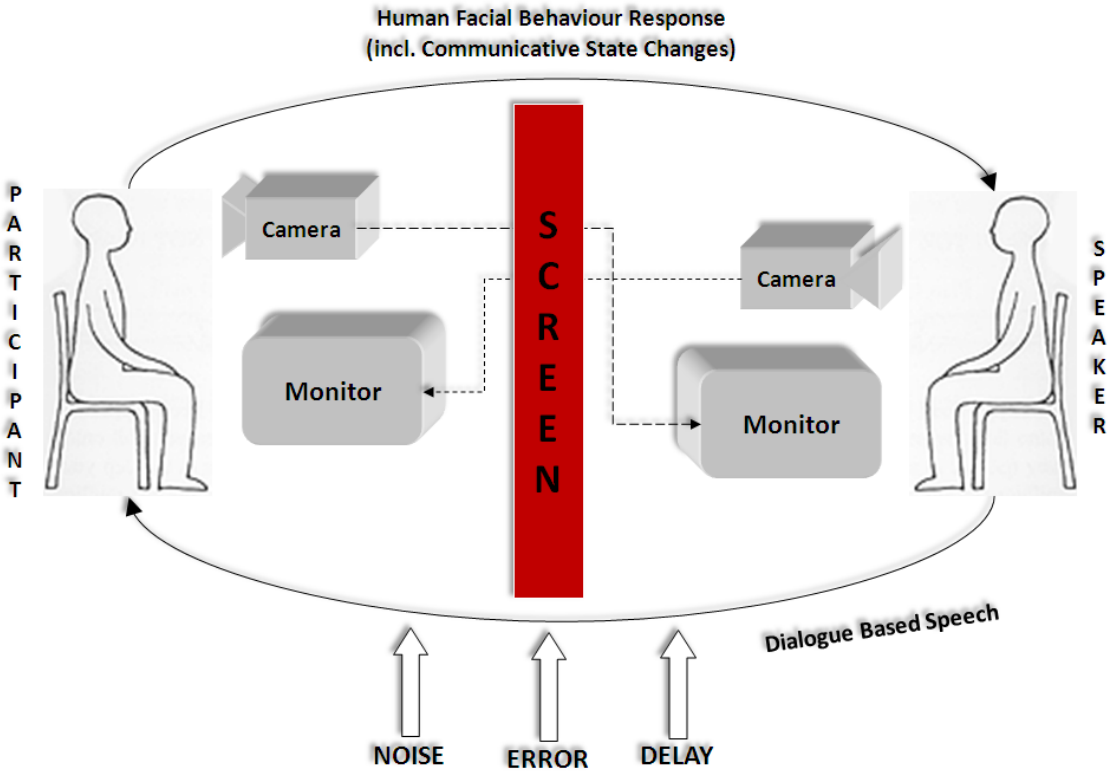


Figure 2-1 Experimental Design (Ford, Bugmann & Culverhouse, 2010)

Two laptop computers and four cameras were used to display and capture all speech and non-verbal facial behaviour during each dialogue (Figure 2-1 & Figure 2-2). Two webcams were each attached to one of the laptop computers to display an image of the

interlocutor and participants faces to each other on the laptop screen placed in front of them. Two camcorders were used to record the voice and facial movements of both the participant and interlocutor for post-experiment analysis. Participants were separated by a divider to visually obscure body gesture/pose and to ensure they looked at the interlocutors face on the laptop and also to enable quick and reasonable imitation of communication with a social robotic/ECA system, thus potentially eliciting specific non-verbal communicative behaviour arising from this technology-driven and face-only style of user interaction. This experimental layout was designed based upon a prior experiment looking at human communicative behaviour and HRI (Raidt, Bailly & Elisei, 2007).

Figure 2-2 Experimental Setup (Ford, Bugmann & Culverhouse, 2010)

As previously discussed in the introduction to this thesis, the experimental setup was designed based on the requirement for the creation of communicative models for use in

HRI/HCI systems providing facial non-verbal feedback, such as that of the LightHead social robotic system (Delaunay, De Greeff & Belpaeme, 2009) and the GRETA ECA (Mancini et al., 2008). Therefore the experimental setup implemented this constrained visual communication channel through the use of interlocutor face projection on the laptop screens. This forced communication between the experimenter and participants to be based purely on speech and non-verbal facial behaviour, as opposed to complete non-verbal body language (including bodily gestures and pose).

The cameras recording the experimenter and participant's speech and facial behaviour were placed just above each laptop. Despite the cameras being above the laptop screen and hence not directly in-line with the participants gaze, it was still possible to correctly determine whether the participants/experimenter were looking either at or away from each other's face. This was acceptable for the requirements of the experiment as the exact gaze direction of the participant/experimenter was not required. Despite the misalignment between the camera and the participants/experimenter gaze, communication between the participant and experimenter appeared not to be affected as all participants except one looked at the screen during the communication and not directly at the video camera.

The video recordings of the participants/experimenter performances were made at 24frames per second (fps), PAL standard and at a resolution of 720x576 pixels (576p). The frame rate and frame resolution were high enough to gain the level of detail required to analyse and map the defined non-verbal facial behaviour for model creation. Specifically, when looking at human blink morphology, we see a mean minimum blink attack time of 1/9 second (24/9 = 2.66 frames, which is within the required resolution for reproduction accuracy. This information is translated from the blink model to the face animation system running on the LightHead social robotic system (Delaunay, De

Greeff & Belpaeme, 2009), which runs at 60fps (60/9 = 6.66… frames) thus it is able to express a blink animation in a resolution that comfortably imitates human blink morphology.

The interlocutor (experimenter) knew the requirements of the experiment and led the participant through the conversation utilising a defined dialogue script (see Section 2.3). This knowledge may have led to a possible dominance effect on the participant (i.e. where the participants may have felt some level of subordination to the interlocutor (experimenter) during the communication process), thus subtly affecting the participants non-verbal behaviour throughout the communication. However, this effect, if present, would actually create suitable data for the design of appropriate robot/ECA communicative behaviour in HRI/HCI relations, where studies have shown that human preference is for social robotic/ECA systems to express subservience to their human users (Bugmann & Copleston, 2011; Dautenhahn et al., 2005; Oestreicher & Eklundh, 2006).

The video data recorded from the conversations was captured to AVI video file (including the dialogue audio stream) and the participants facial behaviours were then transcribed to FaceML (our proprietary XML format) ready for detailed analysis (Sections 2.5 and 3 respectively). The mental communicative states of thought, misunderstanding, understanding and uncertainty (Figure 2-3) were derived based upon the experimenters coding of the participants speech (context) and non-verbal facial behaviour during the communication process.

Figure 2-3 Snapshot of behaviour from each Mental Communicative State (Ford, Bugmann & Culverhouse, 2010) *(Clockwise from top left: thought, understanding, misunderstanding, uncertainty. Derived from participants speech (context) and communicative non-verbal facial behaviour)*

Figure 2-4 to Figure 2-7 display temporal collage snapshots of human communicative behaviour for each mental communicative state. Time taken for capture between frames was based on the duration of the mental communicative state performance. Details of the common human communicative behaviour elicited by these mental communicative states are shown in Section 3 .

Figure 2-4 Temporal Collage of Thought Mental State Behaviour

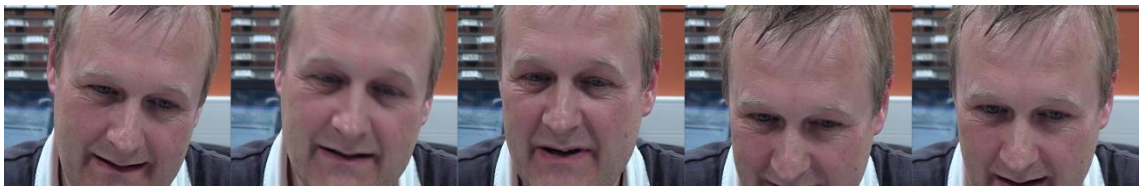


Figure 2-5 Temporal Collage of Misunderstanding Mental State Behaviour

Figure 2-6 Temporal Collage of Understanding Mental State Behaviour

Figure 2-7 Temporal Collage of Uncertainty Mental State Behaviour

Both written and verbal instructions were given to each participant prior to the beginning of the experiment and they then decided whether they still wished to participate in the study. No instructions were given on communication behaviour such that participants would then act naturally during the communication interactions. A total of thirteen participants took part in the experiment. Subjects were recruited from within the Plymouth University Science & Technology department within two phases: Phase 1 - Three colleagues of the experimenter became participants for the pilot study, Phase 2 - 10 further (non-colleague) participants were recruited for the second experiment run. All participants were native English-speaking students and staff from the University of Plymouth, with gender split between seven males and six females, and within an age range of 27 to 45 years. Each participant was identified for the purposes of the experiment by a pre-generated participant number and self-reported age and gender details. A post experiment questionnaire to test the efficacy of the experimental methodology (Appendix V-e) was also completed by the participants.

Question 1 - "*Did you feel like you were talking to another human being?*" Response choices: *All the time*, *Most of the time* and *None of the time*. 10 participants (77%)

responded *All the time* and 3 participants (23%) responded *Most of the time*.

Question 2 – "*Communication Experience Rating*" utilised a likert scale choice between 1 to 10, where 1 described "*Much worse than a normal face-to-face communication*" and 10 described "*Much better than a normal face-to-face communication*". The results (Figure 2-8) display a mean perceptual response of 5.54 with SD of 1.664, and a 95% confidence interval falling between 4.53 and 6.54, suggesting participant's communicative experience was positively comparative to natural face-to-face communicative behaviour. Of interest, based on their responses and ratings, two outlying participants (1 and 13) seemed to enjoy this mode of communication more than normal face-to-face interaction.

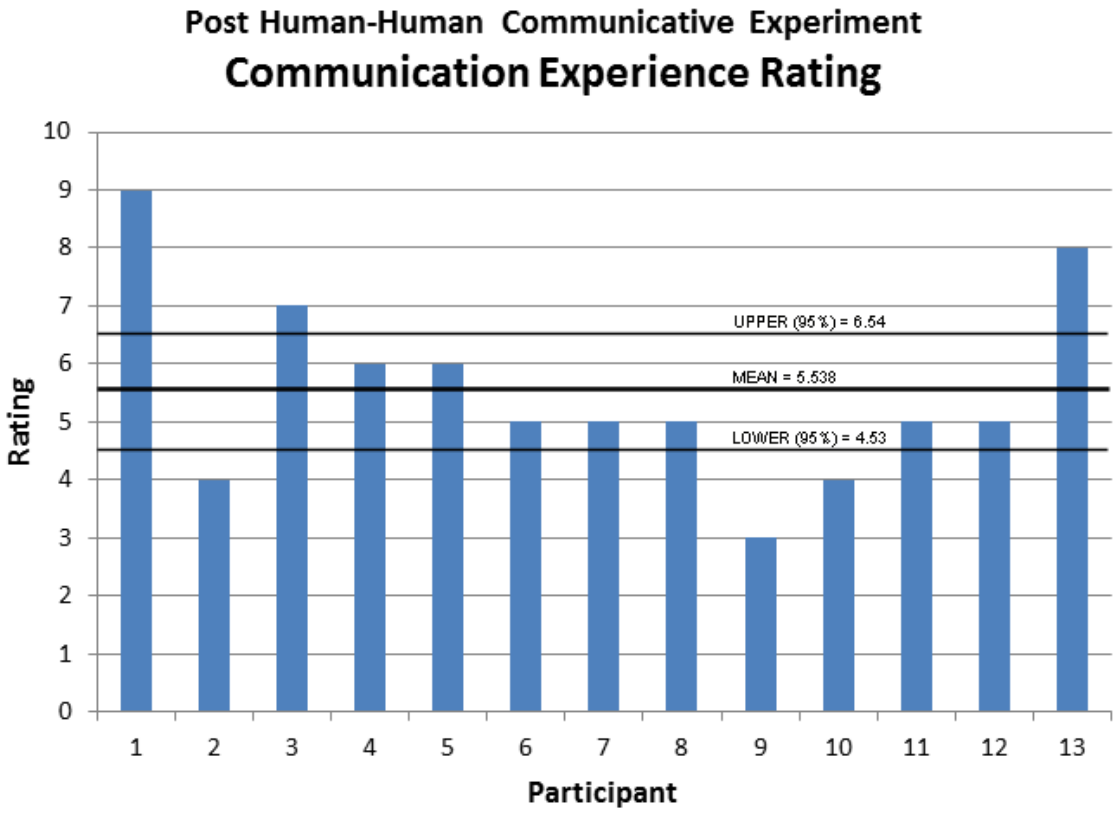


Figure 2-8 Communication Experience Rating

Question 3 – "*Did the communication run smoothly throughout the dialogues?*" had defined response choices: *Yes* or *No*. 9 participants (69%) responded *Yes* and 4 participants (31%) responded *No*.

The overall results suggest that the experimental setup, specifically the element of viewing a computer monitor to communicatively engage with only the face of the interlocutor did not seem to have a negative effect on the communicative behaviour of the participants.

Data from one of our thirteen participants (no. 4, male) was not usable when analysed as it was found that they had looked at the camera throughout the experiment process, and not at the interlocutors face projected on the laptop as instructed (Figure 2-1 & Figure 2-2) and as such this data could not be taken as evidence due to the errors detrimental effect on the performance of natural communicative behaviour.

2.5 Non-Verbal Facial Behaviour Transcription

The complexity of human communicative behaviour makes transcription very complex. To capture and catalogue this complex data, a bespoke XML schema was defined entitled Face Mark-up Language (FaceML).

2.5.1 FaceML – Bespoke XML Schema

FaceML (Figure 2-9) was created for video transcription purposes to enable temporal mark-up of participants non-verbal facial behaviour primitives, building a detailed data corpus of participants communicative behaviour for each dialogue script. Table 2-1 displays the FaceML morphology variable descriptions for each of the transcribed primitives.

```
<Dialogue xmlns:xsi=http://www.w3.org/2001/xmlschema-instance
xsi:nonamespaceschemalocation="script_template.xsd" participant="" script="">

        // participant/interlocutor utterances
        <sspeech starttime="" endtime=""></sspeech>
        <pspeech starttime="" endtime=""></pspeech>
        // participant eye movements
        <pem starttime="" endtime="">
                <pems startindex="-" starttime="" endtime="" angle="" distance="" />
        </pem>

        // participant eye gaze
        <peg starttime="" endtime="" looking="" />

        // participant head movements
        <phg starttime="" endtime="">
                <phgs startindex="" starttime="" endtime="" direction="" distance="" endangle="" />
        </phg>

        // participant blink
        <pbl starttime="" endtime="" type="" attack="" sustain="" decay="" />

        // participant facial expression
        <pfe starttime="" endtime="" expression="" />

        // participant cognitive state
        <pco starttime="" endtime="" state="" />

        // participant stare
        <pst starttime="" endtime="" />

</dialogue>
```

Figure 2-9 Facial ACtion Encoding Mark-up Language - XML Schema (Ford, Bugmann & Culverhouse, 2010)

Prior XML scripts have been created such as HumanML (Human Mark-up Language) and MURML (Multimodal Utterance Representation Mark-up Language) (Kranstedt, Kopp & Wachsmuth, 2002; Peltz & Thunga, 2005), but these were unsuitable for encapsulating all of the elements of the behavioural characteristics that we wished to annotate, therefore we created our own XML script and schema entitled FaceML (Facial ACtion Encoding Mark-up Language) for this purpose.

2.5.1.1 FaceML variables defined via FACS

Commonly, social robotic/ECA systems utilise the Facial Action Coding System model (Ekman *et al.*, 1978) to express facial non-verbal communicative behaviour (Section 1.2.3) and as such our primitives were further defined to be expressed by this

model. A description of the FACS Action Units (AUs) associated with each relevant communicative behaviour primitive of the FaceML schema follows:

- **Eye Movement (labelled as PEM)**
    - **Saccades (within a PEM) (labelled as PEMS)**

      AU 61: Eyes turn left, ***AU62:*** Eyes turn right, ***AU63:*** Eyes up, ***AU64:*** Eyes down.

- **Eye Gaze (labelled as PEG)**

  Looking At: AU69: Eyes positioned to look at other person. (NOTE: AU 4,5, or 7, alone or in combination, occur while the eye position is fixed on the other person in the conversation).

  Looking Away: NOT AU69

- **Head Movement (labelled as PHG)**
    - **Head Move (within a PHG) (labelled as PHGS)**

      AU51: Head turn left, ***AU52:*** Head turn right, ***AU53:*** Head up, ***AU54:*** Head down, ***AU55:*** Head tilt left, ***AU56:*** Head tilt right, ***AU57:*** Head forward, ***AU58:*** Head back.

- **Eye Blink (labelled as PBL)**

  Blink: ***AU45*** - A control AU for the following AU sub-set:

  AU4: Brow lowerer (Muscle: *Corrugator supercilii; Depressor supercilii*)

  AU5: Upper lid raiser (Muscle: *Levator palpebrae superioris*)

  AU6: Cheek raiser (Muscle: *Orbicularis oculi, pars orbitalis*)

  AU7: Lid tightener (Muscle: *Orbicularis oculi, pars palpebralis*)

  AU43: Eyes closed (Muscle: Relaxation of *Levator palpebrae superioris; Orbicularis oculi, pars palpebralis*).

(NOTE: AU45 does not include intensity scoring. To imitate the squeeze of the eyelids that occasionally occurs during a blink action, score the intensity for AUs 6 and 7).

- **Facial Expression (labelled as PFE)**

  FACS AUs per expression:

  Smile: ***AU6:*** Cheek raiser (Muscle: *Orbicularis oculi, pars orbitalis*), ***AU12:*** Lip Corner (Muscle: *Zygomaticus major*)

  Down-turned mouth: ***AU15:*** Lip Corner Depressor (Muscle: *Depressor anguli oris* (*a.k.a. Triangularis*)), ***AU17:*** Chin raiser (Muscle: *Mentalis*)

  Pursed lips: AU24: Lip pressor (Muscle: *Orbicularis oris*)

  Squint: ***AU44*** **-** A control AU for the following AU sub-set:

  AU4: Brow lowerer (Muscle: *Corrugator supercilii, depressor supercilii*)

  AU5: Upper lid raiser (Muscle: *Levator palpebrae superioris*)

  AU6: Cheek raiser (Muscle: *Orbicularis oculi, pars orbitalis*)

  AU7: Lid tightener (Muscle: *Orbicularis oculi, pars palpebralis*)

  AU8: Lips towards each other

  AU9: Nose wrinkler (Muscle: *Levator labii superioris alaquae nasi*)

  Furrowed brow: ***AU4:*** Brow lowerer (Muscle: *Corrugator supercilii, depressor supercilii*), ***AU9:*** Nose wrinkler (Muscle: *Levator labii superioris alaquae nasi*)

  Raised brows: ***AU1:*** Inner Brow raiser (Muscle: *Frontalis pars medialis*), ***AU2:*** Outer Brow raiser (Muscle: *Frontalis pars lateralis*), ***AU5:*** Upper lid raiser (Muscle: *Levator palpebrae superioris*).

2.5.2 Data Transcription Process

Data transcription of the communicative non-verbal facial behaviour of the twelve participants performance (from dialogue script #1) was performed over a twelve month

period. This was a labour intensive process, with the experimenter visually transcribing participants behaviour into the FaceML XML schema. An example of human communicative behaviour transcribed to the FaceML XML schema (from Participant 6 – Script 1 dialogue) can be seen in Figure 2-10.

```
<pbl startTime="336" endTime="345" type="full" attack="2" sustain="1" decay="6" />
<pSpeech startTime="336" endTime="358">
        "November"
</pSpeech>
<cState startTime="359" endTime="432" state="thought" />
<sSpeech startTime="384" endTime="418">
        "Do you know which star sign you are?"
</sSpeech>
<pem startTime="413" endTime="434">
        <pems startIndex="1" startTime="413" endTime="415" angle="270" distance="0.3" />
        <pems startIndex="2" startTime="419" endTime="420" angle="300" distance="0.05" />
        <pems startIndex="3" startTime="423" endTime="425" angle="320" distance="0.25" />
        <pems startIndex="4" startTime="431" endTime="436" angle="100" distance="0.6" />
</pem>
<peg startTime="413" endTime="436" looking="awayFace" />
<phg startTime="422" endTime="480">
        <phgs startIndex="1" startTime="422" endTime="432" direction="0" distance="0.1"
endAngle="0" />
        <phgs startIndex="2" startTime="433" endTime="438" direction="180" distance="0.2"
endAngle="0" />
        <phgs startIndex="3" startTime="446" endTime="455" direction="0" distance="0.2"
endAngle="0" />
        <phgs startIndex="4" startTime="456" endTime="460" direction="180" distance="0.05"
endAngle="0" />
        <phgs startIndex="5" startTime="464" endTime="480" direction="180" distance="0.05"
endAngle="0" />
</phg>
<pSpeech startTime="426" endTime="454">
        "Im a Sagittarius"
</pSpeech>
<pbl startTime="432" endTime="439" type="full" attack="2" sustain="1" decay="5" />
<cState startTime="433" endTime="459" state="understanding" />
<peg startTime="437" endTime="594" looking="atFace" />
```

Figure 2-10 Facial ACtion Encoding Mark-up Language – Transcription Example

In late 2009, initial research was performed looking at the possibility of utilising face/eye tracking systems to automate the transcription process (such as those developed by Tobii (http://www.tobii.com) and EyeTech Digital Systems (https://www.eyetechds.com)), however, the systems available at this time were unable to achieve the level of accuracy required for us to create a reliable data corpus and thus the manual process was the only option available to achieve high transcription accuracy.

Upon completion of manual data transcription to the FaceML standard, a C# XML Parser was developed to process the transcribed FaceML data into separate communicative facial behaviour primitives. This allowed the separation of any specified communicative primitives to be processed together (e.g. Blinks and pSpeech Onset or pSpeech Offset with sSpeech Onset) through any specified section of the communication and the results therein saved for statistical analysis.

2.6 Assessing Bias in Mental Communicative State Categorisation

Transcription of mental communicative state behaviour (Section 2.1) is difficult to process in the sense that the rules for instigation of these states is tacit within human communication (Lakin, 2006) and as such we can only analyse these states in a tacit manner. As an example, facial expression onset and offset are clearly easy to define, however, highlighting mental communicative state onsets within a participants (inherently complex) communicative behaviour pose a much greater challenge. Within this study, these mental communicative state onsets were annotated by the experimenter based upon their own non-conscious cognitive knowledge of human communicative behaviour. This transcription process could therefore be seen to add an element of bias to any results expressed from transcribed mental communicative state onset data. Future work (Section 7.2) discusses a dual coding process to test the efficacy of the mental state transcription process.

2.7 Participant perception and categorisation of mental communicative states

A sub-experiment was undertaken to test general perception and categorisation of the four defined mental communicative states from examples of human communicative behaviour within these states.

Twelve short videos were compiled from differing participants from video captured within the one-to-one human communication experiment (Section 2). New naïve participants then viewed each video, initially without audio and then again including audio, thus adding speech context, and were tasked with denoting which mental communicative state was being expressed therein.

Both written and verbal instructions were given to each participant prior to the beginning of the experiment and they then decided whether they still wished to participate in the study. A total of twenty seven participants took part in the experiment. All participants were English-speaking students from the University of Plymouth, with gender split between thirteen males and fourteen females, and within an age range of 23 to 56 years. Each participant was identified for the purposes of the experiment by a pre-generated participant number and self-reported age and gender details. An answer form was provided (Appendix V-b) and completed by the participants whilst viewing each video, the results of which are displayed in the categorisation accuracy confusion matrices displayed in Figure 2-11 and the modal gender accuracy displayed in Figure 2-12.

		Not Including Speech			
		Predicted Class			
		Understanding	Uncertainty	Misunderstanding	Thought
Actual Class	Understanding	*69*	6	22	4
	Uncertainty	5	*30*	32	26
	Misunderstanding	2	29	*21*	14
	Thought	5	16	6	*37*
	Mean	1.30	2.68	2.14	3.04
	Mode	1	2	2	4
	Std Deviation	0.64	0.77	0.82	0.99
	Categorisation Accuracy %	85.19%	37.04%	25.93%	45.68%

		Including Speech			
		Predicted Class			
		Understanding	Uncertainty	Misunderstanding	Thought
Actual Class	Understanding	*70*	8	3	3
	Uncertainty	4	*41*	38	22
	Misunderstanding	3	21	*37*	5
	Thought	4	11	3	*51*
	Mean	1.27	2.43	2.49	3.28
	Mode	1	2	2	4
	Std Deviation	0.58	0.72	0.40	0.98
	Categorisation Accuracy %	87.65%	50.62%	45.68%	62.96%

Figure 2-11 Mental Communicative State – Categorisation Accuracy (%)

The overall accuracy of mental communicative state categorisation accuracy for both tests (i.e. not including speech / including speech) displays an above chance (25%) result of 49% (M=2.29, SD=0.80) and 62% (M=2.37, SD=0.67) respectively. The modal response from the addition of speech context shows 11 of 12 (92%) correctly categorised mental communicative states.

To test whether speech context improved mental communicative state categorisation accuracy, either an equal or unequal variance T-Test was used (dependant on F-Test results) on each mental communicative state type for both including speech and not including speech data sets. The results follow:

There was no improvement (p=0.84) in the accuracy of participants classification of

understanding; a slight improvement (p=0.07) in the classification of uncertainty; a significant improvement (p=0.004) in the classification of misunderstanding and no significant improvement (p=0.11) in the classification of thought. These results suggest that speech context aids in the categorisation of misunderstanding, and to a lesser extent, uncertainty, but has little to no effect on the categorisation of understanding and thought. The improvement in the categorisation accuracy of the thought mental communicative state is therefore likely to be based on participants having a second viewing of the behaviour.

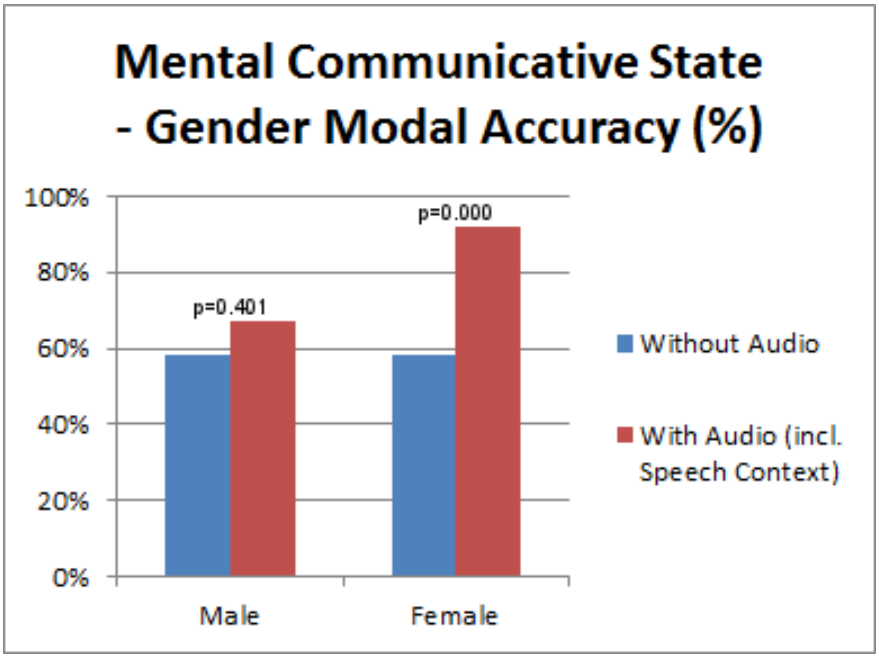


Figure 2-12 Mental Communicative State – Gender Modal Accuracy (%)

Also of interest, a significant increase in mental communicative state categorisation accuracy was found when speech (context) was included in the viewed behaviour for female participants above their male counterparts (Male $t(13)=0.855$, p = 0.401, Female $t(12)=4.361$, p=.000) (Figure 2-12).

3 Human Communicative Non-Verbal Facial Behaviour

3.1 Introduction

This chapter describes the analysis processes and results of our transcription of blink behaviour co-occurrence with communicative non-verbal facial behaviour in a one-to-one human-human communication experimental scenario. Results are displayed which define the common human communicative facial behaviour primitives, their blink trigger probabilities and parameters for the definition of a blinks morphology. Initially we give an overview of the design of the human facial communication system (Section 4.1), designed to simulate human communicative facial behaviour for each of the mental communicative states of misunderstanding, uncertainty, understanding, thought through the creation of real-time communicative behaviour complexes (an array of temporally linked communicative behaviour primitives). Discriminant Analysis results further define how the mental communicative state changes could be categorised and therefore computationally modelled by extrapolating their distinct communicative facial characteristics through the use of multiple discriminant analysis. Modelling the communicative behaviour of the mental communicative state changes is important as they are used to trigger behaviour changes in the human facial communication system and as blink triggers within the computational blink model. Finally we define the human communicative blink process through probabilistic blink trigger statistics relating to each of the communicative facial behaviour primitives, blink presence surrounding each defined primitive and the detailed analysis of human blink morphology parameters.

3.2 Analysis of Human Communicative Non-Verbal Facial Behaviour

The data output from the FaceML Parser was utilised to create a timeline of all (or any number of chosen) communicative facial behaviour primitives (Figure 3-1), as an initial

stage of the data analysis process. The timeline displays the communicative facial behaviour primitives (y-axis) mapped against time (x-axis).

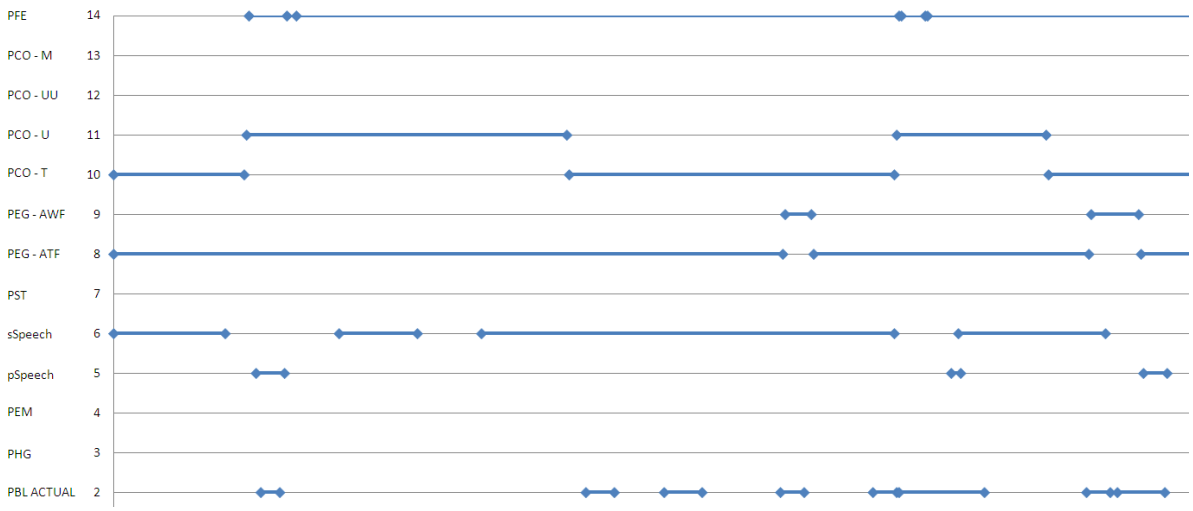


Figure 3-1 Section of Communicative Facial Behaviour Timeline (Ford, Bugmann & Culverhouse, 2010)

The timeline representation gives a temporal view of all defined human communicative facial behaviour primitives as they occur within a participants communicative performance, creating an initial reference for visualising and measuring behavioural trends and co-occurrence of communicative facial behaviour primitives within the captured (twelve subject) human communication corpus.

An example description of a participants common communicative behaviour performed within a thought mental state (PCO-T) follows, taken from the second occurrence of the thought mental state within the behaviour timeline sub-section (from Participant 6 – Script 1) as shown in Figure 3-1:

- Blink (PBL-ACTUAL) just after thought mental state onset (PCO-T) and at onset of eye gaze turned away from interlocutor (PEG-AWF)

- Eyes look away from interlocutor (PEG-AWF), (infer: breaking shared attention for processing).

- Head rotates 10^{o} (0^{o} = Head facing interlocutor). Head angled 5^{o} (0^{o} = Head vertical) (Note: PHG is not displayed in Figure 3-1).

- Smile expression (PFE) starts at the thought mental state offset (i.e. the transition point to the next mental state, in this case understanding (PCO-U)).

3.3 Communicative Behaviour Analysis of Mental Communicative States

Through detailed analysis of each participants timeline from their Script 1 dialogue performance (Table 2-1), the count of specific non-verbal facial behaviour primitives occurring within each of the five mental communicative states was analysed.

Table 3-1 displays the mapping for the overall number of mental communicative states and the number of participants that performed them from the complete data corpus.

Table 3-1 Mental Communicative State – Performance Count.

Mental State	Count	No. of Participants (out of 12) displaying Mental State
Misunderstanding	16	8
Uncertainty	43	10
Understanding	83	12
Thought (Listening)	92	12
Thought (Processing)	21	7

Figure 3-2 to Figure 3-6 display the percentage of specific derivations of non-verbal facial behaviour primitives occurring within each mental communicative state.

An example of the display of blink behaviour data within these graphs follows: If ten misunderstanding states occurred and all ten had at least one Start Blink and five had at least one End Blink, the percentiles shown in the graph would be Start Blink – 100% and End Blink – 50%.

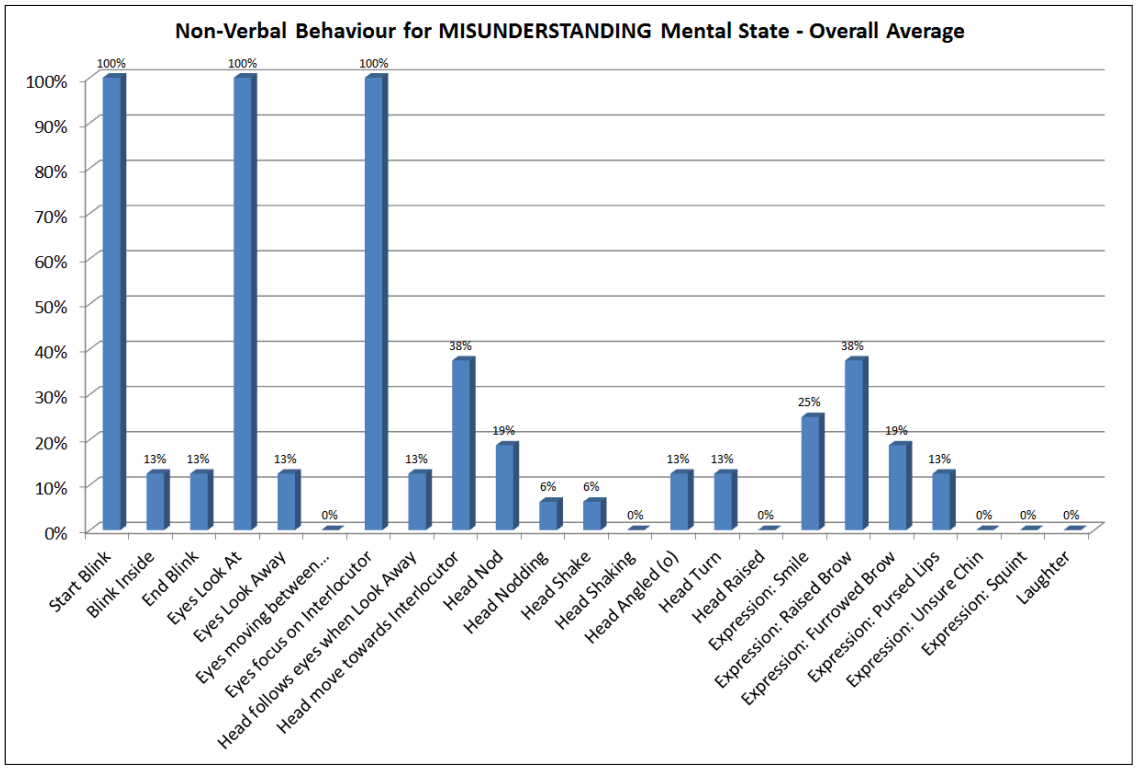


Figure 3-2 Non-Verbal Behaviour co-occurrence for Misunderstanding

Misunderstanding

Blink occurrence at the instigation of a misunderstanding mental state happens consistently (100%). Misunderstanding state contains the most significant occurrence of head moving forward towards interlocutor (38%) and the highest chance of Facial Expressions: (Forced) Smile (25%), Raised Brow (38%), Furrowed Brow (19%) and Pursed Lips (13%).

Within the Misunderstanding mental state, blinks are used consistently to help emphasise the instigation of this state along with the possibility of a head movement towards the interlocutor. Could this mean that getting closer to the interlocutor aids the senses

of vision and hearing to better receive the transferred information as well as stating the importance of this mental state? Focus is consistently placed on the interlocutor along with the light use of expression (with the pursed lips expression being specific to this state) to emphasise this mental state to the interlocutor throughout its duration.

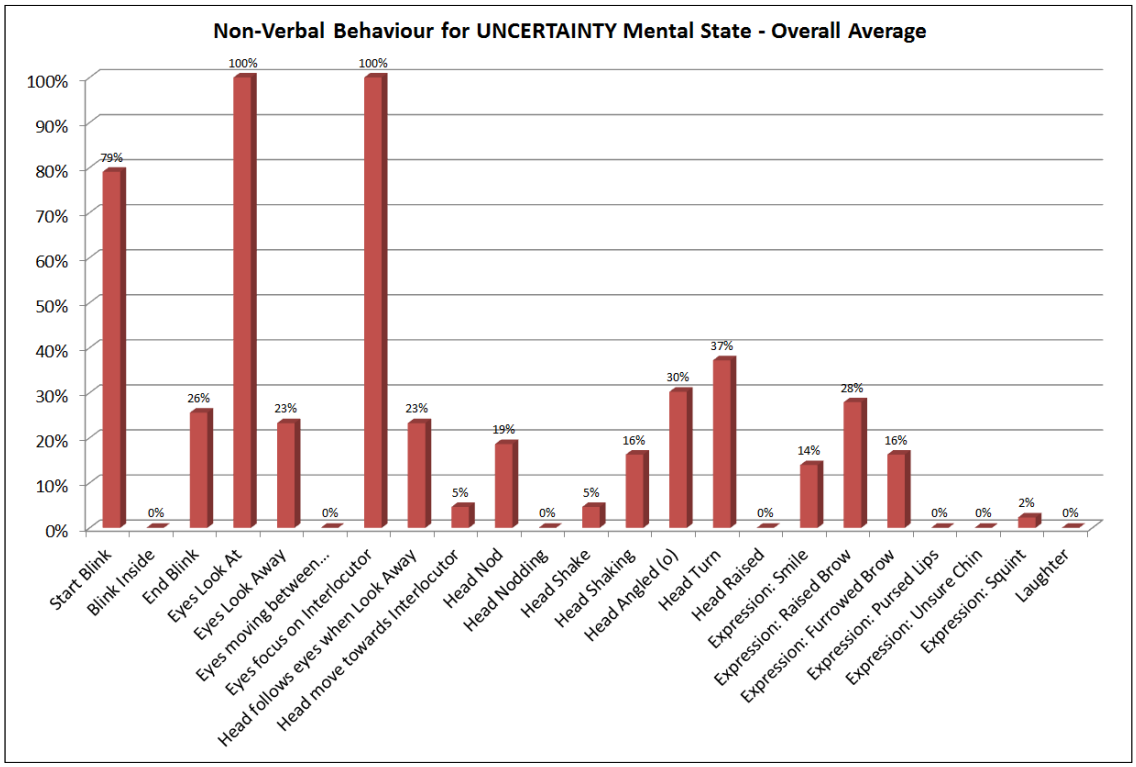


Figure 3-3 Non-Verbal Behaviour co-occurrence for Uncertainty

Uncertainty

Blink occurrence at the instigation of an uncertainty mental state happens reasonably consistently (79%). Uncertainty state displays reasonable chance of blink occurrence at mental state completion (26%), eyes looking away from the interlocutor and the head following this gaze movement (23%). Also, the most significant occurrence of Head Shaking (16%), Head Turn (37%) and Angling of the Head (30%) and reasonable chance of Facial Expressions: (Forced) Smile (14%), Raised Brow (28%) and Furrowed Brow (16%).

Within the Uncertainty mental state, blinks are used consistently to help emphasise the instigation of this state along with a reasonable chance of occurrence at its completion. Occasionally the eyes will perform a very short look away from the interlocutor with head movement following this gaze direction and angling laterally from the interlocutor. This eye gaze behaviour occurs commonly in some participants and rarely (if at all) in others, with its occurrence being most common in female participants. Head shaking occurs most commonly within this mental state. Focus is consistently placed on the interlocutor and expressions of confusion are reasonably common throughout its duration.

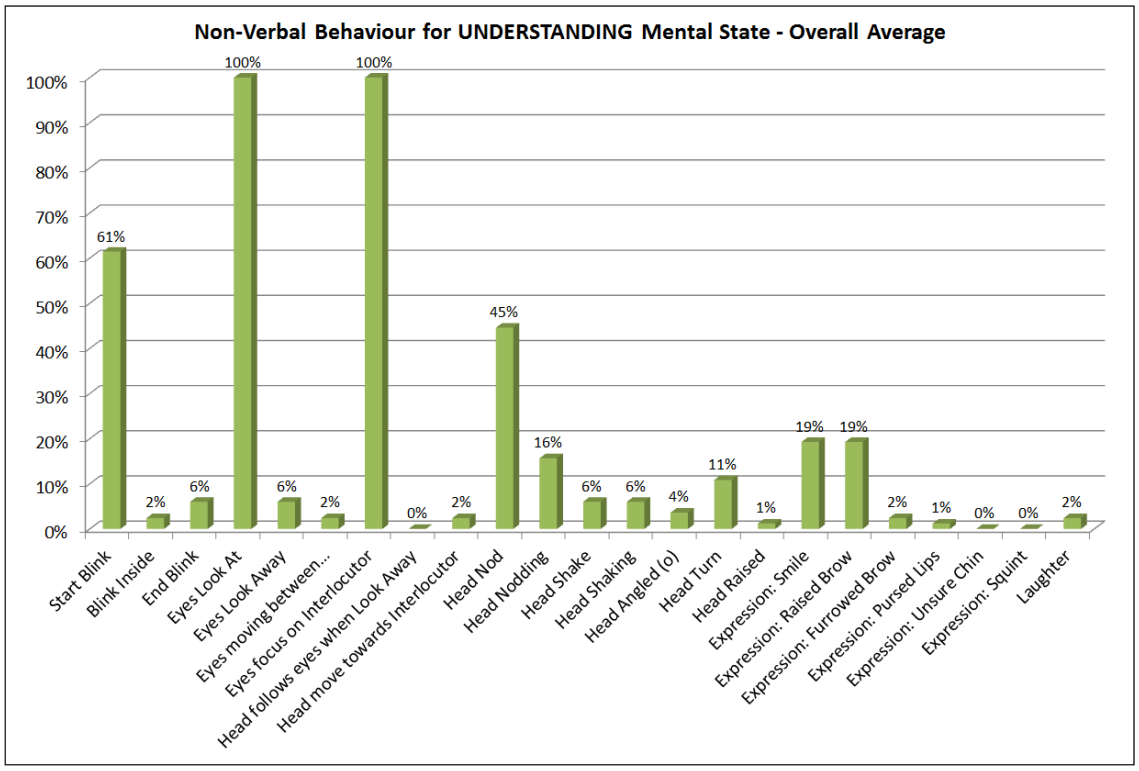


Figure 3-4 Non-Verbal Behaviour co-occurrence for Understanding

Understanding

Blink occurrence at the instigation of an understanding mental state happens reasonably consistently (61%). Understanding state displays significant occurrence of Head Nod (45%) / Head Nodding (16%) in agreement and a reasonable chance of Facial Expressions: Smile (19%) and Raised Brow (19%).

Within the Understanding mental state, blinks are used reasonably consistently to help emphasise the instigation of this state. Head Nod / Nodding behaviour is common to express this state along with a reasonable chance of smiling and (happy) raised brow expressions.

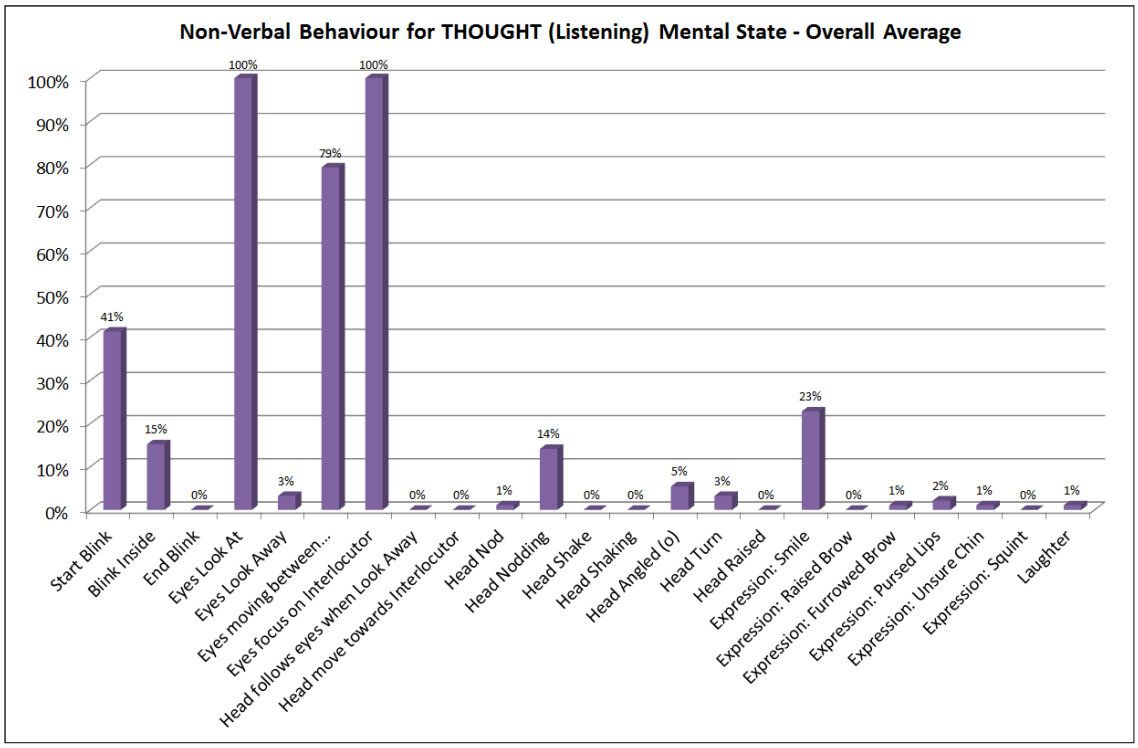


Figure 3-5 Non-Verbal Behaviour co-occurrence for Thought-Listening

Thought (Listening)

Thought (Listening) mental state displays the most significant occurrence of a blink during a mental state (15%) as well as distinct saccadic eye movement between eyes, nose and mouth of the interlocutor (79%). Also, participants looking away from the interlocutor is very rare (3%) and head nodding (14%) and smiling (23%) are both reasonably significant.

Within the Thought (Listening) mental state, blink occurrence is decreased compared to the other mental states. Conceptually, this this seems to be an inhibitive behaviour

which improves both reliability in discerning subtle semantic information transmitted by the interlocutor and overall communication grounding. Eyes are almost consistently focussing on the interlocutor with very little deviation from the interlocutors face. The saccadic eye movement between the triangular focus points of the face (eyes (nose) and mouth) are extremely pronounced. Head Nodding behaviour is common to express this state along with a reasonable chance of smiling.

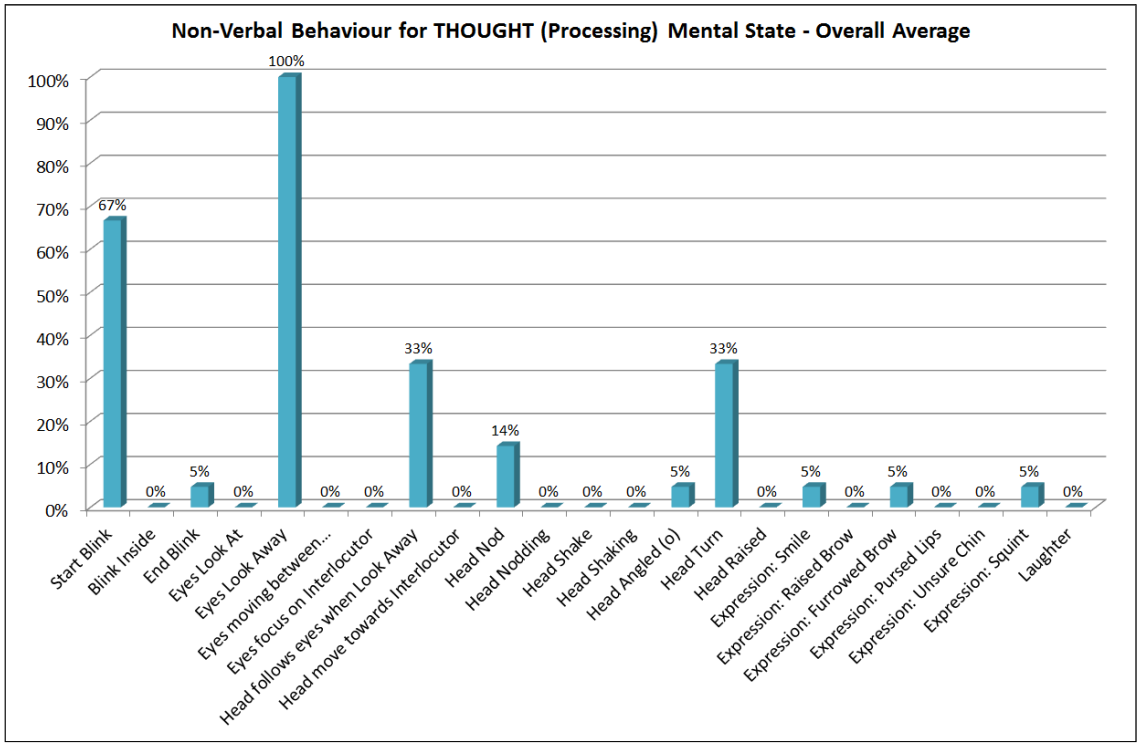


Figure 3-6 Non-Verbal Behaviour co-occurrence for Thought-Processing

Thought (Processing)

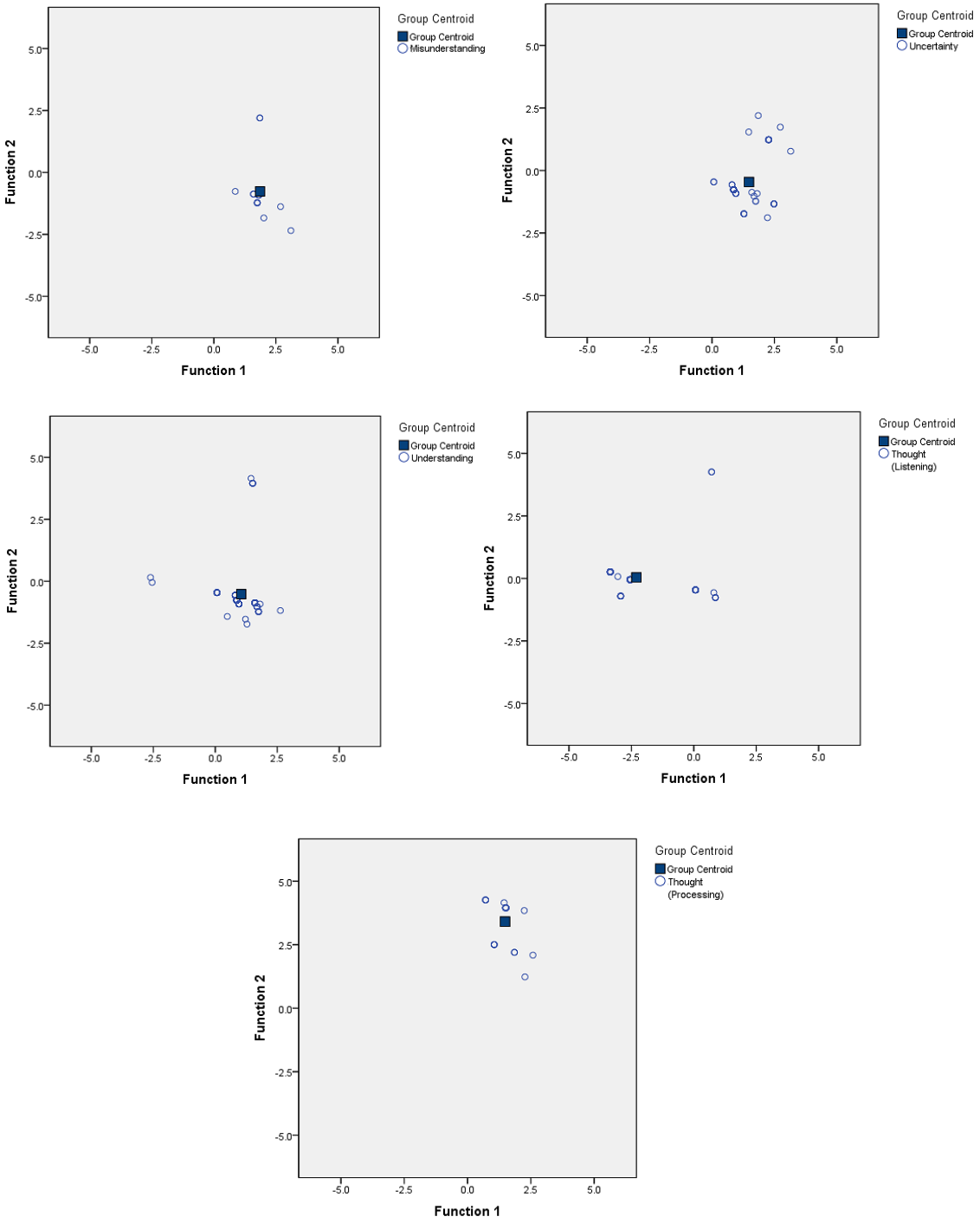
Blink occurrence at the instigation of the thought (processing) mental state happens reasonably consistently (67%). Thought (processing) state, participants consistently look away from the interlocutor (100%) and never look at the interlocutor (0%). Also, participants head movements following their eye movement trajectory is reasonably common (33%) and the chance of a head nod (14%) is reasonably significant.

Within the Thought (Processing) mental state, blinks are used reasonably consistently to help emphasise the instigation of this state. However, a major difference in behaviour of this state is that the eyes are always focussed away from the interlocutor. Conceptually, this seems to a non-verbal action used to break shared attention, expressing the need of the participant for time to process a response and also as a request to the interlocutor for them not to communicate until mutual gaze is resumed. Head Nod behaviour is occasionally enacted which we believe to be based on an internal affirmation of process understanding.

Communicative mental states seem to aid in the control of communication grounding within a 1:1 or 1:many human-human communication, defining the flow and turn-taking processes that lead to satisfactory completion of a communication.

3.4 Modelling Mental Communicative States through Discriminant Analysis

The behavioural differences between each mental state allow them to be reasonably well identified within a model for use within character communicative expression, allowing their discrimination by a human observer when embedded within a social robotic/ECA system. Discriminant analysis is a statistical technique commonly used to profile an item into the category that it belongs, based on its profiled variables. The discriminant function defines a weight which is processed against each independent variable to obtain the discriminant score for that variable in a discriminant category. Three or more categories change the title of this technique to multiple discriminant analysis (MDA).



Figures 3-7a-e Multiple Regression Analysis for each Mental Communicative State (Order: Misunderstanding, Uncertainty, Understanding, Thought (L), Thought (P)).

Figures 3-7 a-e display the (four function) MDA results, which show the communicative behaviour variance within each mental state category. Figure 3-8 displays the amalgamated discriminant analysis of all mental state behavioural characteristics.

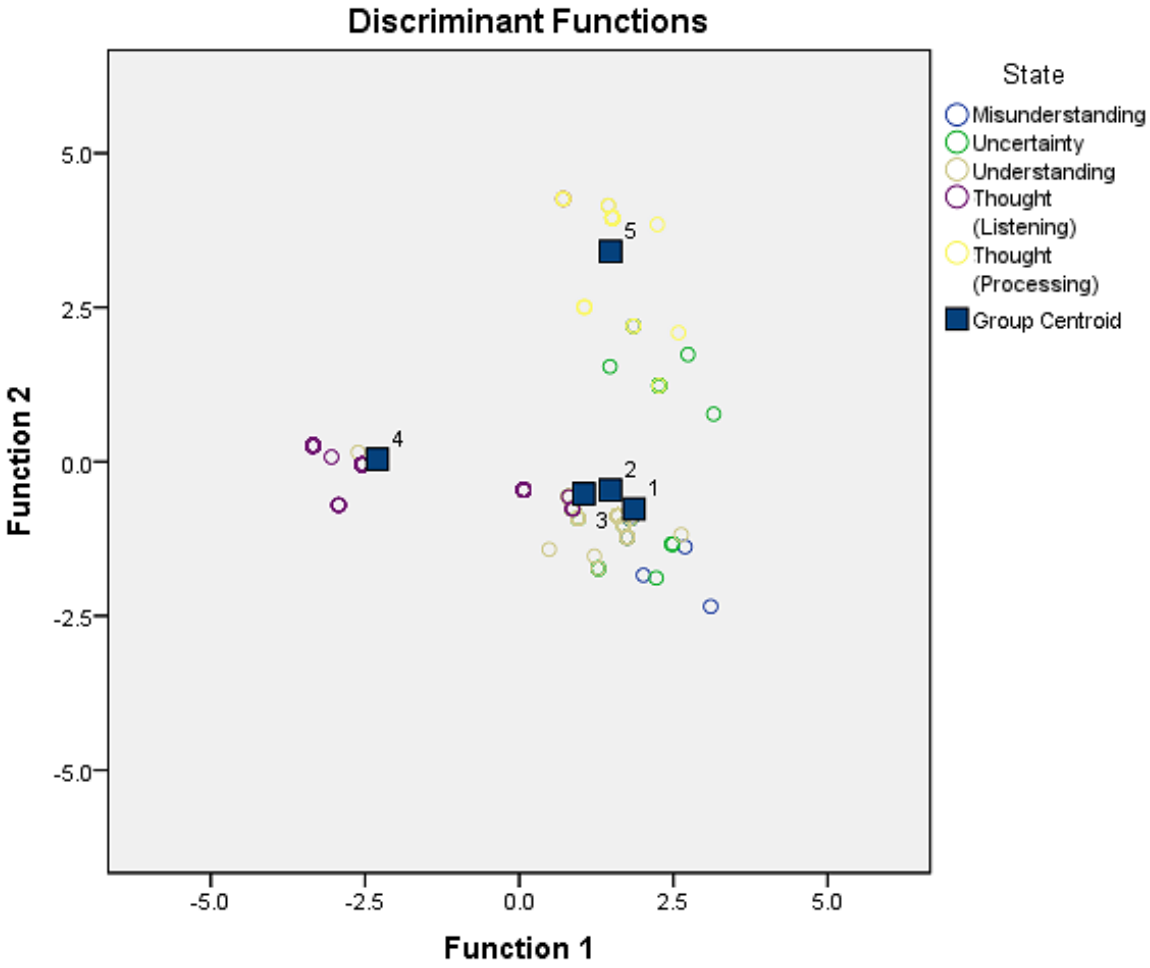


Figure 3-8 Amalgamated Regression Analysis of all Mental Communicative States

Within Figure 3-8, Thought Listening (4) and Thought Processing (5) are shown to have very specific behavioural characteristics, allowing them to be well distinguished from all other mental states, whereas Misunderstanding (1), Uncertainty (2) and Understanding (3) have strong behavioural similarities, as can be seen through the close mapping of their group centroids. However, Uncertainty, as shown in Figures 3-7b, has a very clear mapping of behaviour variables away from its centroid and thus would likely also have a high chance of modelling success through finding these outliers within any received data. Misunderstanding and Understanding, as shown in Figures 3-7a/c respectively, also have a few outliers in their behavioural data which fall near the Thought (Listening) (Figures 3-7d) and Thought (Processing) (Figures 3-7e) centroids which may allow for a

restricted level of modelling success through finding these outliers within any received data, dependant on the distinct behaviours captured / displayed.

Of note, the MDA results do not include the temporal information required to create the posited communicative behaviour complexes that would allow real-time categorisation and expression of each mental communicative state over time within HRI, however, with respect to blink behaviour, these results could formulate a model to predict a mental communicative state change allowing blink behaviour to be successfully implemented for this trigger within a social robotic/ECA system. Future work would look at the development of a Bayesian Network to process this role through embedding the MDA results (Figures 3-7 a-e and Figure 3-8) as categorisation data, along with temporal communicative behavioural data from the timeline graphs (of which an example is given in Figure 3-1).

3.5 Blink Co-Occurrence in Human-Human Facial Communicative Behaviour

From the data transcription process and specifically the resultant behavioural timeline graphs, we observed that blinks were co-occurring regularly with other facial communicative behaviour primitives (Section 2.2). This data defined the underlying functionality of our blink model and gave strength to the concept that blinks have a role to play within human-human communication.

The timeline in Figure 3-9 (below) allows us to temporally view the human communicative facial behaviour primitives (Section 2.2) as they occur within a participants communicative performance, creating an initial reference for visualising and measuring behavioural trends and co-occurrence of communicative facial behaviour primitives within the captured (twelve subject) human communication corpus.

Blink co-occurrence was stated to have occurred if a blink action fell within a specific window of time surrounding a differing communicative facial behaviour primitive onset or offset. This time window was chosen by the research team and set at +/-375ms (or +/-9frames) to differentiate between seperate blinks (i.e. set as greater than the derived blink modal duration of 333ms (8frames) found within the 2007 blinks captured within the corpus.

The C# XML Parser was then updated to capture and output this blink co-occurrence behaviour data against any differing communicative facial behaviour primitives chosen.

3.5.1 Examples of Blink Co-Occurrence

Our results have shown significant blink co-occurrence with other conversational behaviour primitives. Examples of blink co-occurrence can be seen in Figure 3-9 to Figure 3-11.

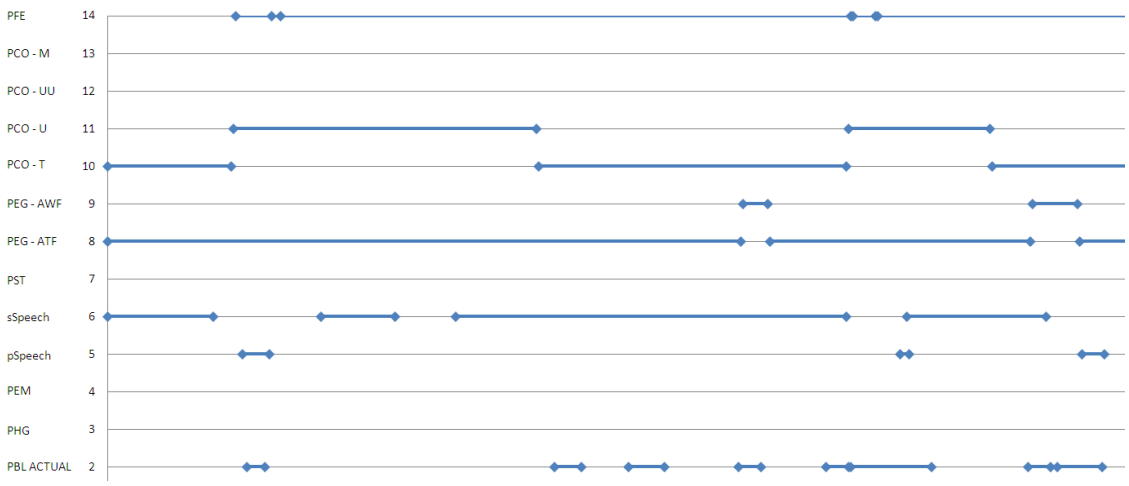


Figure 3-9 Behaviour timeline from Participant 6 XML transcription (24 frames per second (fps)) Blinks are shown on the bottom line (marked PBL-ACTUAL). (See Section 2.2 for communicative facial behaviour primitive descriptions).

Figure 3-9 shows that all participant blinks (PBL-ACTUAL), bar one, occur at the same time as either the start of participant speech (pSpeech onset), the start of a thought process (PCO-T), the start of looking away from the interlocutors face (PEG-AWF), the

end of participant speech (pSpeech offset) and/or the end of interlocutor speech (sSpeech offset).

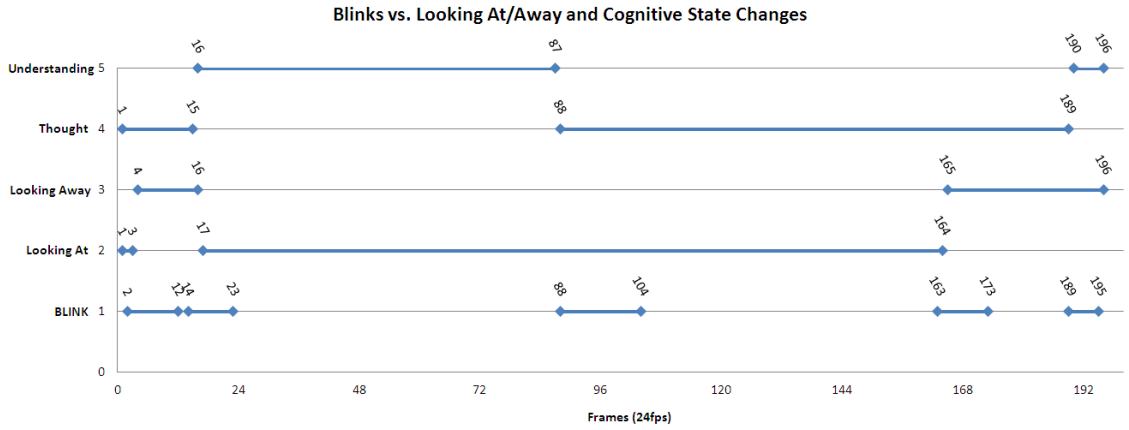


Figure 3-10 Behavioural timeline showing a subset of Looking At/Away and Mental Communicative State Change behaviours - Participant 6

Figure 3-10 shows the participant looking at and away from the interlocutors face during Mental Communicative State changes between "thought" (PCO-T) and "understanding". (PCO-U). Blinks in this instance correlate well with these mental state changes and looking at/away (head and eye movement) behaviours. Note that all behavioural timeline graphs show timelines based upon camera frame counts, as this was the video sample interval (set at 24fps).

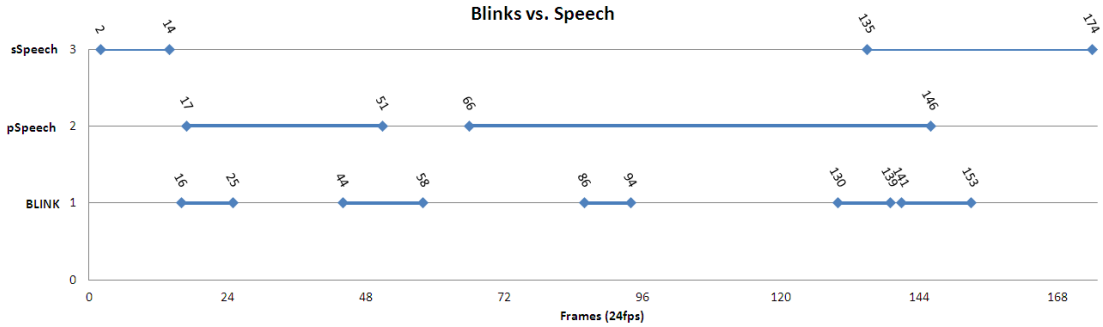


Figure 3-11 Blinks relating to Utterance Behaviour Timings - Participant 6

Figure 3-11 shows a participants blink actions based upon their own (pSpeech) and their interlocutors utterances (sSpeech). Strong blink co-occurrence between both utterance

onset/offset behaviours is shown. Blink (frame 86) is not related to utterance behaviour.

3.5.2 Blink co-occurrence rates per participant

Table 3-2 indicates the overall participant co-occurrence rate of blinks with all communicative facial behaviours (Section 2.1.2) of Interlocutor Speech (onset/offset), Participant Speech (onset/offset), Looking At / Away, Facial Expression (onset/offset) and Mental Communicative State Change. On average, 71% of participants blinks co-occur with these behaviours, well above the random blink co-occurrence chance of 23%. (The random blink co-occurrence chance % is the probability that a blink and communicative facial behaviour both fall within a +/-375ms (19 frames) window).

Table 3-2 Blink / Communicative Facial Behaviour Primitive Co-occurrence

Participant Number / Gender	Total Dialogue Duration (min sec)	Total no. *(m)* of blinks performed	Total no. *(n)* of blinks co-occurring with a behaviour primitive (within +/- 375ms)	Blink Co-occurrence % *(m/n)*	Random Blink Co-Occurrence Chance % (within +/- 375ms)
01 / M	6min 25sec	76	64	84%	11%
02 / M	5min 06sec	49	37	76%	13%
03 / M	4min 46sec	134	100	75%	21%
05 / M	3min 46sec	124	78	63%	18%
06 / M	4min 02sec	135	92	68%	21%
09 / M	5min 10sec	63	48	76%	9%
07 / F	5min 21sec	272	201	74%	49%
08 / F	6min 59sec	350	286	82%	47%
11 / F	5min 50sec	232	138	60%	30%
12 / F	5min 59sec	166	102	61%	21%
13 / F	7min 31sec	237	164	69%	25%
14 / F	6min 36sec	169	116	69%	16%
TOTAL	**1h 07m 31s**	**2007**	**1430**	**71%**	**23%**

Average blink frequency of all 2007 captured blinks is 30 blinks/min is slightly increased from the value of 26 blinks/min during conversation (compared to 17 blinks/min during rest and 4.5 blinks/min during reading), as reported by Bentivoglio *et al.* (1997).

Table 3-3 Total Count of Observed Communicative Facial Behaviour Primitives.

Participant No. / Gender	Participant Speech	Interlocutor Speech	Looking At/Away	Facial Expression.	Mental State Change
01 / M	238 (37/min)	148 (23/min)	43 (7/min)	164 (26/min)	105 (16/min)
02 / M	156 (31/min)	136 (27/min)	11 (2/min)	36 (7/min)	67 (13/min)
03 / M	108 (23/min)	98 (21/min)	37 (8/min)	110 (23/min)	64 (13/min)
05 / M	62 (16/min)	80 (21/min)	5 (1/min)	40 (11/min)	65 (17/min)
06 / M	70 (17/min)	84 (21/min)	58 (15/min)	46 (11/min)	77 (19/min)
09 / M	100 (19/min)	150 (29/min)	22 (4/min)	90 (17/min)	82 (16/min)
07 / F	174 (33/min)	216 (40/min)	33 (6/min)	128 (24/min)	74 (14/min)
08 / F	222 (32/min)	234 (33/min)	101 (14/min)	156 (22/min)	132 (19/min)
11 / F	112 (19/min)	154 (26/min)	29 (5/min)	128 (22/min)	112 (19/min)
12 / F	106 (18/min)	112 (19/min)	35 (6/min)	146 (24/min)	126 (21/min)
13 / F	128 (17/min)	160 (21/min)	68 (9/min)	206 (27/min)	165 (22/min)
14 / F	88 (13/min)	114 (17/min)	65 (10/min)	124 (19/min)	119 (18/min)
TOTAL	**1564 (23/min)**	**1686 (25/min)**	**507 (8/min)**	**1374 (20/min)**	**1188 (18/min)**

3.5.3 Blink co-occurrence rates with specific facial behaviours

In this section we examine the communicative facial behaviours of Speech Onset/Offset

and Looking At/Away from the interlocutor, Facial Expression Onset/Offset and Mental Communicative State Change and their associated blinks to find which behaviours had co-occurrence values beyond their chance values and thus commonly trigger a blink within human-human communication.

Figure 3-12 to Figure 3-15 display the per-participant and mean blink co-occurrence % with all other transcribed communicative facial behaviour primitives. (*Co-Occurrence Actual (%)* defines the number of the communicative facial behaviour onset/offset (from the participants total) that co-occur with a blink (within a +/-375ms (19 frame) capture window). *Co-Occurrence Chance (%)* is the average probability that one of the facial behaviours and one of the blinks both fall by chance (within a +/-375ms (19 frame) capture window).

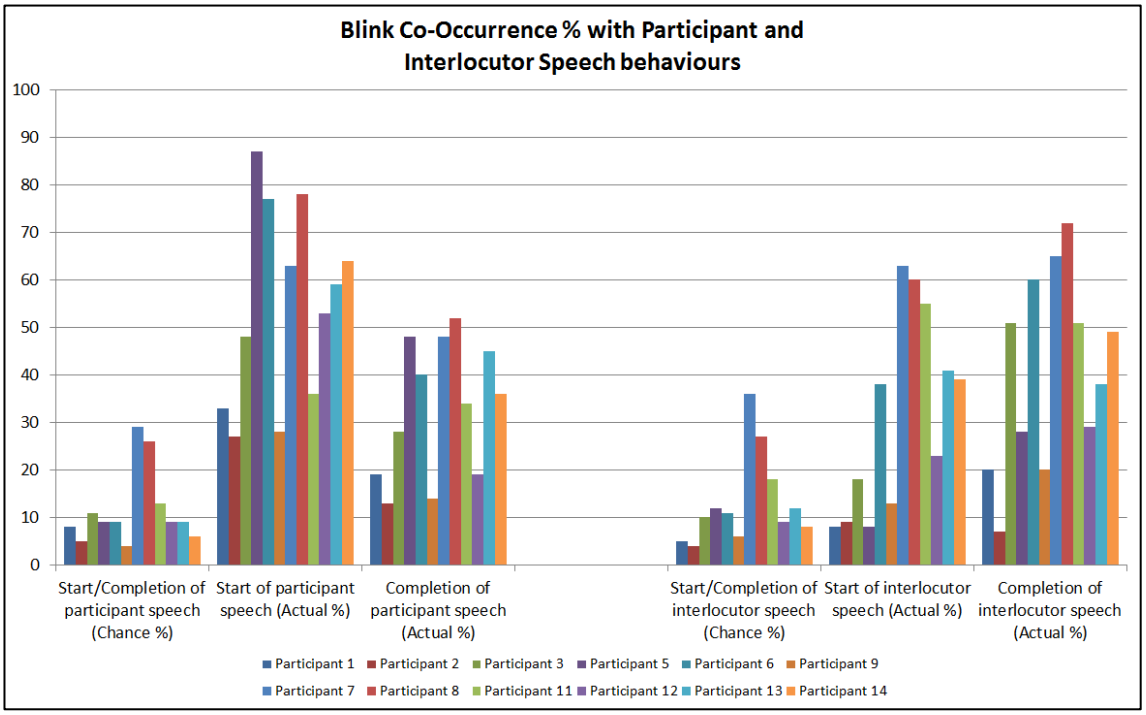


Figure 3-12 Blink Co-Occurrence % with Participant and Interlocutor Speech behaviours

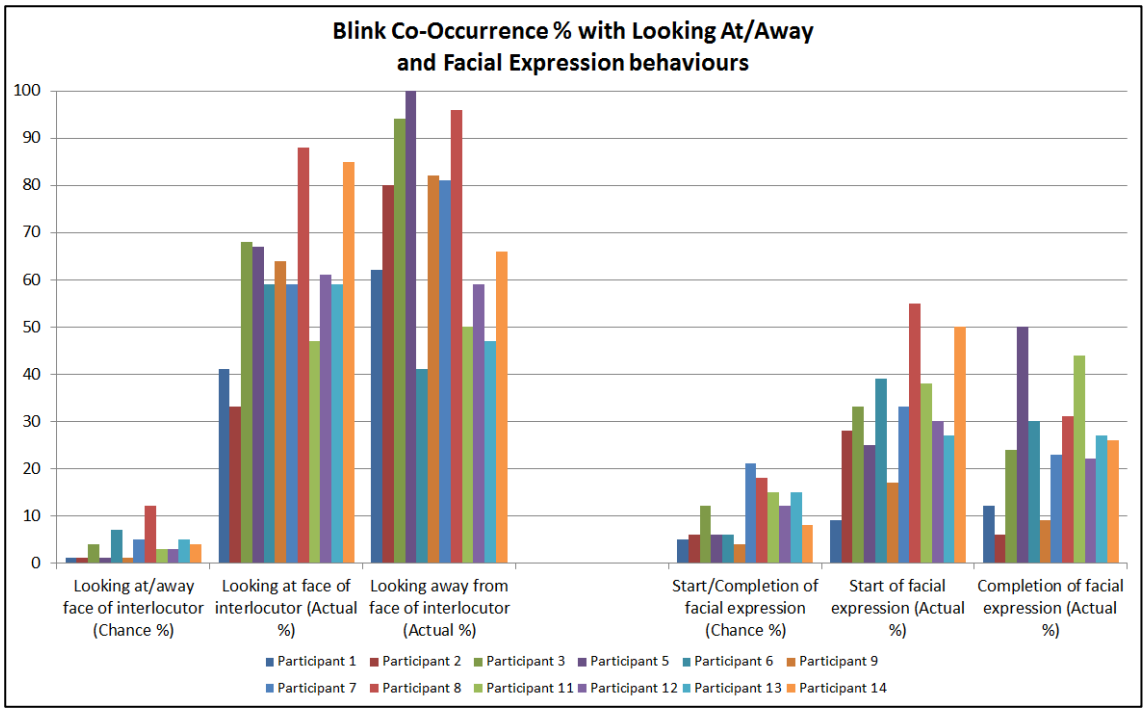


Figure 3-13 Blink Co-Occurrence % with Looking At/Away and Facial Expression behaviours

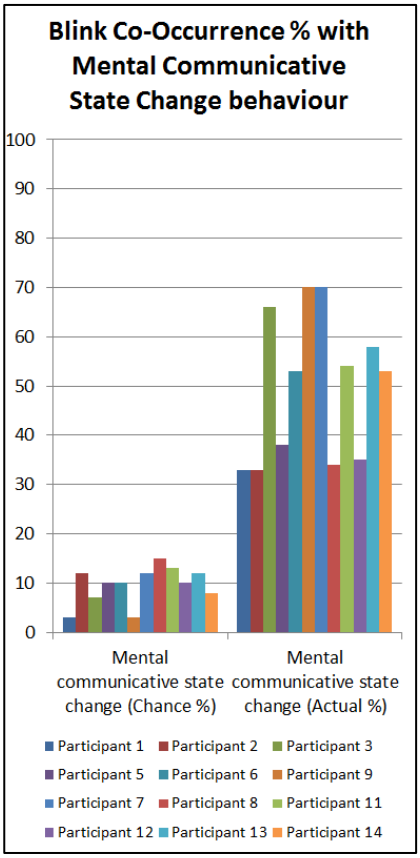


Figure 3-14 Blink Co-Occurrence % with Mental Communicative State Change behaviours

Figure 3-12 shows a strong blink co-occurrence with Participant Speech (specifically Participant Speech onsets) and Figure 3-13 with Looking At/Away changes. Figure 3-14 also clearly shows a strong blink co-occurrence with Mental Communicative State changes.

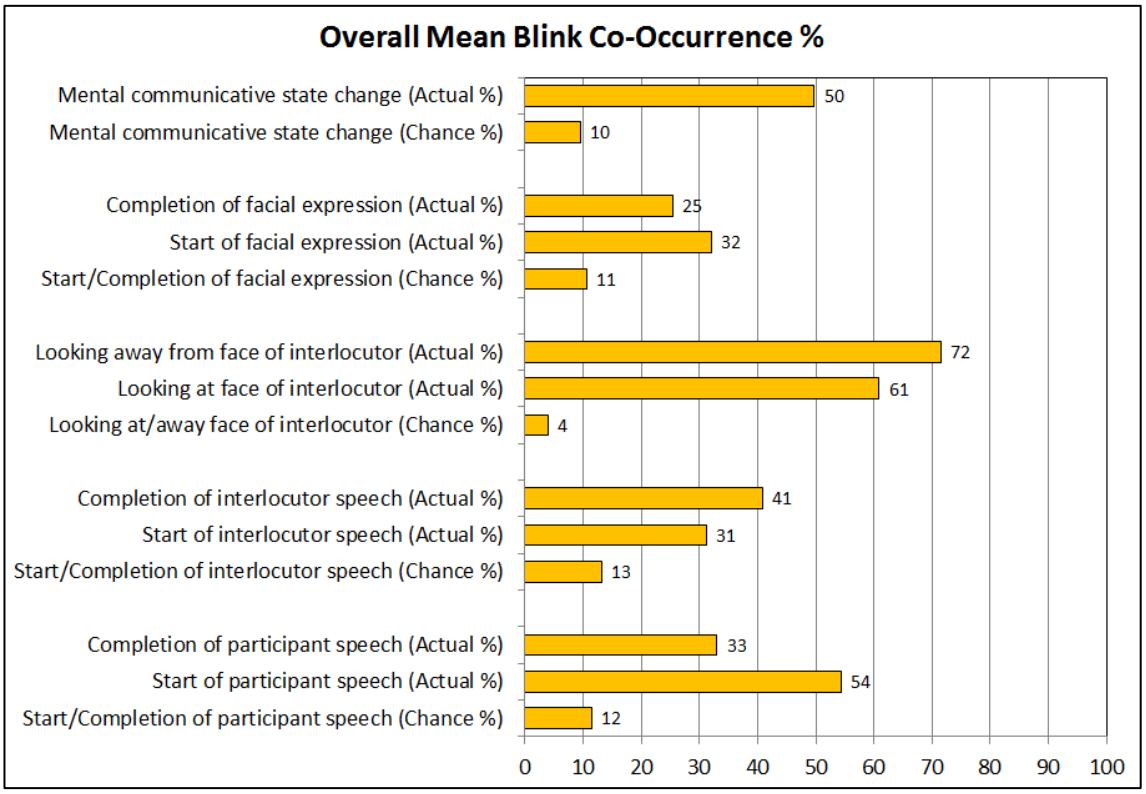


Figure 3-15 Overall Mean Blink Co-Occurrence %

All blink co-occurrence rates in our experiment are greater than their chance level (Figure 3-15) which would suggest that a large fraction of blinks are generated as part of communicative behaviour and are not just a baseline increase of the physiological blink frequency (Al-Abdulmunem & Briggs, 1999). Our additions to the knowledge of human blink behaviour are within blink behaviour triggers of Facial Expression Onset / Offset, Interlocutor Speech Onset and Mental Communicative State Change and therein the inclusion of the additional mental communicative state of misunderstanding. The *Overall Mean Blink Co-Occurrence %* values shown in Figure 3-15 are currently

averaged for all participants and as such create androgynous values. Figure 3-16 displays the gender differences, allowing for the future creation of specific gender based computational blink models.

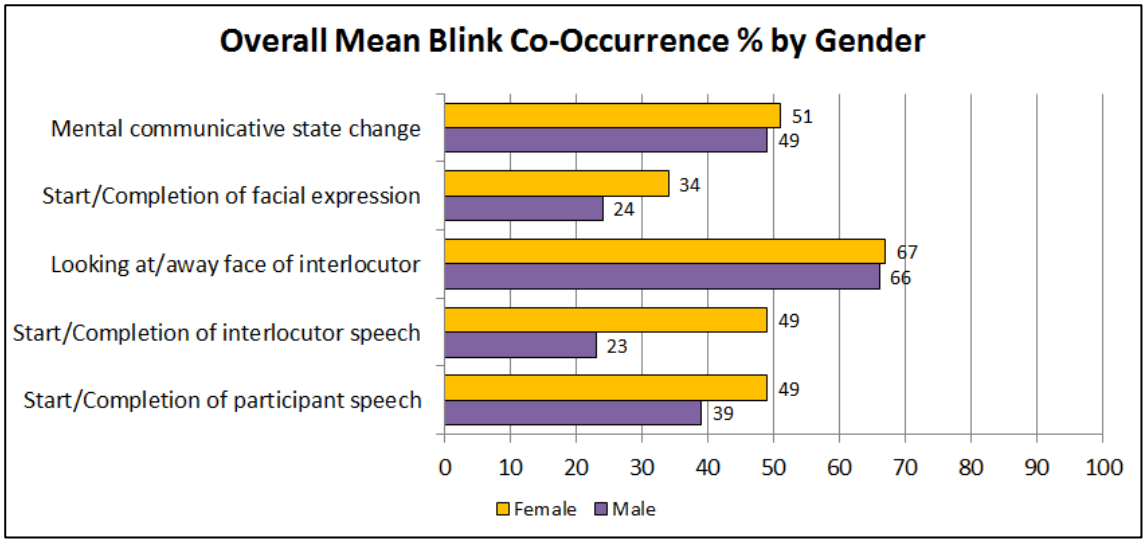


Figure 3-16 Overall Mean Blink Co-Occurrence % by Gender

Females seem to blink almost twice as much as their male counterparts within our data corpus (with blink rates of 20blinks per minute (bpm) for male participants and 38bpm for female participants). However, there are also differences in blink rate per participant, which change significantly within each gender group (Table 3-2). This high female blink rate leads to slightly higher average blink co-occurrence coverage across each of the communicative facial behaviours (Figure 3-16), although with only very slight gains with the behaviours of Looking At/Away and Mental Communicative State Change. The average blink co-occurrence values, even within females with their increased blink rate, are still significantly above chance.

3.5.4 Blink Co-occurrence through blink presence display

Blink co-occurence can also be visualized using *blink presence* histograms, as displayed in Figure 3-17 to Figure 3-26. These represent the presence of blinks within a -72 to +72 frame (-3sec to +3sec) time window surrounding a communicative facial behaviour

primitive onset or offset and mental state changes. Blink presence defines where a blink exists at a specific time. For example a blink lasting (and having a presence of) 10 frames would contribute to 10 bins in the histogram from its inception point. Given the average duration of a blink (8 frames) even perfect synchronisation between blink and behaviour would result in a peak of width 8 in the histogram starting from the bahaviour onset/offset (at frame 0). On the other hand, blinks not synchronized with the behaviour under consideration will contribute to an average background level of blink presence.

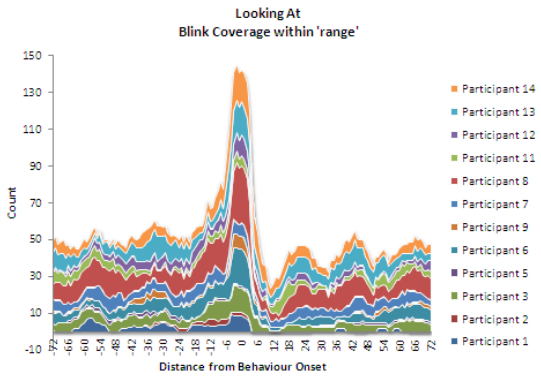


Figure 3-17 Blink presence surrounding Looking At behaviour events

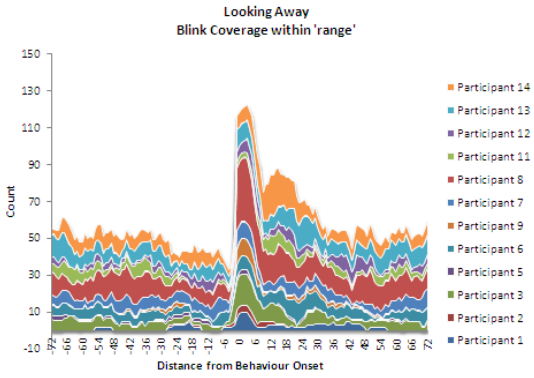


Figure 3-18 Blink presence surrounding Looking Away behaviour events

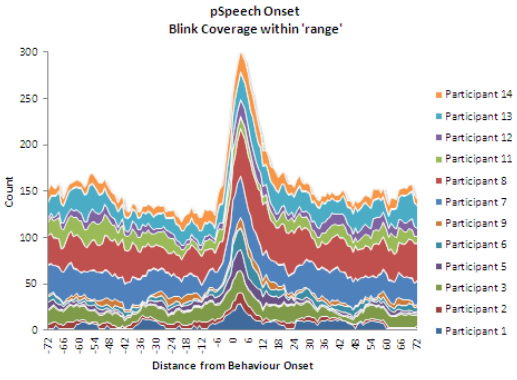


Figure 3-19 Blink presence surrounding Participant Speech Onset behaviour events

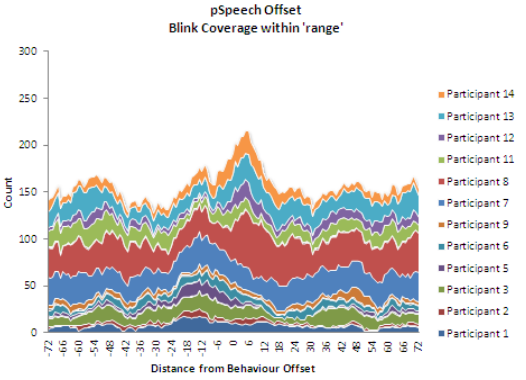


Figure 3-20 Blink presence surrounding Participant Speech Offset behaviour events

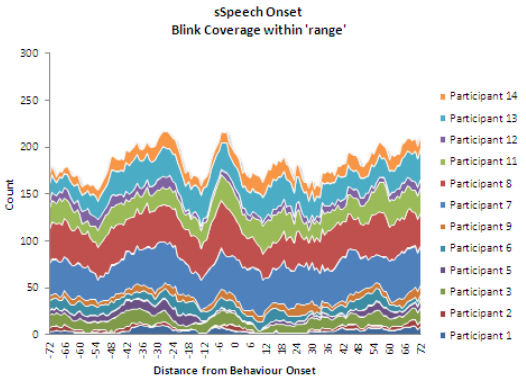


Figure 3-21 Blink presence surrounding Interlocutor Speech Onset behaviour events

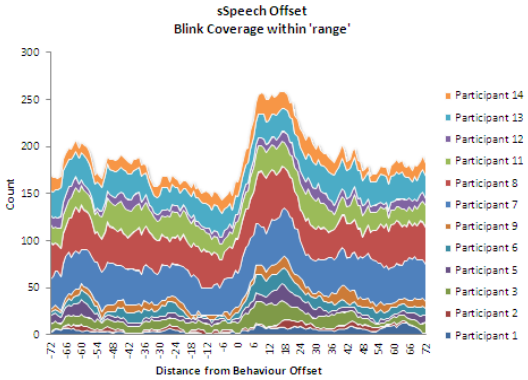


Figure 3-22 Blink presence surrounding Interlocutor Speech Offset behaviour events

Caution should be taken with the Interlocutor Speech (labelled sSpeech in the figures) offset behaviour peak displayed in Figure 3-22, as this, as we show through Figure 3-26 a/b, is largely an effect of Participant Speech (pSpeech) onset behaviours occurring almost concurrently.

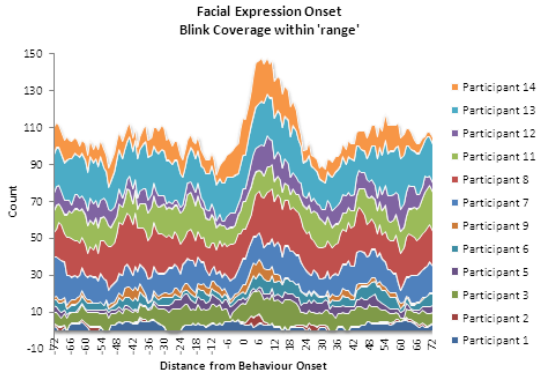


Figure 3-23 Blink presence surrounding Facial Expression Onset behaviour events

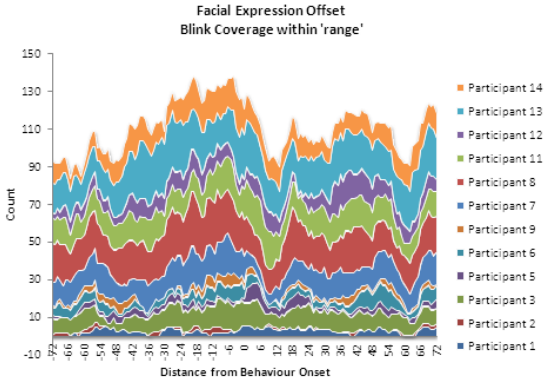


Figure 3-24 Blink presence surrounding Facial Expression Offset behaviour events

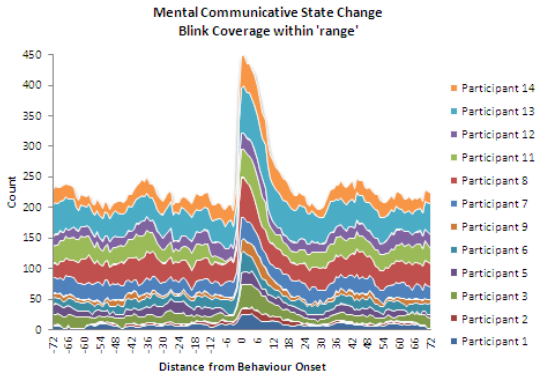


Figure 3-25 Blink presence surrounding Mental Communicative State Change behaviour events

The Looking At behaviour has a high co-occurrence (66%) above chance (4%) (Figure 3-13). Figure 3-17 shows blinks occuring consistently between -6 to +2 frames around the instantiation of this behaviour. This shows that during dialogue-based communication we generally blink closely around starting the movement of the head and eyes to look at the interlocutor, thus we propose that this (along with the head and eye movement back to the interlocutor) could be used as a cue of attention.

The Looking Away behaviour also shows a high behaviour co-occurrence (69%) above chance (4%) (Figure 3-13). Figure 3-18 shows blinks occuring consistently between -2 to +4 frames around the start of this behaviour. This displays the effect that during dialogue-based communication we generally blink closely around starting the movement of the head and eyes to look away from the interlocutor, thus we propose that this (along with the head and eye movement away from the interlocutor) gives a cue to the interlocutor that we are entering a thought state and for them to await our response.

The Participant Speech Onset behaviour shows a high behaviour co-occurrence (52%) above chance (12%) (Figure 3-12). Figure 3-19 shows blinks occuring consistently between -6 to +4 frames around the start of this behaviour. We propose that this could reinforce the signal from the participant that they are taking their turn to speak.

The Participant Speech Offset behaviour displays a behaviour co-occurrence effect (33%) above chance (12%) (Figure 3-12). Figure 3-20 shows blinks occuring between -8 to +14 frames around the start of this behaviour. This result shows that during dialogue-based communication we occassionally blink around the completion of a speech segment, which may give a cue to the interlocutor that it is their turn within the dialogue flow.

The Interlocutor Speech Onset behaviour shows infrequent blink behaviour upon completion of a facial expression despite a behaviour co-occurrence effect (35%) above chance (13%) (Figure 3-12). Figure 3-21 however does show a higher blink count occuring consistently both between -46 to -20 frames and -8 to +4 frames around the start of this behaviour. Hence, we propose that blink behaviour is occassionally used as acknowledgement of interlocutor start of speech and as such, acceptance by the interlocutor of their turn within the dialogue flow.

The Interlocutor Speech Offset behaviour shows strong behaviour co-occurrence of 43% above chance (13%) (Figure 3-12). Figure 3-22 shows blinks occuring consistently between -2 to +8. However, there is evidence that these blinks are actually associated with the start of speech of the participant taking his turn. The following analysis provides this evidence.

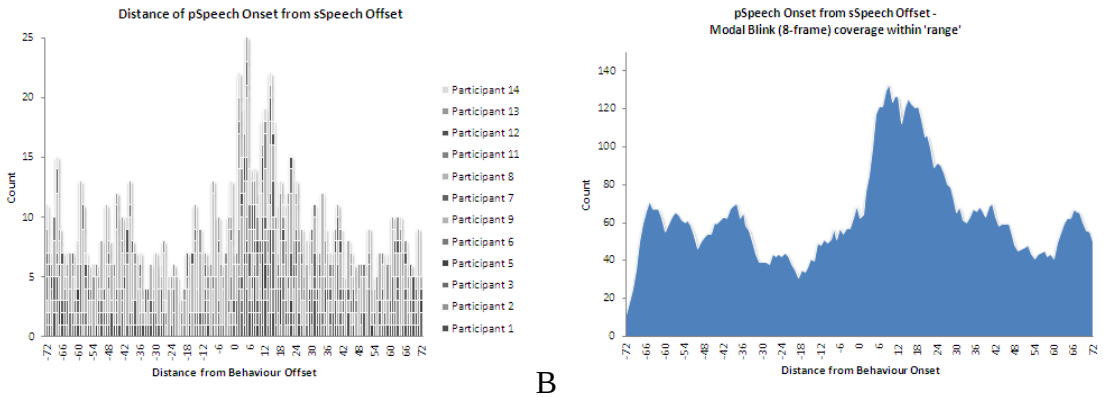
The Facial Expression Onset behaviour displays a behaviour co-occurrence effect (33%) above chance (11%) (Figure 3-13). Figure 3-23 shows blinks occuring consistently between -2 to +20 frames around the start of this behaviour. This shows that during dialogue-based communication we occassionally blink prior to facial expression instigation, thus we propose that this could be used as a cue of semantic accentuation.

The Facial Expression Offset behaviour shows infrequent blink behaviour when a

interlocutor starts speaking despite a behaviour co-occurrence effect of 29% above-chance (11%) (Figure 3-13). Figure 3-24 however does show a higher blink count occuring consistently between -30 to +2 frames around the start of this behaviour. Hence, we propose that blink behaviour is occassionally used to accentuate facial expression completion.

The Mental Communicative State Change behaviour has a high behaviour co-occurrence (66%) above chance (4%) (Figure 3-14). Figure 3-25 shows blinks occuring consistently between -2 to +12 frames around the start of this behaviour. This shows that during dialogue-based communication we generally blink closely around a change in Mental Communicative State (i.e. between thought, understanding, uncertainty and misunderstanding), thus we propose that this (along with concurrent behaviour instigations) could be used as a cue of attention for the current state, thus affecting an interlocutors grounding behaviour (such as turn-taking).

A histogram of the Participant Speech Onset times surrounding Interlocutor Speech Offset behaviours (Figure 3-26A) displays a trend similar to Figure 3-22/Figure 3-26B of blink presence surrounding Interlocutor Speech Offset behaviours. Based upon Figure 3-19, which shows Participant Speech Onset co-occuring blinks to closely surround the onset of participant speech, and using information from Figure 3-29 displaying the most common blink duration to be 8 frames (334 ms), we created an initial blink behaviour model. By applying this model to the Participant Speech Onset data from Figure 3-26A we produced a synthetic blink presence histogram shown in Figure 3-26B.



A B

Figure 3-26 A. Participant Speech Onset events surrounding Interlocutor Speech Offset events B. Modelled Participant Speech Onset blink behaviour surrounding Interlocutor Speech Offset events

The moderately strong Pearson Correlation ($r(2)=0.862$, $p=0.05$) between this modelled Participant Speech Onset blink behaviour (Figure 3-26B) and the output of the captured Interlocutor Speech Offset blink behaviour (Figure 3-22) leads us to propose that the Interlocutor Speech Offset behaviour results (Figure 3-12) are actually produced mainly through Participant Speech Onset blink behaviour and, as such, are not commonly used as a trigger for blink generation during dialogue-based communication as their behaviour co-occurrence value suggests.

Based upon these results, a blink generation model (Figure 4-2) has been created that utilises eight of the nine behaviours analysed (i.e. Participant Speech Onset/Offset, Interlocutor Speech Onset, Looking At/Away from the interlocutors face, Facial Expression Onset/Offset and Mental Communicative State Change) as blink triggers along with their respective mean average co-occurrence weightings (Figure 3-12 to Figure 3-14).

3.6 Human Blink Morphology

Knowing when to activate a blink is only the first step in creating an accurate model of human blink behaviour in communication. The other step is the definition of the

morphology of the blink to be produced. The importance of blink morphology in creating believable human blink behaviour cannot be understated.

Table 3-4 Blink Morphology Statistics

Single Blink Occurrence	85%
Multiple Blink Occurrence	15%
Occurrence of Double vs. Triple Blink	80% vs. 20% (of above 15% total)
Occurrence of Full / Half Blink Type	91% / 9%
Full Blink Duration (Mean)	432ms
Full Blink Duration (Standard Deviation)	72ms
Full Blink Attack (Mean)	111ms
Full Blink Attack (Standard Deviation)	31ms
Full Blink Sustain	Remainder of duration
Full Blink Decay (Mean)	300ms
Full Blink Decay (Standard Deviation)	123ms
Half Blink Duration (Mean)	266ms
Half Blink Duration (Standard Deviation)	40ms
Half Blink Attack (Mean)	97ms
Half Blink Attack (Standard Deviation)	28ms
Half Blink Sustain	Remainder of duration
Half Blink Decay (Mean)	148ms
Half Blink Decay (Standard Deviation)	64ms

Table 3-4 displays the statistical results for the morphology of the human blink action derived from our data corpus. The variables used within the corpus to define the blink

morphology are blink type, either half, where the eyelid is only half closed when the blink action is performed, but the pupil is still covered (Figure 3-27) or full and duration (in parts of a second), which is further broken down into attack (the duration taken to close the eyelid), sustain (the duration the eyelid is kept closed) and decay (the duration taken to re-open the eyelid) (Figure 3-28).

Figure 3-27 Half Blink – Example

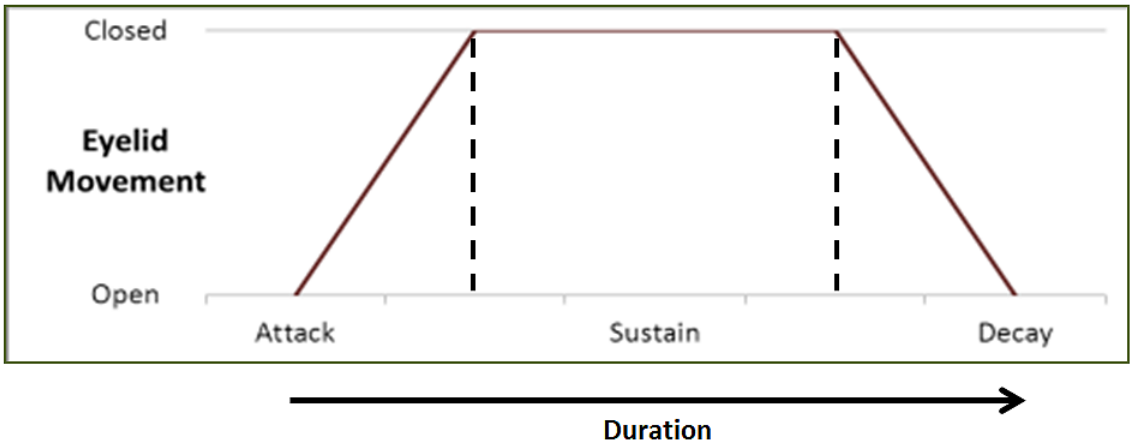


Figure 3-28 Blink Duration Envelope

Blink morphology occurrence is split between 91% full blinks and 9% half blinks within the 2,007 blinks captured. Multiple blink actions (where smaller duration blinks (generally of two or three blink actions) happen almost concurrently to each other)

make up approximately 15% of the total blinks performed. Approximately 20% of these multiple blinks will be in the form of a triple blink (three blinks in quick succession) as opposed to a double blink (two blinks in quick succession). The triple blink has the same duration, attack, sustain, and decay morphology as a double blink.

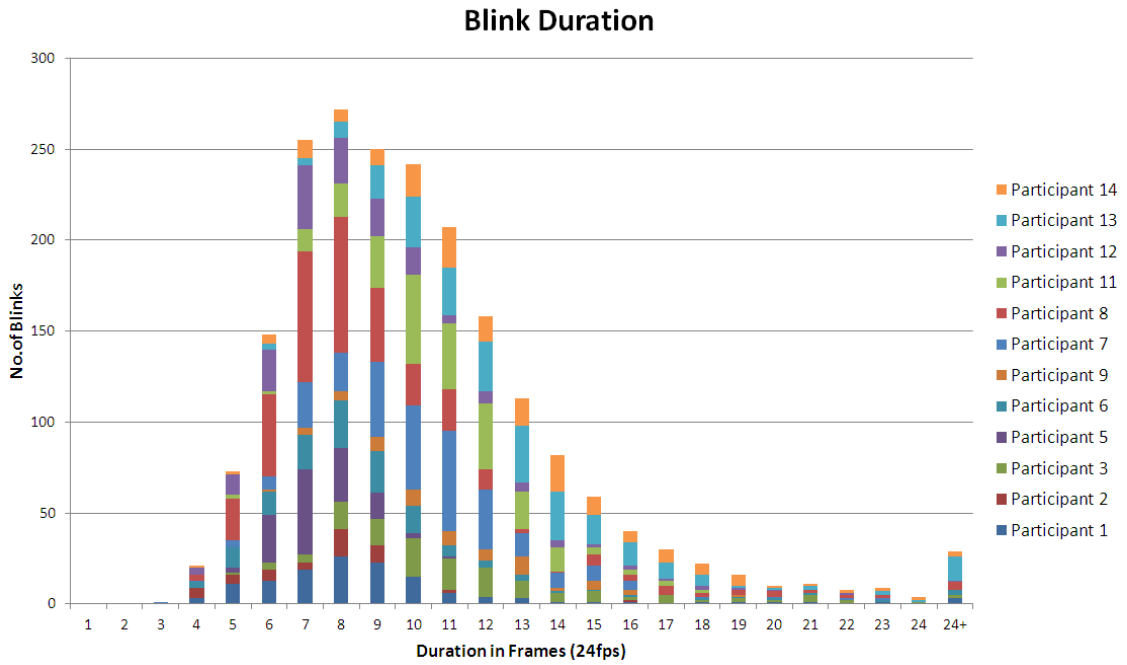


Figure 3-29 Histogram of all blink durations (12 subjects).

Figure 3-29 displays the duration values of all 2,007 blinks captured in our corpus. Differences in modal blink duration for each participant can be clearly seen, ranging from between 7 frames (Participant 12) and 13 frames (Participant 13). The modal blink duration of all participants is 8 frames (333ms).

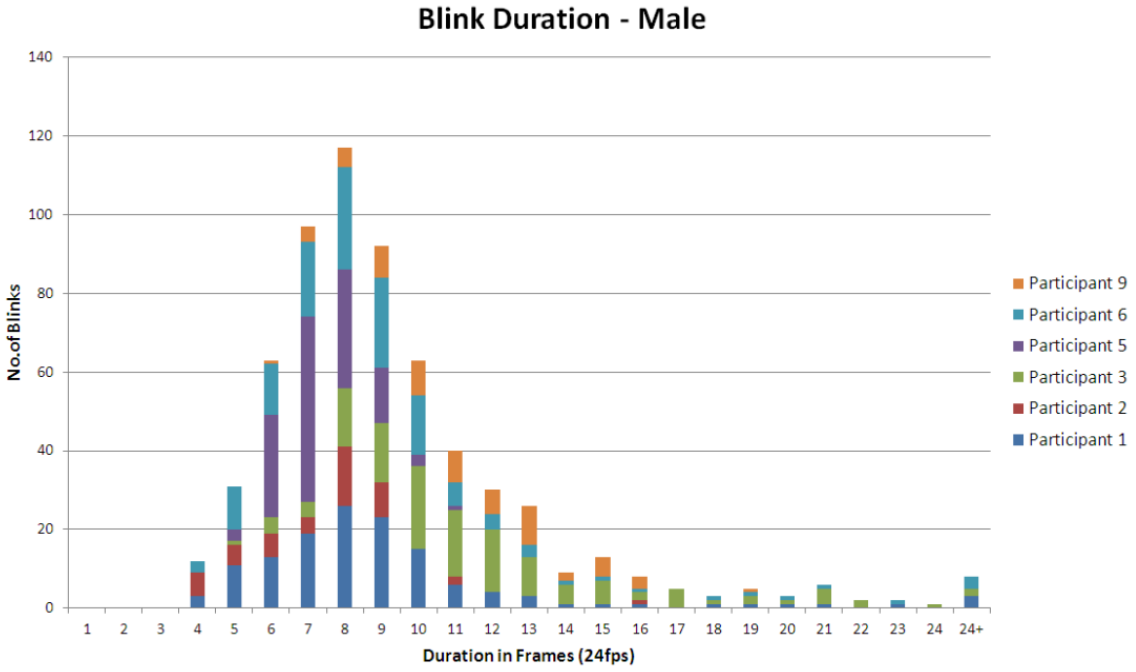


Figure 3-30 Histogram of male blink durations (6 subjects).

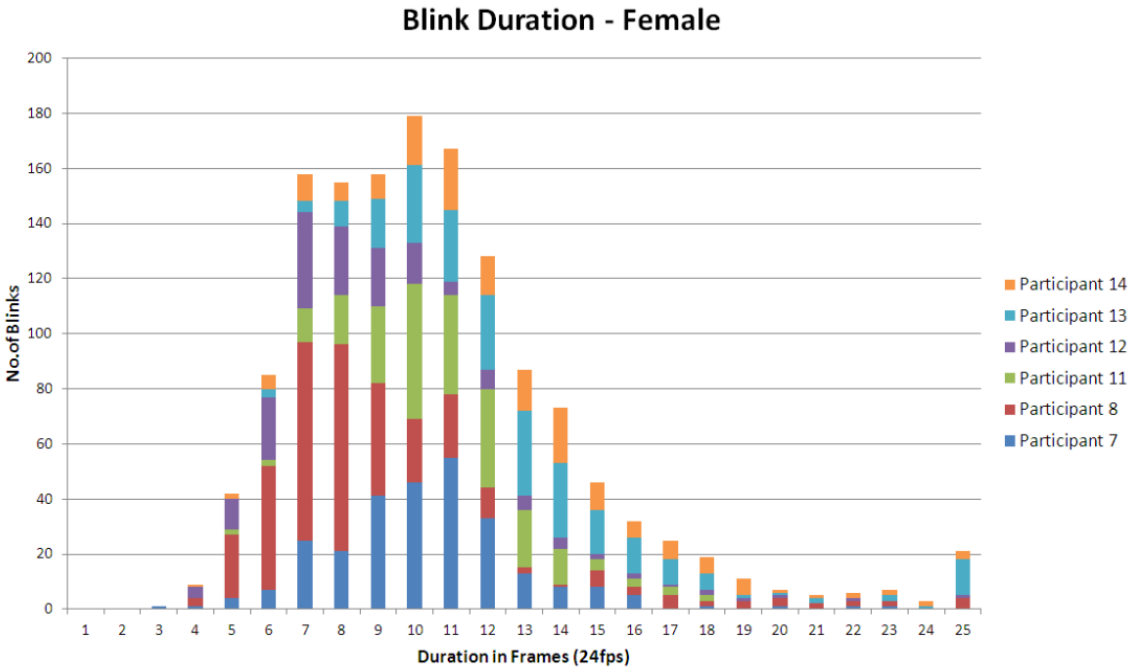


Figure 3-31 Histogram of female blink durations (6 subjects).

Figure 3-30 and Figure 3-31 display blink duration values for male and female participants respectively. The gender based modal values of blink duration are male = 8 frames (333ms) and female = 10 frames (417ms).

3.7 Summary

A summary of Chapter 3 results highlights:

- The concept of the communicative behaviour complex is posited (i.e. linked communicative facial behaviour primitives displayed over time that express the current mental communicative state of the expresser).

- The mental communicative states of Misunderstanding, Uncertainty, Understanding, Thought (Listening) and Thought (Processing) are shown to incorporate reasonably distinct communicative behaviour characteristics.

- The Multi Discriminant Analysis (MDA) communicative facial behaviour categorisation process for each mental communicative state suggests that each state could be differentiated between within a computational mental communicative state categorisation/expression model using the MDA results and associated temporal communicative facial behaviour primitives for each mental state embedded within a Bayesian Network.

- Early research posited that blinks were solely physiological in function. Successive researchers have however, progressively identified some behavioural correlates of blinking, such as start of own speech, gaze shifts (towards and away from an interlocutor) and changes of limited mental states. Thus, an increasing fraction of blinks were given a communicative, rather than purely physiological function. This research has extended the knowledge of human blink behaviour, showing that (based on our corpus) between 48% to 71% of blinks co-occur with other communicative facial behaviours through the identification of new blink triggers of Facial Expression Onset / Offset, Interlocutor Speech Onset and Mental Communicative State Changes, including

newly investigated mental communicative state of misunderstanding. These co-occurrence values are shown to be above levels of chance (Figure 3-12 to Figure 3-15).

- Females blink almost twice as much as their male counterparts within our data corpus (with an average SEBR of 20bpm for male participants and 38bpm for female participants). However, there are also differences in blink rate per participant, which change significantly within each gender group (Table 3-2).

- Higher female blink rates lead to slightly higher average blink co-occurrence coverage across each of the communicative facial behaviours (Figure 3-16), although with only very slight gains with the behaviours of Looking At/Away and Mental Communicative State Change. Average female blink co-occurrence values, even with their increased blink rate, are still significantly above chance.

4 Design and Implementation of a Human Blink Model

This chapter presents design and implementation details for the computational human blink model and the communicative saccadic eye movement model for speaker / listener states as well as conceptual design details for their parent mental communicative state driven human facial communication system.

4.1 Human Facial Communication System

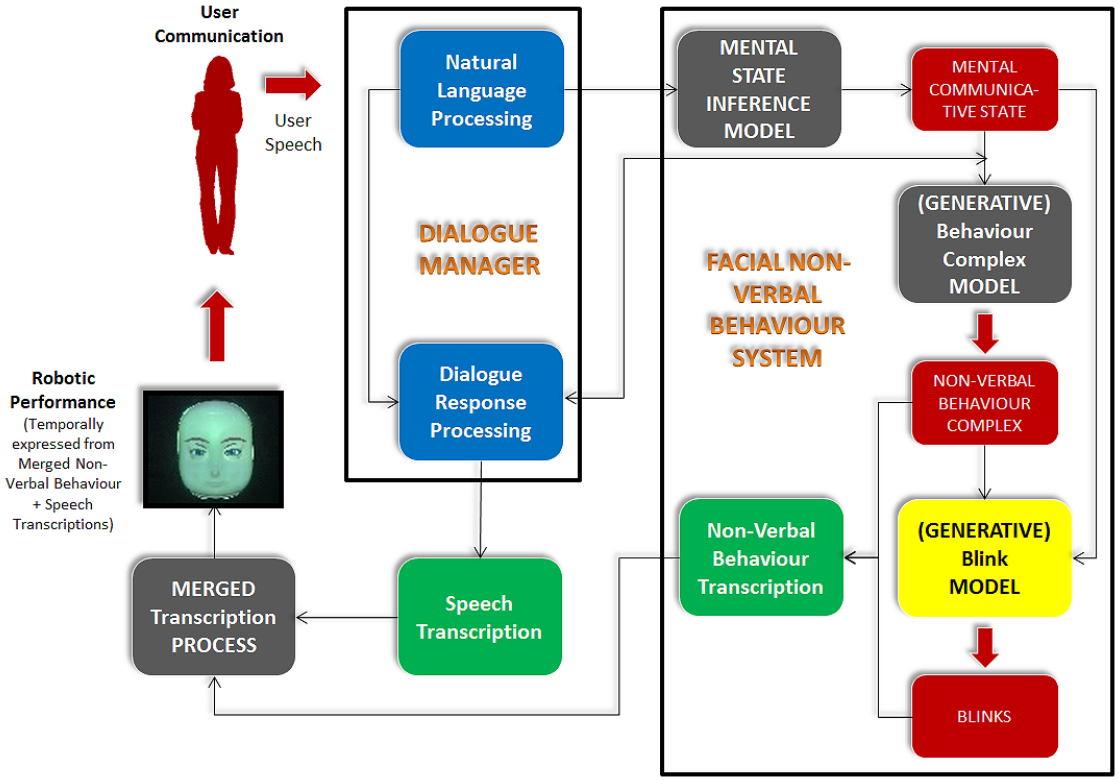


Figure 4-1 Human Facial Communication System – Flow Diagram

The Human Facial Communication System (Figure 4-1) is designed to generate the complete communicative response output of a social robotic/ECA system (including verbal and non-verbal facial behaviour) based upon the speech input received from a user (interlocutor).

The output from the system will be controlled by a simple grounding model which initially enters a listening state (and a mental communicative state of Thought

(Listening)) when awaiting input by a user. This will require a NLP system to await and capture verbal input from a user. During this listening state, the robotic/ECA system will utilise face tracking for orienting towards and surveying the face of the user, incorporating an eye gaze listening model, which gazes in a repeating triangular-like motion from each eye to the mouth of the user (where most of the attention time is given) until they have finished communicating with the system. The eye gaze listening model behaviour was implemented using human-human communicative gaze patterns whilst listening, derived from research by Raidt, Bailly and Elisei (2007).

The physiological function of the computational blink model (Section 4.2) is always engaged whenever the system is switched on. Also, an initial function of the computational blink model will be engaged during the human facial communication system listening state, awaiting interlocutor speech onset, with which it generates a blink behaviour if the co-occurrence probabilistic weighting function instantiates a blink trigger.

Upon completion of user speech capture, the system enters a processing state (and a mental communicative state of thought (processing)) in which it processes the users speech, utilising the dialogue manager to formulate its own speech response and to infer its response based internal mental communicative state (of misunderstanding, understanding or uncertainty). The expression of a look away (from the user) behaviour (and its associated blink behaviour) is likely to be instigated by the system within this state based on their co-occurrence probabilistic weighting function (Section 3.3). The defined response speech text and mental communicative state are used to generate the non-verbal facial behaviour complex (or temporal facial behaviour animation transcription) including blink behaviour (Section 3.3 and 3.6), which is further merged temporally with the speech response text as a response transcription used to define the

physical performance by the robotic/ECA system.

Upon completion of processing, the response mental communicative state (of misunderstanding, understanding or uncertainty) is entered. The physical performance begins with a looking at (the user) behaviour if a look away (from the user) behaviour was performed during the processing state. The associated blink behaviour will be determined based upon its co-occurrence probabilistic weighting function (Section 3.3). The physical performance of the response transcription is then instigated.

Upon completion of the physical performance, the system returns to the listening state (and a mental communicative state of thought (listening)) awaiting the next response from the user, unless it reached an Understanding mental state and has understood the requirements of the users task request.

4.2 Computational Blink Model

Our proposed computational blink generation model (Figure 4-2), which forms a sub-part of the overall human facial communication system (Figure 4-1), uses as its blink trigger input the detection of the interlocutors speech onset/offset and the response based mental communicative states generated by the NLP system. From the mental states, which in-turn defines a sequence of facial non-verbal communicative behaviours, blinks are triggered based on the defined communicative behaviour co-occurrence probabilistic weighting (displayed in Figure 3-12 to Figure 3-14 and Section 4.5).

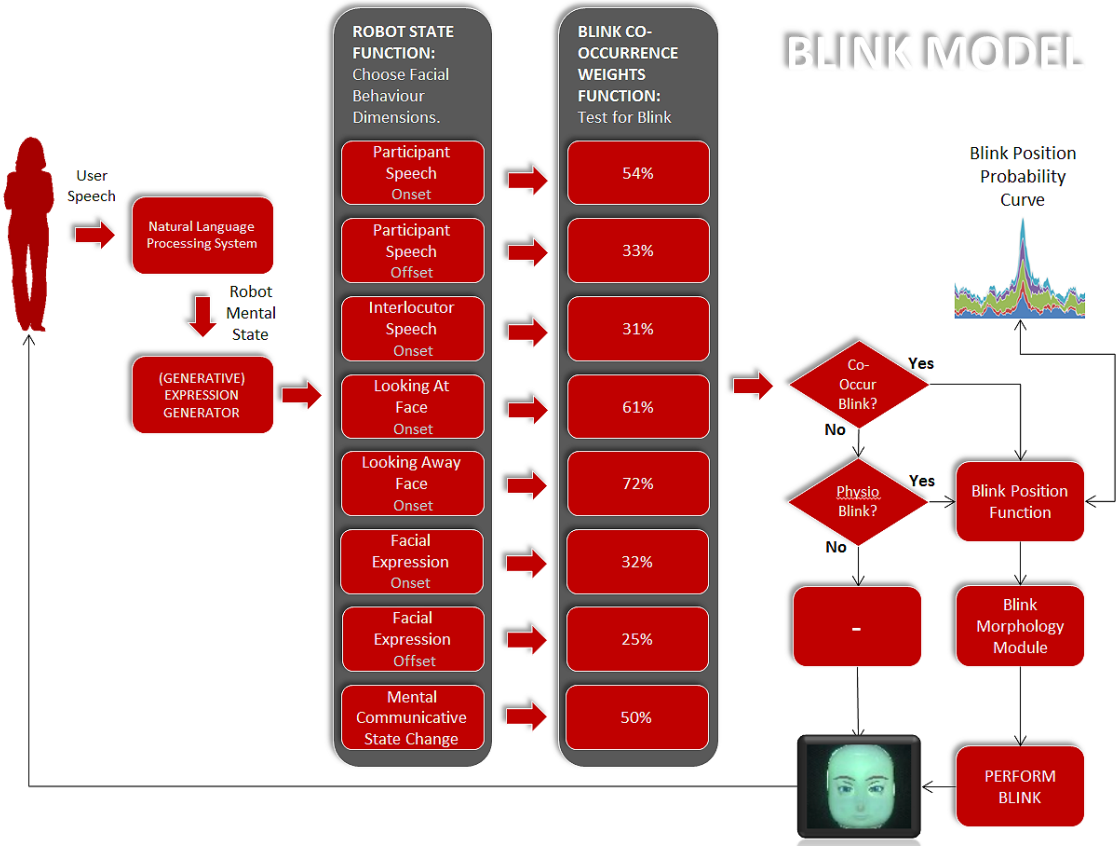


Figure 4-2 Computational Blink Generation System – Flow Diagram

If a blink occurrence is triggered, all other communicative behaviours are ignored by the computational blink model for the duration of the blink(s) generated as this blink behaviour would already be co-occurring with these communicative behaviours as they were instantiated.

The position (or delay) in producing a blink is determined through use of the blink position probability curve of the communicative behaviour in question (Figure 3-17 to Figure 3-21 and Figure 3-23 to Figure 3-25). The physical morphology of the blink(s) is determined through the blink morphology module (Figure 4-4) process flow, discussed further in Section 4.4.

A physiological blink mechanism (for simulating cleaning/humidifying/oxygenating of the eye) is also included in the model, commonly performing a blink action within a

timeframe of 1.96 - 10.2sec (mean 4.78sec) where no prior blink has been instantiated (Carney & Hill, 1982).

Therefore, the computational blink model triggers a blink action either on receiving and accepting (through a weighted probabilistic function) User Speech Onset, a Robot/Avatar own Speech Onset/Offset, Looking At/Away, Facial Expression Onset/Offset and Mental Communicative State Change communicative behaviours (based on their specific probability weighting value (Figure 3-12 to Figure 3-14)) or when a physiological blink is instantiated.

It is important to note that the current implemented version of the blink model utilises both male and female co-occurrence data to define its probabilistic values and hence could be said to be androgynous in its behaviour. Gender variants of the model could be created by utilising only the gender specific blink co-occurrence data.

4.3 Computational Blink Model – An Example of Functionality

An example scenario of the computational blink model (Figure 4-2) functioning as part of the higher level Human Facial Communication System can be conceived as follows:

As previously stated, the physiological function of the computational blink model (Section 4.2) is always engaged whenever the robotic/ECA system is switched on.

An initial function of the computational blink model will be engaged during the human communication systems listening state, which awaits interlocutor speech onset and then generates a blink behaviour if the co-occurrence probabilistic weighting function instantiates a blink trigger.

Once the robot is engaged in speaking, the full blink model will be engaged to trigger communicative blink behaviour according to the probability of co-occurrence (Figure

3-12 to Figure 3-14). An example is shown in Figure 4-3, where subsets of participant 3s communicative behaviours were used as input triggers to an early prototype computational blink model. The resultant co-occurring blinks generated by the prototype model (which excluded blink morphology, and thus used the defined average blink duration of 8 frames (334ms)) are displayed on the y-axis as PBL-MODEL. A description of the model blink behaviour follows:

- PSpeech behaviour (frame 60) is matched by both a human and a model blink.
- Looking Away behaviour (frame 283) and Looking At behaviour (frame 295) are matched by both a human and a model blink.
- Looking Away behaviour (frame 412), Looking At behaviour (frame 433) and pSpeech behaviour are each matched by both human and model blinks.
- The model however, does miss the pSpeech behaviour (frame 353), which co-occurred with a very long (and rare) 1+sec human blink.

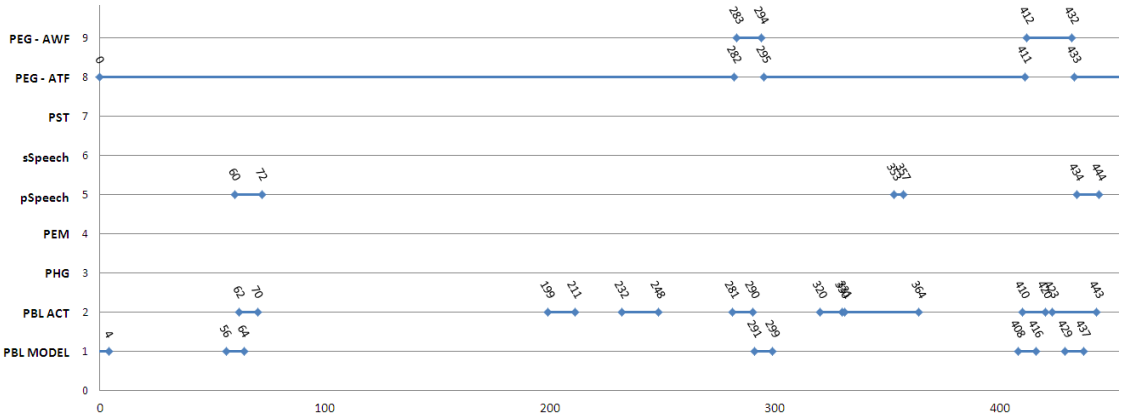


Figure 4-3 Sample of participant 3 behaviour data (lines 2 – 9) and output of the Computational Blink Model (line 1- labelled PBL MODEL). (A constant blink duration of 8 frames (333ms) was used for the PBL MODEL).

Some differences between human and model blink behaviour are to be expected, with the model both missing blinks and also adding blinks (where participants did not instantiate one within the captured data), due to the probabilistic nature of the model

design, thus leading to a 48% to 71% computational blink model accuracy (i.e. blink co-occurrence % maximum (71%) – blink co-occurrence chance % maximum (23%)) at imitating human blink behaviour in communication (Figure 3-12 to Figure 3-14).

4.4 Blink Morphology Module

Figure 4-4 represents the blink morphology as a computational module for use within the computational blink model (Figure 4-2).

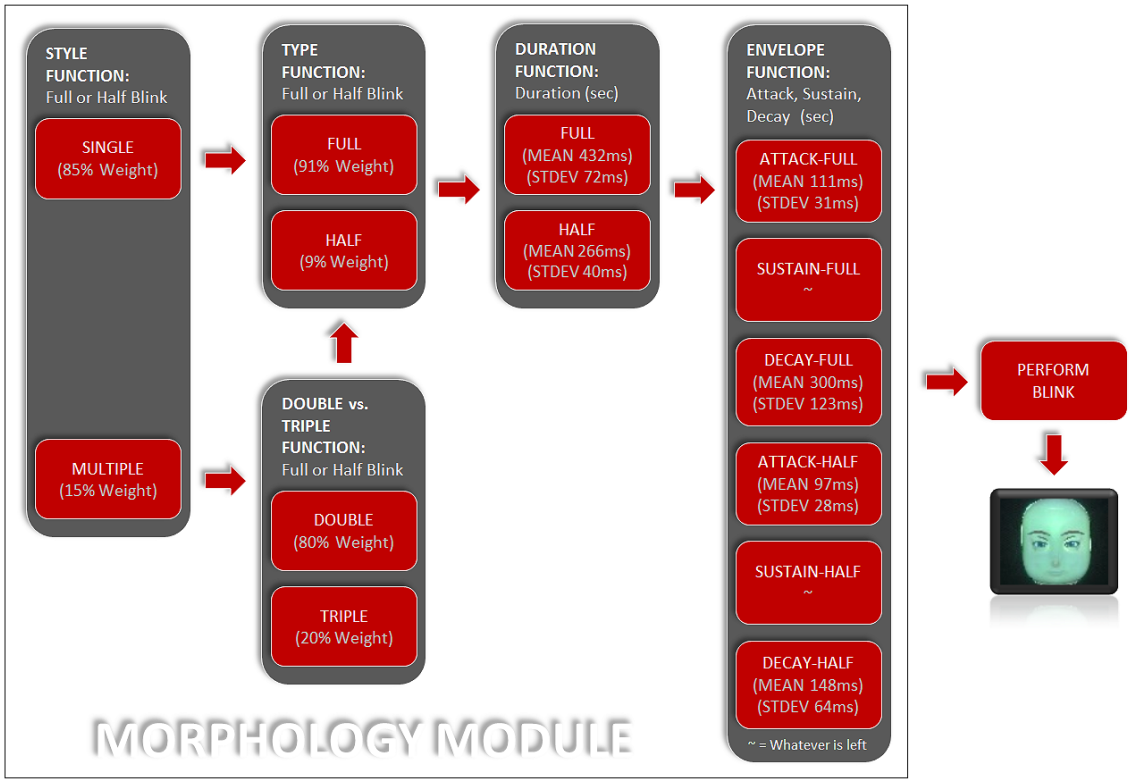


Figure 4-4 Blink Morphology Module – Flow Diagram

The morphology module is called upon instantiation of a blink within the computational blink model and follows a functional weighted process flow which defines the blink style and count (if the multiple style is instigated), followed by each blinks type definition, duration and ASD envelope properties (Section 4.5). These details are fed back to the non-verbal behaviour transcription of the human non-verbal facial behaviour

system, formulating the blink behaviour of the overall non-verbal facial behaviour performed by the robotic/ECA system along with the speech output defined by the dialogue system.

4.5 Computational Blink Model – Pseudo code

```
//////////////////////
// START MAIN Function

// VARIABLES
int   currentRunTime              // Time in ms of current duration of robot communication (vision / hearing) program run time.
                                  // Initialised as 0.
bool  blinkOn                     // Set to true if Blink Instantiation currently being performed.  Initialised as false.
bool  blinkAvailable              // Set to true if timeUntilBlinkReAvailability == 0.  Initialised as true.

int   blinkStyle                  // Style of Blink Instatiation (1 = Single (85%), 2 = Multiple (15%))
int   blinkCount                  // No of blinks in current Blink Instatiation (2 (80%) or 3 (20%)) if blinkStyle = 2 (Multiple)
int   blink01Type                 // Type of 1st Blink. Initialised as 0. Used in Single / Multiple Blink Style.
int   blink01Duration             // Total Duration of 1st Blink. Initialised as 0. Used in Single / Multiple Blink Style.
int   blink01AtkDuration          // Duration of 1st Blink Attack.
int   blink01SusDuration          // Duration of 1st Blink Sustain.
int   blink01DcyDuration          // Duration of 1st Blink Decay.
int   blink02Type                 // Type of 2nd Blink. Initialised as 0. Used in Single / Multiple Blink Style.
int   blink02Duration             // Total Duration of 2nd Blink. Initialised as 0. Used in Multiple Blink Style (Double or Triple).
int   blink02AtkDuration          // Duration of 2nd Blink Attack.
int   blink02SusDuration          // Duration of 2nd Blink Sustain.
int   blink02DcyDuration          // Duration of 2nd Blink Decay.
int   blink03Type                 // Type of 3rd Blink. Initialised as 0. Used in Single / Multiple Blink Style.
int   blink03Duration             // Total Duration of 3rd Blink. Initialised as 0. Used in Multiple Blink Style (Triple Only).
int   blink03AtkDuration          // Duration of 3rd Blink Attack.
int   blink03SusDuration          // Duration of 3rd Blink Sustain.
int   blink03DcyDuration          // Duration of 3rd Blink Decay.
int   blinkInstantiationDuration  // Total Duration of Overall Blink Instatiation. Initialised as 0.
```

```
int    timeUntilBlinkReAvailability     // Holds total time of blink instantiation duration plus 375ms after blink completion to stop blink
                                        // instantiation processing (blinkOn = true whilst != 0).  Initialised as 0.
int    timeSinceLastBlink               // Timer for duration since last blink (i.e. time since blinkAvailable set to true).  Initialised as 0.
bool   participantSpeechOn              // Set to true at Start of robots own speech - triggered.  Initialised as false.
bool   participantSpeechOff             // Set to true at End of robots own speech - triggered.  Initialised as false.
bool   interlocutorSpeechOn             // Set to true at Start of users speech - triggered.  Initialised as false.
                                        // (Microphone required to pick up users speech (as part of the on-board NLP system)).
bool   lookAtFace                       // Set to true at Start of robot head move towards face of user  - triggered.
                                        // Initialised as false.
bool   lookAwayFace                     // Set to true at Start of robot head move away from face of user - triggered.
                                        // Initialised as false.
bool   facialExpressionOn               // Set to true at Start of robot facial expression - triggered.  Initialised as false.
bool   facialExpressionOff              // Set to true at End of robot facial expression - triggered.  Initialised as false.
bool   mentalCommStateChange            // Mental Communicative State Change within Robot
                                        // (i.e. Thought, Understanding, Misunderstanding and
                                        // Uncertainty, defined by NLP system) - triggered.  Initialised as false.

//
// DEFINE SET & GET FUNCTIONS FOR ALL ABOVE VARS.
//

Random randGenerator = new Random();    // Random Generator Definition
```

... as part of system update cycle (generally (16.6msec) 60 per second (clock tick)) ..
On each timer update from the main system that the Blink Model is to be incorporated, call BlinkBehaviourModule() if blinkOn == false and a communicative behaviour (i.e. Robot State Function) has triggered a blink behaviour possibility.

IF New Blink Possible?
    IF Robot / User Communicative Behaviour occured that may trigger a blink instantiation?
        Call the Probabilistic Blink Instantiation Module (for processing possibility of Blink Instantiation)

Update Timers relevant for Blink Instantiation Creation and Control and animate blink if Blink Instantiation currently running
IF Blink Instantiation is not currently running (i.e. blinkOn == false)
Increment the timeSinceLastBlink. //This value is used for probabilistic processing within the
// Biological Blink Instantiation process
Decrement Blink Cool Down time after Blink animation for controlling reset of Blink Availability flag.
i.e. IF timeUntilBlinkReAvailability > 0
Decrement timeUntilBlinkReAvailability (Last 375ms countdown to Blink Availability)
IF timeUntilBlinkReAvailability == 0
SET blinkAvailability = true;

ELSE (Blink Instantiation currently running (i.e. blinkOn == true)
Animate blink animation step using current blink morphology data vars (blink number, type, and atk, sus, dcy durations)
and then update these blink morphology data variables as required for next animation step (i.e. if in blink attack phase,
decrement blink number X atk duration counter.

Decrement Count Down Timers: blinkInstantiationDuration and timeUntilBlinkReAvailability
On final blink animation frame, reset flags to show Blink Instantiation is completed.
I.e. IF blinkInstantiationDuration == 0
SET blinkOn = false and timeSinceLastBlink = 0;

Update (Increment) currentRunTime

// END MAIN Function
//////////////////////

```
//////////////////////////////////////////
// START BlinkInstantiationModule Function
// This function defines when blinks occur based upon receiving at least one Robot / User Communicative Behaviour trigger.
// i.e. BlinkInstantiationModule(int tSinceLastBlink, bool blinkkAvailable, bool pSpeechOn, bool pSpeechOff, bool iSpeechOn, bool lookingAt,
// bool lookingAway, bool faceExprOn, bool faceExprOff, bool mCStateChange)

// VARIABLES
int max = 0;
int RandomValue = 0;

Find highest rated behaviour to initialise max for use in probabilistic test of blink instantiation.
IF (pSpeechOn) AND max < 54 THEN SET max = 54
IF (pSpeechOff) AND max < 33 THEN SET max = 33
IF (iSpeechOn) AND max < 31 THEN SET max = 31
IF (lookingAt) AND max < 61 THEN SET max = 61
IF (lookingAway) AND max < 72 THEN SET max = 72
IF (faceExprOn) AND max < 32 THEN SET max = 32
IF (faceExprOff) AND max < 25 THEN SET max = 25
IF (mCStateChange) AND max < 50 THEN SET max = 50

Check for Interaction Blink Instantiation by generating a random percentile to check against weighted possibility of Blink instantiation
i.e. randomValue = randGenerator.Next(1, 100);

Define and implement behavioural blink instantiation morphology if probability of a behavioural blink is within probabilistic weight
i.e. IF (randomValue <= max)
        SET blinkOn = true and CALL BlinkMorphologyModule function                    // Creation of Behavioural Blink Instantiation

If a Behavioural Blink Instantiation is not created, check for a possible Physiological Blink Instantiation...
(Physiological Blink Instantiation occurs between 2.4 and 10.2sec from prior blink instantiation completion).
i.e. ELSE IF (blinkAvailable && tSinceLastBlink >= 144)          // No current blink instantiation and at least 2.4secs since last blink
```

```
        randomValue = randGenerator.Next(1, 100);       // Generate random percentile
        max = (tSinceLastBlink / 612) * 100;            // Sets max between 144 (2.4sec) and 612 (10.2sec),
                                                        // such that a rising chance of a biological blink
                                                        // increases and definitely occurs when max = 100
                                                        // (i.e. 10.2 secs passed since last blink instantiation)

        Define and implement physiological blink instantiation morphology if probability of a blink is within probabilistic weight
        if (randomValue <= max)
                SET blinkOn = true and CALL BlinkMorphologyModule function          // Creation of Behavioural Blink Instantiation

// END BlinkInstantiationModule Function
////////////////////////////////////////


////////////////////////////////////////////
// START BlinkMorphologyModule Function
// Defines the Blink Morphology (i.e. style, type, duration (attack, sustain, decay))
// I.e. BlinkMorphologyModule()

// VARIABLES
int randomValue = 0;

Generate Blink Style (Single (85%) or Multiple (15%) and Blink Count (from Blink Style result) for this Blink Instantiation)
randomValue = randGenerator.Next(1, 100);           // Generate random percentile
IF (randomValue > 85)                               // Multiple Blinks?

        Generate Number of Blinks (2 or 3) for Multiple Blink Style
        randomValue = randGenerator.Next(1, 100);   // Generate random percentile
        IF (randomValue > 80)                       // No. of Multiple Blinks?
                SET blinkCount = 3;                 // 3 Blinks in this Blink Instantiation
```

```
        ELSE
                SET blinkCount = 2;                     // 2 Blinks in this Blink Instantiation

        ELSE                                            // Single Blink
                SET blinkCount = 1;                     // 1 Blink in this Blink Instantiation


Define Morphology for each blink in this blink instantiation (based on value of blinkCount through switch construct)
switch (blinkCount)
{
        case 1:
                Define blink01 MORPHOLOGY

                Generate Blink Type
                randomValue = randGenerator.Next(1, 100);       // Generate random percentile
                IF (randomValue > 91) THEN blink01Type = 2;     // Half Blink Type
                ELSE blink01Type = 1;                           // Full Blink Type

                Define Duration Morphology for Full Blink Type
                IF (blink01Type == 1)
                        Set Blink Duration (i.e. SET blink01Duration = BlinkDurationGenerator(432, 72);)
                        Set Blink Attack Duration (i.e. SET blink01AtkDuration = BlinkDurationGenerator(111, 31);)
                        Set Blink Decay Duration (i.e. SET blink01DcyDuration = BlinkDurationGenerator(300, 123);)

                // Define Duration Morphology for Half Blink Type
                ELSE IF (blink01Type == 2)
                        Set Blink Duration (i.e. SET blink01Duration = BlinkDurationGenerator(266, 40);)
                        Set Blink Attack Duration (i.e. SET blink01AtkDuration = BlinkDurationGenerator(97, 28);)
                        Set Blink Decay Duration (i.e. SET blink01DcyDuration = BlinkDurationGenerator(148, 64);)
```

```
            Set Blink Sustain Duration
            IF ((blink01AtkDuration + blink01DcyDuration) < blink01Duration)
                  blink01SusDuration = blink01Duration - (blink01AtkDuration + blink01DcyDuration);
            ELSE blink01SusDuration = 0 and blink01Duration = blink01AtkDuration + blink01DcyDuration;

            Set Overall Blink Instantiation Duration        // (i.e. SET blinkInstantiationDuration = blink01Duration;)

            break;

      case 2:
            As in case 1 (above), but define type and duration morphology for blink01 and blink02

            Set Overall Blink Instantiation Duration        // (i.e. SET blinkInstantiationDuration = blink01Duration + blink02Duration;)

            break;

      case 3:
            As in case 1 (above), but define type and duration morphology for blink01, blink02 and blink03

            Set Overall Blink Instantiation Duration        // (i.e. SET blinkInstantiationDuration = blink01Duration +
                                                            // blink02Duration + blink03Duration;)

            break;
}

Set timeUntilBlinkReAvailability to Blink Instantiation Duration + 375ms (i.e. Blink Cool Down Time).
timeUntilBlinkReAvailability = blinkInstantiationDuration + 23;

Set Blink Availability
blinkAvailability = false;
```

```
// END BlinkMorphologyModule Function
//////////////////////////////////////////


//////////////////////////////////////////
// START BlinkDurationGenerator Function
// Generates and returns a duration value (60th sec) based on Mean and Standard Deviation (millisecond) parameters
// for the blink/duration types i.e. int BlinkDurationGenerator(int mean, int stDev)

// VARIABLES
double duration = 0.0;

Set duration based on mean and StDev parameters (i.e. SET duration = double(randGenerator.Next(mean - stDev, mean + stDev)) / 16.66666;)
RETURN int(duration);

// END BlinkDurationGenerator Function
//////////////////////////////////////////
```

4.6 Communicative Saccadic Eye Movement Model for Listening / Speaking Communicative States

A saccadic eye movement model which ran during speaking and listening states of the LightHead robots communicative performance was also implemented as an internal real-time communicative module, utilising saccadic eye movement data from a study by Raidt, Bailly and Elisei (2007). This model defined the saccadic gaze behaviour on the communicative focus points of the interlocutors face (i.e. left eye, right eye, nose and mouth) during the higher communicative states of speaking and listening. This models functionality was a requirement for acceptable levels of human-like believability of the LightHead communicative performance, as the collated data corpus from participants in the prior human-human communication study did not include minor saccadic eye movement, as the requirement was specifically for measurement of eye movements only when they were non-saccadic in nature and therefore linked to mental state change / cognitive communicative behaviour. It was observed that this lack of saccadic gaze behaviour gave the LightHead non-verbal facial communicative performance a semi-continuous and non-humanlike gaze-based stare behaviour. This non-humanlike behaviour was felt to be detrimental to a participants experience of the LightHead communicative performance and therefore would add unacceptable bias to participant responses.

For the requirements of this chapter, an explanation of the probabilistic design of the communicative saccadic eye movement model for speaker / listener states follows:

1. **Looking at face whilst listening**. Move between areas of looking at the mouth and looking at the eyes until end of participant speech, with a bias to mouth of 60%, eyes 30% (15% each) and nose 10%. Switch off this behaviour when an eye movement (PEM) occurs within the animation transcription and switch this

behaviour back on upon completion of the eye movement.

2. **Looking at face whilst speaking**. Move between areas of looking at the mouth and looking at eye regions until end of robot speech, with a bias to the eyes of 70% (35% each), mouth 25% and nose 5%. Switch off this behaviour when an eye movement (PEM) occurs within the animation transcription and switch this behaviour back on upon completion of the eye movement.

Based on observation of participants captured communicative behaviour from our one-to-one human communication experiment videos (Section 2), saccadic gaze duration functionality (time focussing on either of the interlocutors eyes, mouth or nose) was set as follows:

- Minimum Duration = 12 frames (500ms)
- Maximum Duration = 62frames (2sec 584ms).
- Mean Duration = 28frames (1sec 167ms)
- Standard Deviation = 22frames (917ms)
- Reset saccadic eye gaze duration each 5seconds on the fly during the time the Communicative Saccadic Eye Movement Model is switched on. (NOTE: This is not taken from human behaviour, but is a necessary variable for the means of coding randomisation into the saccadic gaze duration values produced by the system).

An explanation of the experimental methodology used in the design of the computational saccadic eye movement model will be discussed in Section 5.3.1.3.

4.7 Summary

A summary of Chapter 4 results highlights:

- A generative human facial communication system design has been created for accurate formulation and expression of imitative human communicative behaviour in real-time HRI.

- A computational imitative human blink model has been designed as part of the higher-level human communication system. This model creates accurate human-like communicative blink behaviour with respect to both communicative and physiological blink instigation timing and overall blink morphology. Pseudo-code for implementing the model can be found in Section 4.5.

- A computational imitative human saccadic eye movement model for speaker / listener communicative states has been designed to alleviate experimental bias as this missing eye behaviour creates a stare-like gaze behaviour that does not exist in natural human-human communicative eye gaze behaviour.

"The single biggest problem with communication is the illusion that it has taken place."

George Bernard Shaw.

PART III

HUMAN PERCEPTION OF A COMPUTATIONAL BLINK MODEL

5. Perception Testing of the Computational Blink Model

This chapter presents a detailed description of the design and methodology of two user-based perception experiments, designed to test the efficacy and acceptability of the computational blink model with naïve participants. Participants are requested to view a video of a simulated human communicative performance by the LightHead social robotic system, derived using both real-time computational models of human communicative blink and saccadic eye movement behaviour and actual human communicative behaviour data collated from the data corpus of our one-to-one human communication experiment (Section 2). A detailed description is also given of the processes involved in implementing the computational blink model and saccadic eye movement model within the LightHead robotic/ECA system, ready for the simulated human communicative performance.

5.1 Overview

The experimental protocol was designed to implement the computational blink model (Sections 4.2 to 4.4) and saccadic eye movement model (Section 4.6) within a humanoid social robotic/ECA system capable of reproducing near-life-like human non-verbal facial behaviour (at a resolution of at least 24Hz) and thus able to closely simulate a human communication performance from the communicative behaviour data corpus collated from our one-to-one human communication experiment (Section 2). Within this performance, the computational blink model would be able to be switched on or off and where necessary swapped for differing blink behaviour types, thus enabling testing of the models overall efficacy and level of acceptability through interaction with human subjects.

5.2 The LightHead Social Robotic System

The robot chosen to implement the derived computational blink model was the

LightHead robotic system (Figure 5-1) created by Delaunay and Belpaeme (2012). This system was chosen due to its perfect fit for our requirements of high-resolution imitation of human communicative behaviour. From concept to design, the LightHead robotic system was created to fulfil human-robot socio-communication requirements, and more specifically, as Delaunay and Belpaeme (2012) state "*…to use non-verbal HRI to elicit natural social-emotional communication.*" A number of social robotic/ECA systems could have been used to implement and test our computational blink model, such as Mask-bot (Kuratate *et al.*, 2011; Kuratate, Pierce & Cheng, 2011) and GRETA (Niewiadomski et al., 2009; Pasquariello & Pelachaud, 2002; Poggi et al., 2005), however, the LightHead system was being developed concurrently with this study within the Centre for Robotics and Neural Systems (CRNS) at Plymouth University, therefore this was an in-house collaboration that allowed for easy access to the system and its designers and further, for the system to be co-developed to cater for the human facial non-verbal communication models created from this study. LightHead was therefore considered an ideal platform for the implementation of the computational blink model, saccadic eye movement model and the detailed imitative human communicative performance required for a user-based study of the models overall level of human acceptability and its perceptual effect within real-time face-to-face human-robot communication.

Figure 5-1 LightHead Robotic/ECA system (Delaunay & Belpaeme, 2012)

The system utilises a 3D translucent mask upon which a rear-projected animated face (developed in Blender 3D design and rendering software) is displayed at a refresh rate of 60Hz using a 65 lumen 3M MP220 mini projector produced by the 3M Corporation. The head is attached to a Neuronics Katana robot arm for representation of head movement and the robots speech is performed via the Acapela text-to-speech system. The functionality of the system is controlled through bespoke open-source software designed in the Python programming language.

The LightHead systems facial animation module runs at 60Hz and uses the FACS coding system (Ekman *et al.*, 1978), allowing realistic human communicative facial behaviour to be accurately simulated and expressed at a musculature level.

5.3 Computational Blink Model Implementation within LightHead

The computational blink model, including the blink morphology module (Sections 4.2

to 4.4) were implemented within the LightHead social robotic systems open source control software as one of its internal communication code modules, allowing blink behaviour to be triggered in real-time based upon received communicative behaviours from its own performance (e.g. start of own speech, a mental communicative state change or completion of a facial expression), the physiological blink process and from received interlocutors speech onset triggers.

5.3.1 Creating a Human-Like LightHead Communicative Performance

The LightHead communicative performance was generated for this experiment from detailed human communicative behaviour data, derived from a human communicative performance from one of the participant interviews from the prior human-human communicative interaction experiment (Ford, Bugmann & Culverhouse, 2010; Ford, Bugmann & Culverhouse, 2013). This concept was chosen as we wished all the non-verbal facial communicative behaviour elicited from the LightHead system to be as humanlike as possible such that as much abnormal communicative bias (which could affect participants response and overall perception of the LightHead imitative communicative performance) was removed.

5.3.1.1 Translating Human Communicative Performance Data

For the purposes of translation between participant's non-verbal communicative behaviour and the LightHead communicative performance, a translation code module was developed which converted the collated human communicative performance data into the required LightHead real-time performance instruction lines. This was a two-stage process, with the original captured human communicative performance data (FaceML) initially being transcribed by hand into a pseudo-translated state ready for translation completion by the translation code module (Appendix III-a).

5.3.1.2 Translating Human Communicative Facial Expressions

The captured human communicative performance data (FaceML) was also used to create performance definitions for the expressed facial expressions where required. The actual expression definitions detail the movement of the relevant FACS Action Units (AU) which define control of differing muscle groups in the facial behaviour of the LightHead robotic/ECA system, as defined within the Facial Action Coding System (FACS) created by Ekman *et al.* (1978) (Section 2.5.1.1).

The facial expression pseudo translation and facial expression FACS definitions designed for the LightHead communicative performance can be seen in Appendix IV-c. An example explanation of a facial expression FACS definition for the raised brow expression follows:

```
"rb_bmt": (
  ( (01 ,0.1, 0.13), (02 ,0.2, 0.13), ),
  ( (01 ,0.2, 0.13), (02 ,0.3, 0.13), ),
  ( (01 ,0.4, 0.46), (02 ,0.4, 0.46), ),
  ( (01 ,0.0, 0.17), (02 ,0.0, 0.17), ),
  ),
```

The FACS definition title of “rb_bmt” encapsulates the expression animation stages, of which we have four for this particular expression animation. Each of these animation stages encapsulates two FACS Action Units, each representing specific muscle groups in the human face, in this instance, AU01 and AU02 (Inner Brow Raiser (frontalis (pars medialis)) and Outer Brow Raiser (frontalis (pars lateralis)) respectively). Each AU entry of an animation stage also incorporates an intensity of movement (normalised between 0 (at rest (or neutral)) and 1 (full extension)) and the duration (in milliseconds)

to move between the prior intensity (initially set to a value from the neutral pose) to the new intensity value. These are translated in real-time by the LightHead robotic/ECA system during the imitative communicative performance.

5.3.1.3 Implementation of Human-Like Saccadic Eye Movement

Some extra experimental work was required for completion of this transcription code module as the eye movements had been transcribed in FaceML as "relative" (2D) values (made up of the pupils angle of movement (stated as 0^{o} to 359^{o}) and its distance of travel from the centre of the eye to the furthest point possible in the defined angle of movement (normalised as 0 (eye centre) to 1 (furthest point possible))) recorded from the prior experiments corpus videos, whereas the LightHead robotic/ECA system requires Cartesian (3D) co-ordinates to perform the correct head and eye movements in 3D-space during any real-time communicative interaction.

To overcome this issue, we defined a generic distance of 1meter depth from a participant to their computer monitor (as a focal point measure for the expected common experimental setup) and using this setup, then proceeded to record two participants (1 male and 1 female) eye distance data from a central point out to the zenith of their view at each 45degree point (Figure 5-2).

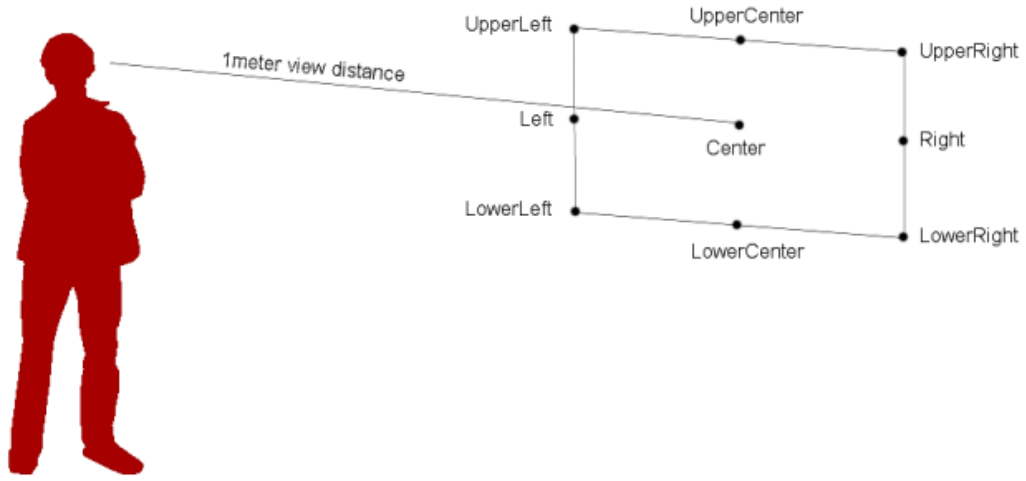


Figure 5-2 Absolute (2D) to Cartesian (3D) Space - Experimental Process

Taking an average of these recorded gaze points from both participants (Table 5-1), code was created within the transcription code module that performed real-time conversion of the relative 2D co-ordinates held in our data corpus to their Cartesian 3D variants. This conversion process allowed the LightHead robotic/ECA system to accurately display humanlike communicative eye movements based on the transcribed communicative instructions received from the human communicative performance data.

Table 5-1 Relative 2D to Cartesian (3D) Pupil/Head Movement Conversion Data

	Height (m)	**Width (m)**	**Depth (m)**
Center	-	-	1.00
UpperCenter	1.01	-	1.47
LowerCenter	1..57	-	1.84
Left	-	1.42	1.72
Right	-	1.13	1.54
UpperLeft	0.66	1.17	2.11
UpperRight	0.54	1.02	1.57
LowerLeft	1.55	1.17	2.24
LowerRight	1.55	1.02	1.70

The saccadic eye movement model (Section 4.6) which details the subtle saccadic eye movements between the eyes, mouth and nose of the interlocutor during the "speaking" and "listening" states of the LightHead robotic/ECA systems communicative performance was also implemented within LightHead as an internal real-time communicative code module.

5.3.1.4 Performance Variations for Four Blink Behaviour States

Overall, the completed translation process and additional real-time communicative code modules allowed for a very humanlike communicative performance[3] (Ford & DeLaunay, 2012), used as a canvas for each of the four differing blink behaviour states of human blink, computational blink model, isochronal blink and no blink. The human blink behaviour was translated from the above mentioned human communicative performance data, whereas the isochronal blink behaviour was implemented dynamically on a specified 5 second cycle. These blink performances along with the no blink performance had the blink model switched off within the LightHead system. The blink model variant describes the overall performance with the real-time computational blink model switched on and taking its probabilistic blink trigger cues from the translated human communicative performance data and streamed interlocutor data, as well as the physiological blink process. The model output, as expected, differed slightly each time the LightHead robotic/ECA system performed the translated human communicative performance data due to the computational blink model and saccadic eye movement model probabilistic trigger design and the blink morphology module functionality.

Video was then captured of the LightHead robotic/ECA systems communicative

[3] Video of LightHead communicative performance - http://youtu.be/Tp6Fx_t45f4

performance for each of the four differing blink behaviour types (i.e. human blink, computational blink model, isochronal blink and no blink.) The relevant communication dialogue of the initial experimenter from the prior human-human communicative interaction experiment was then embedded into each video at the correct time-stamps utilising the Vegas Pro video creation software (Sony_Corporation, 2012). These videos were then uploaded online for viewing by participants within each of the user-based perception testing experiments.

5.4 Summary

A summary of Chapter 5 results highlights:

- The computational Blink Model (incl. Blink Morphology Module) and Saccadic Eye Movement Model were implemented within the LightHead social robotic system for human communicative behaviour performance requirements.

- The remainder of the human communicative behaviour required (beyond the computational models) for completion of the human communicative behaviour performance by the LightHead social robotic system was created through the translation of transcribed FaceML human communicative performance data of a single participant from the one-to-one human communicative behaviour experiment.

- Data collection was performed on the extremities of gaze from two participants (1 male and 1 female) to allow transcription of FaceML absolute 2D gaze data to allow for translation to 3D Cartesian space for correct LightHead gaze behaviour performance.

- Overall, the finalised LightHead simulated human communicative performance was considered very humanlike compared to other cutting edge social robotic

systems (Dautenhahn et al., 2009; Kuratate *et al.*, 2011; Nishio, Ishiguro & Hagita, 2007).

6. User-Based Blink Behaviour Perception Experiments

This chapter presents a description of human response behaviour from two psychological perception studies which test the efficacy of the computational blink model: A Turing-Like test between real human blink behaviour verses the computational blink model behaviour, where participants try to choose the real human blink behaviour from videos of the two performances running concurrently side-by-side; A semantic differential-based connotation study on participants perceptions between four robotic communicative performances (based on the transcription data from an actual human communicative performance), each with differing blink behaviours: computational blink model, human blink, isochronal blink (5sec interval) and no blink.

Video assets where utilised for our experiments allowing participants global access to the LightHead communicative performance (removing the requirement for participants to be physically in the presence of LightHead) and ensuring that each participant is delivered exactly the same communicative performance, an extremely important factor in experiments in which subtle variance in behaviour are to be measured (i.e. changes only in a robots blink behaviour) and where high numbers of results are required to gain statistical significance. Differences between participant responses from live versus video assets in HRI studies have been found to have acceptable response correlation, thus backing up the use of video assets in HRI behavioural studies (Bethel & Murphy, 2010; Woods et al., 2006).

Our results from these perception experiments show that the computational blink model is an acceptable substitute for human blink behaviour (Section 6.1) and that subtle differences in perception of four blink behaviour types show that human blink behaviour is marginally preferred over our computational blink model behaviour, followed closely by no blink and isochronal blink behaviours respectively. These subtle

differences are perceived within connotations of friendly_unfriendly, serious_fun, lively_deadpan, impersonal_personal and decisive_indecisive (Section 0). Overall, these results suggest, albeit on a sub-conscious level, that blink behaviour is taken into account during human-human communication and thus has a role to play as part of the human communication process.

6.1 User-Based Blink Behaviour Perception Test #1

6.1.1 Method

An initial blink model differentiation experiment was defined to suggest whether the blink model was acceptable to human users and thus whether the blink behaviour perception experiment was worthwhile to pursue.

The pilot study took the form of a visual presentation of the computational blink model and human blink behaviour communicative performances running concurrently side by side in video form (Figure 6-1) allowing participants to choose which they believed to be the human blink behaviour performance.

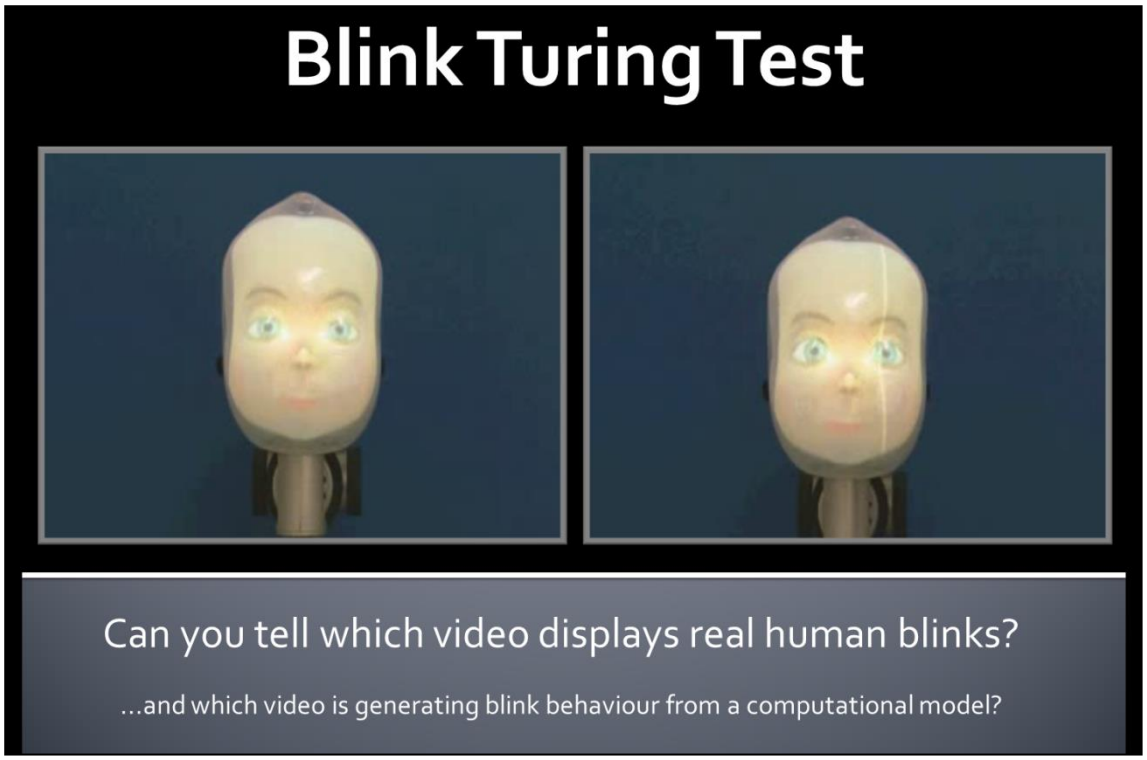


Figure 6-1 User-Based Blink Behaviour Perception Test #1 - Presentation

Both written and verbal instructions were given to each participant prior to viewing the presentation, explaining the concept of the computational blink model as well as the data to be captured. Each participant then decided whether they still wished to take part in the study. Age and gender based information were taken from those that agreed to take part, followed by a binary based question: "*Which of these two videos (either left or right) displays real human communicative blink behaviour and not that derived from an imitative computational blink model?*", collated in a questionnaire (Appendix V-a). At the end of the presentation, the participants given answer, as to which video displayed the real human blink behaviour, was recorded. No answer was given to any of the participants with regards to the correctness of their response. The correct answer was given at a specified time (which concluded data capture for this experiment), thus alleviating the bias issue of completed participants passing on the correct answer to future participants.

6.1.2 Results

38 participants' data was captured, with a gender split of 20 Male and 18 Female.

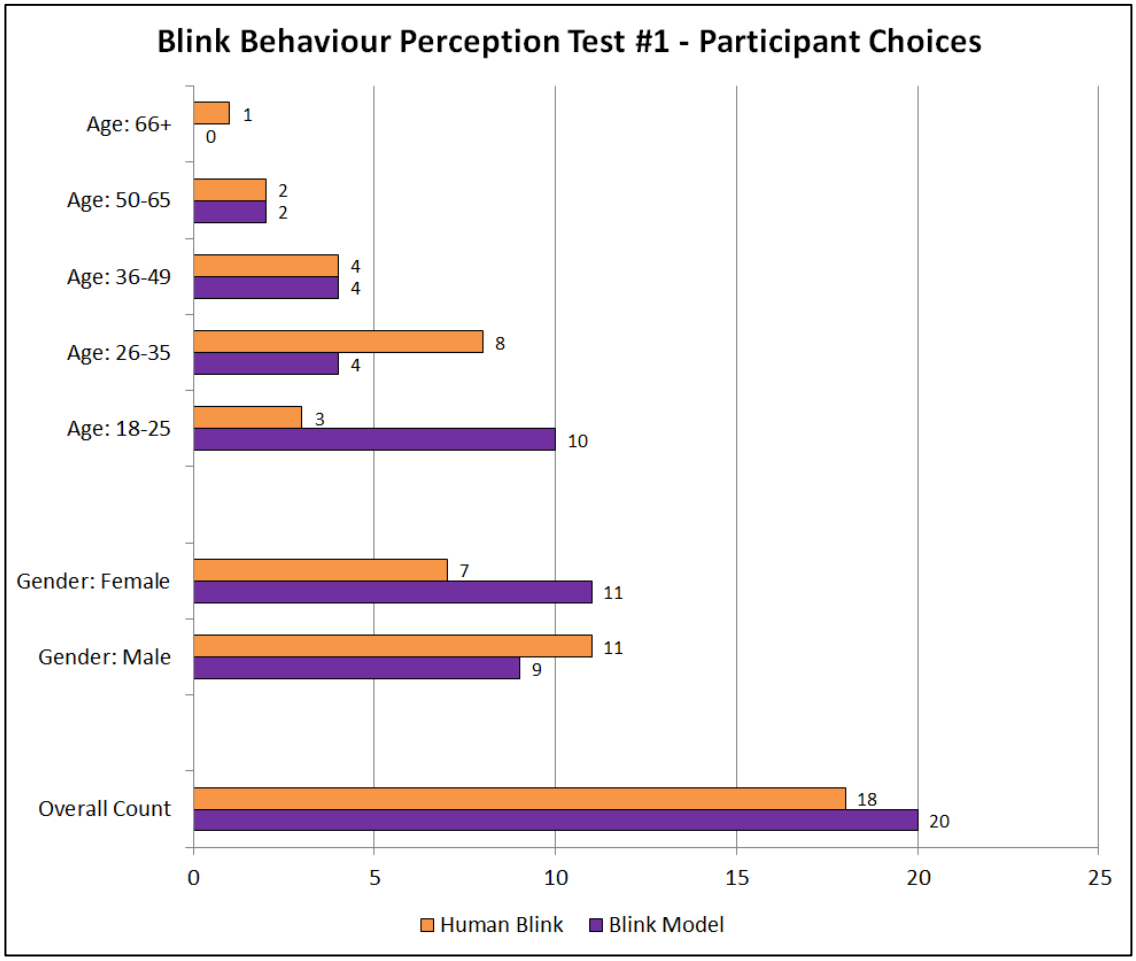


Figure 6-2 User-Based Blink Behaviour Perception Test #1 – Participant Choices

Chi-Square tests show participants human blink performance preference for three data sets: overall $\chi^2(37, N=38)=19$, $p=.424$, age range $\chi^2(4, N=38)=9.038$, $p=.216$ and gender $\chi^2(1, N=38)=0.934$, $p=.321$, displaying no significant difference in participant's perceptual response between the computational blink model and human blink behaviour performances. These results suggest that the simulated blink behaviour expressed by the computational blink model would be acceptable as a substitute for natural human blink behaviour.

6.2 User-Based (Online) Blink Behaviour Perception Test #2

6.2.1 Method

The success of the pilot study (Test #1) led to the implementation of the more detailed online blink behaviour perception test which, as previously stated, was defined to ascertain the computational blink models overall level of human acceptability and its perceptual effect within real-time face-to-face human-robot/ECA communication, compared to the performances of other blink behaviours of human blink, isochronal blink and no blink. The hypothesis was slightly re-defined to test whether the computational blink model behaviour was acceptable to human viewers as a substitute for actual human blink behaviour and an improvement over the additional isochronal blink and no blink behaviours.

A questionnaire (Appendix V-b) and associated code book (Appendix V-c) were developed (with inter-disciplinary help from the Department of Psychology), utilising semantic differential questions (using a likert scale of one (maximum negative perception) to seven (maximum positive perception)). An example semantic differential question is shown in Figure 6-5.

Figure 6-3 Semantic Differential Question – Example

Responses to these semantic differential questions were then analysed utilising non-parametric statistical tests to judge in subtle detail the differences in participant perception of each of the four blink behaviour states.

The questionnaire (with embedded video) was coded electronically using CrowdFlower

Mark-up Language (CML) (Appendix V-d) for distribution to participants as a data collection job through the CrowdFlower online crowd-sourcing data collection website[4].

Upon choosing the job, instructions for the experiment were given to participants, who were able to opt out at this time if they desired. Once a participant accepted to take part in the experiment, the online data collection process began. Gender and age details were initially retrieved before one of the four LightHead communicative performance videos (each with a differing blink behaviour state) was chosen at random and displayed to the participant. The participant would then watch the video in question to its completion and then fill out the main questionnaire in full. All questions were mandatory.

The collated data was then analysed with respect to how acceptable the computational blink model performance was with regard to human perception and also measured against results from each of the other three blink behaviour types. The results of this perception test can be viewed in Section 6.2.3.

6.2.2 Data Robustness Analysis

The experiment ran until 14 participants data had been collected for each of the four blink behaviour videos (wherein, once a specific blink behaviour video had been chosen for 14 participants, e.g. isochronal blink performance video, it was then removed from the random choice process), leading to an expected total of 56 participant responses collected. However, only 12 responses were collected for the isochronal blink behaviour video and 13 for the human and model blink behaviours.

The final collated data was cleaned utilising the following data robustness rule set:

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[4] 'CrowdFlower' Crowdsourcing Website – http://www.crowdflower.com

1. Any participants that took less than 3mins to perform the task were deemed as not having fully viewed the performance video.

2. A single likert question “Dishonest/Honest” was incorporated twice (as a robustness check), with its positive and negative direction reversed for each variant (i.e. Dishonest/Honest and Honest/Dishonest). These two questions were checked for response parity, with a +/-1 deviation allowed.

3. Two average response values were created for both the amalgamated positive/negative and negative/positive groups of likert responses from all semantic differential questions per participant. These two values were then checked for parity in participant response, with a +/-1 value of deviation allowed in either direction, as per point 2 (above). An example of the functionality of this acceptance test can be seen in Table 6-1. An example of the functionality of the acceptance test for tests 2 and 3 can be seen in Table 6-1.

Table 6-1 Semantic Differential Acceptance Test - Examples

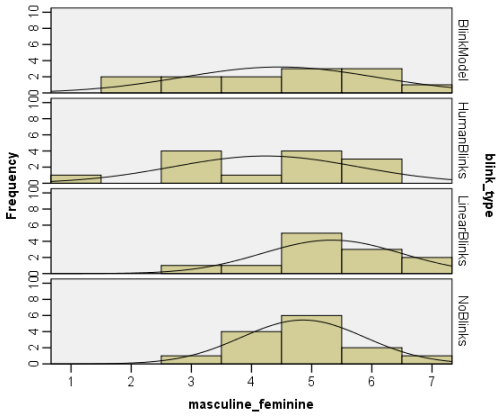
Honest/Dishonest	Dishonest/Honest	Accepted?
3	5	No Deviation Accepted
7	1	No Deviation Accepted
3	6	+1 Deviation Accepted
2	5	-1 Deviation Accepted
3	7	+2 Deviation Not Accepted

No participants failed the data robustness rule set, therefore 52 participant questionnaire responses were used to formulate the perceptual response data set.

6.2.3 Results

6.2.3.1 Question Specific Results

Participant perceptual responses to each semantic differential question for each of the four blink behaviour types can be seen within Figure 6-4 (1a to 34b). These display, for each semantic differential question, a histogram (a) (containing participant response count and normal distribution curve) and a box and whisker plot (b) (containing minimum, maximum, q1, q3 and median).



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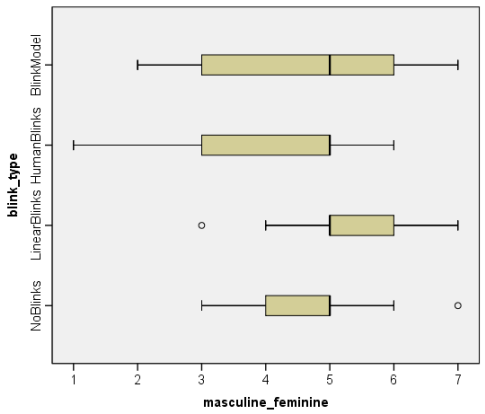

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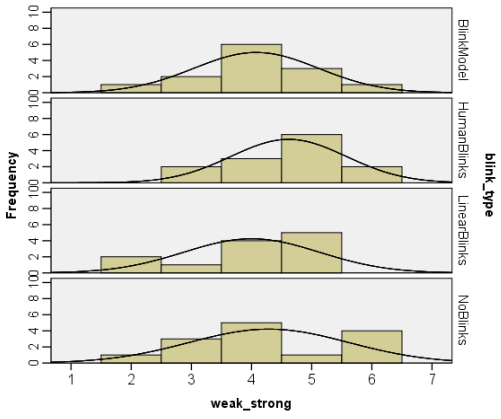

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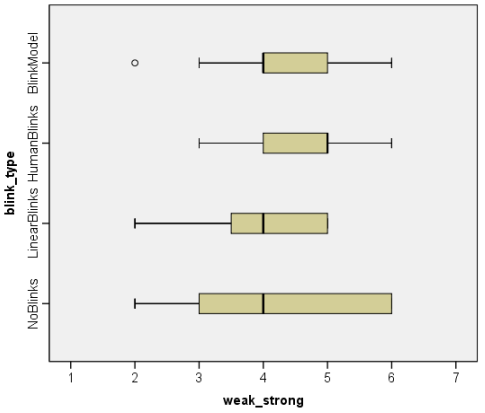

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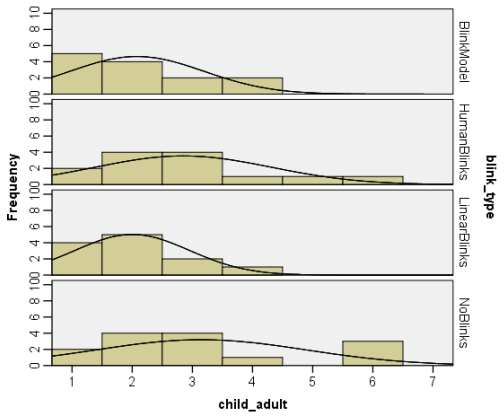

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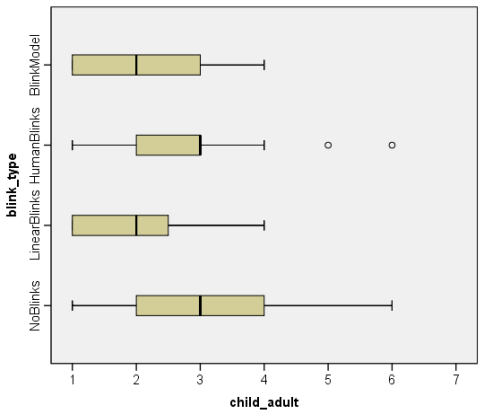

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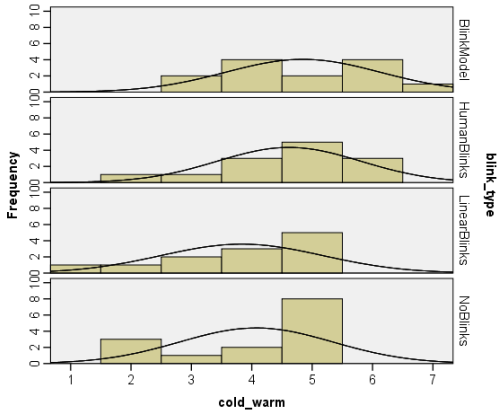

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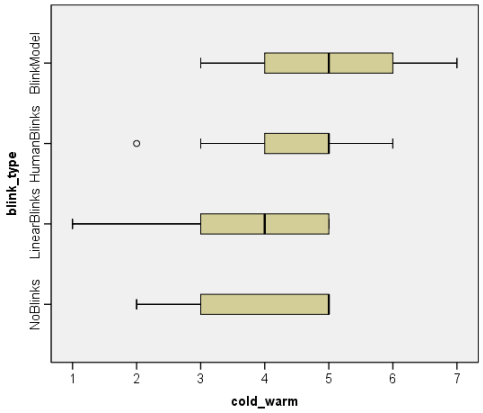

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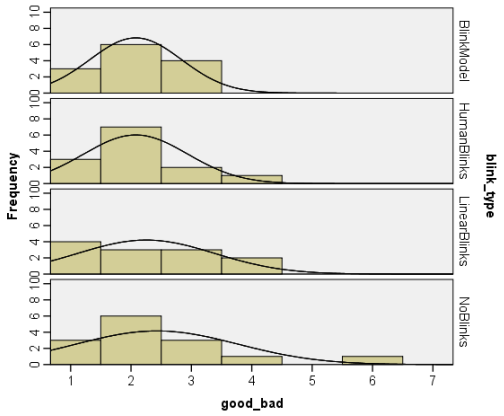

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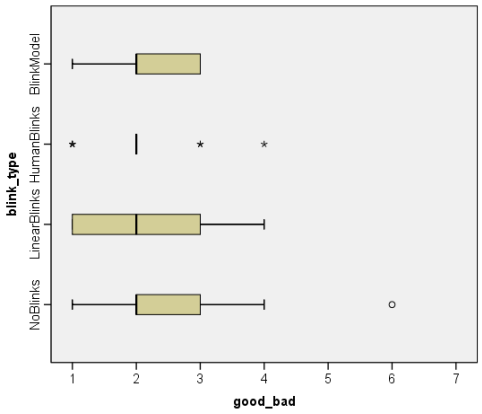

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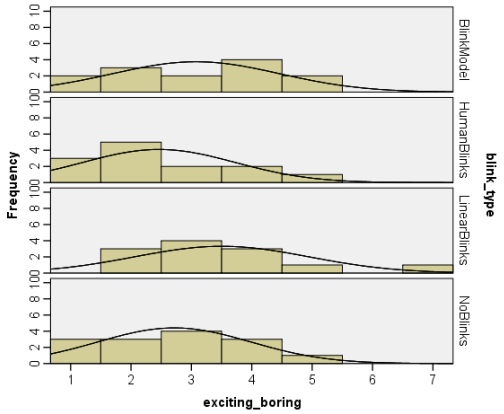

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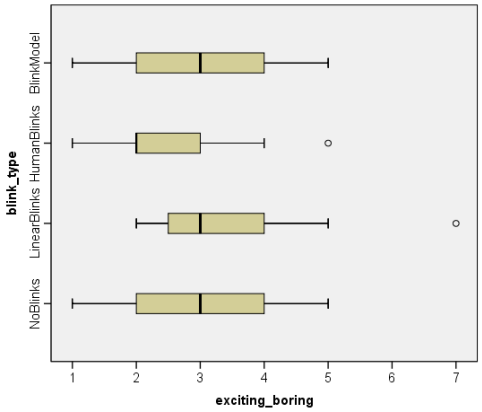

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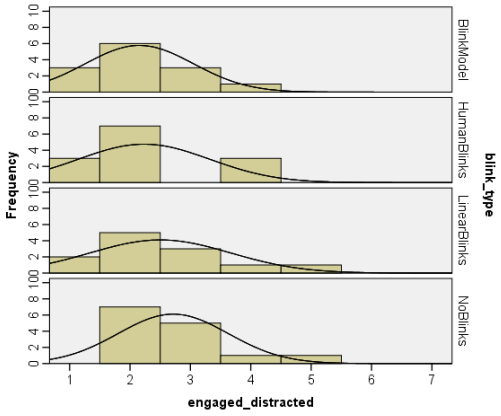

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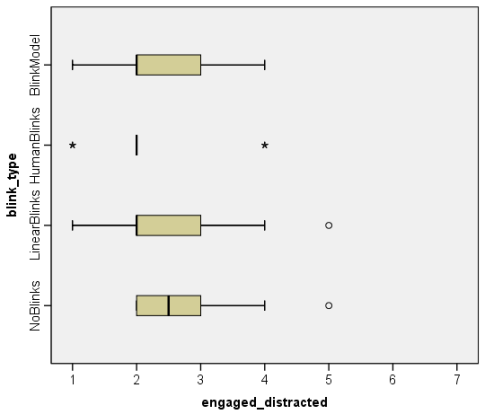

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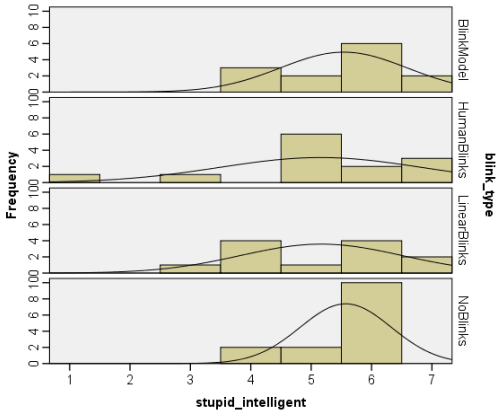

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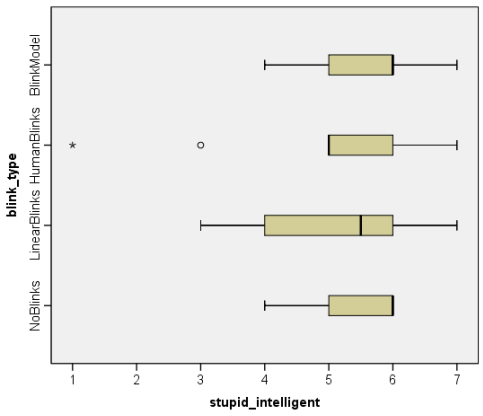

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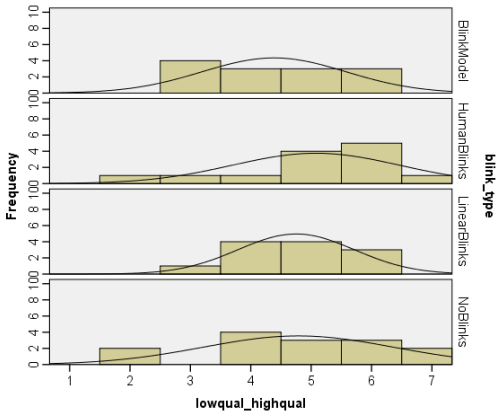

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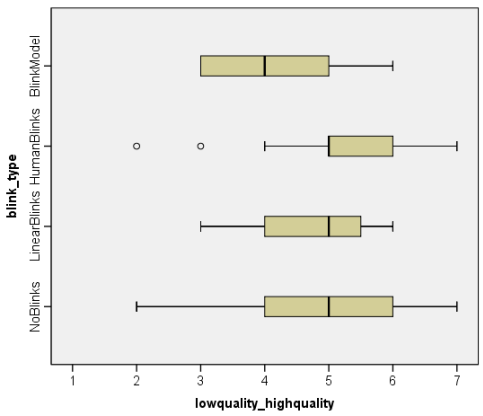

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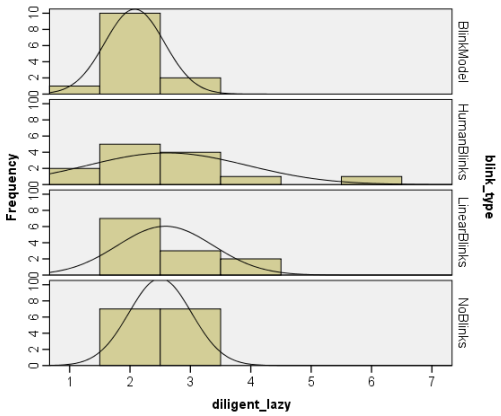

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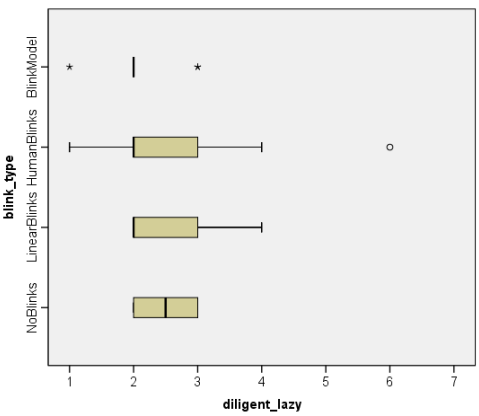

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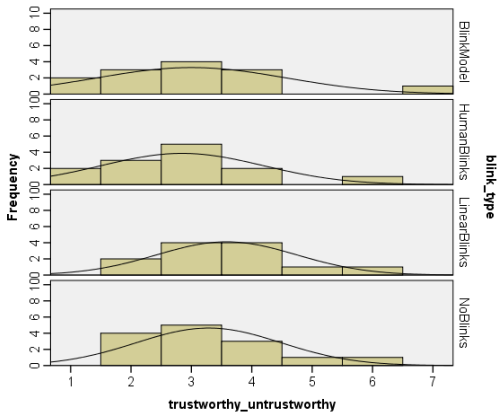

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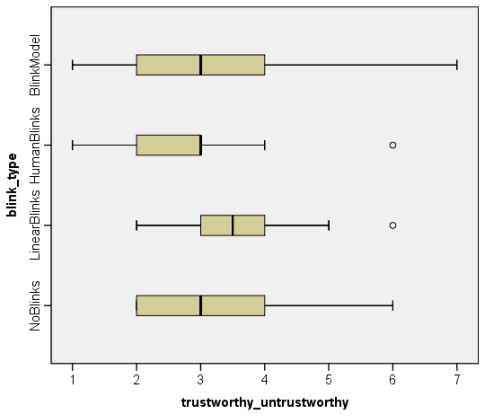

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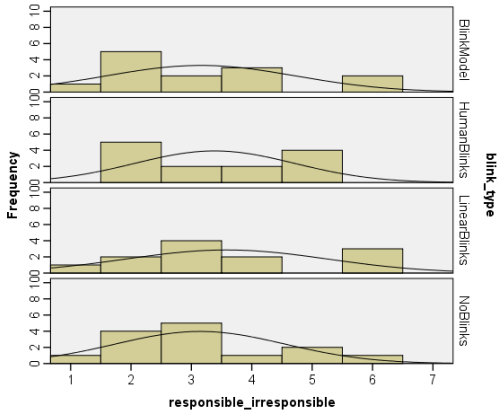

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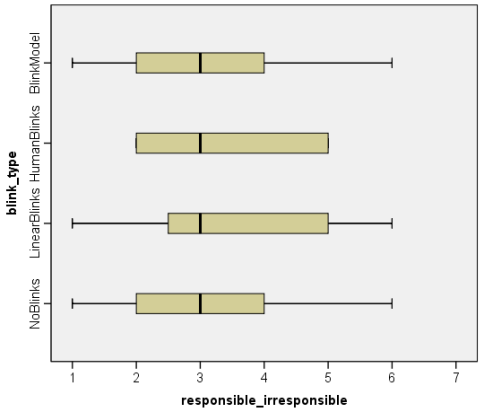

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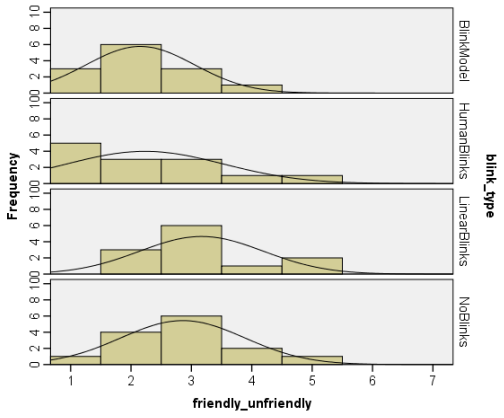

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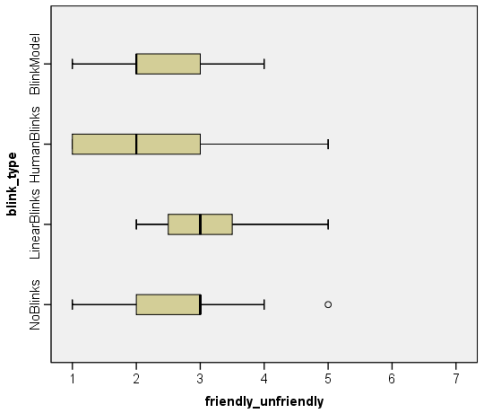

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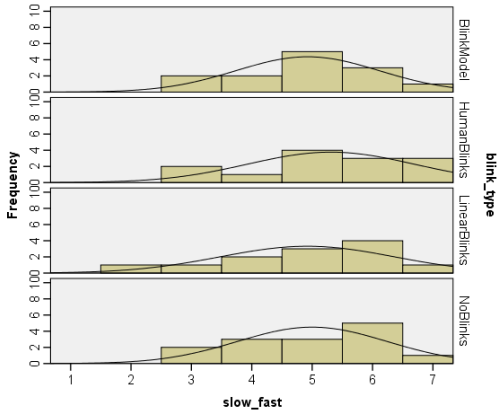

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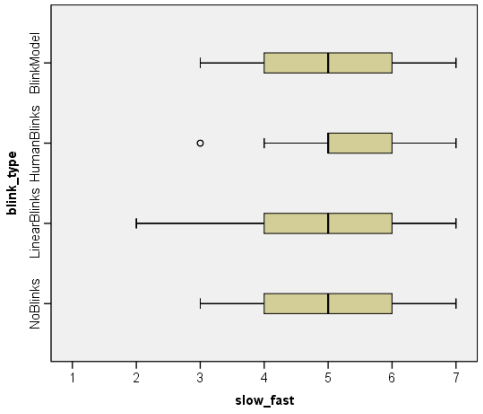

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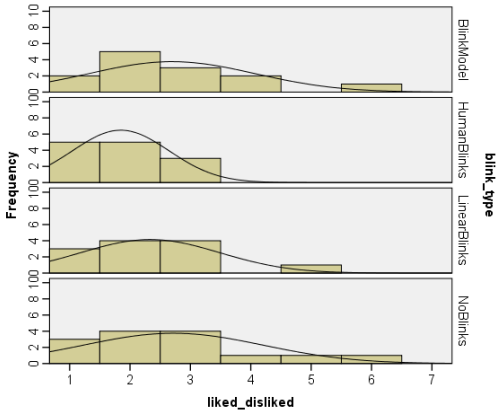

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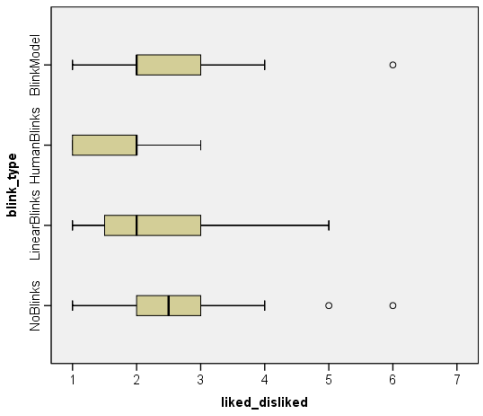

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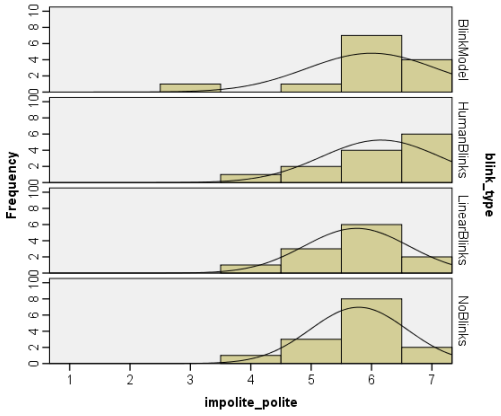

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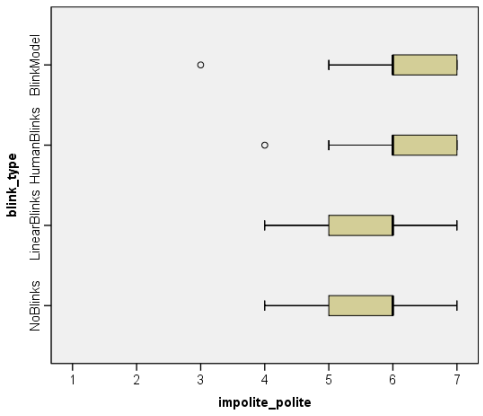

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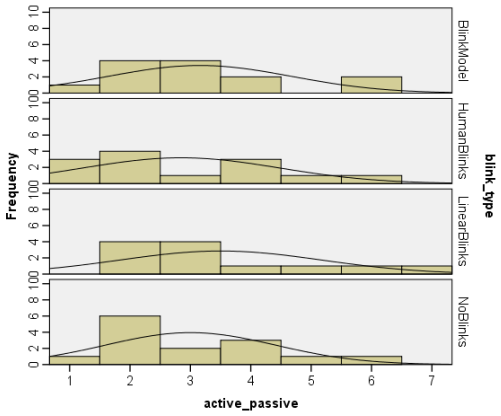

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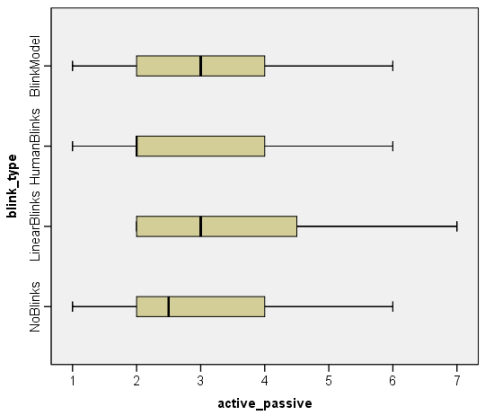

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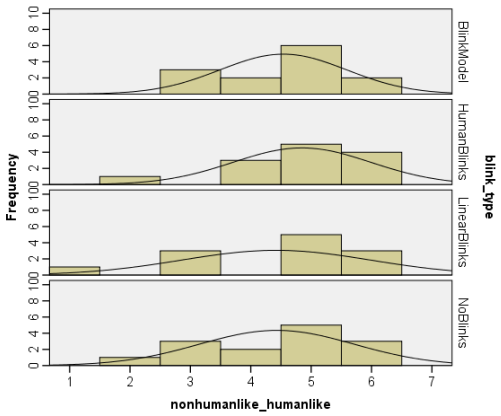

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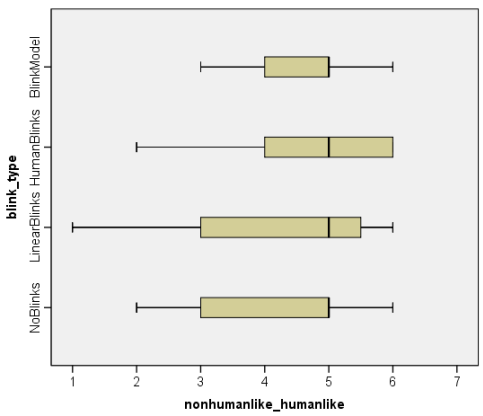

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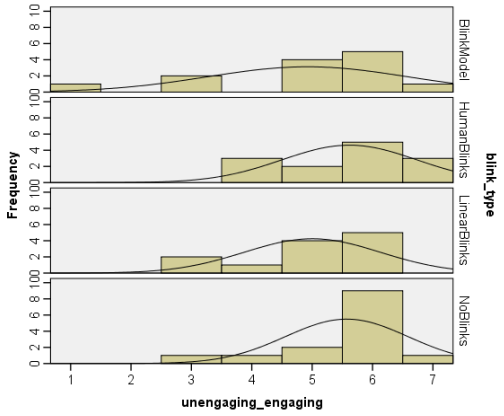

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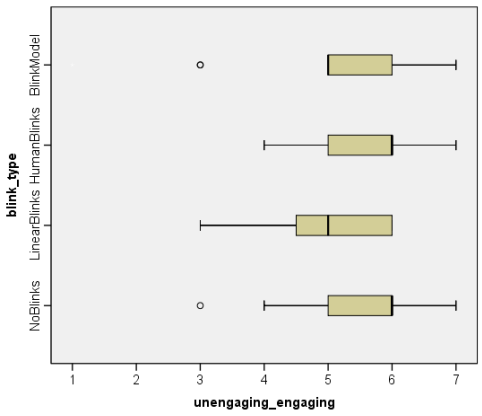

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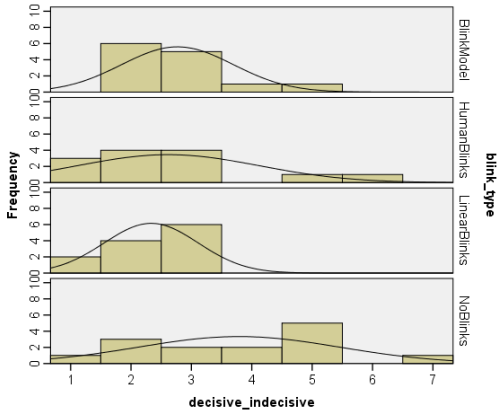

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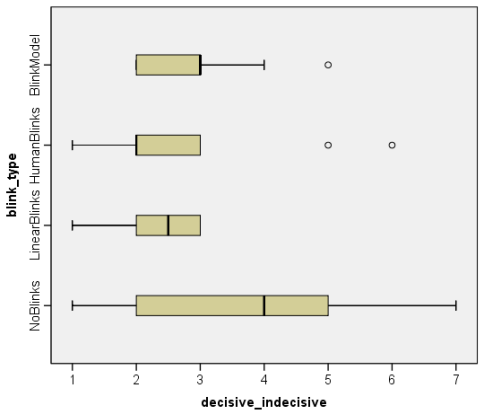

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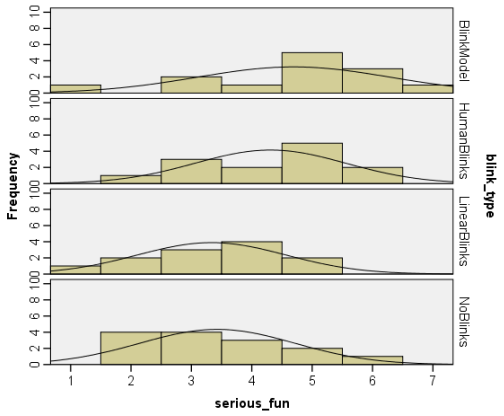

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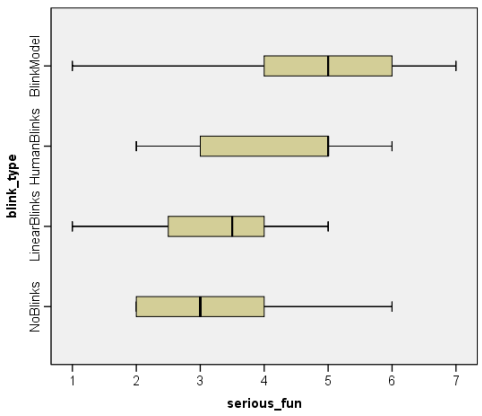

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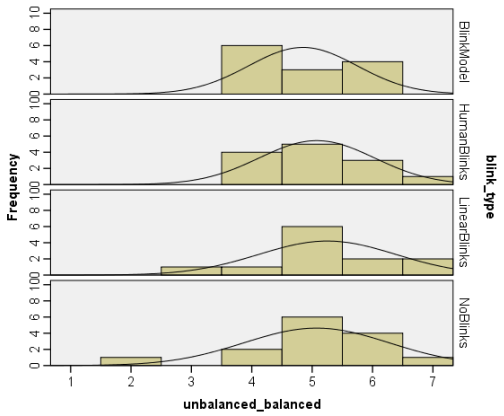

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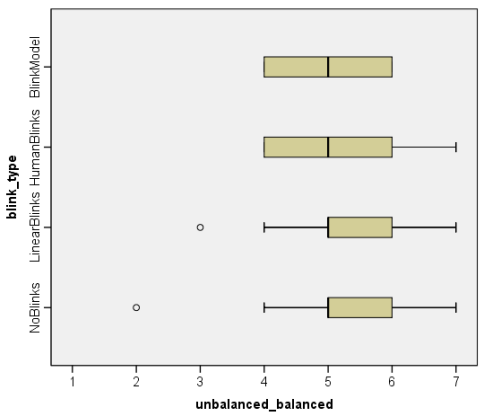

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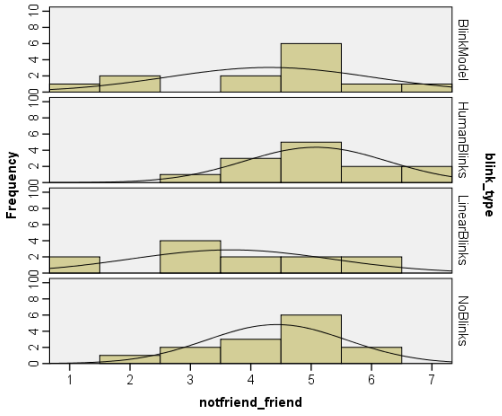

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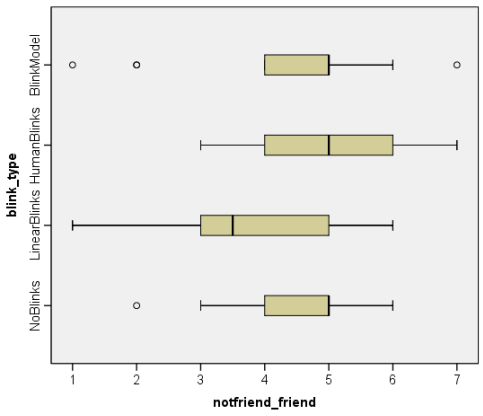

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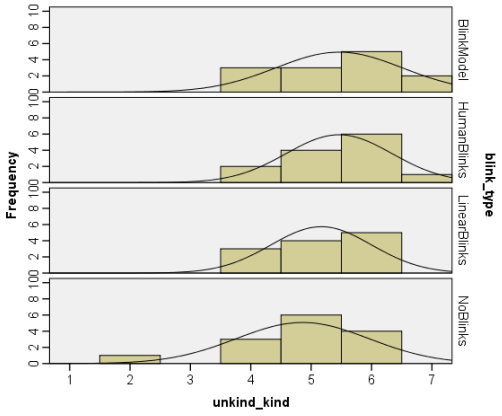

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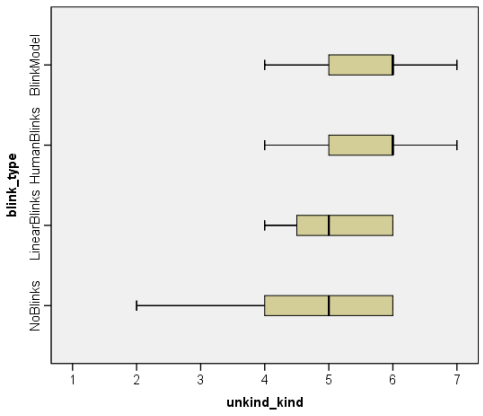

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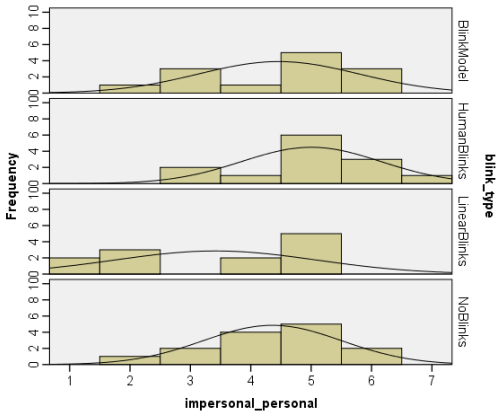

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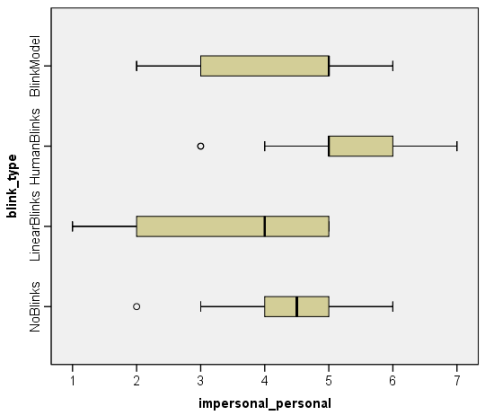

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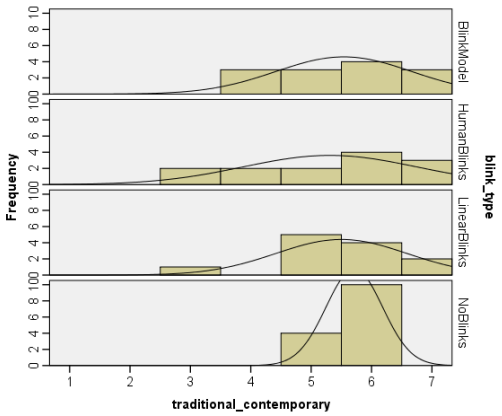

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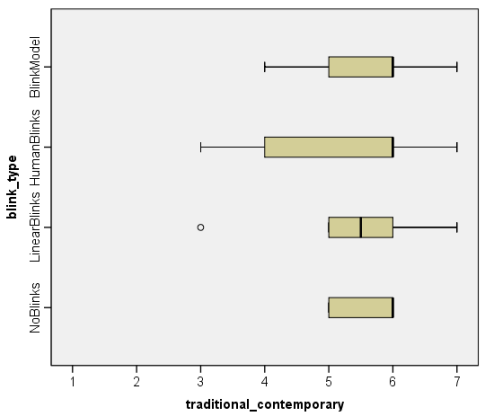

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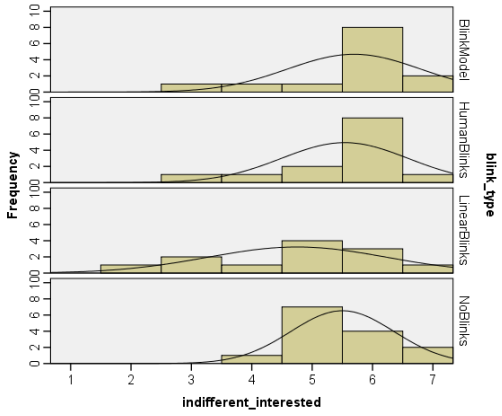

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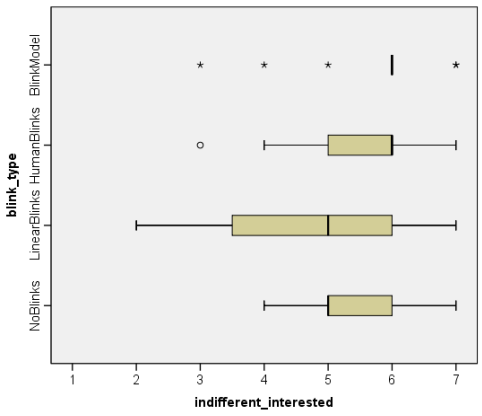

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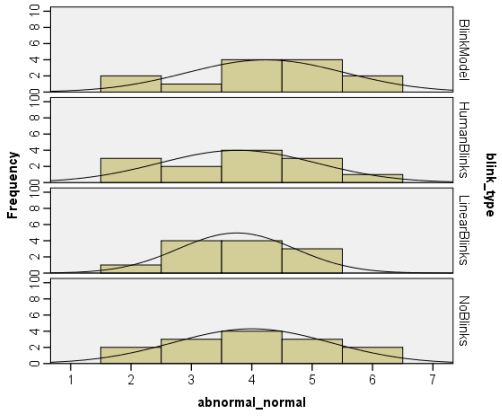

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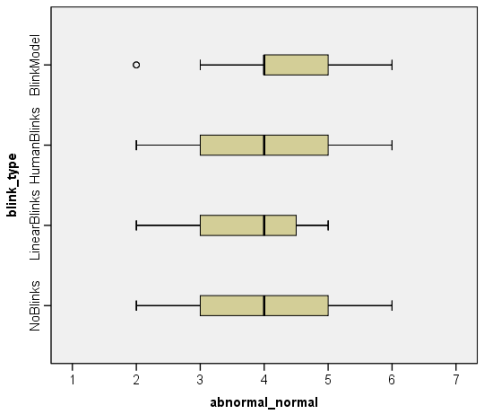

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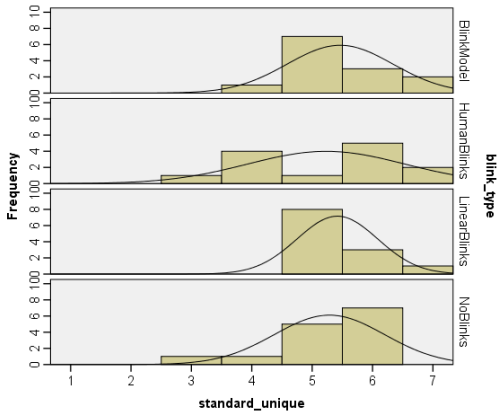

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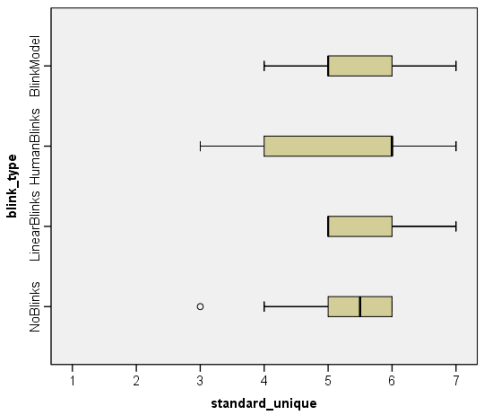

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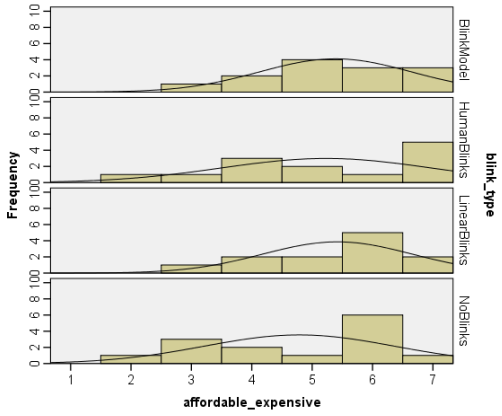

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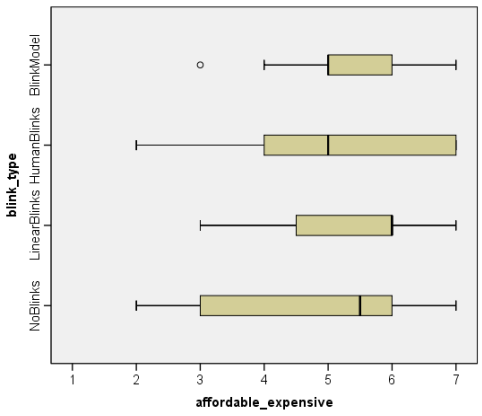

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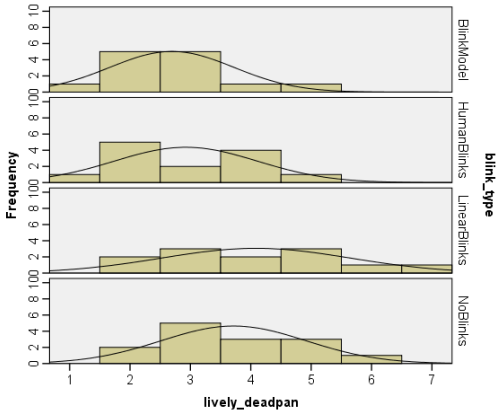

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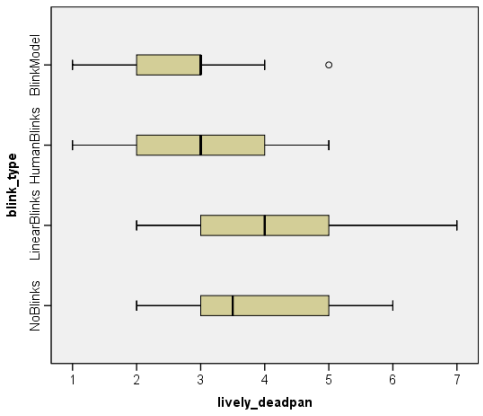

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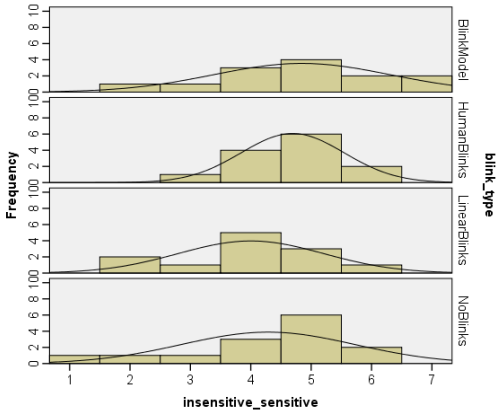

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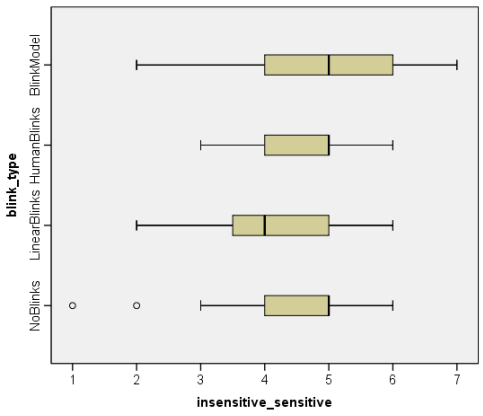

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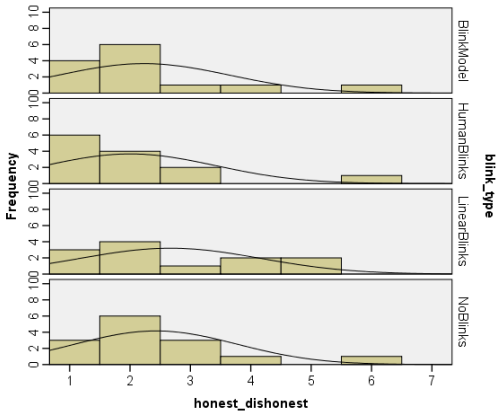

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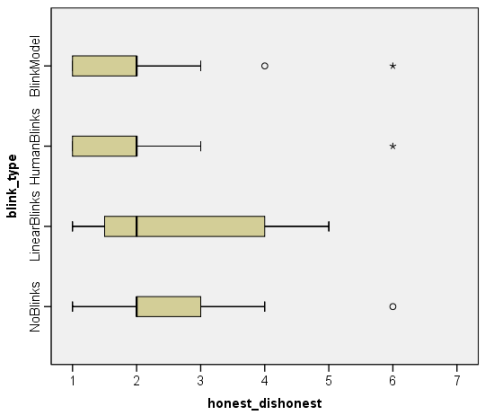

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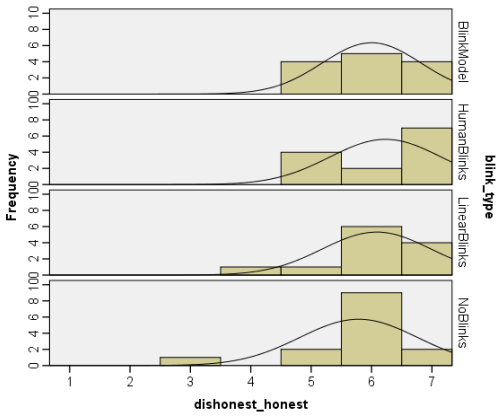

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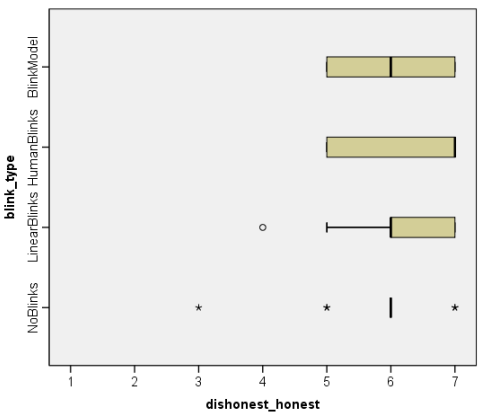

34b

Figure 6-4 Participant Perceptual Response Results per Semantic Differential

Two specific questions relate to the participants perception of the gender (Q01 - Figure 6-4 01a/b) and age (Q03 - Figure 6-4 03a/b) expressed by the LightHead communicative performance. The blink model performance variant was commonly perceived as feminine (Mdn=5, M=4.46, SD=1.61) and childlike (Mdn=2, M=2.07, SD=1.11). This was a trend for all blink behaviour variants, leading to the belief that the physical design of the LightHead system (including the voice synthesis style) was strongly affecting participants perception of these physical properties.

As an interesting aside, actors tend not to blink very often to express strength in their character as a high rate of blinking is suggested to display weakness (Bordwell, 2003; Caine, 2000; Pudovkin, 1935). Results from the semantic differentials of weak_strong (Figure 6-4-02b) and serious_fun (Figure 6-4-21b) would suggest that the act of suppressing blink behaviour does not express greater strength (No blink behaviour: Q1 = 3, Q3 = 6, Mdn = 4. Human blink behaviour: Q1 = 4, Q3 = 5, Mdn = 5) but rather an increased expression of seriousness (No blink behaviour: Q1 = 3, Q3 = 6, Mdn = 4. Human blink behaviour: Q1 = 4, Q3 = 5, Mdn = 5).

6.2.3.2 Blink Behaviour Type Results

Participant's responses were tested to ascertain if there were any perceptual differences between blink behaviour types. The results (where all participant responses were averaged for each set of positive/negative and negative/positive semantic differential responses), suggested that participants overall perception of the LightHead communicative performance was generally positive (Mdn=5.26, M=4.89 (4.00 = neutral choice), SD=1.24).

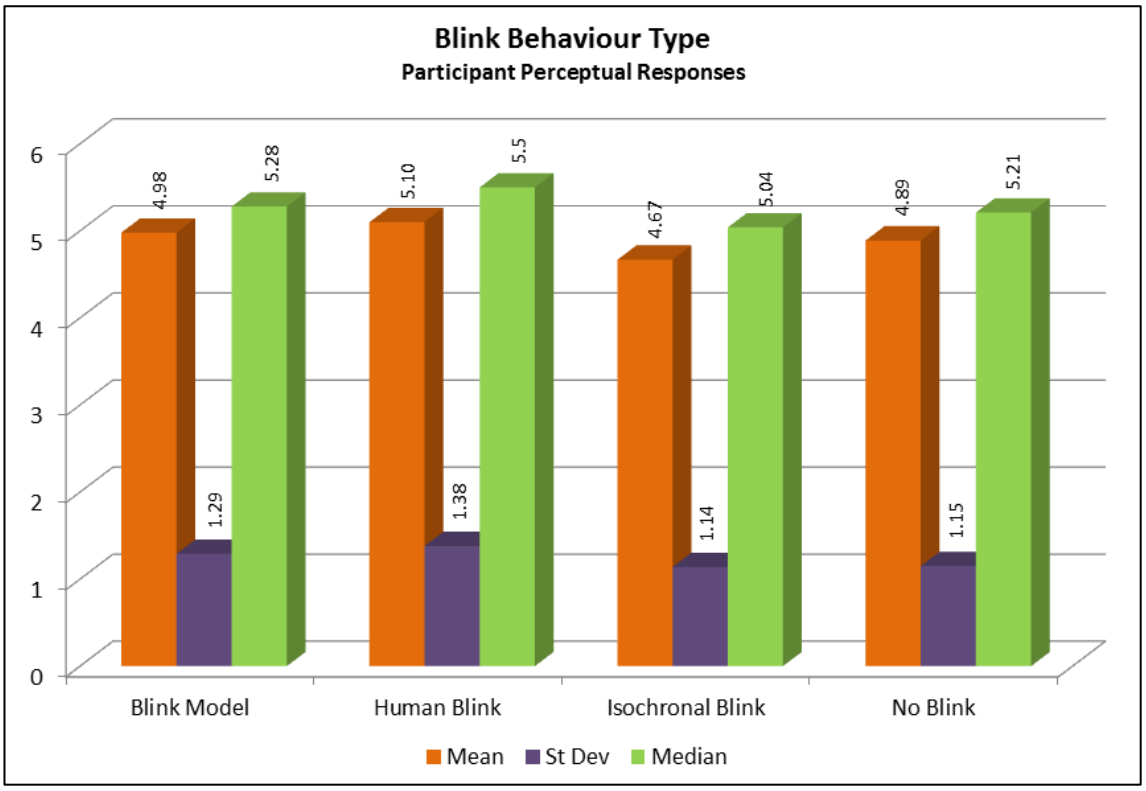

Figure 6-5 Participant Blink Behaviour - Perceptual Preference

Participants perceptual responses for the four differing blink behaviour performance types suggest that the human blink behaviour (Mdn=5.50, M=5.10, SD=1.38) was perceptually most liked, followed by the computational blink model behaviour (Mdn=5.28, M=4.98, SD=1.29), no blink behaviour (Mdn=5.21, M=4.81, SD=1.15) and isochronal blink behaviour (Mdn=5.04, M=4.67, SD=1.14) respectively (Figure 6-5). Of note, all blink behaviours were perceived as positive (with both a Median and Mean beyond 4.00 (neutral)), due we suggest to the human-like qualities of the overall LightHead communicative performance.

To ascertain which semantic differentials derived the displayed perceptual differences a Kruskal-Wallace one-way analysis of variance was performed. Strong significance ($p<0.05$) was found in participant connotation to the semantic differential questions: serious_fun ($p=0.03$) and lively_deadpan ($p=0.039$) and medium significance ($p<0.10$)

in participant connotation to the semantic differential questions: friendly_unfriendly (p=0.052), impersonal_personal (p=0.079) and decisive_indecisive (p=0.091). Participants were able to subtly perceive connotation differences between the four blink behaviour types.

To ascertain which blink type pairs differed in perceptual response from the Kruskall-Wallace semantic differential results and also to show which perceived connotations affected each blink type pair, Mann-Whitney U tests were performed displaying results of $p < 0.1$. Human blink and isochronal blink behaviours differed between the semantic differentials of friendly_unfriendly (U(25)=43.5, p=.07) and impersonal_personal (U(25)=34, p=.017). Human blink and no blink behaviours differed between the semantic differentials of serious_fun (U(27)=56, p=.081) and decisive_indecisive (U(27)=55, p=.074). Isochronal blink and no blink behaviours differed between the semantic differential of decisive_indecisive (U(26)=41, p=.023). Blink model and isochronal blink behaviours differed between the semantic differentials of serious_fun (U(25)=35.5, p=.018), lively_deadpan (U(25)=37, p=.021), friendly_unfriendly (U(25)=36.5, p=.017) and impersonal_personal (U(25)=48, p=.09). Blink model and no blink behaviours differed between the semantic differentials of serious_fun (U(27)=46, p=.026), lively_deadpan (U(27)=47.5, p=.028), friendly_unfriendly (U(27)=55.5, p=.07) and decisive_indecisive (U(27)=57.5, p=.09). p-values and power are displayed for clarity in Figure 6-6 and Figure 6-7 respectively.

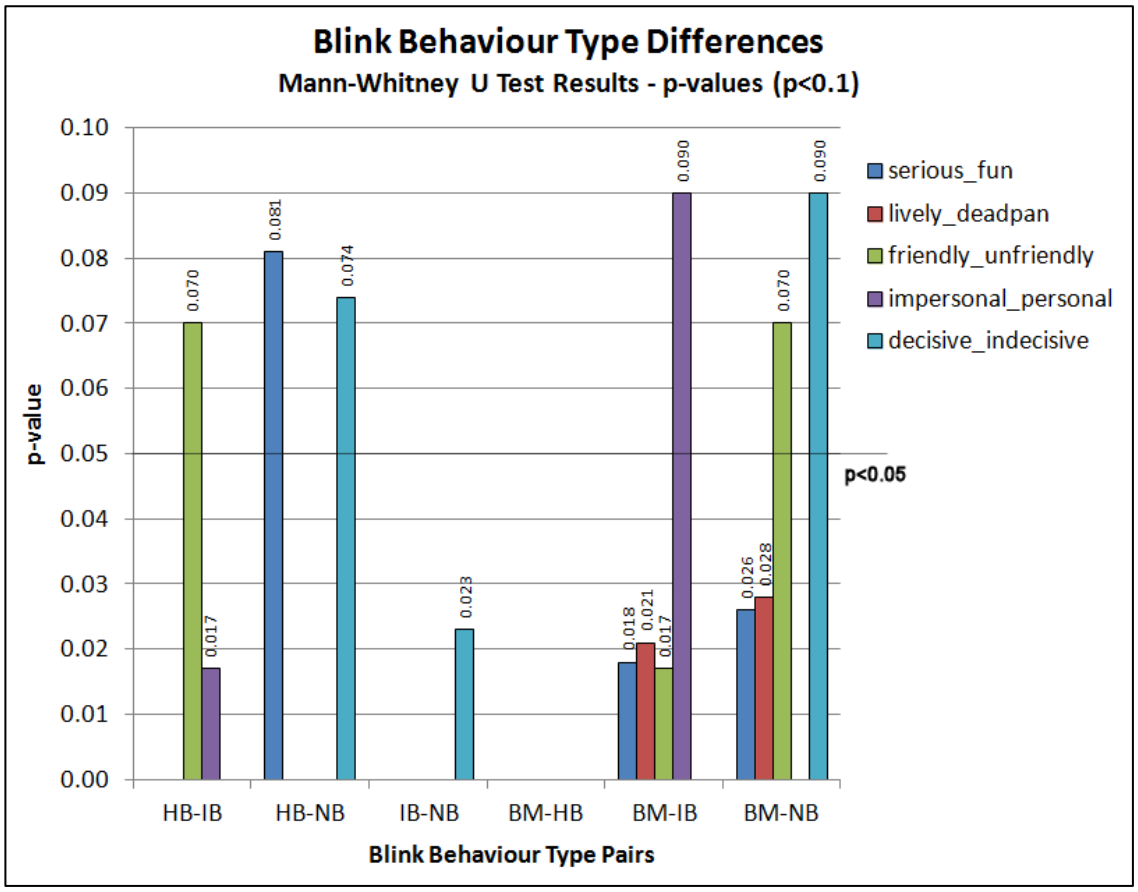

Figure 6-6 Perceptual Blink Behaviour Type Differences – p-values

Blink model and human blink behaviours (BM-HB) were seen by participants as having no perceptual differences between them. These results show that participants perceived the blink model to most closely imitate human blink behaviour in communication, as opposed to isochronal blink (5sec interval) and no blink behaviours. However, isochronal (IB) and no blink (NB) behaviours were perceptually shown to be more closely related to human blink (HB) behaviour than they are to the blink model (BM) behaviour, thus suggesting that there is still further work to be completed to perfect the blink model behaviour. Also of note is that the overall perceptual differences found are very slight, with only 5 (15%) of 34 semantic differential questions registering any perceptual difference between blink behaviour types. Further, at $p<0.1$ only 2 (6%) semantic differential questions make up the perceptual differences between human blink behaviour and isochronal blink behaviour (HB-IB) / no blink behaviour (HB-NB) and at

p<0.05 only 1 (3%) semantic differential question makes up the perceptual difference between human blink behaviour and isochronal blink behaviour (HB-IB) whereas there is no perceptual difference between human blink behaviour and no blink behaviour (HB-NB) making it equivalent to the blink model behaviour at this level of significance.

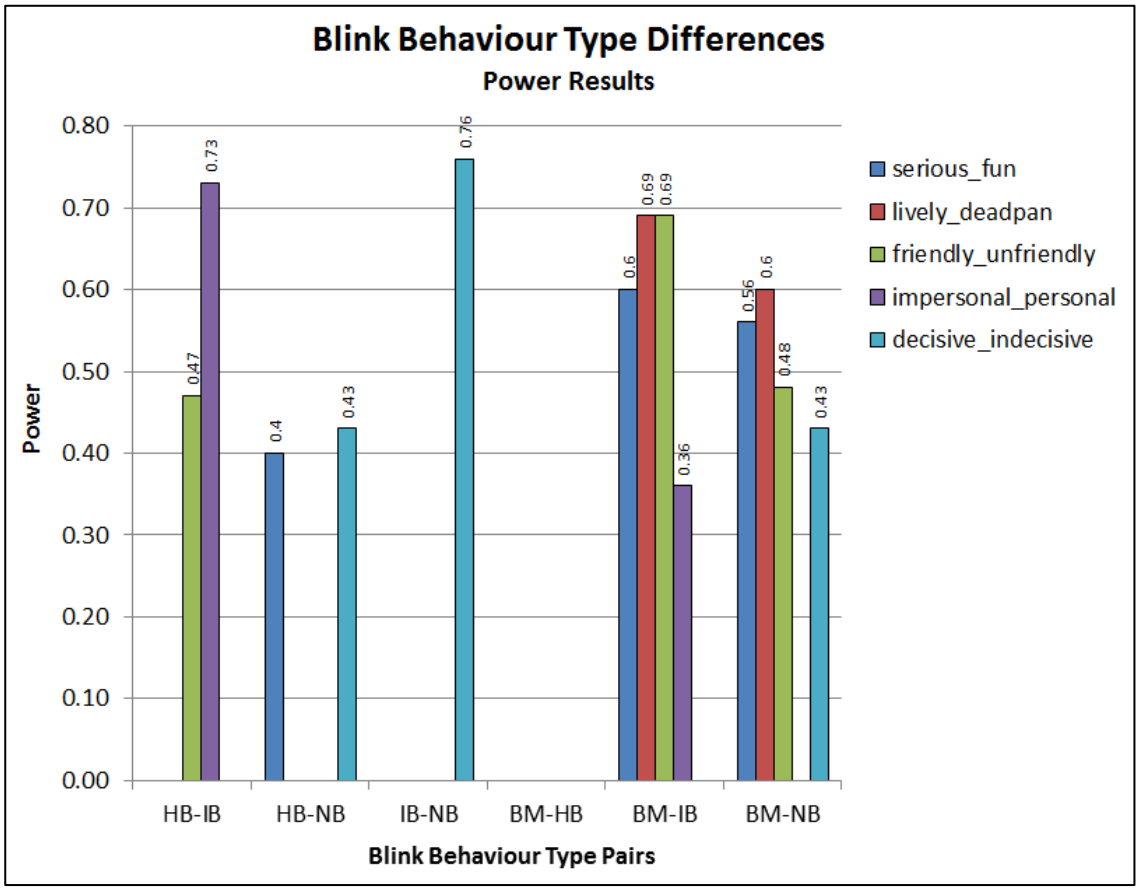

Figure 6-7 Perceptual Blink Behaviour Type Differences – Power

All Power values (Figure 6-7) are <.80 and therefore suggest that more participants are required to strengthen the significance of these findings. To reach >.80 power on these values, we require between 15 (best case) to 36 (worst case) participants to be tested for each blink behaviour.

6.2.4 Factor Analysis Results

The initial analysis of the semantic differential perceptual responses for each of the four blink performance types suggested that there were specific behavioural groupings being

used by participants in their perceptual responses, specifically differentiating their responses around traits linked to the personality and physical behaviour of the LightHead communicative performance. To test this theory, Factor Analysis, a common Psychological statistical process, was used. Factor Analysis (Spearman, 1904) is a statistical process used to describe the variables of a data set as a sub-set of indices that help to interpret the affinity between the variables in question.

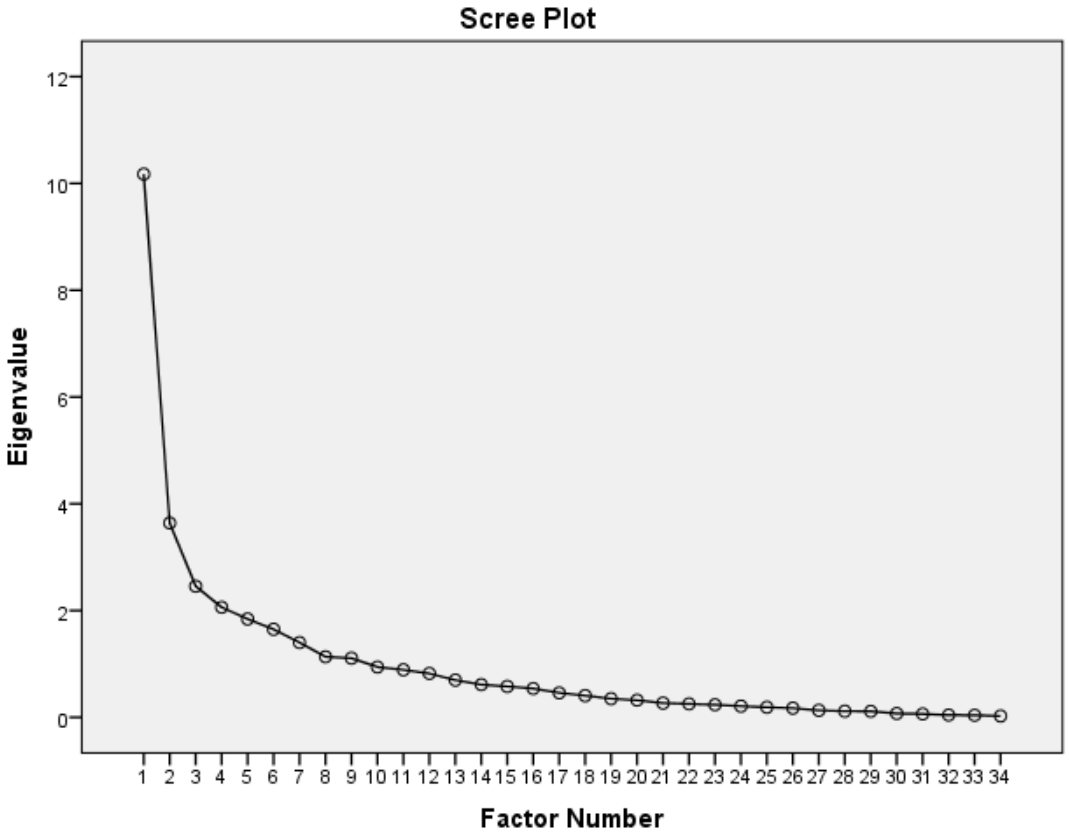

Figure 6-8 Scree Plot for 2-Factor Maximum Likelihood Factor Analysis

Figure 6-8 strongly suggests that our collated responses to the semantic differential questions have only two factor indices, with the first of these indices being significantly more common than the second. From this result a 2-factor analysis was performed.

Table 6-2 Factor Analysis Results (2 Factors)

	Factor	
	1	2
masculine_feminine	.066	.511
weak_strong	.620	.177
child_adult	-.008	-.240
cold_warm	.658	-.288
good_bad	-.588	-.018
exciting_boring	-.720	-.091
engaged_distracted	-.656	.016
stupid_intelligent	.471	.033
lowqual_highqual	.481	.330
diligent_lazy	-.321	-.387
trustworthy_untrustworthy	-.474	.321
responsible_irresponsible	-.201	-.254
friendly_unfriendly	-.785	.086
slow_fast	.532	.376
liked_disliked	-.664	.098
impolite_polite	.526	.424
active_passive	-.590	-.011
nonhumanlike_humanlike	.435	.034
unengaging_engaging	.660	-.060
decisive_indecisive	-.296	-.333
serious_fun	.417	-.193
unbalanced_balanced	.405	.074
notfriend_friend	.673	-.251
unkind_kind	.630	-.190
impersonal_personal	.698	-.394
traditional_contemporary	.081	.417
indifferent_interested	.688	-.045
abnormal_normal	.325	-.291
standard_unique	.314	.384
affordable_expensive	.172	.470
lively_deadpan	-.729	.213
insensitive_sensitive	.764	-.166
honest_dishonest	-.535	-.379
dishonest_honest	.449	.661

Table 6-2 shows the Factor Analysis results for the 2-factor analysis process. The highest response factor for each semantic differential has been highlighted in yellow and from these results we can posit that the two indices are suggested as being related to *personality* behaviour, incorporating intelligence and emotive behaviour traits (seen in

the left-hand factor) and *physical* behaviour, incorporating the look and feel of the LightHead communicative performance (seen in the right-hand factor).

A few anomalies fall inside the physical behaviour indices with semantic differentials of diligent/lazy, responsible/irresponsible and decisive/indecisive. These have a small response factor differential of less than .07 between their indices values and as such can be considered to have been viewed both as part of the physicality and personality of the LightHead communicative performance within different participants responses. The dishonest/honest anomaly does however seem unexplainable, what with honest/dishonest falling almost equally as strongly into the expected personality indices. Also, non-humanlike/humanlike falling in the personality indices also seems like an anomaly, however, the strength of its response factor suggests that this was commonly viewed from a personality viewpoint, as opposed to a physical viewpoint, triggering perception responses aimed commonly towards the LightHead expressed intellectual and emotive elements through its imitative communicative performance.

6.3 Summary

A summary of Chapter 6 results highlights is given below.

- The high complexity of imitating human communicative behaviour within HRI goes beyond the inherent difficulty in capturing, analysing and modelling the behavioural characteristics, but further, through the elaborate process of imbuing a robot/avatar with these modelled characteristics.

- Perception Test #1 proved the hypothesis that participants could not differentiate between the LightHead communicative performances of human blink and computational blink model behaviour. (Overall $\chi^2(83, N=84)=21$, $p=.449$, age range $\chi^2(6, N=84)=10.49$, $p=.106$ and gender $\chi^2(1, N=84)=0.43$, $p=.510$).

84 participants (37 Male and 47 Female) were split 50%/50% with 42 participants responding to each of the human and model blink behaviour types as their choice of real human blink behaviour.

- Perception Test #2 displayed participants preference of the four differing blink behaviour types suggesting that human blink behaviour (Mdn=5.50, M=5.10, SD=1.38) was perceptually most liked, with the computational blink model behaviour (Mdn=5.28, M=4.98, SD=1.29) following closely thereafter, beyond the no blink behaviour (Mdn=5.21, M=4.81, SD=1.15) and isochronal blink behaviour (Mdn=5.04, M=4.67, SD=1.14) respectively. Non-parametric significance testing (Kruskal-Wallace and Mann-Whitney U ad-hoc tests) showed that the computational blink model behaviour was perceptually seen as no different to human blink behaviour, whereas the no blink and isochronal blink behaviours were found to be slightly different to human blink behaviour in participants perceptual responses. All blink behaviours were perceived as positive, due we suggest to the human-like qualities of the overall communicative performance expressed by the LightHead social robotic system.

- Factor Analysis results posit that participants perceptual semantic differential responses fell within two indices, relating to personality behaviour (incorporating intelligence and emotive behaviour traits) and physical behaviour (incorporating the physical look and feel of the LightHead System and its level of success within its imitative human communicative performance).

"There can be as much value in the blink of an eye as in months of rational analysis."

Malcolm Gladwell, *Blink: The Power of Thinking without Thinking*

PART IV

IN THE BLINK OF AN EYE

Conclusions and the Future…

7. Conclusions and Future Work

7.1 Conclusions

In Chapter 1, the aim of this work has been set out as a contribution to knowledge in the research fields of HRI and HCI, both to improve user communication with a social robotic/ECA system and to show the importance of blink behaviour in human-human communication. The route taken to achieve these aims was through the design and implementation of a computational blink model / saccadic eye movement model and the conceptual design of a mental state driven human facial communication system for social robotic/ECA system implementation. These models and system were developed through the capture and detailed analysis of human non-verbal facial behaviour from actual human-human communication. Further, their temporal and morphological functionality was defined through human communicative behavioural definitions of internal mental communicative states (i.e. thought (listening), thought (processing), understanding, uncertainty and misunderstanding). The main objectives of these models and system were to improve user interaction with social robotic/ECA systems to aid attention and grounding of a communication and to express that blink behaviour plays a role (albeit a subconscious and subtle role) within human-human communication (Ford, Bugmann & Culverhouse, 2010; Ford, Bugmann & Culverhouse, 2013).

Early research of human blink behaviour posited that blinks were solely physiological in function (i.e. eye surface cleaning/oxygenating/humidifying). Successive researchers have however, progressively identified some behavioural correlations with blink behaviour, such as start of own speech, gaze shifts (towards and away from an interlocutor) and changes of limited mental states (i.e. thought and understanding). Thus, an increasing fraction of blinks were given a communicative, rather than purely physiological function.

Through the analysis of communicative blink co-occurrence behaviour, new blink triggers have been identified unique to this study: Facial Expression Onset / Offset, Interlocutor Speech Onset and Mental Communicative State Change (including the newly investigated mental communicative state of misunderstanding). Of note, during the analysis process, it was found that interlocutor speech (sSpeech) offset was not a common blink trigger in human communicative behaviour as its high co-occurrence values were actually triggered significantly by the own speech (pSpeech) onset behaviour (Figure 3-19 and Figure 3-26), hence blinks are not generally used as acknowledgement of turn taking in our experiment, with only 3% of total blinks co-occurring with this pSpeech onset behaviour primitive.

The blink co-occurrence results derived from the collated human communicative behaviour data corpus from this project posit that from 48% to 71% of blinks can now be associated with communicative behaviour, with the remainder likely fulfilled through the physiological process, for cleaning, oxygenating and dehumidifying the eyes (Ford, Bugmann & Culverhouse, 2013). It must be stated however, that this is not evidence that blinks are carrying communicative information in their own right, but suggests that blinks have a communicative aspect as part of overall human communicative non-verbal facial behaviour (Ford, Bugmann & Culverhouse, 2013), which itself has a significant role within human communication, strongly influencing semantic information within human-human communicative message delivery (Knapp & Hall, 2010; Koneya & Barbour, 1976).

To show the depth of the role that blinks play within human-human communication, the computational models were implemented within the LightHead social robotic system as part of an imitative human dialogue-based communicative performance. The main facial performance was utilised within four separate performances, each with a differing

blink behaviour type of human blink, computational blink model, isochronal blink (5sec interval) and no blink behaviour. Videos of these blink behaviour type performances were utilised within two user-based experiments designed to test the efficacy of the computational blink model with respect to human perception and to show that blinks play a role within human-human communication respectively.

The results of the initial perceptual study showed that participants were unable to differentiate between the computational blink model and actual human blink behaviour (Chi Square results from three data sets: overall $\chi^2(83, N=84)=21$, $p=.449$, age range $\chi^2(6, N=84)=10.49$, $p=.106$ and gender $\chi^2(1, N=84)=0.43$, $p=.510$), suggesting that participants found the computational blink model acceptable as a substitute for natural human blink behaviour.

The results of the second perceptual study showed that participants subtly preferred real human blink behaviour above the computational blink model behaviour, followed closely by the isochronal blink and no blink behaviours. These differences in blink behaviour preference were shown in the semantic differentials of friendly_unfriendly, impersonal_personal, serious_fun, decisive_indecisive and lively_deadpan, as shown in the Mann-Whitney U test results: Human blink and isochronal blink behaviours differed between the semantic differentials of friendly_unfriendly ($U(25)=43.5$, $p=.07$) and impersonal_personal ($U(25)=34$, $p=.017$). Human blink and no blink behaviours differed between the semantic differentials of serious_fun ($U(27)=56$, $p=.081$) and decisive_indecisive ($U(27)=55$, $p=.074$). Isochronal blink and no blink behaviours differed between the semantic differential of decisive_indecisive ($U(26)=41$, $p=.023$). Blink model and isochronal blink behaviours differed between the semantic differentials of serious_fun ($U(25)=35.5$, $p=.018$), lively_deadpan ($U(25)=37$, $p=.021$), friendly_unfriendly ($U(25)=36.5$, $p=.017$) and impersonal_personal ($U(25)=48$, $p=.09$).

Blink model and no blink behaviours differed between the semantic differentials of serious_fun
($U(27)=46$, $p=.026$), lively_deadpan ($U(27)=47.5$, $p=.028$), friendly_unfriendly ($U(27)=55.5$, $p=.07$) and decisive_indecisive ($U(27)=57.5$, $p=.09$).

These studies have extended current knowledge of human blink behaviour within human-human communication, showing that blink actions are closely linked to onsets and offsets of other specific communicative non-verbal facial behaviours and therefore are not just physiological in nature (Section 3) and further, and more importantly that, albeit on a subtle subconscious level, blink behaviour is perceived during human-human communication (Section 6). This is not evidence that blinks are carrying communicative information in their own right, but suggests that blinks have a communicative aspect within human communicative non-verbal facial behaviour.

Additionally, new knowledge has been added through the understanding of gender-specific blink behaviour, through the gender-specific definition of mean/overall blink duration and blink trigger probabilities (for all analysed communicative facial behaviour primitives) and within the definition of blink morphology, wherein the concept of the half blink type has been defined, where upon blink instantiation, the upper eyelid only half covers the eye, but still covers the pupil, therefore inhibiting vision as would a full blink type (Ford, Bugmann & Culverhouse, 2013).

The results of the user-based tests of the computational blink model implementation on the LightHead social robotic system, having shown that it is possible to model human communicative behaviours to an acceptable level of imitation, suggest that human communicative non-verbal models can be created and utilised that will allow social

robotic/ECA systems to express humanlike communicative non-verbal facial behaviour that will be both accepted and understood by human users.

New knowledge has been added by this study in this direction, wherein the results of the analysis of mental communicative states within human communicative non-verbal facial behaviour show that the states of thought (listening), thought (processing), understanding, uncertainty and misunderstanding have differing communicative non-verbal facial behaviour characteristics (especially with respect to the thought (listening) and thought (processing) states). This behavioural data could therefore be used to computationally model the communicative non-verbal facial behaviour characteristics of each mental communicative state, enabling these states to be non-verbally expressed on a social robotic/ECA system, and through this expression, differentiated and categorised by human users.

Overall, the presented studies have established clear links between communicative behaviour primitives of head movement, eye movement, blink behaviour, speech, mental state changes and facial expression within human social communication. Blinks specifically are seen to commonly co-occur with all other communicative behaviour primitives defined (above levels of chance) and thus their behaviour is shown to be perceived during human-human communication. These findings lead us to state that blinks have a role within human-human communication and therefore would hold an important place in any simulation of human communicative non-verbal facial behaviour. To this end, our computational blink model has been shown to be acceptable as a substitute for actual human blink behaviour, and it is therefore suggested that this model would indeed aid a user to more comfortably interact with a social robotic/ECA system within which the model was installed.

7.2 Future Work

7.2.1 Quality of Human Communicative Behaviour Coding

Transcription coding of all human communicative behaviour was performed by the experimenter. The accuracy of the transcription coding could be called into question, therefore a process of checking the level of accuracy should be performed by allowing naïve participants to transcribe (using the project transcription code book (Appendix V-d) the non-verbal facial behaviour throughout a single dialogue video. The accuracy found between participants transcription code and the initial experimenter's transcription code would define the overall accuracy of the transcription process.

7.2.2 Affecting Communicative Behaviour through Personality, Gender and Age

Data captured in the blink co-occurrence analysis process shows that individual participant's communicative non-verbal facial behaviours were highly variable in number (Table 3-3) and morphology. Participants also varied in the number of blinks performed (Table 3-2) and the length of time taken in concluding the experimental dialogue (Table 3-2), however initiating conversation and smooth turn-taking therein were never affected by individual communicative behaviour. These results display a significant difference in an individual's communicative behaviour traits, which interestingly suggests a cogent tolerance of individual social communicative dynamics within the scope of a successful social communicative interaction. This could be proposed as an expression of an individual's personality traits and could be useful in the setup and control of a social robotic/ECA systems personality.

Following this concept, gender-specific communicative behaviour traits could also be used in the expression of a social robotic/ECA systems gender portrayal, if required. For example, females blink almost twice as much as their male counterparts during

human communication, with blink rates of 20blinks per minute (bpm) for male participants and 38bpm for female participants (Ford, Bugmann & Culverhouse, 2013). However, there are also differences in blink rate per participant, which change significantly within each gender group (Table 3-2).

It is important to state that the current blink model is androgynous in nature, taking as it does its blink trigger behaviour and blink morphology statistics from both male and female participants (Figure 3-12 to Figure 3-14). Possible future work could incorporate implementation of gender-specific blink models (incl. blink morphology) from our current human communicative behaviour data corpus by altering the blink trigger probability weighting values and morphology timings to their respective gender-based values. These gender-based blink models could then be tested for user perceptual response via the experimental question: *Is there a tendency for genders to prefer either their own or the opposite genders blink behaviour?*

Possible future work could also incorporate the extension of the human communicative behaviour data corpus, generally improving the low-level accuracy of any derived computational models. Also, increasing the participant sample (a known requirement for future work to truly define the efficacy of the computational blink model, as derived from the Mann-Whitney U test power results (Figure 6-7)) would allow for a more diverse age range of participants data to be collated. The mapping of social communicative behavioural traits linked to age would also allow the age of a social robotic/ECA system to be (user) defined, along with its personality and gender.

Allowing users to choose the personality, gender and age of their social robotic/ECA system would likely improve usability within the field of social robotics (Kuo et al., 2009; Lee et al., 2006; Siegel, Breazeal & Norton, 2009), allowing a social robotic/ECA

system to behave in a suitable/acceptable communicative manner based on (user) selected choices.

Of further interest, restricting the model to data from a single participant allows the social robotic/ECA system to imitate the communicative non-verbal facial behaviour defined through the chosen participants gender, age and personality. Personality tuning could also be incorporated by moving between communicative behaviour mapping of different participants with the same gender and age profiles. This concept could optimise the social robotic/ECA systems communicative behaviour and increase its human-like communicative qualities.

Possible future work in the definition of experiments for testing further imitative communicative performances (based on computational models derived from gender, age and personality controlled communicative behaviour concepts) could lead to interesting interdisciplinary HRI/sociology/psychology collaborative studies, focussing on the effects of gender, age and personality within human social communication.

7.2.3 Removal of Bias in Human-Human Communicative Non-Verbal Facial Behaviour Data Collection

A number of areas of bias could be highlighted with respect to the collection of human-human communicative non-verbal facial behaviour within the initial experiment. The following tests would strengthen this study if utilised in any future human-human communicative non-verbal facial behaviour data collection:

- Upon entering the experiment environment, a pre-question process should be utilised to define both the mood and emotion of the participant and their relevant eye health (i.e. do they need/use prescription glasses/contact lenses). Analysis to test communicative behaviour effects of participant emotion, mood and eye health could then be performed.

- Check the timings of the controller's blinks against those of the participant to check for possible mirrored blink behaviour. This may affect the robustness of the blink model results.
- Check for gender bias in communicative behaviour. This study utilised a male controller only, hence the data corpus contains male → female and male → male communicative behaviour data only. Collecting and testing female → female and female → male gender and role data also needs to be performed. Analysis to test communicative behaviour effects of gender and role could then be performed.

7.2.4 Completion of the Communicative Non-Verbal Facial Behaviour System

Completion of the human communicative facial behaviour system (Section 4.1), for full expression of all captured communicative facial behaviours on a social robotic/ECA system would involve the following future work:

- Analysis of the temporal morphology of all captured communicative non-verbal facial behaviour for each mental communicative state. Further analysis herein could look at temporal communicative behaviour grouping and any link therein to both contextual and temporal aspects of associated speech.
- Creation of a task-specific dialogue system utilising user speech interaction to define the robotic/ECA system speech response, which in-turn defines the description of the required communicative non-verbal facial behaviour and its temporal morphology.
- Creation of a conversational grounding system (Section 1.2.2), implemented to surround the communicative non-verbal facial behaviour system, performing methods of conversational instigation, completion, interest holding and turn-taking with social robotic/ECA system users, through robust face tracking, eye

tracking and blink detection software design.

7.2.5 Mind Reading – Modelling the Categorisation of Mental Communicative States

Moving away from HRI, the development of a vision system that reads the communicative non-verbal facial behaviour of human users and from this data, infers their mental communicative state would likely have an impact on many areas of human behaviour data collection. The system would function by utilising a camera video feed to capture a user's communicative non-verbal facial behaviour in real-time. This data would then be used as input to the prior defined model of communicative non-verbal facial behaviour related to each mental communicative state, which would categorise a users mental communicative state in real-time through the utilisation of a Bayesian Network (using the prior defined Multiple Discriminant Analysis results (Section 3.4) and further temporal data defined from the human communicative behaviour data corpus. Following are a few examples of functions/roles that this system could be designed to perform:

- *Advert analysis*: Hardware design of a billboard with embedded webcam would allow this system to gain feedback on where readers of an advert understood, misunderstood, were uncertain or were within thought with regard to specific sections of the advertisement. This functionality would allow advert designers to amend their designs based on this novel knowledge.
- *Computer game story branching*: Utilising current games console cameras (such as the Microsoft Kinect (Microsoft_Corporation, 2013) and Sony Playstation Camera (Sony_Computer_Entertainment, 2013), inference of a players mental communicative state in real-time would allow for branching of interactive dialogue and through this, changes in the direction of the story being told.
- *E-Learning control system*: Using a PC webcam with E-Learning software, the

system could infer the mental state of the student in real-time, giving feedback from a students learning session on which subject areas the student understood, misunderstood or was uncertain about. This functionality would allow teachers and parents to understand students learning requirements in greater detail, allowing the targeting of subject areas requiring further learning and based on this knowledge, either update or instigate new learning methodologies to help improve students' knowledge.

7.2.6 A Model of Context

During the analysis of human communicative non-verbal facial behaviour throughout this study, it has become greatly apparent that an oft ignored, but none-the-less extremely important part of human communicative behaviour is that of context. Our social interaction is heavily influenced by many contextual elements, such as, mood/emotion, personal goals and beliefs, interlocutor dynamics (e.g. work relationship, family/personal relationship, age and gender) interaction environment (e.g. venue, gathering type) , interlocutor communicative content (i.e. speech and non-verbal behaviour) and task dependency.

These contextual elements are no doubt complex, not least in how they interact with each other in subtle yet elaborate ways to formulate a communicative response, but it is posited that a model of context would form a highly accurate means of defining the required morphology of a communicative response (i.e. speech and associated non-verbal communicative behaviour) from an imitative human communicative behaviour system, beyond that of probabilistic-based systems.

The complexity within the concept of context makes this type of study seem daunting or even impractical, however, the initial model would of necessity need to be greatly simplified to enable the timely creation of a prototype proof-of-concept context model.

The creation of this initial context model is currently believed to be an achievable objective based on a methodological process that would use purely the speech context element as a contextual driver of non-verbal facial behaviour imitation within a specific task-based domain (e.g. speech output for direction giving within a specific venue).

Dissemination of research relating to the most common requested task requirements of social robotic/ECA systems (Bugmann & Copleston, 2011; Oestreicher & Eklundh, 2006) could logically inform the choice of the initial task domain on which to focus efforts in the analysis of the effect of speech context in the creation of non-verbal communicative behaviour. The results from this analysis would then inform the creation of both a task-based dialogue system (for robot response dialogue generation from received user dialogue) and the context model (which creates the temporal mapping of non-verbal behaviour through processing of the robot response dialogue based on the models derived contextual rules).

7.2.7 Testing User Perception of Random Blink Behaviour

Our research has already proven that blinks are not random in nature, with the blink models behavioural primitives being shown to be well beyond chance (Figure 3-12 to Figure 3-14), however; user perception testing of our blink generation model (Chapter 6) also needs to be tested against a random blink generation model, as this may be closer in perceptual response than the currently tested isochronal blink (5s interval) and no blink behaviour variants.

7.3 Adding to the future of HRI

The aims of this study, set out in the introduction, were to improve user communication with a social robotic/ECA system and to analyse the co-occurrence of blinks with other communicative non-verbal facial behaviour onsets/offsets and thus to define the

relevance of human blink behaviour within human-human communication.

The work presented in this thesis has made progress on the second aim through the development and implementation of computational models of human blink behaviour in communication, which has been proven to be an acceptable substitute of natural human blink behaviour by human subjects, and saccadic eye movement (defined for both listening and speaking communicative states) in human-robot communication and also through the conceptual development of an imitative computational human communicative facial behaviour system and the mapping of human communicative non-verbal facial behaviour to specific mental communicative states (of Thought (Listening), Thought (Processing), Understanding, Uncertainty and Misunderstanding).

The work presented in this thesis has made progress on the initial aim through the analysis of blink co-occurrence with other human communicative non-verbal facial behaviour primitives and speech; the results of which show that during human-human communication, blinks are closely linked to onsets and offsets of speech and other specific communicative non-verbal facial behaviour primitives and are therefore not just physiological in nature. These results suggest that blinks have a communicative aspect as part of overall human communicative non-verbal facial behaviour as part of human communicative non-verbal facial behaviour (Ford, Bugmann & Culverhouse, 2013).

A major limitation of this study was the difficulty and time-consuming nature of the capture and analysis of human communicative behaviour due to its denseness and complexity. This could well be seen as a major limitation in the future development of computational human communication systems/models for integration within social robotic/ECA systems. However, even though there is still much work to perform in the analysis and understanding of human communicative behaviour to achieve the goal of seamless human-robot/ECA interaction through human communicative behaviour, it is

important to point out that this thesis also expresses, in our analysis of human communicative behavioural data, that there are inherent possibilities in revealing further novel behavioural knowledge (from both a psychological and sociological perspective) within human-human communication. Upon publication of this thesis, our human communicative data corpus and FaceML XML transcription corpus will both be released online for access and use by the research community at large. We believe that such a data corpus has not yet been released (and this statement is backed up by Cummins (2011) who states that such a corpus was not available for his research studies) and expect that this would be a useful resource for the HRI, Psychology and Sociology research communities for use within future human communicative behavioural studies.

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9. Publications

All published papers relating to this PhD thesis can be accessed from the author's web site at http://www.ccford.co.uk.

"Electric communication will never be a substitute
for the face of someone who with their soul
encourages another person to be brave and true."

Charles Dickens, 'The Wreck of the Golden Mary', Page 10, Column 2, 1856.

APPENDIX

Appendix

I. Blink Co-Occurrence Tables

Table 9-1 Fraction of communicative facial behaviour primitives during which a blink starts (within a +/-375ms window from the behaviours onset/offset). p(Blink / Behaviour) - Part I

Participant Number	Participant Speech (on/off)	Interlocutor Speech (on/off)	Looking (At/Away)
01	26% (33%/19%)	14% (8%/20%)	51% (41%/62%)
Chance %	*8%*	*5%*	*1%*
02	20% (27%/13%)	8% (9%/7%)	55% (33%/80%)
Chance %	*5%*	*4%*	*1%*
03	38% (48%/28%)	35% (18%/51%)	81% (68%/94%)
Chance %	*11%*	*10%*	*4%*
05	68% (87%/48%)	18% (8%/28%)	80% (67%/100%)
Chance %	*9%*	*12%*	*1%*
06	59% (77%/40%)	49% (38%/60%)	50% (59%/41%)
Chance %	*9%*	*11%*	*7%*
09	21% (28%/14%)	17% (13%/20%)	73% (64%/82%)
Chance %	*4%*	*6%*	*1%*
07	56% (63%/48%)	64% (63%/65%)	70% (59%/81%)
Chance %	*29%*	*36%*	*5%*
08	65% (78%/52%)	66% (60%/72%)	92% (88%/96%)
Chance %	*26%*	*27%*	*12%*
11	35% (36%/34%)	53% (55%/51%)	48% (47%/50%)
Chance %	*13%*	*18%*	*3%*
12	36% (53%/19%)	26% (23%/29%)	60% (61%/59%)
Chance %	*9%*	*9%*	*3%*
13	52% (59%/45%)	39% (41%/38%)	53% (59%/47%)
Chance %	*9%*	*12%*	*5%*
14	50% (64%/36%)	44% (39%/49%)	75% (85%/66%)
Chance %	*6%*	*8%*	*4%*
Totals:			
Co-Occur Average	**44%** (54%/33%)	**36%** (31%/41%)	**66%** (61%/72%)
Co-Occur Chance %	***12%***	***13%***	***4%***

Table 9-2 Fraction of communicative facial behaviour primitives during which a blink starts (within a +/-375ms window from behaviour onset/offset). p(Blink / Behaviour) - Part II

Participant Number and Chance %	Facial Expression (on/off)	Mental Communicative State Change
1	11% (9%/12%)	33%
Chance %	*5%*	*3%*
2	17% (28%/6%)	33%
Chance %	*6%*	*12%*
3	29% (33%/24%)	66%
Chance %	*12%*	*7%*
5	33% (25%/50%)	38%
Chance %	*6%*	*10%*
6	35% (39%/30%)	53%
Chance %	*6%*	*10%*
9	13% (17%/9%)	70%
Chance %	*4%*	*3%*
7	38% (33%/23%)	70%
Chance %	*21%*	*12%*
8	43% (55%/31%)	34%
Chance %	*18%*	*15%*
11	41% (38%/44%)	54%
Chance %	*15%*	*13%*
12	26% (30%/22%)	35%
Chance %	*12%*	*10%*
13	27% (27%/27%)	58%
Chance %	*15%*	*12%*
14	38% (50%/26%)	53%
Chance %	*8%*	*8%*
Total:		
Co-Occur Average	**29%** (32%/25%)	**50%**
Co-Occur Chance %	***11%***	***10%***

Table 9-3 Gender-based fraction of communicative facial behaviour primitives during which a blink starts (within a +/-375ms window from the behaviours onset/offset). p(Blink / Behaviour) - Part III

	pSpeech (on/off)	sSpeech (on/off)	Looking (At/Away)	Facial Expression (on/off)	Mental Communicative State Change
Male:					
Co-Occur Average	**39%**	**23%**	**66%**	**24%**	**49%**
Co-Occur Chance %	***8%***	***8%***	***3%***	***7%***	***8%***
Female:					
Co-Occur Average	**49%**	**49%**	**67%**	**34%**	**51%**
Co-Occur Chance %	***15%***	***18%***	***5%***	***15%***	***12%***

II. Dialogue Scripts #1 to #4

a. Script #1 (Standard Dialogue (Block of Errors at End))

Speaker: **Hi There! My name is Chris. What's your name?**
Participant: [name] given.

Speaker: **[name], it's a pleasure to meet you.**

Speaker: **During this conversation I will be asking you a number of questions. Please do your best to answer them honestly.**
Participant:

Speaker: **So, what month were you born in?**
Participant:

Speaker: **Do you know which star sign you are?**
Participant:

Speaker: **I was born in mid November. Do you know which star sign I am?**
Participant:

Speaker: **I'm not sure I believe in the information gleaned from star signs, do you?**
Participant:

Speaker: Hmm**. That's interesting. So, why do you believe this?**
Participant:

Speaker: **Good answer. So, what time of day where you born?**
Participant:

Speaker: **Ahh, a [sun / moon] baby.**

Speaker: **Do you know the distance between the earth and the [moon / sun]?** (If they say 'No', ask them to guess).
Participant:

Speaker: **The distance from the earth to the**
[Sun is min - 146 million km (91 million miles) and max 152 million km (94.5 million miles)]
[Moon is 386,242km (240,000 miles)]

Participant:

Speaker: **Could you please (in your own words) explain the difference between miles and kilometres?**
Participant:

Speaker: **Do you know the ratio between miles and kilometres?**
[5:8]
Participant:

Speaker: **I always found math's to be a difficult subject at school. How about you?**

Participant:

Speaker: **Much of it depends on the lecturer though. Mine was so strict! Do you remember your English lecturer at school?**
Participant:

Speaker: **OK. Let's test you then… What is the sum of 2 + 2?**
Participant:

Speaker: **What is the sum of 5 + 10?**
Participant:

Speaker: **What is the sum of 1 + 0?**
Participant:

Speaker: **What is the sum of a + b?**
Participant:

Speaker: **Well, that's enough engines for now.**
Participant:

Speaker: **Did you experience the enjoy?**
Participant:

Speaker: **That's good. Me folbeckarai too!**
Participant:

Speaker: **Thanks for being such a great participant…**
Participant:

Speaker: **Goodbye.**
Participant:

b. Script #2 (Standard Dialogue (Block of Errors at the beginning))

Speaker: **[name], it's a pleasure to hear you again.**
Participant:

Speaker: **So, what can I help you with?**
Participant:

Speaker: **I am sorry, I didn't understand you. Could you repeat what you said please?**
Participant:

Speaker: **Oh well, let's play a game.**
Participant:

Speaker: **A general knowledge quiz. I will ask you 6 questions, each increasing in difficulty. Please answer them as best you can…**
Participant:

1 **Which of these is a drink made with fruit juices, spices and often wine and spirits?**

○ Knock ○ Whack ○ Thump ◉ Punch

2 **A large portable video recorder with built-in speakers is known as a ghetto...?**

○ Blarer ◉ Blaster ○ Blower ○ Banger

3 **Which of these is a type of hat?**

◉ Pork Pie ○ Potato Crisp ○ Sausage Roll ○ Scotch Egg

4 **Which singer was regularly ridiculed by Morecambe and Wise in their TV shows?**

◉ Des O'Connor ○ Gracie Fields ○ Rolf Harris B ○ Barry Manilow

5 **Which of these has to pass a test on "The Knowledge" to get a licence in London?**

◉ Taxi Drivers ○ Bus Drivers ○ Ambulance Drivers ○ Police Officers

6 **In 2001, Donald Campbell's Bluebird was recovered from which lake?**

○ Keilder Water ○ Lake Windermere ○ Coniston Water ◉ Bala Lake
Speaker:

Speaker: **So, how many questions do you think you answered correctly?**
Participant:

Speaker: **You answered [n] questions correctly. Well done.**

Participant:

Speaker: **How did you feel whilst performing the quiz?**
Participant:

Speaker: **Well, thanks for being such a great participant…**
Participant:

Speaker: **Goodbye.**
Participant:

c. Script #3 (Standard Dialogue (Errors Interspersed))

Speaker**: [INCORRECT name], it's a pleasure to meet you again.**
Participant:

Speaker: **Could you place the following in priority order, starting with the most important…**

Speaker: **Friends / Colleagues / Family**
Participant:

Speaker: **So, your [last choice (not first)] are of highest priority to you… That's interesting… Your choice is different to most…**
Participant:

Speaker: [**first choice] are usually the highest priority!**
Participant:

Speaker: **OK. I like you… your interesting. As such, I would like to ask you some interesting questions. Please answer honestly…**
Participant:

Speaker: **What will tomorrow look like?**
Participant:

Speaker: **Hmm. Fascinating answer…**
Participant:

Speaker: **What's the sound of air hitting water?**
Participant:

Speaker: **Again, great answer!**
Participant:

Speaker: **Have you ever been burned?**
Participant:

Speaker: **Do you have a red shirt?**
Participant:

Speaker: **What's your favourite song?**
Participant:

Speaker: **Good choice!**
Participant:

Speaker: **Do you talk to yourself when you read?**
Participant:

Speaker: **Can you repeat what I just said?**
Participant:

Speaker: **Can you repeat what I just said?**
Participant:

Speaker: **Thanks for being such a great participant…**
Participant:

Speaker: **Goodbye.**
Participant:

d. Script #4 (Standard Dialogue (Errors Interspersed, No Eye Contact))

Speaker**: [name], it's always a pleasure to see you.**
Participant:

Speaker: **Again, I have some questions for you…**

Speaker: **Can you picture a sunset with lightening?**
Participant:

Speaker: **What is the eighth word from our National Anthem – "God save the Queen"?**
Participant:

Speaker: **Have you ever taken an ice-cold shower?**
Participant:

Speaker: **Who was the first person you saw today?**
Participant:

Speaker: **How does your doorbell sound?**
Participant:

Speaker: **What do you really want to do in life?**
Participant:

Speaker: **OK. So, you answered those questions extremely well.**
Participant:

Speaker: **Just one final question before we finish up…**
Participant:

Speaker: **Have you enjoyed our conversations?**
Participant:

Speaker: **Thanks for being such a great participant…**
Participant:

Speaker: **Goodbye.**
Participant:

III. Translating Human Communicative Performance Data

Translation from the transcribed FaceML code to the LightHead communicative performance code was processed by the experimenter. An example of these translation stages follows:

Below is a sub-section of the captured human FaceML XML data from Participant 6:

```
<pfe startTime="602" endTime="622" expression=”raised_brows” />
<phg startTime="602" endTime="644">
    <phgs startIndex="1" startTime="602" endTime="606" direction="270" distance="0.2" endAngle="0" />
    <phgs startIndex="2" startTime="608" endTime="614" direction="80" distance="0.3" endAngle="0" />
    <phgs startIndex="3" startTime="616" endTime="626" direction="270" distance="0.5" endAngle="10" />
    <phgs startIndex="4" startTime="627" endTime="630" direction="100" distance="0.1" endAngle="0" />
    <phgs startIndex="5" startTime="633" endTime="644" direction="110" distance="0.3" endAngle="0" />
</phg>
<pSpeech startTime="607" endTime="646">
    “Probably Sagittarian as well, I suppose”
</pSpeech>
<pbl startTime="608" endTime="614" type=”full” attack=”3” sustain=”0” decay=”4” />
<cState startTime="609" endTime="656" state=”uncertainty” />
<peg startTime="612" endTime="883" looking=”atFace” />
<cState startTime="657" endTime="713" state=”thought” />
```

The FaceML behaviour code is initially translated into a pseudo script (which is used for conversion by the LightHead translation code module) an example of which is displayed in Table 9-4:

Table 9-4 Partial Pseudo Translation of LightHead Communicative Performance

Type	Onset	Duration	Intensity	No. of Repetitions	Description	Start/end words
EXPRESSION #1	602	89	-	1	rb_bmt	"Probably Sagittarian as well, I suppose"
Head Move	602	5	0.2	-	270deg/0deg	-
Speech	607	40	-	-	"Probably Sagittarian as well, I suppose"	-
Head Move	608	7	0.3	-	80deg/0deg	"Probably Sagittarian as well, I suppose"
Mental State	609	48	-	-	Uncertainty	-
Eye Move	609	3	0.9	-	110deg	"Probably Sagittarian as well, I suppose"
Head State	612	180	-	-	"Looking At" – Listening Model On	"Probably Sagittarian as well, I suppose"
Head Move	616	11	0.5	-	270deg/10deg	"Probably Sagittarian as well, I suppose"
Head Move	627	4	0.1	-	100deg/0deg	"Probably Sagittarian as well, I suppose"
Head Move	633	12	0.3	-	110deg/0deg	"Probably Sagittarian as well, I suppose"
Mental State	657	57	-	-	Thought	-

An explanation of the headings will help to explain the pseudo translation process:

- **Type**

  The descriptive title for the communicative behaviour primitive in question. This is used by the translator module to define the correct LightHead instruction lines/processes required).

- **Onset**

  The frame required for the inception of the named communicative behaviour.

- **Duration**

  The overall duration of the behaviour in frames (24fps).

- **Intensity**

  The strength of the communicative behaviour, which changes its definition based on the behaviour type. For example, within head and eye movement this defines the distance of travel from the centre to the outside of the eye, whereas within an expression it defines the overall intensity of the overall expression movement.

- **Attack**

  Time duration of the blink behaviours attack phase. Not shown in Table 9-4.

- **Sustain**

  Time duration for the blink behaviours sustain phase. Not shown in Table 9-4.

- **Decay**

  Time duration for the blink behaviours decay phase. Not shown in Table 9-4.

- **Description**

  A descriptor which defines extraneous data relating to the named communicative behaviour. For example, eye movements use this field to define the angle of pupil movement, whereas head movements use this field to define X (forward) and Y (sideways) angular directions of movement trajectory and speech uses this field to define the text to be sent to the Text-To-Speech (TTS) system.

- **No. of Events**

  Used to define the required number of repetitions of an expression behaviour. For example, a head nod animation can be described once and then repeated as many times as required.

- **Start/End Words**

  This field is actually unused in the current iteration of the translator module, but was defined to hold the start word and end word of speech behaviours surrounding the behaviour in which they were entered, such that if the LightHead system timings were to go awry then a behaviour could start and stop based on the timings of the word in question being performed by the TTS speech module.

Note that blink behaviour displayed in the FaceML data was excluded from the pseudo translation code displayed above. These blink behaviours were included in the human blink performance variant.

To reiterate, this pseudo translation process allowed for a clean conversion between the captured FaceML human communicative data to the required behaviour primitive, timing and FACS instructions for the LightHead robotic/ECA system to simulate this human communicative behaviour.

a. Hand-Coded Translation of Partial Participant FaceML

Type	Onset	Dura-tion	Intensi-ty	Attack	Sustain	Decay	Description	No. Of events	Start/end words
Mental State	0	32	-	-	-	-	Thought	-	-
Head State	0	413	-	-	-	-	Looking At	-	-
Mental State	1	-	-	-	-	-	on-locutor-speech	-	-
Mental State	32	38	-	-	-	-	Understanding	-	-
Head Move	48	7	0.2	-	-	-	0deg/0deg	-	"…I''m light head"
Head Move	55	8	0.2	-	-	-	180deg/0deg	-	"I''m light head"
Speech	51	12	-	-	-	-	"I'm light head"	-	-
Mental State	69	264	-	-	-	-	Thought	-	-
Mental State	74	-	-	-	-	-	on-locutor-speech	-	-
Mental State	130	-	-	-	-	-	on-locutor-speech	-	-
EXPRESSION #7	162	154	-	-	-	-	nod1_bmt	11	-
Mental State	289	-	-	-	-	-	on-locutor-speech	-	-
Mental State	315	-	-	-	-	-	expression-off	-	-
Mental State	333	26	-	-	-	-	Understanding	-	-
Head Move	334	4	0.2	-	-	-	0deg/0deg	-	"_November "
Speech	336	23	-	-	-	-	"November"	-	-
Head Move	338	7	0.2	-	-	-	180deg/0deg	-	"November "
Mental State	359	74	-	-	-	-	Thought	-	-
Mental State	384	-	-	-	-	-	on-locutor-speech	-	-
Head State	413	24	-	-	-	-	Looking Away	-	-
Eye Move	413	4	.3	-	-	-	270deg	-	-
Eye Move	419	2	.05	-	-	-	300deg	-	-
Head Move	422	11	0.1	-	-	-	0deg/0deg	-	"…I'm a Sagittarius"

Eye Move	423	3	.25	-	-	-	320deg	-	"…I'm a Sagittarius"
Speech	426	29	-	-	-	-	"I'm a Sagittarius"	-	-
Eye Move	431	6	.6	-	-	-	100deg (Re-Center)	-	"I'm a Sagittarius"
Mental State	433	27	-	-	-	-	Understanding	-	-
Head Move	433	6	0.2	-	-	-	180deg/0deg	-	"…I'm a Sagittarius"
Head State	437	158	-	-	-	-	Looking At	-	"…I'm a Sagittarius"
Head Move	446	10	0.2	-	-	-	0deg/0deg	-	"…I'm a Sagittarius"
Head Move	456	5	0.05	-	-	-	180deg/0deg	-	-
Mental State	460	149	-	-	-	-	Thought	-	-
Head Move	464	17	0.05	-	-	-	180deg/0deg	-	-
Mental State	487	-	-	-	-	-	on-locutor-speech	-	-
Head State	595	17	-	-	-	-	Looking Away	-	-
Eye Move	595	2	0.4	-	-	-	300deg	-	-
Eye Move	597	2	0.1	-	-	-	270deg	-	-
Eye Move	602	3	0.4	-	-	-	300deg	-	-
EXPRESSION #1	602	21	-	-	-	-	rb_bmt	1	"Probably Sagittarian as well, I suppose"
Head Move	602	5	0.2	5	-	-	270deg/0deg	-	-
Speech	607	40	-	-	-	-	"Probably Sagit-tarian as well, I suppose"	-	-
Head Move	608	7	0.3	7	-	-	80deg/0deg	-	"Probably Sagittarian as well, I suppose"
Mental State	609	48	-	-	-	-	Uncertainty	-	-
Eye Move	609	3	0.9	-	-	-	110deg	-	"Probably Sagittarian as well, I suppose"
Head State	612	180	-	-	-	-	Looking At	-	"Probably Sagittarian as well, I suppose"
Head Move	616	11	0.5	11	-	-	270deg/10deg	-	"Probably Sagittarian as well, I suppose"

Mental State	622	-	-	-	-	-	expression-off	-	-
Head Move	627	4	0.1	4	-	-	100deg/0deg	-	“Probably Sagittarian as well, I suppose”
Head Move	633	12	0.3	12	-	-	110deg/0deg	-	“Probably Sagittarian as well, I suppose”
Mental State	657	57	-	-	-	-	Thought	-	-
Mental State	669	-	-	-	-	-	on-locutor-speech	-	-
EXPRESSION #2	691	159	-	-	-	-	smile1_bmt	1	-
Mental State	714	90	-	-	-	-	Understanding	-	-
Speech	728	16	-	-	-	-	“Right, Ok”	-	-
Head Move	731	8	0.5	5	-	-	20deg/5deg	-	“Right, Ok”
Head Move	736	8	0.5	6	-	-	180deg/5deg	-	“Right, Ok”
Head Move	745	8	0.1	8	-	-	200deg/5deg	-	-
Mental State	751	-	-	-	-	-	on-locutor-speech	-	-
Head Move	765	6	0.2	6	-	-	355deg/5deg	-	-
Head Move	771	5	0.1	5	-	-	185deg/0deg	-	-
Head Move	780	5	0.1	5	-	-	175deg/0deg	-	-
Mental State	790	-	-	-	-	-	on-locutor-speech	-	-
Head State	791	30	-	-	-	-	Stare	-	-
Mental State	804	96	-	-	-	-	Thought	-	-
Head State	821	64	-	-	-	-	Looking At	-	-
Mental State	850	-	-	-	-	-	expression-off	-	-
Eye Move	876	3	0.15	-	-	-	160deg	-	-
Head State	884	22	-	-	-	-	Looking Away	-	-
Eye Move	884	5	0.3	-	-	-	270deg	-	-
Eye Move	891	3	0.2	-	-	-	10deg	-	-
Head Move	891	10	0.3	10	-	-	300deg/10deg	-	-

Speech	894	25	-	-	-	-	"No, not really"	-	-
Eye Move	897	5	0.3	-	-	-	140deg	-	"No, not really"
Mental State	900	37	-	-	-	-	Understanding	-	"No, not really"
Head Move	901	5	0.1	5	-	-	120deg/10deg	-	"No, not really"
Head State	906	48	-	-	-	-	Looking At	-	"No, not really"
EXPRESSION #3	910	41	-	-	-	-	smile2_bmt	1	"No, not really"
Head Move	911	24	0.1	24	-	-	175deg/5deg	-	"No, not really"
Mental State	928	-	-	-	-	-	on-locutor-speech	-	-
Mental State	937	40	-	-	-	-	Thought	-	-
Mental State	951	-	-	-	-	-	expression-off	-	-
Eye Move	952	4	0.3	-	-	-	300deg	-	-
Head State	953	31	-	-	-	-	Looking Away	-	-
Eye Move	963	3	0.1	-	-	-	90deg	-	-
Head Move	967	8	0.2	8	-	-	5deg/5deg	-	-
Eye Move	968	3	0.5	-	-	-	310deg	-	-
Head Move	975	5	0.1	5	-	-	180deg/5deg	-	"...Seems unlikely that 1/12th of..."
Eye Move	975	7	0.7	-	-	-	130deg (Re-Center)	-	"...Seems unlikely that 1/12th of..."
Speech	976	133	-	-	-	-	"Seems unlikely that one 12th of the population would have the same things happening to them, at the same time..., so..."	-	-
Mental State	977	131	-	-	-	-	Understanding	-	"...Seems unlikely that 1/12th of..."
Head Move	983	12	0.1	12	-	-	180deg/5deg	-	"...Seems unlikely that 1/12th of..."
Head State	984	124	-	-	-	-	Looking At	-	"...Seems unlikely that 1/12th of..."
Head Move	995	4	0.02	4	-	-	0deg/5deg	-	"...Seems unlikely that 1/12th of..."

Head Move	999	5	0.1	5	-	-	180deg/5deg	-	"…Seems unlikely that 1/12th of…"
Head Move	1004	13	0.2	13	-	-	5deg/0deg	-	"…Seems unlikely that 1/12th of…"
Head Move	1017	3	0.1	3	-	-	90deg/0deg	-	"… the population would have the same things happening to them all the time, so…"
Head Move	1020	8	0.1	8	-	-	190deg/0deg	-	"… the population would have the same things happening to them all the time, so…"
Head Move	1028	6	0.1	6	-	-	170deg/0deg	-	"… the population would have the same things happening to them all the time, so…"
Mental State	1099	-	-	-	-	-	on-locutor-speech	-	-
Mental State	1115	28	-	-	-	-	Thought	-	-
Head State	1115	27	-	-	-	-	Looking Away	-	-
Eye Move	1115	4	0.7	-	-	-	270deg	-	-
Eye Move	1132	2	0.1	-	-	-	90deg	-	-
Head Move	1134	7	0.2	7	-	-	90deg/0deg	-	-
Eye Move	1137	5	0.7	-	-	-	90deg	-	-
Speech	1139	42	-	-	-	-	"It doesn't seem like it has much…"	-	-
Head Move	1141	4	0.1	4	-	-	270deg/5deg	-	"It doesn't seem like it has much…"
Head State	1142	99	-	-	-	-	Looking At	-	"It doesn't seem like it has much…"
Mental State	1143	54	-	-	-	-	Understanding	-	"It doesn't seem like it has much…"
Head Move	1145	4	0.1	4	-	-	100deg/5deg	-	"It doesn't seem like it has much…"
Eye Move	1145	3	0.1	-	-	-	0deg	-	"It doesn't seem like it has much…"
EXPRESSION #4	1174	156	-	-	-	-	smile3_bmt	1	"It doesn't seem like it has much…"
Head Move	1178	5	0.2	5	-	-	180deg/0deg	-	-

Head Move	1183	6	0.1	6	-	-	315deg/0deg	-	-
Head Move	1191	8	0.2	8	-	-	90deg/0deg	-	-
Mental State	1193	-	-	-	-	-	on-locutor-speech	-	-
Mental State	1197	25	-	-	-	-	Thought	-	-
Mental State	1222	46	-	-	-	-	Uncertainty	-	-
Head Move	1229	7	0.1	7	-	-	90deg/0deg	-	-
Speech	1236	17	-	-	-	-	“Being correct?”	-	-
Head Move	1236	4	0.1	4	-	-	0deg/0deg	-	“Being correct?”
Eye Move	1240	3	0.4	-	-	-	240deg	-	“Being correct?”
Head State	1241	12	-	-	-	-	Looking Away	-	“Being correct?”
Mental State	1242	-	-	-	-	-	on-locutor-speech	-	-
Head Move	1247	6	0.1	6	-	-	180deg/0deg	-	“Being correct?”
Head State	1253	133	-	-	-	-	Looking At	-	-
Eye Move	1253	2	0.2	-	-	-	30deg	-	-
Head Move	1259	5	0.1	5	-	-	45deg/0deg	-	-
Eye Move	1259	3	0.2	-	-	-	60deg	-	-
Head Move	1266	14	0.1	14	-	-	90deg/-5deg	-	-
Mental State	1268	256	-	-	-	-	Thought	-	-
Mental State	1270	-	-	-	-	-	on-locutor-speech	-	-
Mental State	1330	-	-	-	-	-	expression-off	-	-
Speech	1352	6	-	-	-	-	“Umm…”	-	-
EXPRESSION #7	1364	28	-	-	-	-	nod1_bmt	2	-
Eye Move	1385	3	0.2	-	-	-	270deg	-	-
Head State	1386	10	-	-	-	-	Looking Away	-	-
Mental State	1392	-	-	-	-	-	expression-off	-	-
Eye Move	1393	3	0.2	-	-	-	90deg	-	-

Head State	1396	252	-	-	-	-	Looking At	-	-
Head Move	1396	15	0.05	-	-	-	180deg/3deg	-	-
Mental State	1404	-	-	-	-	-	on-locutor-speech	-	-
Head State	1443	56	-	-	-	-	Stare	-	-
Head Move	1456	4	0.01	-	-	-	180deg/3deg	-	-
Head Move	1460	4	0.01	-	-	-	0deg/3deg	-	-
Head Move	1464	4	0.02	-	-	-	180deg/3deg	-	-
Head Move	1468	5	0.01	-	-	-	0deg/3deg	-	-
Head Move	1473	3	0.01	-	-	-	180deg/3deg	-	-
Head Move	1476	4	0.01	-	-	-	0deg/3deg	-	-
Head Move	1480	5	0.01	-	-	-	180deg/3deg	-	-
Head Move	1485	4	0.01	-	-	-	5deg/3deg	-	-
Head Move	1489	4	0.01	-	-	-	185deg/3deg	-	-
Head Move	1493	3	0.01	-	-	-	315deg/3deg	-	-
Head Move	1496	4	0.01	-	-	-	185deg/3deg	-	-
Head Move	1500	4	0.01	-	-	-	45deg/3deg	-	-
Head Move	1504	5	0.01	-	-	-	180deg/3deg	-	-
Head State	1509	14	-	-	-	-	Stare	-	-
Head Move	1509	3	0.01	-	-	-	0deg/3deg	-	-
Head Move	1512	5	0.05	-	-	-	180deg/3deg	-	-
Speech	1522	9	-	-	-	-	“Ok”	-	-
Mental State	1524	10	-	-	-	-	Understanding	-	“Ok”
Head Move	1527	12	0.1	-	-	-	5deg/3deg	-	“Ok”
Mental State	1533	-	-	-	-	-	on-locutor-speech	-	-
Mental State	1534	36	-	-	-	-	Thought	-	-
Head Move	1570	4	0.15	-	-	-	5deg/3deg	-	-

Mental State	1571	12	-	-	-	-	Understanding	-	"...Four"
Speech	1574	7	-	-	-	-	"Four"	-	-
Head Move	1574	6	0.1	-	-	-	185deg/3deg	-	"Four"
Head Move	1580	4	0.05	-	-	-	5deg/3deg	-	"Four"
Mental State	1583	68	-	-	-	-	Thought	-	-
Head Move	1584	7	0.05	-	-	-	155deg/3deg	-	-
Head Move	1591	4	0.02	-	-	-	355deg/3deg	-	-
Head Move	1595	13	0.05	-	-	-	185deg/3deg	-	-
Mental State	1599	-	-	-	-	-	on-locutor-speech	-	-
Head State	1615	26	-	-	-	-	Stare	-	-
Mental State	1641	51	-	-	-	-	Understanding	-	"...Fifteen"
Head Move	1641	6	0.02	-	-	-	5deg/3deg	-	"...Fifteen"
Head Move	1647	8	0.2	-	-	-	185deg/3deg	-	"Fifteen"
Eye Move	1647	2	0.2	-	-	-	260deg	-	"Fifteen"
Head State	1648	5	-	-	-	-	Looking Away	-	"Fifteen"
Speech	1649	13	-	-	-	-	"Fifteen"	-	-
Eye Move	1651	3	0.2	-	-	-	80deg	-	"Fifteen"
Head State	1653	70	-	-	-	-	Looking At	-	"Fifteen"
Head Move	1657	11	0.15	-	-	-	35deg/3deg	-	"Fifteen"
Mental State	1675	-	-	-	-	-	on-locutor-speech	-	-
Mental State	1692	31	-	-	-	-	Thought	-	-
Head State	1692	31	-	-	-	-	Stare	-	-
Head State	1723	10	-	-	-	-	Looking Away	-	"...One"
Mental State	1723	40	-	-	-	-	Understanding	-	"...One"
Head Move	1723	4	0.1	-	-	-	0deg/3deg	-	"...One"
Speech	1727	13	-	-	-	-	"One"	-	-

Head Move	1727	4	0.2	-	-	-	185deg/3deg	-	"One"
Head Move	1731	14	0.5	-	-	-	35deg/5deg	-	"One"
Head State	1733	55	-	-	-	-	Looking At	-	"One"
Head Move	1745	13	0.03	-	-	-	180deg/5deg	-	-
Mental State	1749	-	-	-	-	-	on-locutor-speech	-	-
Head Move	1761	7	0.01	-	-	-	180deg/5deg	-	-
Mental State	1763	25	-	-	-	-	Thought	-	-
Head State	1763	25	-	-	-	-	Stare	-	-
Eye Move	1787	3	0.3	-	-	-	260deg	-	-
Mental State	1788	28	-	-	-	-	Uncertainty	-	-
Head State	1788	27	-	-	-	-	Looking Away	-	-
Eye Move	1794	4	0.2	-	-	-	260deg	-	-
EXPRESSION #5	1797	166	-	-	-	-	smile4_bmt	-	-
Eye Move	1801	2	0.3	-	-	-	10deg	-	-
Head Move	1806	7	0.3	-	-	-	260deg/5deg	-	"...Cant answer that. Don't know what a and b are"
Speech	1808	35	-	-	-	-	"Can't answer that. I don't know what a and b are"	-	-
Eye Move	1813	3	0.3	-	-	-	90deg	-	"Cant answer that. Don't know what a and b are"
Head Move	1813	3	0.1	-	-	-	95deg/5deg	-	"Cant answer that. Don't know what a and b are"
Head State	1815	368	-	-	-	-	Looking At	-	"Cant answer that. Don't know what a and b are"
Mental State	1816	90	-	-	-	-	Understanding	-	"Cant answer that. Don't know what a and b are"
Head Move	1816	3	0.02	-	-	-	0deg/5deg	-	"Cant answer that. Don't know what a and b are"
Head Move	1819	3	0.05	-	-	-	100deg/5deg	-	"Cant answer that. Don't know what a and

									b are”
Head Move	1822	4	0.05	-	-	-	180deg/5deg	-	“Cant answer that. Don’t know what a and b are”
Head Move	1826	7	0.2	-	-	-	10deg/3deg	-	“Cant answer that. Don’t know what a and b are”
Head Move	1833	5	0.05	-	-	-	210deg/4deg	-	“Cant answer that. Don’t know what a and b are”
Head Move	1838	2	0.02	-	-	-	95deg/4deg	-	“Cant answer that. Don’t know what a and b are”
Head Move	1840	8	0.1	-	-	-	175deg/4deg	-	“Cant answer that. Don’t know what a and b are”
Head Move	1851	3	0.02	-	-	-	185deg/4deg	-	-
Head Move	1854	2	0.05	-	-	-	280deg/4deg	-	-
Head Move	1856	3	0.05	-	-	-	235deg/4deg	-	-
Head Move	1859	3	0.05	-	-	-	5deg/4deg	-	-
Head Move	1862	5	0.1	-	-	-	155deg/4deg	-	-
Head Move	1867	4	0.05	-	-	-	325deg/4deg	-	-
Head Move	1871	5	0.02	-	-	-	180deg/4deg	-	-
Head Move	1876	2	0.02	-	-	-	45deg/4deg	-	-
Mental State	1877	-	-	-	-	-	on-locutor-speech	-	-
Head Move	1878	6	0.02	-	-	-	315deg/4deg	-	-
Mental State	1906	108	-	-	-	-	Thought	-	-
Head State	1937	72	-	-	-	-	Stare	-	-
Mental State	1942	-	-	-	-	-	on-locutor-speech	-	-
Mental State	1963	-	-	-	-	-	expression-off	-	-
Eye Move	1999	4	0.4	-	-	-	10deg	-	-
Head Move	2006	8	0.2	-	-	-	5deg/3deg	-	-
Eye Move	2012	3	0.4	-	-	-	190deg	-	-

Mental State	2014	59	-	-	-	-	Misunderstanding	-	"...Did I experience any joy did you say?"
Head Move	2014	6	0.3	-	-	-	300deg/2deg	-	"...Did I experience any joy did you say?"
Speech	2015	41	-	-	-	-	"Did I experience any joy did you say?"	-	-
Head Move	2020	5	0.15	-	-	-	260deg/1deg	-	"Did I experience any joy did you say?"
Head Move	2027	15	0.8	-	-	-	180deg/1deg	-	"Did I experience any joy did you say?"
Head Move	2043	15	0.15	-	-	-	5deg/1deg	-	"Did I experience any joy did you say?"
Mental State	2073	79	-	-	-	-	Thought	-	-
Mental State	2078	-	-	-	-	-	on-locutor-speech	-	-
Head Move	2080	4	0.01	-	-	-	0deg/1deg	-	-
Head Move	2084	4	0.01	-	-	-	180deg/1deg	-	-
Head Move	2088	4	0.01	-	-	-	0deg/1deg	-	-
Head Move	2092	4	0.02	-	-	-	180deg/1deg	-	-
Head State	2094	58	-	-	-	-	Stare	-	-
Head Move	2096	6	0.01	-	-	-	355deg/1deg	-	-
Head Move	2147	8	0.1	-	-	-	0deg/1deg	-	"...The enjoy? I can't make sense of your sentence!"
Speech	2148	64	-	-	-	-	"The enjoy? I can't make sense of your sentence!"	-	-
Mental State	2152	67	-	-	-	-	Misunderstanding	-	"The enjoy? I can't make sense of your sentence!"
Head Move	2155	11	0.15	-	-	-	0deg/1deg	-	"The enjoy? I can't make sense of your sentence!"
Head Move	2166	4	0.25	-	-	-	340deg/0deg	-	"The enjoy? I can't make sense of your sentence!"
Head Move	2170	4	0.05	-	-	-	180deg/0deg	-	"The enjoy? I can't make sense of your sentence!"

Head Move	2174	5	0.1	-	-	-	90deg/0deg	-	“The enjoy? I can’t make sense of your sentence!”
Eye Move	2175	3	0.2	-	-	-	260deg	-	“The enjoy? I can’t make sense of your sentence!”
Head Move	2179	3	0.02	-	-	-	0deg/0deg	-	“The enjoy? I can’t make sense of your sentence!”
Eye Move	2181	2	0.4	-	-	-	315deg	-	“The enjoy? I can’t make sense of your sentence!”
Head Move	2182	5	0.3	-	-	-	185deg/0deg	-	“The enjoy? I can’t make sense of your sentence!”
Head State	2183	18	-	-	-	-	Looking Away	-	“The enjoy? I can’t make sense of your sentence!”
Head Move	2187	3	0.05	-	-	-	355deg/0deg	-	“The enjoy? I can’t make sense of your sentence!”
Head Move	2190	4	0.4	-	-	-	175deg/0deg	-	“The enjoy? I can’t make sense of your sentence!”
Eye Move	2191	11	0.7	-	-	-	120deg	-	“The enjoy? I can’t make sense of your sentence!”
Head Move	2195	5	0.25	-	-	-	325deg/-1deg	-	“The enjoy? I can’t make sense of your sentence!”
Head Move	2200	10	0.25	-	-	-	45deg/-1deg	-	“The enjoy? I can’t make sense of your sentence!”
Head State	2201	43	-	-	-	-	Looking At	-	“The enjoy? I can’t make sense of your sentence!”
Head Move	2210	7	0.2	-	-	-	225deg/-1deg	-	“The enjoy? I can’t make sense of your sentence!”
Head Move	2217	8	0.1	-	-	-	125deg/-1deg	-	-
Mental State	2219	12	-	-	-	-	Thought	-	-
Mental State	2250	-	-	-	-	-	on-locutor-speech	-	-
Head Move	2271	5	0.01	-	-	-	180deg/-1deg	-	-
Head Move	2276	4	0.01	-	-	-	0deg/-1deg	-	-

Head Move	2280	4	0.01	-	-	-	180deg/-1deg	-	-
Head Move	2284	5	0.01	-	-	-	0deg/-1deg	-	-
Head Move	2289	4	0.01	-	-	-	180deg/-1deg	-	-
Mental State	2294	23	-	-	-	-	Understanding	-	"...Yes"
Head Move	2293	6	0.4	-	-	-	0deg/0deg	-	"...Yes"
Speech	2296	7	-	-	-	-	"Yes"	-	-
Head Move	2299	2	0.02	-	-	-	180deg/0deg	-	"Yes"
Head Move	2302	4	0.2	-	-	-	0deg/0deg	-	"Yes"
Head Move	2306	5	0.1	-	-	-	180deg/0deg	-	-
Head Move	2312	5	0.1	-	-	-	215deg/0deg	-	-
Mental State	2317	-	-	-	-	-	on-locutor-speech	-	-
Mental State	2317	27	-	-	-	-	Thought	-	-
Head Move	2324	5	0.1	-	-	-	200deg/0deg	-	-
EXPRESSION #6	2326	118	-	-	-	-	smile5_bmt	-	-
Mental State	2329	115	-	-	-	-	Understanding	-	-
Head Move	2336	5	0.05	-	-	-	160deg/0deg	-	-
Head Move	2356	4	0.05	-	-	-	340deg/0deg	-	-
Head Move	2360	4	0.1	-	-	-	180deg/0deg	-	-
Mental State	2367	-	-	-	-	-	on-locutor-speech	-	-
EXPRESSION #7	2442	14	-	-	-	-	neutral	-	-
Mental State	2444	-	-	-	-	-	expression-off	-	-
Mental State	2456	-	-	-	-	-	expression-off	-	-

IV. Encoding of 'LightHead' Facial Expression Behaviours

a. Facial Expression Pseudo Translations

Type	Onset	Dura-tion	Intensi-ty	Attack	Sustain	Decay	Description	No. Of events	Start/end words
EXPRESSION #1	602	89	-	-	-	-	Raised Brows	1	-
Facial Expression	-	13	1.0	9	4	0	-	-	"Probably Sagittari-an as well, I sup-pose"
Facial Expression	-	13	1.0	11	2	0	-	-	"Probably Sagittari-an as well, I sup-pose"
Facial Expression	-	46	1.0	42	4	0	-	-	"Probably Sagittari-an as well, I sup-pose"
Facial Expression	-	17	1.0	17	0	0	-	-	"Probably Sagittari-an as well, I sup-pose"
EXPRESSION #2	691	159	-	-	-	-	Smile 1	1	-
Facial Expression	691	16	1.0	16	0	0	Lips together (Attack Pt 1)	-	-
Facial Expression	712	143	1.0	17	77	49	Lips open	-	-
EXPRESSION #3	910	41	-	-	-	-	Smile 2	1	-
Facial Expression	-	-	1.0	7	11		Lips Open	-	-
EXPRESSION #4	1174	156	-	-	-	-	Smile 3	1	"It doesn't seem like it has much..."
Facial Expression	1174	16	1.0	9	7	0	Lips open	-	"It doesn't seem like it has much..."
Facial Expression	1190	19	1.0	7	12	0	Lips open	-	-
Facial Expression	1209	16	1.0	9	7	0	Lips closed	-	-
Facial Expression	1189	105	1.0	10	73	22	Lips open	-	-

EXPRESSION #5	5169	166	-	-	-	-	Smile 4	1	-
Facial Expression	5169	166	1.0	26	116	24	Lips open	-	-

EXPRESSION #6	5612	205	-	-	-	-	Smile 5	1	-
Facial Expression	5612	90	1.0	5	85	-	Lips open	-	-
Facial Expression	5702	115	1.0	9	64	42	Lips open	-	-

EXPRESSION #7			-	-	-	-	Nod1	1	-
Head Move		3	1.0	-	-	-	0deg/0deg	-	-
Head Move		6	1.0	-	-	-	180deg/0deg	-	-
Head Move		3	1.0	-	-	-	0deg/0deg	-	-

b. Pseudo Translation Script for LightHead Communicative Performance

Mental State, 0, 32, -, -, -, -, Thought, -, -

Head State, 0, 413, -, -, -, -, "Looking At" - Listening Model, -, -

Mental State, 32, 38, -, -, -, -, Understanding, -, -

Head Move, 48, 7, 0.2, -, -, -, 0deg/0deg, -, "...I'm Phil"

Head Move, 55, 8, 0.2, -, -, -, 180deg/0deg, -, "I'm Phil"

Speech, 51, 12, -, -, -, -, "I’m Phil", -, -

Mental State, 69, 264, -, -, -, -, Thought, -, -

Head Move, 162, 7, .1, -, -, -, 0deg/0deg, -, -

Head Move, 169, 7, .1, -, -, -, 180deg/0deg, -, -

Head Move, 176, 7, .1, -, -, -, 0deg/0deg, -, -

Head Move, 183, 7, .1, -, -, -, 180deg/0deg, -, -

Head Move, 190, 7, .1, -, -, -, 0deg/0deg, -, -

Head Move, 197, 7, .1, -, -, -, 180deg/0deg, -, -

Head Move, 204, 7, .1, -, -, -, 0deg/0deg, -, -

Head Move, 211, 7, .1, -, -, -, 180deg/0deg, -, -

Head Move, 218, 7, .1, -, -, -, 0deg/0deg, -, -

Head Move, 225, 7, .1, -, -, -, 180deg/0deg, -, -

Head Move, 232, 7, .1, -, -, -, 0deg/0deg, -, -

Head Move, 239, 7, .1, -, -, -, 180deg/0deg, -, -

Head Move, 246, 7, .1, -, -, -, 0deg/0deg, -, -

Head Move, 253, 7, .1, -, -, -, 180deg/0deg, -, -

Head Move, 260, 7, .1, -, -, -, 0deg/0deg, -, -

Head Move, 267, 7, .1, -, -, -, 180deg/0deg, -, -

Head Move, 274, 7, .1, -, -, -, 0deg/0deg, -, -

Head Move, 281, 7, .1, -, -, -, 180deg/0deg, -, -

Head Move, 288, 7, .1, -, -, -, 0deg/0deg, -, -

Head Move, 295, 7, .1, -, -, -, 180deg/0deg, -, -

Head Move, 302, 7, .1, -, -, -, 0deg/0deg, -, -

Head Move, 309, 7, .1, -, -, -, 180deg/0deg, -, -

Mental State, 333, 26, -, -, -, -, Understanding, -, -

Head Move, 334, 4, 0.2, -, -, -, 0deg/0deg, -, " November "

Speech, 336, 23, -, -, -, -, "November", -, -

Head Move, 338, 7, 0.2, -, -, -, 180deg/0deg, -, "November "

Mental State, 359, 74, -, -, -, -, Thought, -, -

Head State, 413, 24, -, -, -, -, Looking Away, -, -

Eye Move, 413, 4, .3, -, -, -, 270deg, -, -

Eye Move, 419, 2, .05, -, -, -, 300deg, -, -

Head Move, 422, 11, 0.1, -, -, -, 0deg/0deg, -, " I’m a Sagittarius"

Eye Move, 423, 3, .25, -, -, -, 320deg, -, " I’m a Sagittarius"

Speech, 426, 29, -, -, -, -, "I’m a Sagittarius", -, -

Eye Move, 431, 6, .6, -, -, -, 100deg (Re-Center), -, "I’m a Sagittarius"

Mental State, 433, 27, -, -, -, -, Understanding, -, -

Head Move, 433, 6, 0.2, -, -, -, 180deg/0deg, -, " I’m a Sagittarius"

Head State, 437, 158, -, -, -, -, "Looking At" – Listening Model, -, " I’m a Sagittarius"

Head Move, 446, 10, 0.2, -, -, -, 0deg/0deg, -, " I’m a Sagittarius"

Head Move, 456, 5, 0.05, -, -, -, 180deg/0deg, -, -

Mental State, 460, 149, -, -, -, -, Thought, -, -

Head Move, 464, 17, 0.05, -, -, -, 180deg/0deg, -, -

Head State, 595, 17, -, -, -, -, Looking Away, -, -

Eye Move, 595, 2, 0.4, -, -, -, 300deg, -, -

Eye Move, 597, 2, 0.1, -, -, -, 270deg, -, -

Eye Move, 602, 3, 0.4, -, -, -, 300deg, -, -

EXPRESSION #1, 602, 89, -, -, -, -, rb_bmt, 1, "Probably Sagittarian as well, I suppose"

Head Move, 602, 5, 0.2, -, -, -, 270deg/0deg, -, -

Speech, 607, 40, -, -, -, -, "Probably Sagittarian as well, I suppose", -, -

Head Move, 608, 7, 0.3, -, -, -, 80deg/0deg, -, "Probably Sagittarian as well, I suppose"

Mental State, 609, 48, -, -, -, -, Uncertainty, -, -

Eye Move, 609, 3, 0.9, -, -, -, 110deg, -, "Probably Sagittarian as well, I suppose"

Head State, 612, 180, -, -, -, -, "Looking At" – Listening Model, -, "Probably Sagittarian as well, I suppose"

Head Move, 616, 11, 0.5, -, -, -, 270deg/10deg, -, "Probably Sagittarian as well, I suppose"

Head Move, 627, 4, 0.1, -, -, -, 100deg/0deg, -, "Probably Sagittarian as well, I suppose"

Head Move, 633, 12, 0.3, -, -, -, 110deg/0deg, -, "Probably Sagittarian as well, I suppose"

Mental State, 657, 57, -, -, -, -, Thought, -, -

EXPRESSION #2, 691, 159, -, -, -, -, smile1_bmt, 1, -

Mental State, 714, 90, -, -, -, -, Understanding, -, -

Speech, 728, 16, -, -, -, -, "Right, Ok", -, -

Head Move, 731, 8, 0.5, -, -, -, 20deg/5deg, -, "Right, Ok"

Head Move, 736, 8, 0.5, -, -, -, 180deg/5deg, -, "Right, Ok"

Head Move, 745, 8, 0.1, -, -, -, 200deg/5deg, -, -

Head Move, 765, 6, 0.2, -, -, -, 355deg/5deg, -, -

Head Move, 771, 5, 0.1, -, -, -, 185deg/0deg, -, -

Head Move, 780, 5, 0.1, -, -, -, 175deg/0deg, -, -

Head State, 791, 30, -, -, -, -, Stare – Eyes straight ahead, not moving. Switch off listening model., -, -

Mental State, 804, 96, -, -, -, -, Thought, -, -

Head State, 821, 64, -, -, -, -, "Looking At" – Listening Model, -, -

Eye Move, 876, 3, 0.15, -, -, -, 160deg, -, -

Head State, 884, 22, -, -, -, -, Looking Away, -, -

Eye Move, 884, 5, 0.3, -, -, -, 270deg, -, -

Eye Move, 891, 3, 0.2, -, -, -, 10deg, -, -

Head Move, 891, 10, 0.3, -, -, -, 300deg/10deg, -, -

Speech, 894, 25, -, -, -, -, "No, not really", -, -

Eye Move, 897, 5, 0.3, -, -, -, 140deg, -, "No, not really"

Mental State, 900, 37, -, -, -, -, Understanding, -, "No, not really"

Head Move, 901, 5, 0.1, -, -, -, 120deg/10deg, -, "No, not really"

Head State, 906, 48, -, -, -, -, "Looking At" – Listening Model, -, "No, not really"

EXPRESSION #3, 910, 41, -, -, -, -, smile2_bmt, 1, "No, not really"

Head Move, 911, 24, 0.1, -, -, -, 175deg/5deg, -, "No, not really"

Mental State, 937, 40, -, -, -, -, Thought, -, -

Eye Move, 952, 4, 0.3, -, -, -, 300deg, -, -

Head State, 953, 31, -, -, -, -, Looking Away, -, -

Eye Move, 963, 3, 0.1, -, -, -, 90deg, -, -

Head Move, 967, 8, 0.2, -, -, -, 5deg/5deg, -, -

Eye Move, 968, 3, 0.5, -, -, -, 310deg, -, -

Head Move, 975, 5, 0.1, -, -, -, 180deg/5deg, -, " Seems unlikely that 1/12th of "

Eye Move, 975, 7, 0.7, -, -, -, 130deg (Re-Center), -, " Seems unlikely that 1/12th of "

Speech, 976, 133, -, -, -, -, "Seems unlikely that 1/12th of the population would have the same things happening to them all the time, so ", -, -

Mental State, 977, 131, -, -, -, -, Understanding, -, " Seems unlikely that 1/12th of "

Head Move, 983, 12, 0.1, -, -, -, 180deg/5deg, -, " Seems unlikely that 1/12th of "

Head State, 984, 124, -, -, -, -, "Looking At" – Listening Model, -, " Seems unlikely that 1/12th of "

Head Move, 995, 4, 0.02, -, -, -, 0deg/5deg, -, " Seems unlikely that 1/12th of "

Head Move, 999, 5, 0.1, -, -, -, 180deg/5deg, -, " Seems unlikely that 1/12th of "

Head Move, 1004, 13, 0.2, -, -, -, 5deg/0deg, -, " Seems unlikely that 1/12th of "

Head Move, 1017, 3, 0.1, -, -, -, 90deg/0deg, -, " the population would have the same things happening to them all the time, so "

Head Move, 1020, 8, 0.1, -, -, -, 190deg/0deg, -, " the population would have the same things happening to them all the time, so "

Head Move, 1028, 6, 0.1, -, -, -, 170deg/0deg, -, " the population would have the same things happening to them all the time, so "

Mental State, 1115, 28, -, -, -, -, Thought, -, -

Head State, 1115, 27, -, -, -, -, Looking Away, -, -

Eye Move, 1115, 4, 0.7, -, -, -, 270deg, -, -

Eye Move, 1132, 2, 0.1, -, -, -, 90deg, -, -

Head Move, 1134, 7, 0.2, 7, -, -, 90deg/0deg, -, -

Eye Move, 1137, 5, 0.7, -, -, -, 90deg, -, -

Speech, 1139, 42, -, -, -, -, "It doesn’t seem like it has much ", -, -

Head Move, 1141, 4, 0.1, -, -, -, 270deg/5deg, -, "It doesn’t seem like it has much "

Head State, 1142, 99, -, -, -, -, "Looking At" – Listening Model, -, "It doesn’t seem like it has much "

Mental State, 1143, 54, -, -, -, -, Understanding, -, "It doesn’t seem like it has much "

Head Move, 1145, 4, 0.1, -, -, -, 100deg/5deg, -, "It -doesn’t seem like it has much "

Eye Move, 1145, 3, 0.1, -, -, -, 0deg, -, "It doesn’t seem like it has much "

EXPRESSION #4, 1174, 156, -, -, -, -, smile3_bmt, 1, "It doesn’t seem like it has much "

Head Move, 1178, 5, 0.2, -, -, -, 180deg/0deg, -, -

Head Move, 1183, 6, 0.1, -, -, -, 315deg/0deg, -, -

Head Move, 1191, 8, 0.2, -, -, -, 90deg/0deg, -, -

Mental State, 1197, 25, -, -, -, -, Thought, -, -

Mental State, 1222, 46, -, -, -, -, Uncertainty, -, -

Head Move, 1229, 7, 0.1, -, -, -, 90deg/0deg, -, -

Speech, 1236, 17, -, -, -, -, "Being correct?", -, -

Head Move, 1236, 4, 0.1, -, -, -, 0deg/0deg, -, "Being correct?"

Eye Move, 1240, 3, 0.4, -, -, -, 240deg, -, "Being correct?"

Head State, 1241, 12, -, -, -, -, Looking Away, -, "Being correct?"

Head Move, 1247, 6, 0.1, -, -, -, 180deg/0deg, -, "Being correct?"

Head State, 1253, 133, -, -, -, -, "Looking At" – Listening Model, -, -

Eye Move, 1253, 2, 0.2, -, -, -, 30deg, -, -

Head Move, 1259, 5, 0.1, -, -, -, 45deg/0deg, -, -

Eye Move, 1259, 3, 0.2, -, -, -, 60deg, -, -

Head Move, 1266, 14, 0.1, -, -, -, 90deg/355deg, -, -

Mental State, 1268, 232, -, -, -, -, Thought, -, -

Speech, 1352, 6, -, -, -, -, "Hmm ", -, -

Head Move, 1354, 4, .1, -, -, -, 0deg/0deg, -, -

Head Move, 1368, 4, .1, -, -, -, 180deg/0deg, -, -

Head Move, 1372, 4, .1, -, -, -, 0deg/0deg, -, -

Head Move, 1376, 4, .1, -, -, -, 180deg/0deg, -, -

Head Move, 1380, 4, .1, -, -, -, 0deg/0deg, -, -

Head Move, 1384, 4, .1, -, -, -, 180deg/0deg, -, -

Eye Move, 1385, 3, 0.2, -, -, -, 270deg/0deg, -, -

Head State, 1386, 10, -, -, -, -, Looking Away, -, -

Eye Move, 1393, 3, 0.2, -, -, -, 90deg, -, -

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SECTION 2, , , , , , , , ,

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Head State, 4768, 252, -, -, -, -, "Looking At" – Listening Model, -, -

Head State, 4815, 56, -, -, -, -, Stare – Eyes straight ahead, not moving. Switch off listening model., -, -

Head Move, 4828, 4, 0.01, -, -, -, 180deg/3deg, -, -

Head Move, 4832, 4, 0.01, -, -, -, 0deg/3deg, -, -

Head Move, 4836, 4, 0.02, -, -, -, 180deg/3deg, -, -

Head Move, 4840, 5, 0.01, -, -, -, 0deg/3deg, -, -

Head Move, 4845, 3, 0.01, -, -, -, 180deg/3deg, -, -

Head Move, 4848, 4, 0.01, -, -, -, 0deg/3deg, -, -

Head Move, 4852, 5, 0.01, -, -, -, 180deg/3deg, -, -

Head Move, 4857, 4, 0.01, -, -, -, 5deg/3deg, -, -

Head Move, 4861, 4, 0.01, -, -, -, 185deg/3deg, -, -

Head Move, 4865, 3, 0.01, -, -, -, 315deg/3deg, -, -

Head Move, 4868, 4, 0.01, -, -, -, 185deg/3deg, -, -

Head Move, 4872, 4, 0.01, -, -, -, 45deg/3deg, -, -

Head Move, 4876, 5, 0.01, -, -, -, 180deg/3deg, -, -

Head State, 4881, 14, -, -, -, -, Stare – Eyes straight ahead, not moving. Switch off listening model., -, -

Head Move, 4881, 3, 0.01, -, -, -, 0deg/3deg, -, -

Head Move, 4884, 5, 0.05, -, -, -, 180deg/3deg, -, -

Speech, 4894, 9, -, -, -, -, "Ok", -, -

Mental State, 4896, 10, -, -, -, -, Understanding, -, "Ok"

Head Move, 4899, 12, 0.1, -, -, -, 5deg/3deg, -, "Ok"

Mental State, 4906, 36, -, -, -, -, Thought, -, -

Head Move, 4942, 4, 0.15, -, -, -, 5deg/3deg, -, -

Mental State, 4943, 12, -, -, -, -, Understanding, -, " Four"

Speech, 4946, 7, -, -, -, -, "Four", -, -

Head Move, 4946, 6, 0.1, -, -, -, 185deg/3deg, -, "Four"

Head Move, 4952, 4, 0.05, -, -, -, 5deg/3deg, -, "Four"

Mental State, 4955, 68, -, -, -, -, Thought, -, -

Head Move, 4956, 7, 0.05, -, -, -, 155deg/3deg, -, -

Head Move, 4963, 4, 0.02, -, -, -, 355deg/3deg, -, -

Head Move, 4967, 13, 0.05, -, -, -, 185deg/3deg, -, -

Head State, 4987, 26, -, -, -, -, Stare – Eyes straight ahead, not moving. Switch off listening model., -, -

Mental State, 5013, 51, -, -, -, -, Understanding, -, " Fifteen"

Head Move, 5013, 6, 0.02, -, -, -, 5deg/3deg, -, " Fifteen"

Head Move, 5019, 8, 0.2, -, -, -, 185deg/3deg, -, "Fifteen"

Eye Move, 5019, 2, 0.2, -, -, -, 260deg, -, "Fifteen"

Head State, 5020, 5, -, -, -, -, Looking Away, -, "Fifteen"

Speech, 5021, 13, -, -, -, -, "Fifteen", -, -

Eye Move, 5023, 3, 0.2, -, -, -, 80deg, -, "Fifteen"

Head State, 5025, 70, -, -, -, -, "Looking At" – Listening Model, -, "Fifteen"

Head Move, 5029, 11, 0.15, -, -, -, 35deg/3deg, -, "Fifteen"

Mental State, 5064, 31, -, -, -, -, Thought, -, -

Head State, 5064, 31, -, -, -, -, Stare – Eyes straight ahead, not moving. Switch off listening model., -, -

Head State, 5095, 10, -, -, -, -, Looking Away, -, " One"

Mental State, 5095, 40, -, -, -, -, Understanding, -, " One"

Head Move, 5095, 4, 0.1, -, -, -, 0deg/3deg, -, " One"

Speech, 5099, 13, -, -, -, -, "One", -, -

Head Move, 5099, 4, 0.2, -, -, -, 185deg/3deg, -, "One"

Head Move, 5103, 14, 0.5, -, -, -, 35deg/5deg, -, "One"

Head State, 5105, 55, -, -, -, -, "Looking At" – Listening Model, -, "One"

Head Move, 5117, 13, 0.03, -, -, -, 180deg/5deg, -, -

Head Move, 5133, 7, 0.01, -, -, -, 180deg/5deg, -, -

Mental State, 5135, 25, -, -, -, -, Thought, -, -

Head State, 5135, 25, -, -, -, -, Stare – Eyes straight ahead, not moving. Switch off listening model., -, -

Eye Move, 5159, 3, 0.3, -, -, -, 260deg, -, -

Mental State, 5160, 28, -, -, -, -, Uncertainty, -, -

Head State, 5160, 27, -, -, -, -, Looking Away, -, -

Eye Move, 5166, 4, 0.2, -, -, -, 260deg, -, -

EXPRESSION #5, 5169, 166, -, -, -, -, smile4_bmt, -, -

Eye Move, 5173, 2, 0.3, -, -, -, 10deg, -, -

Head Move, 5178, 7, 0.3, -, -, -, 260deg/5deg, -, " Cant answer that. Don’t know what a and b are"

Speech, 5180, 35, -, -, -, -, "Cant answer that. Don’t know what a and b are", -, -

Eye Move, 5185, 3, 0.3, -, -, -, 90deg, -, "Cant answer that. Don’t know what a and b are"

Head Move, 5185, 3, 0.1, -, -, -, 95deg/5deg, -, "Cant answer that. Don’t know what a

and b are"

Head State, 5187, 368, -, -, -, -, "Looking At" – Listening Model, -, "Cant answer that. Don’t know what a and b are"

Mental State, 5188, 90, -, -, -, -, Understanding, -, "Cant answer that. Don’t know what a and b are"

Head Move, 5188, 3, 0.02, -, -, -, 0deg/5deg, -, "Cant answer that. Don’t know what a and b are"

Head Move, 5191, 3, 0.05, -, -, -, 100deg/5deg, -, "Cant answer that. Don’t know what a and b are"

Head Move, 5194, 4, 0.05, -, -, -, 180deg/5deg, -, "Cant answer that. Don’t know what a and b are"

Head Move, 5198, 7, 0.2, -, -, -, 10deg/3deg, -, "Cant answer that. Don’t know what a and b are"

Head Move, 5205, 5, 0.05, -, -, -, 210deg/4deg, -, "Cant answer that. Don’t know what a and b are"

Head Move, 5210, 2, 0.02, -, -, -, 95deg/4deg, -, "Cant answer that. Don’t know what a and b are"

Head Move, 5212, 8, 0.1, -, -, -, 175deg/4deg, -, "Cant answer that. Don’t know what a and b are"

Head Move, 5223, 3, 0.02, -, -, -, 185deg/4deg, -, -

Head Move, 5226, 2, 0.05, -, -, -, 280deg/4deg, -, -

Head Move, 5228, 3, 0.05, -, -, -, 235deg/4deg, -, -

Head Move, 5231, 3, 0.05, -, -, -, 5deg/4deg, -, -

Head Move, 5234, 5, 0.1, -, -, -, 155deg/4deg, -, -

Head Move, 5239, 4, 0.05, -, -, -, 325deg/4deg, -, -

Head Move, 5243, 5, 0.02, -, -, -, 180deg/4deg, -, -

Head Move, 5248, 2, 0.02, -, -, -, 45deg/4deg, -, -

Head Move, 5250, 6, 0.02, -, -, -, 315deg/4deg, -, -

Mental State, 5278, 108, -, -, -, -, Thought, -, -

Head State, 5309, 72, -, -, -, -, Stare – Eyes straight ahead, not moving. Switch off listening model., -, -

Eye Move, 5371, 4, 0.4, -, -, -, 10deg, -, -

Head Move, 5378, 8, 0.2, -, -, -, 5deg/3deg, -, -

Eye Move, 5384, 3, 0.4, -, -, -, 190deg, -, -

Mental State, 5386, 59, -, -, -, -, Misunderstanding, -, " Did I experience any joy did you say?"

Head Move, 5386, 6, 0.3, -, -, -, 300deg/2deg, -, " Did I experience any joy did you say?"

Speech, 5387, 41, -, -, -, -, "Did I experience any joy did you say?", -, -

Head Move, 5392, 5, 0.15, -, -, -, 260deg/1deg, -, "Did I experience any joy did you say?"

Head Move, 5399, 15, 0.8, -, -, -, 180deg/1deg, -, "Did I experience any joy did you say?"

Head Move, 5415, 15, 0.15, -, -, -, 5deg/1deg, -, "Did I experience any joy did you say?"

Mental State, 5445, 79, -, -, -, -, Thought, -, -

Head Move, 5452, 4, 0.01, -, -, -, 0deg/1deg, -, -

Head Move, 5456, 4, 0.01, -, -, -, 180deg/1deg, -, -

Head Move, 5460, 4, 0.01, -, -, -, 0deg/1deg, -, -

Head Move, 5464, 4, 0.02, -, -, -, 180deg/1deg, -, -

Head State, 5466, 58, -, -, -, -, Stare – Eyes straight ahead, not moving. Switch off listening model., -, -

Head Move, 5468, 6, 0.01, -, -, -, 355deg/1deg, -, -

Head Move, 5519, 8, 0.1, -, -, -, 0deg/1deg, -, " The enjoy? I can’t make sense of your sentence!"

Speech, 5520, 64, -, -, -, -, "The enjoy? I can’t make sense of your sentence!", -, -

Mental State, 5524, 67, -, -, -, -, Misunderstanding, -, "The enjoy? I can’t make sense of your sentence!"

Head Move, 5527, 11, 0.15, -, -, -, 0deg/1deg, -, "The enjoy? I can’t make sense of your sentence!"

Head Move, 5538, 4, 0.25, -, -, -, 340deg/0deg, -, "The enjoy? I can’t make sense of your sentence!"

Head Move, 5542, 4, 0.05, -, -, -, 180deg/0deg, -, "The enjoy? I can’t make sense of your sentence!"

Head Move, 5546, 5, 0.1, -, -, -, 90deg/0deg, -, "The enjoy? I can’t make sense of your

sentence!"

Eye Move, 5547, 3, 0.2, -, -, -, 260deg, -, "The enjoy? I can’t make sense of your sentence!"

Head Move, 5551, 3, 0.02, -, -, -, 0deg/0deg, -, "The enjoy? I can’t make sense of your sentence!"

Eye Move, 5553, 2, 0.4, -, -, -, 315deg, -, "The enjoy? I can’t make sense of your sentence!"

Head Move, 5554, 5, 0.3, -, -, -, 185deg/0deg, -, "The enjoy? I can’t make sense of your sentence!"

Head State, 5555, 18, -, -, -, -, Looking Away, -, "The enjoy? I can’t make sense of your sentence!"

Head Move, 5559, 3, 0.05, -, -, -, 355deg/0deg, -, "The enjoy? I can’t make sense of your sentence!"

Head Move, 5562, 4, 0.4, -, -, -, 175deg/0deg, -, "The enjoy? I can’t make sense of your sentence!"

Eye Move, 5563, 11, 0.7, -, -, -, 120deg, -, "The enjoy? I can’t make sense of your sentence!"

Head Move, 5567, 5, 0.25, -, -, -, 325deg/359deg, -, "The enjoy? I can’t make sense of your sentence!"

Head Move, 5572, 10, 0.25, -, -, -, 45deg/359deg, -, "The enjoy? I can’t make sense of your sentence!"

Head State, 5573, 43, -, -, -, -, "Looking At" – Listening Model, -, "The enjoy? I can’t make sense of your sentence!"

Head Move, 5582, 7, 0.2, -, -, -, 225deg/359deg, -, "The enjoy? I can’t make sense of your sentence!"

Head Move, 5589, 8, 0.1, -, -, -, 125deg/359deg, -, -

Mental State, 5591, 12, -, -, -, -, Thought, -, -

Head Move, 5643, 5, 0.01, -, -, -, 180deg/359deg, -, -

Head Move, 5648, 4, 0.01, -, -, -, 0deg/359deg, -, -

Head Move, 5652, 4, 0.01, -, -, -, 180deg/359deg, -, -

Head Move, 5656, 5, 0.01, -, -, -, 0deg/359deg, -, -

Head Move, 5661, 4, 0.01, -, -, -, 180deg/359deg, -, -

Mental State, 5666, 23, -, -, -, -, Understanding, -, " Yes"

Head Move, 5665, 6, 0.4, -, -, -, 0deg/0deg, -, " Yes"

Speech, 5668, 7, -, -, -, -, "Yes", -, -

Head Move, 5671, 2, 0.02, -, -, -, 180deg/0deg, -, "Yes"

Head Move, 5674, 4, 0.2, -, -, -, 0deg/0deg, -, "Yes"

Head Move, 5678, 5, 0.1, -, -, -, 180deg/0deg, -, -

Head Move, 5684, 5, 0.1, -, -, -, 215deg/0deg, -, -

Mental State, 5689, 27, -, -, -, -, Thought, -, -

Head Move, 5696, 5, 0.1, -, -, -, 200deg/0deg, -, -

EXPRESSION #6, 5698, 118, -, -, -, -, smile5_bmt, -, -

Mental State, 5701, 115, -, -, -, -, Understanding, -, -

Head Move, 5708, 5, 0.05, -, -, -, 160deg/0deg, -, -

Head Move, 5728, 4, 0.05, -, -, -, 340deg/0deg, -, -

Head Move, 5732, 4, 0.1, -, -, -, 180deg/0deg, -, -

, , , , , , , , ,

END, , , , , , , , ,

, , , , , , , , ,

c. ‘LightHead’ Facial Expression FACS Descriptions

```
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  ( ('01',.0, .1), ('02',.0, .1), ('04',.4, .1), ('05',.6, .1),
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  ( ('01' ,0.4, 0.46), ('02' ,0.4, 0.46), ),
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"smile2_bmt": (

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('13',.6, .29), ('14',.5, .29), ('15',.3, .29),),

(('06',.8, .46), ('07',.6, .46), ('10',.4, .46), ('11',.7, .46),

('13',.6, .46), ('14',.5, .46), ('15',.3, .46),),

(('06',.0, .96), ('07',.5, .96), ('10',.0, .96), ('11',.5, .96),

('13',.0, .96), ('14',.0, .96), ('15',.0, .96),),

),

"smile3_bmt": (

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('13',.6, .38), ('14',.5, .38), ('15',.3, .38),),

(('06',.8, .29), ('07',.6, .29), ('10',.3, .29), ('11',.6, .29),

('13',.6, .29), ('14',.5, .29), ('15',.3, .29),),

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('11',.5, .29), ('13',.9, .29), ('14',.5, .29), ('15',.3, .29), ('16',.3, .29),),

(('04',.5, .5), ('05',.5, .5), ('06',.8, .5), ('07',.6, .5), ('10',.4, .5),

('11',.5, .5), ('13',.9, .5), ('14',.5, .5), ('15',.3, .5), ('16',.3, .5),),

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('11',.5, .38), ('13',.9, .38), ('14',.5, .38), ('15',.3, .38), ('16',.5, .38),),

(('04',.5, .29), ('05',.5, .29), ('06',.8, .29), ('07',.6, .29), ('10',.4, .29),

('11',.5, .29), ('13',.9, .29), ('14',.5, .29), ('15',.3, .29), ('16',.5, .29),),

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"smile4_bmt": (
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    ('13',.0, 1.0), ('14',.0, 1.0), ('15',.0, 1.0), ),
  ),

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    ('12',.3, 1.75), ('13',.0, 1.75), ('14',.0, 1.75), ('15',.0, 1.75), ),
  ),
```

V. Questionnaires and Code-Books

a. User-Based Blink Model Pilot Perception Test Questionnaire

Age Group:

○18-25 ○ 26-35 ○ 35-49
○ 50-65 ○ 66+

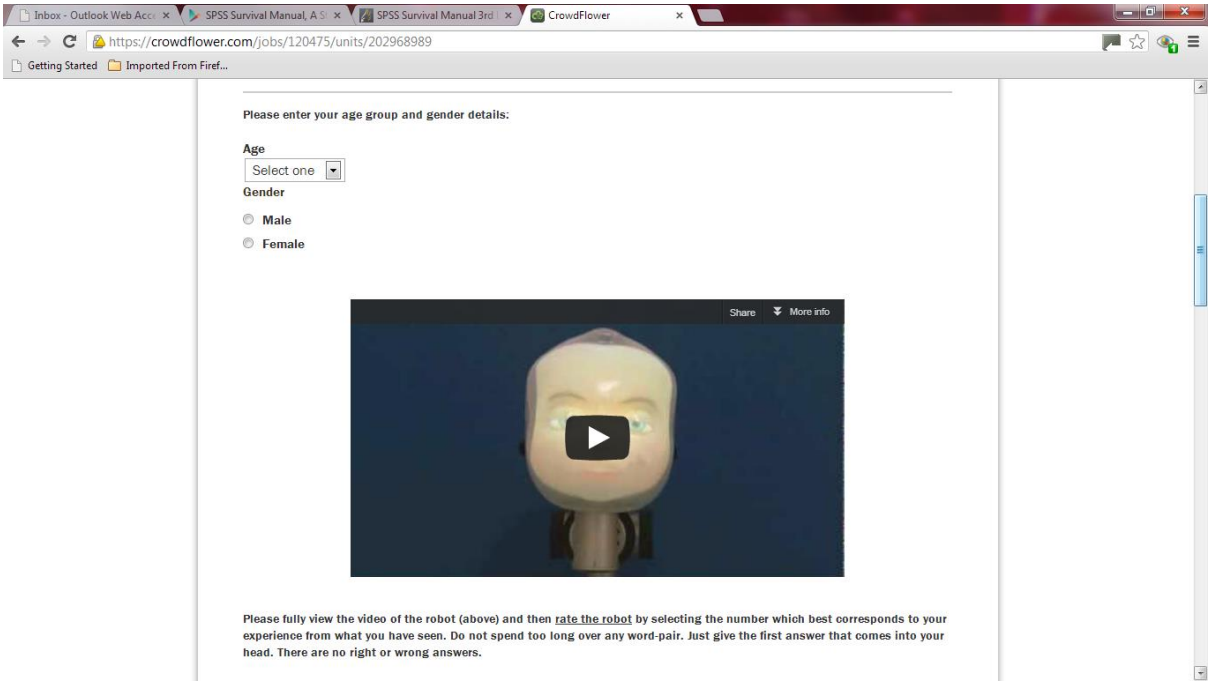
Gender:

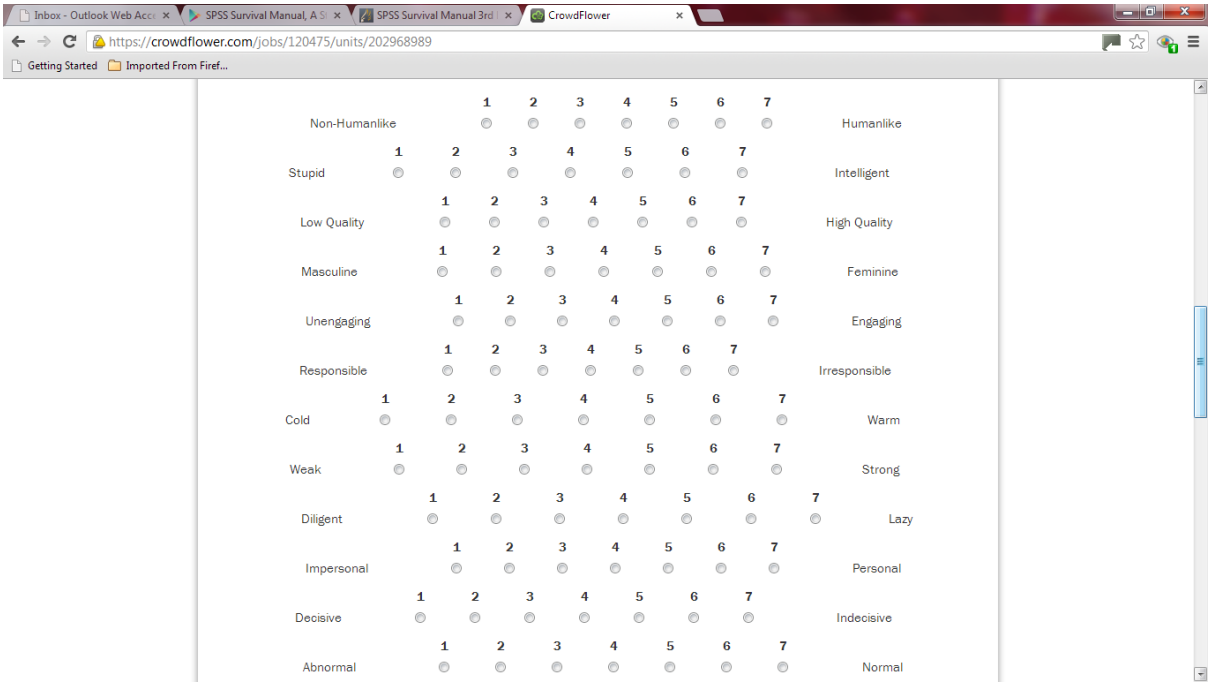
○ Male ○ Female

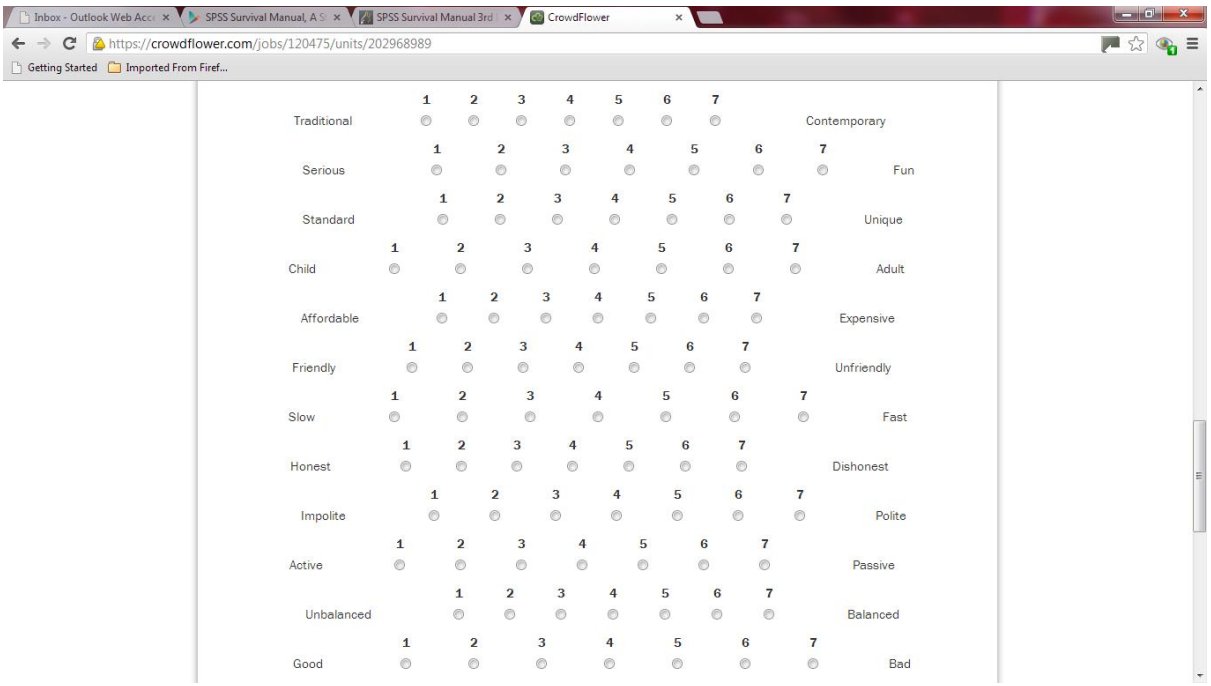
I believe the human blinks were displayed on video..?

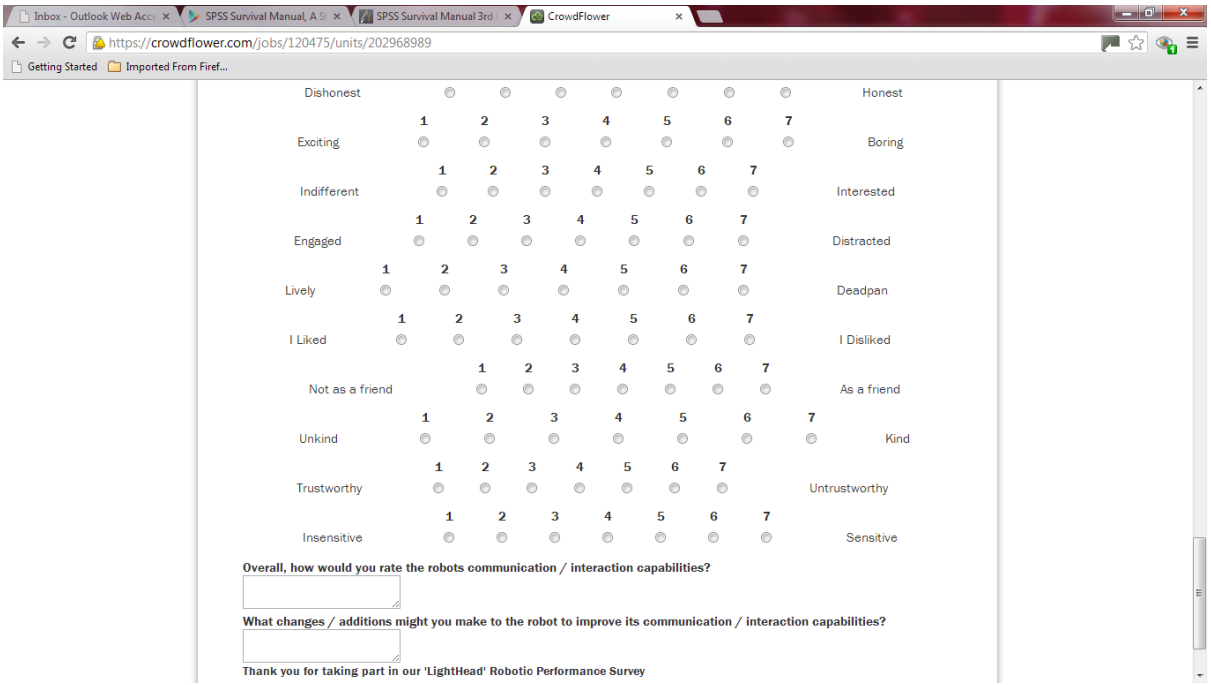
○ Left (Video 1) ○ Right (Video 2)

b. User-Based Online Blink Model Perception Test Questionnaire






Inbox - Outlook Web Acc
SPSS Survival Manual, A S
SPSS Survival Manual 3rd
CrowdFlower
https://crowdflower.com/jobs/120475/units/202968989
Getting Started
Imported From Firef...
1 2 3 4 5 6 7
Traditional Contemporary
Serious Fun
Standard Unique
Child Adult
Affordable Expensive
Friendly Unfriendly
Slow Fast
Honest Dishonest
Impolite Polite
Active Passive
Unbalanced Balanced
Good Bad


Inbox - Outlook Web Acc
SPSS Survival Manual, A S
SPSS Survival Manual 3rd
CrowdFlower
https://crowdflower.com/jobs/120475/units/202968989
Getting Started
Imported From Firef...
Dishonest Honest
Exciting Boring
Indifferent Interested
Engaged Distracted
Lively Deadpan
I Liked I Disliked
Not as a friend As a friend
Unkind Kind
Trustworthy Untrustworthy
Insensitive Sensitive
Overall, how would you rate the robots communication / interaction capabilities?
What changes / additions might you make to the robot to improve its communication / interaction capabilities?
Thank you for taking part in our 'LightHead' Robotic Performance Survey

c. User-Based Blink Model Perception Test Questionnaire Code Book

Variable	SPSS Variable Name	Coding Instructions
Participant ID	workerID	Numeric
Blink Type	blink_type	1 = Blink Model 2 = Human Blinks 3 = Linear Blinks 4 = No Blinks
Gender	gender	1 = Male 2 = Female
Age	age	1 = 18-25 years 2 = 26-35 years 3 = 26-50 years 4 = 51+ years
non-humanlike_humanlike	non-humanlike_humanlike	1 through 7 (humanlike)
stupid_intelligent	stupid_intelligent	1 through 7 (intelligent)
low-quality_high-quality	low-quality_high-quality	1 through 7 (high-quality)
masculine_feminine	masculine_feminine	1 through 7 (feminine)
unengaging_engaging	unengaging_engaging	1 through 7 (engaging)
responsible_irresponsible	responsible_irresponsible	1 through 7 (irresponsible)
cold_warm	cold_warm	1 through 7 (warm)
weak_strong	weak_strong	1 through 7 (strong)
diligent_lazy	diligent_lazy	1 through 7 (lazy)
impersonal_personal	impersonal_personal	1 through 7 (personal)
decisive_indecisive	decisive_indecisive	1 through 7 (indecisive)
abnormal_normal	abnormal_normal	1 through 7 (normal)
traditional_contemporary	traditional_contemporary	1 through 7 (contemporary)

serious_fun	serious_fun	1 through 7 (fun)
standard_unique	standard_unique	1 through 7 (unique)
child_adult	child_adult	1 through 7 (adult)
affordable_expensive	affordable_expensive	1 through 7 (expensive)
friendly_unfriendly	friendly_unfriendly	1 through 7 (unfriendly)
slow_fast	slow_fast	1 through 7 (fast)
honest_dishonest	honest_dishonest	1 through 7 (dishonest)
impolite_polite	impolite_polite	1 through 7 (polite)
active_passive	active_passive	1 through 7 (passive)
unbalanced_balanced	unbalanced_balanced	1 through 7 (balanced)
good_bad	good_bad	1 through 7 (bad)
dishonest_honest	dishonest_honest	1 through 7 (honest)
exciting_boring	exciting_boring	1 through 7 (boring)
indifferent_interested	indifferent_interested	1 through 7 (interested)
engaged_distracted	engaged_distracted	1 through 7 (distracted)
lively_deadpan	lively_deadpan	1 through 7 (deadpan)
i-liked_i-disliked	liked_disliked	1 through 7 (disliked)
not-as-a-friend_as-a-friend	not-friend_friend	1 through 7 (friend)
unkind_kind	unkind_kind	1 through 7 (kind)
trustworthy_untrustworthy	trustworthy_untrustworthy	1 through 7 (untrustworthy)
insensitive_sensitive	insensitive_sensitive	1 through 7 (sensitive)

d. CrowdFlower CML for User-Based Questionnaire

```
<p><b>Please enter your age group and gender details:</b></p>
<cml:group>
  <cml:select label="Age" id="age_range" class="" validates="required">
    <cml:option label="18-25 years" selected=""/>
    <cml:option label="26-35 years" selected=""/>
    <cml:option label="36-50 years" selected=""/>
    <cml:option label="51+ years" selected=""/>
    <cml:option label="Select one" selected=""/>
  </cml:select>
  <cml:radios label="Gender" id="gender" class="" validates="required">
    <cml:radio label="Male"/>
    <cml:radio label="Female"/>
  </cml:radios>
</cml:group>

<cml:group only-if="gender++age">
  <br><br><br>
  <div align="center"><iframe width="560" height="315" src="video_url" frameb
order="0"></iframe></div>
  <p><br><br><b>Please fully view the video of the robot (above) and
then <b><u>rate the robot</u></b> by selecting the number which best
corresponds to your experience from what you have seen.  Do not spend too
long over any word-pair. Just give the first answer that comes into your head.
There are no right or wrong answers.</b></p>
  <cml:ratings class="" from="Non-
Humanlike" to="Humanlike" label="" name="Non-
Humanlike_Humanlike"points="7" instructions="" id="q1-
1" validates="required"/>
  <cml:ratings class="" from="Stupid" to="Intelligent" label="" name="Stupid_
Intelligent" points="7"instructions="" id="q1-2" validates="required"/>
  <cml:ratings class="" from="Low Quality" to="High
Quality" label="" name="Low Quality_High
Quality"points="7" instructions="" id="q1-3" validates="required"/>
  <cml:ratings class="" from="Masculine" to="Feminine" label="" name="Masculi
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  <cml:ratings class="" from="Unengaging" to="Engaging" label="" name="Unenga
ging_Engaging" points="7"instructions="" id="q1-5" validates="required"/>
  <cml:ratings class="" from="Responsible" to="Irresponsible" label="" name="
Responsible_Irresponsible"points="7" instructions="" id="q1-
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  <cml:ratings class="" from="Cold" to="Warm" label="" name="Cold_Warm" point
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oints="7" instructions=""id="q1-8" validates="required"/>
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```

```
nique" points="7"instructions="" id="q1-15" validates="required"/>
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  <cml:ratings class="" from="Good" to="Bad" label="" name="Good_Bad" points=
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  <cml:ratings class="" from="Dishonest" to="Honest" label="" name="Dishonest
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  <cml:ratings class="" from="Exciting" to="Boring" label="" name="Exciting_B
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  <cml:ratings class="" from="Indifferent" to="Interested" label="" name="Ind
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  <cml:ratings class="" from="Engaged" to="Distracted" label="" name="Engaged
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  <cml:ratings class="" from="Lively" to="Deadpan" label="" name="Lively_Dead
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  <cml:ratings class="" from="I Liked" to="I
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  <cml:ratings class="" from="Not as a friend" to="As a
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  <cml:ratings class="" from="Trustworthy" to="Untrustworthy" label="" name="
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  <cml:ratings class="" from="Insensitive" to="Sensitive" label="" name="Inse
nsitive_Sensitive"points="7" instructions="" id="q1-34" validates="required"/>

  <cml:textarea label="Overall, how would you rate the robots communication /
interaction capabilities?"class="" id="q1-35"/>
  <cml:textarea label="What changes / additions might you make to the robot
to improve its communication / interaction capabilities?" class="" id="q1-
36"/>

  <p><b>Thank you for taking part in our 'LightHead' Robotic Performance
Survey</b></p>
</cml:group>
```

e. One-to-One Human Communication Experiment Questionnaire

‘Speaker – Listener’ Experiment Questionnaire

Please could you now take a moment to complete this experiment questionnaire. Thank you in advance for your time.

Gender: ☐ Male ☐ Female

Age: ☐ 18-25 ☐ 26-45 ☐ 45+

Did you feel that you were talking to another human being?

1. All the time
2. Most of the time
3. Half the time
4. Some of the time
5. None of the time

How would you rate this communication experience?

(Vs. a standard face-to-face communication)

On a scale of 1 to 10, where

1 = ‘Much worse than a normal face-to-face communication’

5 = ‘The same as a normal face-to-face communication’

10 = ‘Much better than a normal face-to-face communication:

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩

Did the communication run smoothly throughout the whole conversation?

Yes / No

If ‘No’, please state in the box below what problems occurred during the conversation:

Do you have any comments to make regarding the experiment and/or the questionnaire?

Thank you for participating in this experiment…

f. Mental Communicative State Categorisation Questionnaire

‘Mental Communicative State’ Experiment Questionnaire

This investigation is part of a PhD at the School of Computing Communications and Electronics / University of Plymouth. We perform research into Human – Robot Interaction (HRI) and we want to learn more about how Speaker – Listener conversational interaction is affected through technology transfer. The experiment involves a single session lasting no more than 15 minutes and tasks you with deciding which one of a possible four differing 'mental communicative states' (those of *Understanding, Uncertainty, Misunderstanding* and *Thought*) are displayed within each of twelve very short videos. Initially you will choose based on visual data only and then repeat the task with audio included.

I, the undersigned, agree to participate in this research project. I will allow the data collected to be used for research purposes only. I have the right to withdraw at any time. I need to understand that collection of the data will consist of audio and video recording of my actions and speech. Although demographic information will be collected for profiling purposes only, the research team ensure complete anonymity. No personal details which allow the respondent to be identified at a later stage will be linked with the data collected.

I allow the recorded data to be used by other researchers. I allow the use of extracts from the recorded data to be used for scientific presentations. *(delete as appropriate)*

I understand that this experiment involves a single session lasting approximately 15 minutes.

_____ _____

First name Surname

_____ _____

Signature Date

Please could you now take a moment to complete this experiment questionnaire and thank you in advance for your time.

Gender: ☐ Male ☐ Female

Age: ☐ 16-25 ☐ 26-45 ☐ 45+

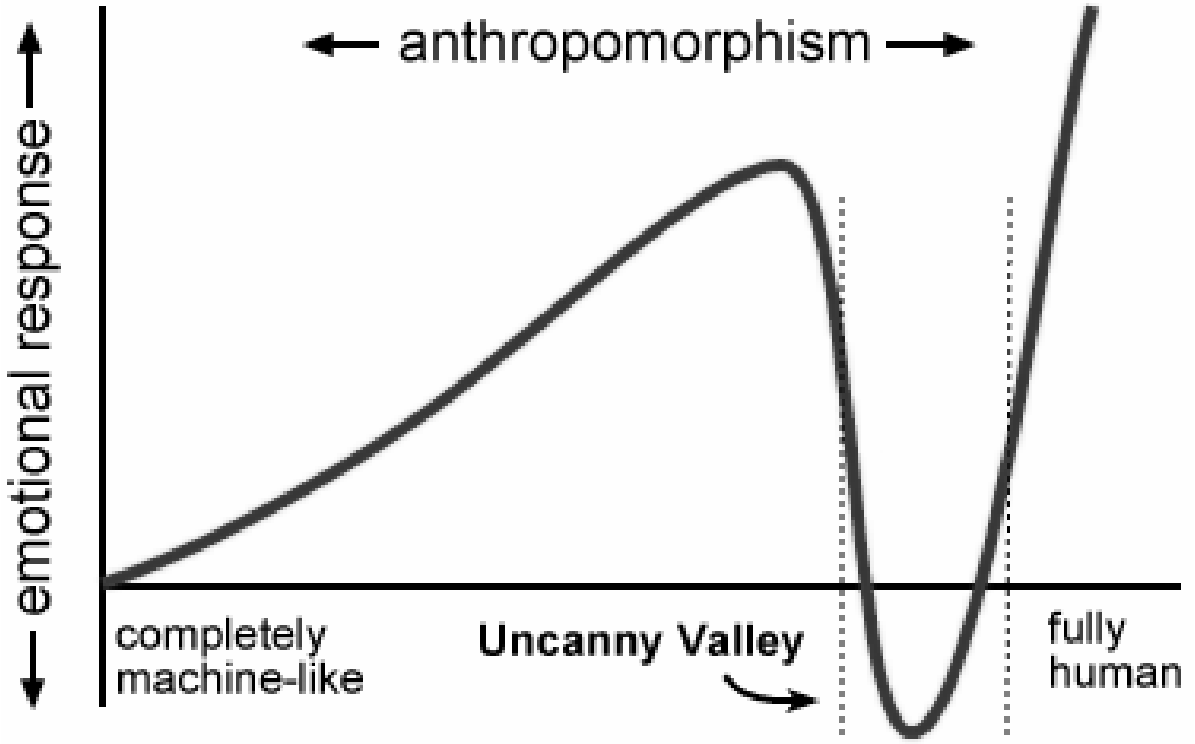
Which Mental Communicative State is displayed? (VISUAL ONLY!)

Video No.	**'Mental Communicative State'** (Understanding, Uncertainty, Misunderstanding or Thought)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	

Which Mental Communicative State is displayed? (AUDIO-VISUAL)

Video No.	**'Mental Communicative State'** (Understanding, Uncertainty, Misunderstanding or Thought)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	

Where in this 'Uncanny Valley' graph do you believe the 'LightHead' Robot actually fall in your estimation…



THANK YOU FOR TAKING PART IN THIS STUDY

VI. Open Question Responses from Blink Model Perception Test #2

a. Open Question #1 Responses

LEGEND	Human Blink	Blink Model	Linear Blink	No Blink

Overall, how would you rate the robots communication/interaction capabilities?

It seemed very capable of processing what was being said and produced expected and relevant replies. It also seemed to handle 'errors' ("Did you experience the enjoy?") pretty well but replied in a rather robotic/unnatural manner (or perhaps just (too?) formal). The movement was quite natural but maybe a little over done. It's nice that it tends to look around, such as when it looks off to the side when "thinking", as a constant stare would be unnerving.
Really good - Fairly human communication
fantastic!
The robot seemed very interactive and didn't seem to have any difficulties in communicating other than when the sentence was non-sensical.
Reasonable - speech synthesis a bit suspect at times, but non-verbal behaviours were largely convincing.
i felt that the robots communication skills and interactive skills were amazing, this must of taken a lot of coding and hours to produce.
The robot was smart and easy to undesrtand human inout, if its put in the right format(sentence).
Passive - only answering questions.
Good.
Fairly good, it seems to be fairly well read and can understand grammar rules and when a sentence doesn't make sense. It understands when a question requires an answer. The speech inflections are quite good, not sounding as robot as most computer speech programmes but still not quite human. The head movements and eye movements are good, making the robot more engaging. It can give an intelligent response to open ended questions, with the star sign question it gave a humanistic opinion which was impressive.
Better than I expected
Good at communicating simple straightforward instructions but as soon as something it doesnt know or understand comes up the robot is not able to answer which makes it very obvious its not human
Very good. It understood speech well and could come up with it's own, well thought out, answers to questions.
4 out of 5
appeared quite life life, aware of grammar
very clear speech and understood the communication towards him.
excellent advancement in technology. The robot seemed to have a grasp of basic maths and human like rationalisation.
Very fun to interact with, and very human-like.
Good interaction capabilities. He gave a friendly and polite impression. He was honest about not understanding things properly.

Very good. It's ability to change voice pitch according to what is being said is rather impressive. It seems to have very fast reaction times too.
Good communication and interaction
Very good.
Overall very advanced and close to how a human communicates, the movement of the head and eyes (including blinking) help to make it appear to be alive and less robotic. The voice is also impressive. Occasionally the illusion is broken though, especially when asked questions that didn't make any sense. The answers to these questions didn't feel natural.
Very good.
look really capable.
Very impressive.
It was good at interacting but it would not initiate conversations or ask questions / change topic.
The robots interaction capabilities were very impressive. The only negative was not being able to work out what "did you experience the enjoy?" until told correctly what the sentence was as this would have made him more life like. I also liked the head movements when the robot was answering questions, it was very natural.
very good, but with the questions asked the responses were very limited. a longer demonstration would be needed.
Good understanding of context but showed no emotion
Would rate the capabilities highly, although was not particularly fast at responding.
Very good for a robot considering that it had little 'learnt' social skills and could not easily pick up on and understnad errors. But overall good communication.
Reacted well to generic (preprocessed) questions, but at times the illusion was broken with typical computer-esque actions such as asking you to rephrase the fragmented sentence, where a human would possibly overlook it. The voice seemed to fit the stereotype of 'friendly robot' (if that stereotype exists... that's what I would envisage it as...), reminded me of a voice over for a machine is a children's TV program.
Quite highly as it appears to answer quickly and accurately and can state why it doesn't understand a phrase. The face is a bit scary though.
Good at keeping a flowing conversation, voice and pronunciation of words slightly alien and inhuman, slight noticeable pauses and didnt ask any questions to keep the conversation going, very passive in conversation.
Excellent! Although it didn't seem to blink i thought the eye movement in particular was life-like and suggested it was thinking.
Very good
Not bad but the voice sounds obviously artificial and the answers are given too fast. Also at the beginning of the video the robot starts nodding and it keeps nodding way too long for it to seem natural, I think. "Body language" is OK.
Very good ability in both
Very good, although the video clip was quite short, and it is possible the robot was only responding to keywords that it specialized in. But the speed and depth of responses was very impressive, and it did seem decidedly 'human' at times, even seeming 'confused' when it could not make sense of the last question.
Too robotic, not believable enough for me.
Good
Very good for a robot

It is very interesting and nice work. I quite liked it.
He/ it is soo good, I really like it. The way he speaks seems soo natural. I must have been the rsult of a hard work.

b. Open Question #2 Responses

LEGEND	Human Blink	Blink Model	Linear Blink	No Blink

What changes/additions might you make to the robot to improve its communication / interaction capabilities?

Formal/informal changes in dialogue. Perhaps if it's being spoken to in a more friendly manner then lean towards more of an informal tone of speech.
Some of the answers weren't particularly human e.g. if you don't hear/understand you'd probably ask them what they're asking etc rather than just saying you don't understand
smiles and greetings!
I would try to give it the capability to understand sentences when they are said in the wrong order.
Better speech synthesis (tempo and intonation).
it depends where the communication and interaction feedback is stored, may be improve on a wider question and answer bank, may be add a few more facts and experiences that light head has incurred. make light head more opinionated. but overall loved it.
More movement differentiating the head movement from the neck as more human features lik d eyelash moving maybe after some seconds.
Body language.
Although it understands questions, it does not seem to understand mannerisms that make it human. At the start when you say it's a pleasure to meet you, standard human reciprocity would normally mean the other person says 'nice to meet you too'. AT the end of the video as well when the interviewer thanks light-head, it does not respond with "that's okay" or "you're welcome" for example. Some sort of typical human response. If the mouth movements matched the speech patterns more accurately this would also make it much more human like.
The head movement looks exaggerated and is distracting
wider range of vocabulary - doesnt talk like a human would. to be able to understand sentences which might not be worded right but a human would understand. Less robotic voice
I'm not sure. I like it already. In the video you only see a head so I'm not sure if it has a body but if it did, hands so it could shake hands and greet people would help it interact in a more human way. Or, if possible let it commence its own conversations, rather than waiting for questions to be asked of it.
Non- ability to ask its own question relating to the topics discussed. This would show more human like interaction and processing thought ability
not sure.
not really sure
Improve it's ability to talk for long sentences. It seems to break for a half-second before continuing with the sentence.
More emotion in it's voice
Appearance could improve for better interaction
The robot is quite passive in the conversation, it didn't ask any questions of its own.
Make responses more personal and gain a better understanding of colloquialisms.
look at me.
More of the same stuff.

I would prefer it to either be more cartoonish or very human like. I find it less pleasing somewhere in between.
Going back to the "did you experience the enjoy?" The robot could have response with a question like "did you mean, 'did I enjoy the experience?"
Facial expressions and body language
Specify gender
Perhaps able to notice errors such as mixing up words and perhaps understanding the human error, and a bit more human looking.
depending on the intended environment, changing the voice to a more adult, less synthe-sised sound would improve the illusion of it being a human. again, if the aim is the illusion of human-like behaviour, unless a sentence is under scrutiny by request of the user, then making the AI overlook slight deviations from correct structure/grammar of a sentence would be beneficial.
Possibly make it appear less human, as it is nearing the edge of the uncanny valley.
possibly making it use topics to expand and flow the conversation naturally without needed to be answering a question
To be more polite; such as saying, 'sorry, I do not understand'. Did not seem very lively in their facial expressions (in comparison to the tone of voice). Change facial expressions more, like squinting when trying to think or raising eyebrows.
I think slightly longer answer time (even if the robot knows the answer immediately) would look more natural. when nodding, two-three cycles should be enough.
Not sure
The science of this goes far above my head but as 'chatbots' such as Cleverbot variety and detail of responses seems to be key.
More human like I suppose.
Make it blink, the constantly open eyes were kind of creepy.
May be when you ask him a question that he doesn't know. I expected him to turn his eyes to one side or produce more blinks.

VII. Transcribed FaceML for Participant 6 Communicative Performance

```
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xsi:noNamespaceSchemaLocation="file:///F:/Exp1Videos/Cut-
Up%20Versions/Video%20Dialogue%20XML%20Script%20Files/script_template.xsd"
participant="6" script="1">

        <cState startTime="0" endTime="31" state="thought" />

        <peg startTime="0" endTime="412" looking="atFace" />

        <sSpeech startTime="1" endTime="47">

                "Hi There! My name is Chris. What"s your name?"

        </sSpeech>

        <cState startTime="32" endTime="68" state="understanding" />

        <pbl startTime="48" endTime="60" type=”full” attack=”2” sustain=”1”
decay=”10” />

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distance="0.2" endAngle="0" />

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distance="0.2" endAngle="0" />

        </phg>

        <pSpeech startTime="51" endTime="63">

                "I"m Phil"

        </pSpeech>

        <cState startTime="69" endTime="332" state="thought" />

        <sSpeech startTime="74" endTime="114">

                "Hi Phil, it"s a pleasure to meet you"

        </sSpeech>

        <pbl startTime="118" endTime="126" type=”full” attack=”2” sustain=”0”
decay=”7” />

        <sSpeech startTime="130" endTime="274">
```

"During this conversation I will be asking you a number of questions. If you could answer as honestly as you can, that would be appreciated"

</sSpeech>

<pbl startTime="164" endTime="176" type=”full” attack=”2” sustain=”0” decay=”11” />

<pbl startTime="243" endTime="251" type=”full” attack=”2” sustain=”1” decay=”6” />

<pbl startTime="284" endTime="294" type=”full” attack=”3” sustain=”0” decay=”8” />

<sSpeech startTime="289" endTime="330">

"So, what month were you born in?"

</sSpeech>

<cState startTime="333" endTime="358" state="understanding" />

<phg startTime="334" endTime="344">

<phgs startIndex="1" startTime="334" endTime="337" direction="0" distance="0.2" endAngle="0" />

<phgs startIndex="2" startTime="338" endTime="344" direction="180" distance="0.2" endAngle="0" />

</phg>

<pbl startTime="336" endTime="345" type=”full” attack=”2” sustain=”1” decay=”6” />

<pSpeech startTime="336" endTime="358">

"November"

</pSpeech>

<cState startTime="359" endTime="432" state=”thought” />

<sSpeech startTime="384" endTime="418">

“Do you know which star sign you are?”

</sSpeech>

<pem startTime="413" endTime="434">

<pems startIndex="1" startTime="413" endTime="415" angle=”270” distance="0.3" />

<pems startIndex="2" startTime="419" endTime="420" angle=”300” distance="0.05" />

<pems startIndex="3" startTime="423" endTime="425" angle=”320” distance="0.25" />

<pems startIndex="4" startTime="431" endTime="436" angle=”100” distance="0.6" />

</pem>

<peg startTime="413" endTime="436" looking=”awayFace” />

<phg startTime="422" endTime="480">

<phgs startIndex="1" startTime="422" endTime="432" direction="0" distance="0.1" endAngle="0" />

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<phgs startIndex="5" startTime="464" endTime="480" direction="180" distance="0.05" endAngle="0" />

</phg>

<pSpeech startTime="426" endTime="454">

“I’m a Sagittarius”

</pSpeech>

<pbl startTime="432" endTime="439" type=”full” attack=”2” sustain=”1” decay=”5” />

<cState startTime="433" endTime="459" state=”understanding” />

<peg startTime="437" endTime="594" looking=”atFace” />

<cState startTime="460" endTime="608" state=”thought” />

<sSpeech startTime="487" endTime="592">

“I was born in mid November. Any ideas which star sign I am?”

</sSpeech>

<peg startTime="595" endTime="611" looking=”awayFace” />

<pem startTime="595" endTime="611">

<pems startIndex="1" startTime="595" endTime="596" angle=”300” distance="0.4" />

<pems startIndex="2" startTime="597" endTime="598" angle=”270” distance="0.1" />

<pems startIndex="3" startTime="602" endTime="604" angle=”300” distance="0.4" />

<pems startIndex="4" startTime="609" endTime="611" angle=”110” distance="0.9" />

</pem>

<pfe startTime="600" endTime="622" expression=”raised_brows” />

<phg startTime="602" endTime="644">

<phgs startIndex="1" startTime="602" endTime="606" direction="270" distance="0.2" endAngle="0" />

<phgs startIndex="2" startTime="608" endTime="614" direction="80" distance="0.3" endAngle="0" />

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<phgs startIndex="4" startTime="627" endTime="630" direction="100" distance="0.1" endAngle="0" />

<phgs startIndex="5" startTime="633" endTime="644" direction="110" distance="0.3" endAngle="0" />

</phg>

<pSpeech startTime="607" endTime="646">

“Probably Sagittarian as well, I suppose”

</pSpeech>

<pbl startTime="608" endTime="614" type=”full” attack=”3” sustain=”0” decay=”4” />

<cState startTime="609" endTime="656" state=”unsure understanding” />

<peg startTime="612" endTime="883" looking=”atFace” />

<cState startTime="657" endTime="713" state=”thought” />

<pbl startTime="666" endTime="677" type=”full” attack=”2” sustain=”0” decay=”10” />

<sSpeech startTime="669" endTime="729">

“Ummm. Not quite, Scorpio actually”

</sSpeech>

<pfe startTime="691" endTime="849" expression=”smile” />

<cState startTime="714" endTime="803" state=”understanding” />

<pSpeech startTime="728" endTime="743">

“Right, OK”

</pSpeech>

<pbl startTime="728" endTime="746" type=”full” attack=”2” sustain=”12” decay=”5” />

<phg startTime="731" endTime="784">

<phgs startIndex="1" startTime="731" endTime="735" direction="20" distance="0.5" endAngle="5" />

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<phgs startIndex="6" startTime="780" endTime="784" direction="175" distance="0.1" endAngle="0" />

</phg>

<sSpeech startTime="751" endTime="779">

“Close, obviously”

</sSpeech>

<pbl startTime="774" endTime="780" type=”full” attack=”2” sustain=”0” decay=”5” />

<sSpeech startTime="790" endTime="890">

“Umm, I’m not sure I believe in the star sign information, how about you?”

</sSpeech>

<pst startTime="791" endTime="820" />

<pbl startTime="802" endTime="810" type=”full” attack=”3” sustain=”0” decay=”6” />

<cState startTime="804" endTime="899" state=”thought” />

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</pem>

<peg startTime="884" endTime="905" looking=”awayFace” />

<phg startTime="891" endTime="934">

<phgs startIndex="1" startTime="891" endTime="900" direction="300" distance="0.3" endAngle="10" />

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<phgs startIndex="3" startTime="911" endTime="934" direction="175" distance="0.1" endAngle="5" />

</phg>

<pSpeech startTime="894" endTime="918">

“No, not really”

</pSpeech>

<pbl startTime="895" endTime="908" type=”full” attack=”2” sustain=”4” decay=”8” />

<cState startTime="900" endTime="936" state=”understanding” />

<peg startTime="906" endTime="952" looking=”atFace” />

<pfe startTime="914" endTime="950" expression=”smile” />

<sSpeech startTime="928" endTime="966">

“Umm. Any reasons for that?”

</sSpeech>

<pbl startTime="937" endTime="945" type=”full” attack=”2” sustain=”0” decay=”7” />

<cState startTime="937" endTime="976" state=”thought” />

<pem startTime="952" endTime="965">

<pems startIndex="1" startTime="952" endTime="955" angle=”300” distance="0.3" />

<pems startIndex="2" startTime="963" endTime="965" angle=”90” distance="0.1" />

</pem>

<peg startTime="953" endTime="983" looking=”awayFace” />

<pbl startTime="966" endTime="971" type=”full” attack=”2” sustain=”1” decay=”3” />

<phg startTime="967" endTime="1148">

<phgs startIndex="1" startTime="967" endTime="974" direction="5" distance="0.2" endAngle="5" />

<phgs startIndex="2" startTime="975" endTime="979" direction="180" distance="0.1" endAngle="5" />

<phgs startIndex="3" startTime="983" endTime="994" direction="180" distance="0.1" endAngle="5" />

<phgs startIndex="4" startTime="995" endTime="998" direction="0" distance="0.02" endAngle="5" />

<phgs startIndex="5" startTime="999" endTime="1003" direction="180" distance="0.1" endAngle="5" />

<phgs startIndex="6" startTime="1004" endTime="1016" direction="5" distance="0.2" endAngle="0" />

<phgs startIndex="7" startTime="1017" endTime="1019" direction="90" distance="0.1" endAngle="0" />

<phgs startIndex="8" startTime="1020" endTime="1027"

direction="190" distance="0.1" endAngle="0" />

<phgs startIndex="9" startTime="1028" endTime="1033" direction="170" distance="0.1" endAngle="0" />

<phgs startIndex="10" startTime="1134" endTime="1140" direction="90" distance="0.2" endAngle="0" />

<phgs startIndex="11" startTime="1141" endTime="1144" direction="270" distance="0.1" endAngle="5" />

<phgs startIndex="12" startTime="1145" endTime="1148" direction="100" distance="0.1" endAngle="5" />

</phg>

<pem startTime="968" endTime="970">

<pems startIndex="1" startTime="968" endTime="970" angle="310" distance="0.5" />

<pems startIndex="2" startTime="975" endTime="981" angle="130" distance="0.7" />

</pem>

<pbl startTime="974" endTime="986" type=”full” attack=”2” sustain=”4” decay=”7” />

<pSpeech startTime="976" endTime="1108">

“Seems unlikely that $1/12^{th}$ of the population would have the same things happening to them all the time, so…”

</pSpeech>

<cState startTime="977" endTime="1114" state=”understanding” />

<peg startTime="984" endTime="1114" looking=”atFace” />

<sSpeech startTime="1099" endTime="1144">

“Hummm, Yep”

</sSpeech>

<pbl startTime="1115" endTime="1123" type=”full” attack=”2” sustain=”0” decay=”7” />

<peg startTime="1115" endTime="1141" looking=”awayFace” />

<cState startTime="1115" endTime="1142" state=”thought” />

<pem startTime="1115" endTime="1147">

<pems startIndex="1" startTime="1115" endTime="1118" angle="270" distance="0.7" />

<pems startIndex="2" startTime="1132" endTime="1133" angle="90" distance="0.1" />

<pems startIndex="3" startTime="1137" endTime="1141" angle="90" distance="0.7" />

<pems startIndex="4" startTime="1145" endTime="1147" angle=”0” distance="0.1" />

</pem>

<pbl startTime="1136" endTime="1144" type=”full” attack=”3” sustain=”1” decay=”5” />

<pSpeech startTime="1139" endTime="1180">

“It doesn’t seem like it has much …”

</pSpeech>

<peg startTime="1142" endTime="1240" looking=”atFace” />

<cState startTime="1143" endTime="1196" state=”understanding” />

<pfe startTime="1175" endTime="1325" expression=”smile” />

<phg startTime="1178" endTime="1198">

<phgs startIndex="1" startTime="1178" endTime="1182" direction="180" distance="0.2" endAngle="0" />

<phgs startIndex="2" startTime="1183" endTime="1188" direction="315" distance="0.1" endAngle="0" />

<phgs startIndex="3" startTime="1191" endTime="1198" direction="90" distance="0.2" endAngle="0" />

</phg>

<sSpeech startTime="1193" endTime="1225">

“Hope of being in…”

</sSpeech>

<cState startTime="1197" endTime="1221" state=”thought” />

<pbl startTime="1203" endTime="1210" type=”full” attack=”3” sustain=”0” decay=”5” />

<cState startTime="1222" endTime="1267" state=”unsure understanding” />

<phg startTime="1229" endTime="1279">

<phgs startIndex="1" startTime="1229" endTime="1235" direction="90" distance="0.1" endAngle="0" />

<phgs startIndex="2" startTime="1236" endTime="1239" direction="0" distance="0.1" endAngle="0" />

<phgs startIndex="3" startTime="1247" endTime="1252" direction="180" distance="0.1" endAngle="0" />

<phgs startIndex="4" startTime="1259" endTime="1263" direction="45" distance="0.1" endAngle="0" />

<phgs startIndex="5" startTime="1266" endTime="1279" direction="90" distance="0.1" endAngle="355" />

</phg>

<pSpeech startTime="1236" endTime="1252">

“Being correct?”

</pSpeech>

<pem startTime="1240" endTime="1242">

<pems startIndex="1" startTime="1240" endTime="1242" angle="240" distance="0.4" />

<pems startIndex="2" startTime="1253" endTime="1254" angle="30" distance="0.2" />

<pems startIndex="3" startTime="1259" endTime="1261" angle=”60” distance="0.2" />

</pem>

<peg startTime="1241" endTime="1252" looking=”awayFace” />

<sSpeech startTime="1242" endTime="1250">

“Yes…”

</sSpeech>

<peg startTime="1253" endTime="1385" looking=”atFace” />

<pbl startTime="1263" endTime="1269" type=”full” attack=”2” sustain=”0” decay=”5” />

<cState startTime="1268" endTime="1499" state=”thought” />

<sSpeech startTime="1270" endTime="1349">

“Temporal kind of stuff doesn’t tend to work quite like that, does it”

</sSpeech>

<pbl startTime="1318" endTime="1327" type=”full” attack=”2” sustain=”0” decay=”8” />

<pSpeech startTime="1352" endTime="1357">

“Hmm…”

</pSpeech>

<pbl startTime="1353" endTime="1362" type=”full” attack=”3” sustain=”0” decay=”7” />

<phg startTime="1354" endTime="1387">

<phgs startIndex="1" startTime="1354" endTime="1358" direction="0" distance="0.05" endAngle="355" />

<phgs startIndex="2" startTime="1359" endTime="1363" direction="180" distance="0.05" endAngle="355" />

<phgs startIndex="3" startTime="1364" endTime="1367" direction="0" distance="0.05" endAngle="355" />

<phgs startIndex="4" startTime="1368" endTime="1370" direction="180" distance="0.05" endAngle="355" />

<phgs startIndex="5" startTime="1371" endTime="1375" direction="0" distance="0.05" endAngle="355" />

<phgs startIndex="6" startTime="1376" endTime="1379" direction="180" distance="0.05" endAngle="355" />

<phgs startIndex="7" startTime="1380" endTime="1383" direction="0" distance="0.05" endAngle="355" />

<phgs startIndex="8" startTime="1384" endTime="1387" direction="180" distance="0.05" endAngle="355" />

</phg>

<pbl startTime="1364" endTime="1372" type=”full” attack=”2” sustain=”1” decay=”6” />

<pbl startTime="1378" endTime="1385" type=”full” attack=”2” sustain=”1” decay=”5” />

<sSpeech startTime="1385" endTime="1466">

“So, good answer. Do you know what time of day you were born?”

```
</sSpeech>

<pem startTime="1385" endTime="1395">

<pems startIndex="1" startTime="1385" endTime="1387" angle="270"
distance="0.2" />

<pems startIndex="2" startTime="1393" endTime="1395" angle="90"
distance="0.2" />

</pem>

<peg startTime="1386" endTime="1394" looking=”awayFace” />

<peg startTime="1395" endTime="1420" looking=”atFace” />

<pbl startTime="1397" endTime="1404" type=”full” attack=”2” sustain=”1”
decay=”5” />

<pem startTime="1415" endTime="1504">

<pems startIndex="1" startTime="1415" endTime="1417" angle="190"
distance="0.1" />

<pems startIndex="2" startTime="1419" endTime="1422" angle="250"
distance="0.3" />

<pems startIndex="3" startTime="1429" endTime="1432" angle="60"
distance="0.3" />

<pems startIndex="4" startTime="1443" endTime="1444" angle="150"
distance="0.1" />

<pems startIndex="5" startTime="1454" endTime="1457" angle="260"
distance="0.3" />

<pems startIndex="6" startTime="1459" endTime="1462" angle="290"
distance="0.4" />

<pems startIndex="7" startTime="1465" endTime="1468" angle="310"
distance="0.2" />

<pems startIndex="8" startTime="1472" endTime="1473" angle="0"
distance="0.4" />

<pems startIndex=”9" startTime="1479" endTime="1481" angle="40"
distance="0.3" />

<pems startIndex="10" startTime="1485" endTime="1494" angle="135"
distance="0.4" />

<pems startIndex="11" startTime="1499" endTime="1504" angle="0"
distance="0" />
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</pem>

<peg startTime="1421" endTime="1430" looking=”awayFace” />

<peg startTime="1431" endTime="1455" looking=”atFace” />

<peg startTime="1456" endTime="1498" looking=”awayFace” />

<phg startTime="1473" endTime="1523">

    <phgs startIndex="1" startTime="1473" endTime="1480"
direction="340" distance="0.3" endAngle="0" />

    <phgs startIndex="2" startTime="1481" endTime="1486"
direction="160" distance="0.2" endAngle="355" />

    <phgs startIndex="3" startTime="1487" endTime="1491"
direction="225" distance="0.1" endAngle="5" />

    <phgs startIndex="4" startTime="1494" endTime="1498"
direction="180" distance="0.1" endAngle="5" />

    <phgs startIndex="5" startTime="1499" endTime="1509"
direction="100" distance="0.2" endAngle="3" />

    <phgs startIndex="6" startTime="1510" endTime="1523"
direction="215" distance="0.1" endAngle="3" />

</phg>

<pSpeech startTime="1481" endTime="1512">

    “About 11am I believe”

</pSpeech>

<pbl startTime="1484" endTime="1501" type=”full” attack=”5” sustain=”8”
decay=”5” />

<cState startTime="1500" endTime="1515" state=”understanding” />

<sSpeech startTime="1522" endTime="1648">

    “11am so, you would be a sun baby as opposed to a moon baby”

</sSpeech>

<peg startTime="1499" endTime="1671" looking=”atFace” />

<cState startTime="1516" endTime=”1769" state=”thought” />

<phg startTime="1546" endTime="1599">

    <phgs startIndex="1" startTime="1546" endTime="1550"
direction="180" distance="0.05" endAngle="3" />
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<phgs startIndex="2" startTime="1551" endTime="1555" direction="0" distance="0.05" endAngle="3" />

<phgs startIndex="3" startTime="1556" endTime="1560" direction="180" distance="0.05" endAngle="3" />

<phgs startIndex="4" startTime="1561" endTime="1565" direction="0" distance="0.05" endAngle="3" />

<phgs startIndex="5" startTime="1566" endTime="1568" direction="180" distance="0.05" endAngle="3" />

<phgs startIndex="6" startTime="1570" endTime="1575" direction="0" distance="0.05" endAngle="3" />

<phgs startIndex="7" startTime="1576" endTime="1590" direction="180" distance="0.05" endAngle="3" />

<phgs startIndex="8" startTime="1593" endTime="1599" direction="180" distance="0.05" endAngle="3" />

</phg>

<pbl startTime="1548" endTime="1558" type=”full” attack=”3” sustain=”0” decay=”8” />

<pst startTime="1583" endTime="1613" />

<phg startTime="1625" endTime="1655">

<phgs startIndex="1" startTime="1625" endTime="1632" direction="0" distance="0.05" endAngle="3" />

<phgs startIndex="2" startTime="1634" endTime="1636" direction="180" distance="0.05" endAngle="3" />

<phgs startIndex="3" startTime="1637" endTime="1641" direction=”0” distance="0.05" endAngle="3" />

<phgs startIndex="4" startTime="1642" endTime="1646" direction="180" distance="0.05" endAngle="3" />

<phgs startIndex="5" startTime="1647" endTime="1651" direction="0" distance="0.05" endAngle="3" />

<phgs startIndex="6" startTime="1652" endTime="1655" direction="180" distance="0.05" endAngle="3" />

</phg>

<pbl startTime="1663" endTime="1670" type=”full” attack=”3” sustain=”1” decay=”4” />

<pfe startTime="1666" endTime="1687" expression=”begrudging_acceptance” />

<sSpeech startTime="1671" endTime="1769">

“So, do you by any chance know the distance from the earth to the sun?”

</sSpeech>

<peg startTime="1672" endTime="1684" looking=”awayFace” />

<pbl startTime="1672" endTime="1678" type=”full” attack=”2” sustain=”0” decay=”5” />

<pem startTime="1673" endTime="1683">

<pems startIndex="1" startTime="1673" endTime="1674" angle="260" distance="0.2" />

<pems startIndex="2" startTime="1681" endTime="1683" angle="0" distance="0" />

</pem>

<phg startTime="1678" endTime="1696">

<phgs startIndex="1" startTime="1678" endTime="1682" direction="0" distance="0.05" endAngle="3" />

<phgs startIndex="2" startTime="1683" endTime="1686" direction="180" distance="0.05" endAngle="3" />

<phgs startIndex="3" startTime="1687" endTime="1691" direction=”0" distance="0.05" endAngle="3" />

<phgs startIndex="4" startTime="1692" endTime="1696" direction="180" distance="0.05" endAngle="3" />

</phg>

<pbl startTime="1680" endTime="1686" type=”full” attack=”2” sustain=”1” decay=”4” />

<peg startTime="1685" endTime="1742" looking=”atFace” />

<pbl startTime="1688" endTime="1694" type=”full” attack=”2” sustain=”0” decay=”5” />

<pem startTime="1742" endTime="1788">

<pems startIndex="1" startTime="1742" endTime="1745" angle="240" distance="0.4" />

<pems startIndex="2" startTime="1755" endTime="1756" angle="230" distance="0.1" />

<pems startIndex="3" startTime="1768" endTime="1771" angle="310" distance="0.4" />

<pems startIndex="4" startTime="1785" endTime="1788" angle="0" distance="0" />

</pem>

<peg startTime="1743" endTime="1788" looking=”awayFace” />

<pst startTime="1744" endTime="1768" />

<phg startTime="1769" endTime="1793">

<phgs startIndex="1" startTime="1769" endTime="1775" direction="0" distance="0.3" endAngle="3" />

<phgs startIndex="2" startTime="1776" endTime="1779" direction="275" distance="0.3" endAngle="10" />

<phgs startIndex="3" startTime="1780" endTime="1793" direction=”120" distance="0.3" endAngle="5" />

</phg>

<cState startTime="1770" endTime=”1788" state=”unsure understanding” />

<pSpeech startTime="1773" endTime="1783">

“I don’t”

</pSpeech>

<pbl startTime="1773" endTime="1792" type=”full” attack=”3” sustain=”8” decay=”9” />

<peg startTime="1789" endTime="1829" looking=”atFace” />

<cState startTime="1789" endTime=”1892" state=”thought” />

<sSpeech startTime="1808" endTime="1830">

“Any ideas at all?”

</sSpeech>

<pem startTime="1828" endTime="1891">

<pems startIndex="1" startTime="1828" endTime="1831" angle="285" distance="0.4" />

<pems startIndex="2" startTime="1833" endTime="1836" angle="255" distance="0.3" />

<pems startIndex="3" startTime="1843" endTime="1846" angle="280" distance="0.1" />

<pems startIndex="4" startTime="1849" endTime="1852" angle="260" distance="0.1" />

<pems startIndex="5" startTime="1877" endTime="1881" angle="90" distance="0.9" />

<pems startIndex="6" startTime="1884" endTime="1885" angle="80" distance="0.1" />

<pems startIndex="7" startTime="1889" endTime="1891" angle="0" distance="0" />

</pem>

<peg startTime="1830" endTime="1892" looking=”awayFace” />

<pbl startTime="1855" endTime="1861" type=”full” attack=”2” sustain=”0” decay=”5” />

<phg startTime="1865" endTime="1897">

<phgs startIndex="1" startTime="1865" endTime="1870" direction="340" distance="0.3" endAngle="8" />

<phgs startIndex="2" startTime="1871" endTime="1874" direction="215" distance="0.2" endAngle="10" />

<phgs startIndex="3" startTime="1875" endTime="1877" direction="15" distance="0.05" endAngle="8" />

<phgs startIndex="4" startTime="1878" endTime="1882" direction="90" distance="0.3" endAngle="3" />

<phgs startIndex="5" startTime="1883" endTime="1884" direction="175" distance="0.1" endAngle="3" />

<phgs startIndex="6" startTime="1885" endTime="1888" direction="15" distance="0.1" endAngle="3" />

<phgs startIndex="7" startTime="1889" endTime="1897" direction="180" distance="0.15" endAngle="3" />

<phgs startIndex="8" startTime="1894" endTime="1897" direction="180" distance="0.1" endAngle="3" />

</phg>

<pSpeech startTime="1865" endTime="1925">

“No, I really have no idea how far that is!”

</pSpeech>

<pbl startTime="1869" endTime="1872" type=”full” attack=”2” sustain=”0” decay=”2” />

<pbl startTime="1888" endTime="1894" type=”full” attack=”2” sustain=”1” decay=”4” />

<cState startTime="1893" endTime=”1920" state=”understanding” />

<peg startTime="1893" endTime="2272" looking=”atFace” />

<sSpeech startTime="1917" endTime="2075">

“Well, I can let you know. Uh, apparently it is between 91 and 94.5 million miles”

</sSpeech>

<cState startTime="1921" endTime=”1947" state=”thought” />

<phg startTime="1939" endTime="1968">

<phgs startIndex="1" startTime="1939" endTime="1945" direction="180" distance="0.1" endAngle="3" />

<phgs startIndex="2" startTime="1946" endTime="1953" direction="0" distance="0.3" endAngle="3" />

<phgs startIndex="3" startTime="1954" endTime="1960" direction=”190" distance="0.3" endAngle="3" />

<phgs startIndex="4" startTime="1961" endTime="1963" direction=”10" distance="0.05" endAngle="3" />

<phgs startIndex="5" startTime="1964" endTime="1968" direction=”180" distance="0.3" endAngle="3" />

</phg>

<pfe startTime="1940" endTime="2040" expression=”smile” />

<pbl startTime="1947" endTime="1953" type=”full” attack=”3” sustain=”1” decay=”3” />

<cState startTime="1948" endTime=”1973" state=”understanding” />

<pbl startTime="1954" endTime="1961" type=”full” attack=”2” sustain=”0” decay=”6” />

<cState startTime="1974" endTime=”2079" state=”thought” />

<phg startTime="1978" endTime="2000">

<phgs startIndex="1" startTime="1978" endTime="1984" direction="180" distance="0.05" endAngle="3" />

<phgs startIndex="2" startTime="1985" endTime="1988" direction="0" distance="0.05" endAngle="3" />

<phgs startIndex="3" startTime="1989" endTime="1992" direction=”180" distance="0.05" endAngle="3" />

<phgs startIndex="4" startTime="1993" endTime="1996" direction="0" distance="0.05" endAngle="3" />

<phgs startIndex="5" startTime="1996" endTime="2000" direction=”180" distance="0.05" endAngle="3" />

</phg>

<pbl startTime="1984" endTime="1992" type=”full” attack=”2” sustain=”0” decay=”7” />

<pst startTime="2011" endTime="2074" />

<pbl startTime="2065" endTime="2069" type=”half” attack=”2” sustain=”1” decay=”2” />

<pbl startTime="2074" endTime="2078" type=”full” attack=”2” sustain=”0” decay=”3” />

<phg startTime="2078" endTime="2092">

<phgs startIndex="1" startTime="2078" endTime="2083" direction="180" distance="0.05" endAngle="3" />

<phgs startIndex="2" startTime="2084" endTime="2092" direction="0" distance="0.1" endAngle="2" />

</phg>

<pbl startTime="2079" endTime="2084" type=”full” attack=”2” sustain=”0” decay=”4” />

<pSpeech startTime="2079" endTime="2088">

“Ok”

</pSpeech>

<cState startTime="2080" endTime=”2090" state=”understanding” />

<pbl startTime="2085" endTime="2094" type=”full” attack=”2” sustain=”1” decay=”7” />

<cState startTime="2091" endTime=”2367" state=”thought” />

<sSpeech startTime="2101" endTime="2119">

“Quite a distance”

</sSpeech>

<pbl startTime="2121" endTime="2129" type=”full” attack=”2” sustain=”0” decay=”7” />

<sSpeech startTime="2140" endTime="2269">

“Ok, Could you please, in your own words, explain to me the difference between miles and kilometres?”

</sSpeech>

<pbl startTime="2183" endTime="2192" type=”full” attack=”2” sustain=”0” decay=”8” />

<pst startTime="2218" endTime="2272" />

<pem startTime="2257" endTime="2332">

<pems startIndex="1" startTime="2257" endTime="2259" angle="260" distance="0.35" />

<pems startIndex="2" startTime="2267" endTime="2268" angle="10" distance="0.2" />

<pems startIndex="3" startTime="2272" endTime="2275" angle="280" distance="0.6" />

<pems startIndex="4" startTime="2292" endTime="2295" angle="290" distance="0.2" />

<pems startIndex="5" startTime="2305" endTime="2307" angle="40" distance="0.1" />

<pems startIndex="6" startTime="2311" endTime="2313" angle="45" distance="0.2" />

<pems startIndex="7" startTime="2318" endTime="2320" angle="90" distance="0.1" />

<pems startIndex="8" startTime="2323" endTime="2325" angle="260" distance="0.3" />

<pems startIndex="9" startTime="2330" endTime="2332" angle="80" distance="0.2" />

</pem>

<peg startTime="2273" endTime="2393" looking=”awayFace” />

<pbl startTime="2278" endTime="2283" type=”full” attack=”2” sustain=”0” decay=”4” />

<phg startTime="2294" endTime="2326">

<phgs startIndex="1" startTime="2294" endTime="2303" direction="300" distance="0.05" endAngle="3" />

<phgs startIndex="2" startTime="2307" endTime="2326" direction="330" distance="0.3" endAngle="8" />

</phg>

<pbl startTime="2297" endTime="2305" type=”full” attack=”3” sustain=”0” decay=”6” />

<pSpeech startTime="2297" endTime="2421">

“Erm… Miles is an imperial measurement”

</pSpeech>

<pbl startTime="2334" endTime="2340" type=”full” attack=”2” sustain=”0” decay=”5” />

<pem startTime="2351" endTime="2392">

<pems startIndex="1" startTime="2351" endTime="2354" angle="70" distance="0.4" />

<pems startIndex="2" startTime="2359" endTime="2362" angle="90" distance="0.1" />

<pems startIndex="3" startTime="2366" endTime="2368" angle="80" distance="0.1" />

<pems startIndex="4" startTime="2376" endTime="2378" angle="90" distance="0.2" />

<pems startIndex="5" startTime="2390" endTime="2392" angle="180" distance="0.3" />

</pem>

<cState startTime="2368" endTime=”2438" state=”unsure understanding” />

<pfe startTime="2368" endTime="2403" expression=”raised_brows” />

<phg startTime="2375" endTime="2653">

<phgs startIndex="1" startTime="2375" endTime="2379" direction="5" distance="0.05" endAngle="3" />

<phgs startIndex="2" startTime="2380" endTime="2397" direction="175" distance="0.4" endAngle="10" />

<phgs startIndex="3" startTime="2407" endTime="2420" direction="265" distance="0.3" endAngle="12" />

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<phgs startIndex="5" startTime="2431" endTime="2436" direction="180" distance="0.05" endAngle="12" />

<phgs startIndex="6" startTime="2437" endTime="2451" direction="5" distance="0.1" endAngle="10" />

<phgs startIndex="7" startTime="2452" endTime="2465" direction="300" distance="0.1" endAngle="8" />

<phgs startIndex="8" startTime="2466" endTime="2474" direction="320" distance="0.2" endAngle="5" />

<phgs startIndex="9" startTime="2475" endTime="2479" direction="5" distance="0.1" endAngle="5" />

<phgs startIndex="10" startTime="2480" endTime="2488" direction="105" distance="0.1" endAngle="5" />

<phgs startIndex="11" startTime="2489" endTime="2499" direction="60" distance="0.2" endAngle="5" />

<phgs startIndex="12" startTime="2501" endTime="2514" direction="90" distance="0.05" endAngle="8" />

<phgs startIndex="13" startTime="2526" endTime="2532" direction="185" distance="0.05" endAngle="8" />

<phgs startIndex="14" startTime="2536" endTime="2540" direction="135" distance="0.05" endAngle="8" />

<phgs startIndex="15" startTime="2543" endTime="2550" direction="195" distance="0.3" endAngle="8" />

<phgs startIndex="16" startTime="2551" endTime="2554" direction="0" distance="0.1" endAngle="8" />

<phgs startIndex="17" startTime="2555" endTime="2568" direction="300" distance="0.05" endAngle="10" />

<phgs startIndex="18" startTime="2569" endTime="2575" direction="5" distance="0.15" endAngle="5" />

<phgs startIndex="19" startTime="2576" endTime="2579" direction="330" distance="0.2" endAngle="3" />

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<phgs startIndex="21" startTime="2585" endTime="2587" direction="90" distance="0.05" endAngle="1" />

<phgs startIndex="22" startTime="2588" endTime="2593" direction="180" distance="0.05" endAngle="2" />

<phgs startIndex="23" startTime="2594" endTime="2598" direction="150" distance="0.1" endAngle="3" />

<phgs startIndex="24" startTime="2599" endTime="2606" direction="220" distance="0.2" endAngle="8" />

<phgs startIndex="25" startTime="2607" endTime="2612" direction="160" distance="0.05" endAngle="3" />

<phgs startIndex="26" startTime="2613" endTime="2617" direction="90" distance="0.1" endAngle="0" />

<phgs startIndex="27" startTime="2618" endTime="2620" direction="200" distance="0.5" endAngle="357" />

<phgs startIndex="28" startTime="2621" endTime="2623" direction="90" distance="0.05" endAngle="357" />

<phgs startIndex="29" startTime="2624" endTime="2626" direction="270" distance="0.05" endAngle="357" />

<phgs startIndex="30" startTime="2627" endTime="2630" direction="90" distance="0.05" endAngle="357" />

<phgs startIndex="31" startTime="2631" endTime="2633" direction="270" distance="0.05" endAngle="357" />

<phgs startIndex="32" startTime="2634" endTime="2653" direction="90" distance="0.15" endAngle="355" />

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<pbl startTime="2389" endTime="2395" type=”full” attack=”3” sustain=”0” decay=”4” />

<peg startTime="2394" endTime="2438" looking=”atFace” />

<pSpeech startTime="2422" endTime="2486">

“Ahh, kilometres is a metric measurement”

</pSpeech>

<pem startTime="2438" endTime="2653">

<pems startIndex="1" startTime="2438" endTime="2441" angle="70" distance="0.2" />

<pems startIndex="2" startTime="2442" endTime="2445" angle="270" distance="0.4" />

<pems startIndex="3" startTime="2452" endTime="2454" angle="280" distance="0.05" />

<pems startIndex="4" startTime="2457" endTime="2459" angle="260" distance="0.2" />

<pems startIndex="5" startTime="2476" endTime="2477" angle="0" distance="0.05" />

<pems startIndex="6" startTime="2481" endTime="2484" angle="90" distance="0.4" />

<pems startIndex="7" startTime="2487" endTime="2489" angle="65" distance="0.3" />

<pems startIndex="8" startTime="2492" endTime="2494" angle="50" distance="0.1" />

<pems startIndex="9" startTime="2498" endTime="2501" angle="250" distance="0.4" />

<pems startIndex="10" startTime="2511" endTime="2514" angle="230" distance="0.4" />

<pems startIndex="11" startTime="2522" endTime="2524" angle="90" distance="0.2" />

<pems startIndex="12" startTime="2547" endTime="2549" angle="180" distance="0.2" />

<pems startIndex="13" startTime="2557" endTime="2559" angle="80" distance="0.2" />

<pems startIndex="14" startTime="2562" endTime="2565" angle="70" distance="0.4" />

<pems startIndex="15" startTime="2568" endTime="2570" angle="80" distance="0.2" />

<pems startIndex="16" startTime="2585" endTime="2588" angle="270" distance="0.2" />

<pems startIndex="17" startTime="2594" endTime="2595" angle="90" distance="0.05" />

<pems startIndex="18" startTime="2610" endTime="2617" angle="90" distance="0.05" />

<pems startIndex="19" startTime="2637" endTime="2653" angle="0" distance="0" />

</pem>

<peg startTime="2439" endTime="2616" looking=”awayFace” />

<cState startTime="2439" endTime=”2616" state=”thought” />

<pbl startTime="2465" endTime="2469" type=”full” attack=”2” sustain=”0” decay=”3” />

<pSpeech startTime="2488" endTime="2573">

“Umm, there are a 1000 miles in a kilometre”

</pSpeech>

<pbl startTime="2504" endTime="2508" type=”full” attack=”2” sustain=”0” decay=”3” />

<pfe startTime="2534" endTime="2549" expression=”raised_brows” />

<pbl startTime="2545" endTime="2548" type=”half” attack=”2” sustain=”0” decay=”2” />

<pbl startTime="2549" endTime="2554" type=”full” attack=”2” sustain=”0” decay=”4” />

<pfe startTime="2562" endTime="2620" expression=”raised_brows” />

<pfe startTime="2564" endTime="2670" expression=”smile” />

<pSpeech startTime="2576" endTime="2678">

“Umm, I can’t convert one to the other without looking up the tables to find out the difference”

</pSpeech>

<pbl startTime="2578" endTime="2554" type=”full” attack=”2” sustain=”0” decay=”5” />

<pbl startTime="2600" endTime="2620" type=”full” attack=”6” sustain=”9” decay=”6” />

<cState startTime="2617" endTime=”2693" state=”unsure understanding” />

<peg startTime="2617" endTime="2693" looking=”atFace” />

<pbl startTime="2656" endTime="2663" type=”full” attack=”3” sustain=”0” decay=”5” />

<pSpeech startTime="2679" endTime="2738">

“Umm, but a mile is certainly further than a kilometre”

</pSpeech>

<phg startTime="2690" endTime="2743">

<phgs startIndex="1" startTime="2690" endTime="2699" direction="15" distance="0.3" endAngle="357" />

<phgs startIndex="2" startTime="2709" endTime="2725" direction="175" distance="0.4" endAngle="357" />

<phgs startIndex="3" startTime="2727" endTime="2733" direction="185" distance="0.1" endAngle="357" />

<phgs startIndex="4" startTime="2734" endTime="2743" direction="270" distance="0.05" endAngle="357" />

</phg>

<pbl startTime="2693" endTime="2697" type=”full” attack=”2” sustain=”0” decay=”3” />

<cState startTime="2694" endTime=”2713" state=”thought” />

<pem startTime="2694" endTime="2726">

<pems startIndex="1" startTime="2694" endTime="2696" angle="20" distance="0.4" />

<pems startIndex="2" startTime="2711" endTime="2713" angle="200" distance="0.5" />

<pems startIndex="3" startTime="2724" endTime="2726" angle="0" distance="0" />

</pem>

<peg startTime="2694" endTime="2713" looking=”awayFace” />

<pbl startTime="2710" endTime="2717" type=”full” attack=”2” sustain=”0” decay=”6” />

<cState startTime="2714" endTime=”2743" state=”understanding” />

<peg startTime="2714" endTime="2885" looking=”atFace” />

<pbl startTime="2736" endTime="2744" type=”full” attack=”3” sustain=”0” decay=”6” />

<cState startTime="2744" endTime=”2884" state=”thought” />

<pbl startTime="2765" endTime="2775" type=”full” attack=”3” sustain=”0” decay=”8” />

<sSpeech startTime="2765" endTime="2882">

“Well, hazarding a guess then, what do you think would be the ratio between miles and kilometres?”

</sSpeech>

<phg startTime="2767" endTime="2771">

<phgs startIndex="1" startTime="2767" endTime="2771" direction="275" distance="0.05" endAngle="355" />

</phg>

<pbl startTime="2820" endTime="2828" type=”half” attack=”2” sustain=”0” decay=”7” />

<pbl startTime="2851" endTime="2858" type=”full” attack=”3” sustain=”0” decay=”5” />

<pst startTime="2867" endTime="2885" />

<cState startTime="2885" endTime=”3041" state=”unsure understanding” />

<pbl startTime="2885" endTime="2894" type=”full” attack=”3” sustain=”2” decay=”5” />

<phg startTime="2886" endTime="3140">

<phgs startIndex="1" startTime="2886" endTime="2894" direction="25" distance="0.3" endAngle="357" />

<phgs startIndex="2" startTime="2895" endTime="2897" direction="90" distance="0.05" endAngle="0" />

<phgs startIndex="3" startTime="2898" endTime="2902" direction="340" distance="0.05" endAngle="357" />

<phgs startIndex="4" startTime="2903" endTime="2906" direction="180" distance="0.1" endAngle="355" />

<phgs startIndex="5" startTime="2907" endTime="2909" direction="340" distance="0.05" endAngle="355" />

<phgs startIndex="6" startTime="2910" endTime="2918" direction="185" distance="0.2" endAngle="355" />

<phgs startIndex="7" startTime="2920" endTime="2925" direction="190" distance="0.1" endAngle="355" />

<phgs startIndex="8" startTime="2927" endTime="2929" direction="80" distance="0.05" endAngle="355" />

<phgs startIndex="9" startTime="2930" endTime="2935"

direction="180" distance="0.05" endAngle="355" />

<phgs startIndex="10" startTime="2936" endTime="2940" direction="315" distance="0.1" endAngle="355" />

<phgs startIndex="11" startTime="2941" endTime="2943" direction="170" distance="0.1" endAngle="355" />

<phgs startIndex="12" startTime="2944" endTime="2948" direction="50" distance="0.05" endAngle="355" />

<phgs startIndex="13" startTime="2949" endTime="2952" direction="190" distance="0.2" endAngle="357" />

<phgs startIndex="14" startTime="2953" endTime="2957" direction="310" distance="0.4" endAngle="357" />

<phgs startIndex="15" startTime="2958" endTime="2961" direction="170" distance="0.05" endAngle="357" />

<phgs startIndex="16" startTime="2962" endTime="2965" direction="40" distance="0.05" endAngle="357" />

<phgs startIndex="17" startTime="2969" endTime="2988" direction="175" distance="0.4" endAngle="355" />

<phgs startIndex="18" startTime="3013" endTime="3018" direction="70" distance="0.1" endAngle="357" />

<phgs startIndex="19" startTime="3019" endTime="3024" direction="340" distance="0.05" endAngle="357" />

<phgs startIndex="20" startTime="3032" endTime="3046" direction="170" distance="0.1" endAngle="357" />

<phgs startIndex="21" startTime="3054" endTime="3058" direction="180" distance="0.05" endAngle="357" />

<phgs startIndex="22" startTime="3059" endTime="3066" direction="0" distance="0.05" endAngle="357" />

<phgs startIndex="23" startTime="3074" endTime="3077" direction="180" distance="0.1" endAngle="357" />

<phgs startIndex="24" startTime="3083" endTime="3098" direction="10" distance="0.1" endAngle="357" />

<phgs startIndex="25" startTime="3099" endTime="3103" direction="180" distance="0.05" endAngle="357" />

<phgs startIndex="25" startTime="3119" endTime="3124" direction="290" distance="0.5" endAngle="3" />

<phgs startIndex="26" startTime="3125" endTime="3129"

direction="160" distance="0.2" endAngle="0" />

<phgs startIndex="27" startTime="3130" endTime="3135" direction="20" distance="0.3" endAngle="4" />

<phgs startIndex="28" startTime="3136" endTime="3140" direction="175" distance="0.1" endAngle="2" />

</phg>

<peg startTime="2886" endTime="2955" looking=”awayFace” />

<pem startTime="2888" endTime="2919">

<pems startIndex="1" startTime="2888" endTime="2892" angle="30" distance="0.3" />

<pems startIndex="2" startTime="2893" endTime="2896" angle="200" distance="0.35" />

<pems startIndex="3" startTime="2915" endTime="2919" angle="0" distance="0" />

</pem>

<pSpeech startTime="2894" endTime="3038">

“Actually, I think I can work it out because I believe a 100 kilometres an hour is 60 miles per hour, or pretty close to”

</pSpeech>

<pbl startTime="2900" endTime="2907" type=”full” attack=”4” sustain=”0” decay=”4” />

<pbl startTime="2910" endTime="2924" type=”full” attack=”2” sustain=”2” decay=”11” />

<pem startTime="2941" endTime="2955">

<pems startIndex="1" startTime="2941" endTime="2943" angle="80" distance="0.2" />

<pems startIndex="2" startTime="2953" endTime="2955" angle="0" distance="0" />

</pem>

<pbl startTime="2950" endTime="2959" type=”full” attack=”3” sustain=”1” decay=”6” />

<peg startTime="2956" endTime="3207" looking=”atFace” />

<pfe startTime="2993" endTime="3010" expression=”squint” />

<pbl startTime="3025" endTime="3032" type=”full” attack=”2” sustain=”0” decay=”6” />

<cState startTime="3042" endTime=”3163" state=”understanding” />

<pSpeech startTime="3054" endTime="3129">

“So, there’s a ratio, 10:6”

</pSpeech>

<pbl startTime="3079" endTime="3087" type=”full” attack=”3” sustain=”0” decay=”6” />

<pbl startTime="3117" endTime="3124" type=”half” attack=”3” sustain=”0” decay=”5” />

<pem startTime="3121" endTime="3140">

<pems startIndex="1" startTime="3121" endTime="3123" angle="90" distance="0.4" />

<pems startIndex="2" startTime="3129" endTime="3140" angle="0" distance="0" />

</pem>

<pbl startTime="3128" endTime="3133" type=”full” attack=”2” sustain=”0” decay=”4” />

<sSpeech startTime="3153" endTime="3288">

“If you divide that back down that would be 5:3 wouldn’t it?”

</sSpeech>

<cState startTime="3164" endTime=”3228" state=”thought” />

<pfe startTime="3192" endTime="3322" expression=”smile” />

<pem startTime="3205" endTime="3248">

<pems startIndex="1" startTime="3205" endTime="3208" angle="325" distance="0.3" />

<pems startIndex="2" startTime="3211" endTime="3212" angle="315" distance="0.1" />

<pems startIndex="3" startTime="3216" endTime="3219" angle="270" distance="0.4" />

<pems startIndex="4" startTime="3230" endTime="3232" angle="135" distance="0.4" />

<pems startIndex="5" startTime="3235" endTime="3236" angle="50" distance="0.1" />

<pems startIndex="6" startTime="3240" endTime="3242" angle="90" distance="0.3" />

<pems startIndex="7" startTime="3247" endTime="3248" angle="0" distance="0" />

</pem>

<phg startTime="3207" endTime="3261">

<phgs startIndex="1" startTime="3207" endTime="3214" direction="5" distance="0.2" endAngle="5" />

<phgs startIndex="2" startTime="3215" endTime="3217" direction="150" distance="0.05" endAngle="2" />

<phgs startIndex="3" startTime="3218" endTime="3222" direction="275" distance="0.05" endAngle="2" />

<phgs startIndex="4" startTime="3223" endTime="3228" direction="210" distance="0.05" endAngle="4" />

<phgs startIndex="5" startTime="3229" endTime="3233" direction="110" distance="0.3" endAngle="0" />

<phgs startIndex="6" startTime="3234" endTime="3244" direction="290" distance="0.2" endAngle="0" />

<phgs startIndex="7" startTime="3245" endTime="3250" direction="90" distance="0.1" endAngle="5" />

<phgs startIndex="8" startTime="3251" endTime="3255" direction="90" distance="0.05" endAngle="3" />

<phgs startIndex="9" startTime="3256" endTime="3261" direction="260" distance="0.05" endAngle="2" />

</phg>

<peg startTime="3208" endTime="3249" looking=”awayFace” />

<pbl startTime="3228" endTime="3232" type=”half” attack=”3” sustain=”0” decay=”2” />

<cState startTime="3229" endTime=”3263" state=”misunderstanding” />

<pbl startTime="3246" endTime="3255" type=”full” attack=”3” sustain=”0” decay=”7” />

<peg startTime="3250" endTime="3436" looking=”atFace” />

<cState startTime="3264" endTime=”3471" state=”thought” />

<pbl startTime="3292" endTime="3297" type=”full” attack=”2” sustain=”0” decay=”4” />

<pSpeech startTime="3292" endTime="3299">

“Huh Hmm”

</pSpeech>

<phg startTime="3293" endTime="3313">

<phgs startIndex="1" startTime="3293" endTime="3297" direction="190" distance="0.05" endAngle="1" />

<phgs startIndex="2" startTime="3298" endTime="3305" direction="300" distance="0.1" endAngle="0" />

<phgs startIndex="3" startTime="3308" endTime="3313" direction="300" distance="0.1" endAngle="1" />

</phg>

<sSpeech startTime="3312" endTime="3449">

“I have actually got a 2:3, er, sorry, 3:2 in that respect. So its 3 kilometres to”

</sSpeech>

<pbl startTime="3333" endTime="3340" type=”full” attack=”2” sustain=”0” decay=”6” />

<pem startTime="3334" endTime="3355">

<pems startIndex="1" startTime="3334" endTime="3459" angle="180" distance="0.05" />

<pems startIndex="2" startTime="3340" endTime="3343" angle="250" distance="0.3" />

<pems startIndex="3" startTime="3353" endTime="3355" angle="0" distance="0" />

</pem>

<phg startTime="3386" endTime="3411">

<phgs startIndex="1" startTime="3386" endTime="3389" direction="180" distance="0.05" endAngle="1" />

<phgs startIndex="2" startTime="3390" endTime="3393" direction="0" distance="0.05" endAngle="0" />

<phgs startIndex="3" startTime="3394" endTime="3398" direction="180" distance="0.05" endAngle="1" />

<phgs startIndex="4" startTime="3399" endTime="3401" direction="0" distance="0.05" endAngle="0" />

<phgs startIndex="5" startTime="3402" endTime="3406" direction="180" distance="0.05" endAngle="1" />

<phgs startIndex="6" startTime="3407" endTime="3411" direction="0" distance="0.05" endAngle="0" />

</phg>

<pbl startTime="3388" endTime="3396" type=”full” attack=”2” sustain=”0” decay=”7” />

<pbl startTime="3436" endTime="3442" type=”full” attack=”3” sustain=”0” decay=”4” />

<peg startTime="3437" endTime="3471" looking=”awayFace” />

<pem startTime="3437" endTime="3473">

<pems startIndex="1" startTime="3437" endTime="3438" angle="60" distance="0.1" />

<pems startIndex="2" startTime="3442" endTime="3445" angle="270" distance="0.1" />

<pems startIndex="3" startTime="3448" endTime="3450" angle="0" distance="0.3" />

<pems startIndex="4" startTime="3456" endTime="3459" angle="45" distance="0.6" />

<pems startIndex="5" startTime="3460" endTime="3461" angle="90" distance="0.2" />

<pems startIndex="6" startTime="3471" endTime="3473" angle="0" distance="0" />

</pem>

<pbl startTime="3454" endTime="3459" type=”full” attack=”2” sustain=”0” decay=”4” />

<pSpeech startTime="3454" endTime="3490">

“Ahh, I must have got something wrong somewhere… hmm”

</pSpeech>

<phg startTime="3454" endTime="3474">

<phgs startIndex="1" startTime="3454" endTime="3459" direction="0" distance="0.4" endAngle="1" />

<phgs startIndex="2" startTime="3460" endTime="3464" direction="180" distance="0.2" endAngle="0" />

<phgs startIndex="3" startTime="3465" endTime="3468" direction="355" distance="0.05" endAngle="0" />

<phgs startIndex="4" startTime="3469" endTime="3474" direction="179" distance="0.2" endAngle="0" />

</phg>

<sSpeech startTime="3460" endTime="3474">

“2 miles”

</sSpeech>

<pbl startTime="3469" endTime="3476" type=”full” attack=”2” sustain=”0” decay=”6” />

<cState startTime="3472" endTime=”3515" state=”understanding” />

<peg startTime="3472" endTime="3738" looking=”atFace” />

<phg startTime="3477" endTime="3580">

<phgs startIndex="1" startTime="3477" endTime="3483" direction="180" distance="0.15" endAngle="0" />

<phgs startIndex="2" startTime="3485" endTime="3488" direction="0" distance="0.2" endAngle="0" />

<phgs startIndex="3" startTime="3490" endTime="3494" direction="180" distance="0.3" endAngle="0" />

<phgs startIndex="4" startTime="3495" endTime="3498" direction="355" distance="0.2" endAngle="0" />

<phgs startIndex="5" startTime="3499" endTime="3502" direction="181" distance="0.1" endAngle="0" />

<phgs startIndex="6" startTime="3504" endTime="3508" direction="355" distance="0.05" endAngle="0" />

<phgs startIndex="7" startTime="3509" endTime="3511" direction="185" distance="0.05" endAngle="0" />

<phgs startIndex="8" startTime="3513" endTime="3514" direction="359" distance="0.05" endAngle="0" />

<phgs startIndex="9" startTime="3516" endTime="3518"

direction="180" distance="0.05" endAngle="0" />

<phgs startIndex="10" startTime="3520" endTime="3522" direction="0" distance="0.05" endAngle="0" />

<phgs startIndex="11" startTime="3523" endTime="3527" direction="180" distance="0.05" endAngle="0" />

<phgs startIndex="12" startTime="3528" endTime="3530" direction="0" distance="0.05" endAngle="0" />

<phgs startIndex="13" startTime="3531" endTime="3535" direction="180" distance="0.1" endAngle="0" />

<phgs startIndex="14" startTime="3536" endTime="3540" direction="0" distance="0.03" endAngle="0" />

<phgs startIndex="15" startTime="3541" endTime="3544" direction="180" distance="0.03" endAngle="0" />

<phgs startIndex="16" startTime="3545" endTime="3549" direction="0" distance="0.03" endAngle="0" />

<phgs startIndex="17" startTime="3550" endTime="3552" direction="180" distance="0.03" endAngle="0" />

<phgs startIndex="18" startTime="3554" endTime="3555" direction="0" distance="0.03" endAngle="0" />

<phgs startIndex="19" startTime="3556" endTime="3558" direction="180" distance="0.01" endAngle="0" />

<phgs startIndex="20" startTime="3560" endTime="3564" direction="0" distance="0.3" endAngle="0" />

<phgs startIndex="21" startTime="3565" endTime="3569" direction="182" distance="0.1" endAngle="0" />

<phgs startIndex="22" startTime="3571" endTime="3572" direction="0" distance="0.01" endAngle="0" />

<phgs startIndex="22" startTime="3574" endTime="3577" direction="180" distance="0.02" endAngle="0" />

<phgs startIndex="23" startTime="3578" endTime="3580" direction="0" distance="0.01" endAngle="0" />

</phg>

<sSpeech startTime="3486" endTime="3600">

“but it’s good as an approximation. But very good! That was well worked out”

```
</sSpeech>

<pbl startTime="3493" endTime="3498" type=”full” attack=”2” sustain=”0” decay=”4” />

<pbl startTime="3499" endTime="3506" type=”full” attack=”2” sustain=”0” decay=”6” />

<cState startTime="3516" endTime=”3581" state=”thought” />

<pbl startTime="3538" endTime="3545" type=”full” attack=”2” sustain=”0” decay=”6” />

<pem startTime="3539" endTime="3564">

    <pems startIndex="1" startTime="3539" endTime="3540" angle="200" distance="0.2" />

    <pems startIndex="2" startTime="3544" endTime="3546" angle="260" distance="0.1" />

    <pems startIndex="3" startTime="3551" endTime="3553" angle="45" distance="0.3" />

    <pems startIndex="3" startTime="3562" endTime="3564" angle="0" distance="0" />

</pem>

<pfe startTime="3558" endTime="3581" expression=”agreement_chin” />

<pbl startTime="3560" endTime="3569" type=”full” attack=”3” sustain=”0” decay=”7” />

<pbl startTime="3571" endTime="3580" type=”full” attack=”2” sustain=”0” decay=”8” />

<cState startTime="3582" endTime=”3647" state=”understanding” />

<pfe startTime="3583" endTime="3722" expression=”smile” />

<phg startTime="3604" endTime="3626">

    <phgs startIndex="1" startTime="3604" endTime="3607" direction="180" distance="0.1" endAngle="0" />

    <phgs startIndex="2" startTime="3612" endTime="3617" direction="180" distance="0.1" endAngle="0" />

    <phgs startIndex="3" startTime="3618" endTime="3621" direction="0" distance="0.01" endAngle="0" />

    <phgs startIndex="4" startTime="3623" endTime="3626" direction="180" distance="0.01" endAngle="0" />
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</phg>

<pbl startTime="3623" endTime="3629" type=”full” attack=”2” sustain=”0” decay=”5” />

<pbl startTime="3630" endTime="3641" type=”full” attack=”2” sustain=”1” decay=”9” />

<sSpeech startTime="3643" endTime="3740">

“I found however, umm, math’s to be a very difficult subject. How about you?”

</sSpeech>

<pem startTime="3647" endTime="3661">

<pems startIndex="1" startTime="3647" endTime="3649" angle="250" distance="0.3" />

<pems startIndex="2" startTime="3659" endTime="3661" angle="0" distance="0" />

</pem>

<cState startTime="3648" endTime=”3738" state=”thought” />

<pbl startTime="3652" endTime="3663" type=”full” attack=”3” sustain=”0” decay=”9” />

<pbl startTime="3713" endTime="3721" type=”full” attack=”2” sustain=”0” decay=”7” />

<pem startTime="3739" endTime="3815">

<pems startIndex="1" startTime="3739" endTime="3740" angle="260" distance="0.4" />

<pems startIndex="2" startTime="3747" endTime="3751" angle="320" distance="0.5" />

<pems startIndex="3" startTime="3753" endTime="3755" angle="0" distance="0.1" />

<pems startIndex="4" startTime="3758" endTime="3760" angle="0" distance="0.2" />

<pems startIndex="5" startTime="3765" endTime="3768" angle="90" distance="0.4" />

<pems startIndex="6" startTime="3771" endTime="3773" angle="90" distance="0.3" />

<pems startIndex="7" startTime="3777" endTime="3779" angle="45" distance="0.2" />

<pems startIndex="8" startTime="3785" endTime="3789" angle="225" distance="0.4" />

<pems startIndex="9" startTime="3792" endTime="3795" angle="225" distance="0.2" />

<pems startIndex="10" startTime="3813" endTime="3815" angle="60" distance="0.4" />

</pem>

<peg startTime="3739" endTime="3790" looking=”awayFace” />

<cState startTime="3739" endTime=”3848" state=”unsure understanding” />

<phg startTime="3753" endTime="3856">

<phgs startIndex="1" startTime="3753" endTime="3764" direction="350" distance="0.5" endAngle="5" />

<phgs startIndex="2" startTime="3765" endTime="3769" direction="10" distance="0.1" endAngle="5" />

<phgs startIndex="3" startTime="3770" endTime="3772" direction="90" distance="0.02" endAngle="5" />

<phgs startIndex="4" startTime="3773" endTime="3782" direction="90" distance="0.1" endAngle="3" />

<phgs startIndex="5" startTime="3783" endTime="3795" direction="175" distance="0.2" endAngle="3" />

<phgs startIndex="6" startTime="3796" endTime="3803" direction="190" distance="0.1" endAngle="1" />

<phgs startIndex="7" startTime="3809" endTime="3814" direction="190" distance="0.1" endAngle="1" />

<phgs startIndex="8" startTime="3818" endTime="3822" direction="30" distance="0.05" endAngle="0" />

<phgs startIndex="9" startTime="3833" endTime="3836" direction="310" distance="0.2" endAngle="359" />

<phgs startIndex="10" startTime="3837" endTime="3842" direction="190" distance="0.3" endAngle="355" />

<phgs startIndex="11" startTime="3843" endTime="3848" direction="5" distance="0.2" endAngle="0" />

<phgs startIndex="12" startTime="3850" endTime="3853"

direction="135" distance="0.05" endAngle="0" />

<phgs startIndex="13" startTime="3854" endTime="3856" direction="45" distance="0.05" endAngle="0" />

</phg>

<pSpeech startTime="3757" endTime="3836">

"Umm… I guess I was OK at the level I went to"

</pSpeech>

<pfe startTime="3762" endTime="3796" expression="raised_brows" />

<pbl startTime="3783" endTime="3792" type="full" attack="2" sustain="4" decay="4" />

<peg startTime="3791" endTime="3814" looking="awayFace" />

<cState startTime="3815" endTime="3875" state="understanding" />

<peg startTime="3815" endTime="4036" looking="atFace" />

<sSpeech startTime="3842" endTime="4060">

"Right, cos I found I had a tough time of it, cos I had a strict lecturer at school. So, do you remember your English lecturer at school?"

</sSpeech>

<pbl startTime="3844" endTime="3851" type="full" attack="3" sustain="0" decay="5" />

<cState startTime="3849" endTime="4077" state="thought" />

<pbl startTime="3864" endTime="3869" type="full" attack="3" sustain="0" decay="3" />

<pbl startTime="3870" endTime="3879" type="full" attack="2" sustain="0" decay="8" />

<pbl startTime="3889" endTime="3898" type="full" attack="3" sustain="0" decay="7" />

<pfe startTime="3905" endTime="3930" expression="nodding" />

<pbl startTime="3975" endTime="3986" type="full" attack="3" sustain="1" decay="8" />

<pbl startTime="3994" endTime="4004" type="full" attack="2" sustain="0" decay="9" />

<pem startTime="4036" endTime="4081">

<pems startIndex="1" startTime="4036" endTime="4038" angle="265" distance="0.3" />

<pems startIndex="2" startTime="4055" endTime="4059" angle="300" distance="0.4" />

<pems startIndex="3" startTime="4079" endTime="4081" angle="120" distance="0.7" />

</pem>

<peg startTime="4037" endTime="4081" looking=”awayFace” />

<pfe startTime="4076" endTime="4106" expression=”raised_brows” />

<cState startTime="4078" endTime=”4125" state=”understanding” />

<pbl startTime="4078" endTime="4086" type=”full” attack=”3” sustain=”1” decay=”5” />

<phg startTime="4078" endTime="4155">

<phgs startIndex="1" startTime="4078" endTime="4081" direction="0" distance="0.2" endAngle="0" />

<phgs startIndex="2" startTime="4082" endTime="4088" direction="185" distance="0.4" endAngle="3" />

<phgs startIndex="3" startTime="4089" endTime="4092" direction="45" distance="0.05" endAngle="3" />

<phgs startIndex="4" startTime="4093" endTime="4096" direction="180" distance="0.02" endAngle="2" />

<phgs startIndex="5" startTime="4098" endTime="4101" direction="315" distance="0.02" endAngle="2" />

<phgs startIndex="6" startTime="4114" endTime="4127" direction="0" distance="0.1" endAngle="2" />

<phgs startIndex="7" startTime="4128" endTime="4145" direction="320" distance="0.6" endAngle="0" />

<phgs startIndex="8" startTime="4146" endTime="4155" direction="225" distance="0.05" endAngle="0" />

</phg>

<pSpeech startTime="4079" endTime="4298">

“My English lecturer? Umm, only vaguely. I can remember one English lecturer from secondary school”

</pSpeech>

<peg startTime="4082" endTime="4126" looking=”atFace” />

<pem startTime="4125" endTime="4200">

<pems startIndex="1" startTime="4125" endTime="4130" angle="310" distance="0.7" />

<pems startIndex="2" startTime="4141" endTime="4142" angle="45" distance="0.2" />

<pems startIndex="2" startTime="4145" endTime="4147" angle="240" distance="0.3" />

<pems startIndex="3" startTime="4152" endTime="4154" angle="45" distance="0.2" />

<pems startIndex="4" startTime="4163" endTime="4166" angle="80" distance="0.3" />

<pems startIndex="5" startTime="4174" endTime="4176" angle="260" distance="0.3" />

<pems startIndex="6" startTime="4183" endTime="4184" angle="315" distance="0.1" />

<pems startIndex="7" startTime="4185" endTime="4188" angle="100" distance="0.5" />

<pems startIndex="8" startTime="4191" endTime="4193" angle="150" distance="0.3" />

<pems startIndex="9" startTime="4198" endTime="4200" angle="0" distance="0" />

</pem>

<cState startTime="4126" endTime=”4150" state=”thought” />

<peg startTime="4127" endTime="4187" looking=”awayFace” />

<cState startTime="4151" endTime=”4198" state=”unsure understanding” />

<phg startTime="4183" endTime="4267">

<phgs startIndex="1" startTime="4183" endTime="4194" direction="120" distance="0.7" endAngle="3" />

<phgs startIndex="2" startTime="4195" endTime="4198" direction="180" distance="0.2" endAngle="0" />

<phgs startIndex="3" startTime="4206" endTime="4211" direction="350" distance="0.3" endAngle="0" />

<phgs startIndex="4" startTime="4212" endTime="4217"

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direction="180" distance="0.6" endAngle="2" />

        <phgs startIndex="5" startTime="4218" endTime="4237"
direction="265" distance="0.3" endAngle="3" />

        <phgs startIndex="6" startTime="4239" endTime="4243"
direction="180" distance="0.1" endAngle="3" />

        <phgs startIndex="7" startTime="4244" endTime="4252"
direction="135" distance="0.5" endAngle="5" />

        <phgs startIndex="8" startTime="4253" endTime="4262" direction="80"
distance="0.2" endAngle="5" />

        <phgs startIndex="9" startTime="4263" endTime="4267" direction="15"
distance="0.15" endAngle="6" />

</phg>

<peg startTime="4188" endTime="4211" looking=”atFace” />

<pbl startTime="4197" endTime="4251" type=”full” attack=”2” sustain=”0”
decay=”3” />

<cState startTime="4199" endTime=”4311" state=” understanding” />

<pfe startTime="4204" endTime="4219" expression=”furrowed_brows” />

<pfe startTime="4211" endTime="4222" expression=”raised_brows” />

<pem startTime="4211" endTime="4251">

        <pems startIndex="1" startTime="4211" endTime="4214" angle="330"
distance="0.7" />

        <pems startIndex="2" startTime="4215" endTime="4217" angle="180"
distance="0.3" />

        <pems startIndex="3" startTime="4218" endTime="4220" angle="270"
distance="0.2" />

        <pems startIndex="4" startTime="4230" endTime="4232" angle="270"
distance="0.2" />

        <pems startIndex="5" startTime="4242" endTime="4245" angle="90"
distance="0.3" />

        <pems startIndex="6" startTime="4248" endTime="4251" angle="0"
distance="0" />

</pem>

<peg startTime="4212" endTime="4268" looking=”awayFace” />
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<pbl startTime="4240" endTime="4244" type=”half” attack=”3” sustain=”1” decay=”1” />

<pbl startTime="4246" endTime="4275" type=”full” attack=”3” sustain=”16” decay=”11” />

<peg startTime="4269" endTime="4349" looking=”atFace” />

<phg startTime="4280" endTime="4311">

<phgs startIndex="1" startTime="4280" endTime="4285" direction="210" distance="0.1" endAngle="6" />

<phgs startIndex="2" startTime="4286" endTime="4288" direction="285" distance="0.03" endAngle="4" />

<phgs startIndex="3" startTime="4293" endTime="4296" direction="0" distance="0.1" endAngle="3" />

<phgs startIndex="4" startTime="4297" endTime="4304" direction="195" distance="0.3" endAngle="3" />

<phgs startIndex="5" startTime="4305" endTime="4307" direction="315" distance="0.05" endAngle="4" />

<phgs startIndex="6" startTime="4308" endTime="4311" direction="235" distance="0.05" endAngle="4" />

</phg>

<pbl startTime="4307" endTime="4317" type=”full” attack=”3” sustain=”0” decay=”8” />

<sSpeech startTime="4309" endTime="4353">

“Right, and Maths lecturer?”

</sSpeech>

<cState startTime="4312" endTime=”4349" state=”thought” />

<pst startTime="4321" endTime="4349" />

<phg startTime="4328" endTime="4353">

<phgs startIndex="1" startTime="4328" endTime="4330" direction="180" distance="0.01" endAngle="3" />

<phgs startIndex="2" startTime="4331" endTime="4334" direction="180" distance="0.01" endAngle="3" />

<phgs startIndex="3" startTime="4335" endTime="4341" direction="0" distance="0.01" endAngle="3" />

<phgs startIndex="4" startTime="4342" endTime="4349" direction="180" distance="0.01" endAngle="3" />

<phgs startIndex="5" startTime="4350" endTime="4353" direction="0" distance="0.01" endAngle="3" />

</phg>

<pem startTime="4348" endTime="4362">

<pems startIndex="1" startTime="4348" endTime="4351" angle="280" distance="0.3" />

<pems startIndex="2" startTime="4353" endTime="4355" angle="290" distance="0.4" />

<pems startIndex="3" startTime="4360" endTime="4362" angle="315" distance="0.1" />

</pem>

<cState startTime="4350" endTime=”4535" state=”unsure understanding” />

<peg startTime="4350" endTime="4536" looking=”awayFace” />

<pfe startTime="4354" endTime="4391" expression=”raised_brows” />

<phg startTime="4354" endTime="4412">

<phgs startIndex="1" startTime="4354" endTime="4367" direction="315" distance="0.6" endAngle="4" />

<phgs startIndex="2" startTime="4368" endTime="4382" direction="280" distance="0.2" endAngle="3" />

<phgs startIndex="3" startTime="4387" endTime="4390" direction="180" distance="0.3" endAngle="3" />

<phgs startIndex="4" startTime="4391" endTime="4395" direction="0" distance="0.3" endAngle="3" />

<phgs startIndex="5" startTime="4396" endTime="4398" direction="180" distance="0.1" endAngle="3" />

<phgs startIndex="6" startTime="4399" endTime="4403" direction="0" distance="0.1" endAngle="3" />

<phgs startIndex="7" startTime="4404" endTime="4407" direction="180" distance="0.1" endAngle="3" />

<phgs startIndex="8" startTime="4408" endTime="4412" direction="0" distance="0.1" endAngle="3" />

</phg>

<pbl startTime="4358" endTime="4362" type=”full” attack=”2” sustain=”0” decay=”3” />

<pSpeech startTime="4366" endTime="4606">

“Ummm… Yes, there was one ummm…… uhhh, yes, one, yeah…, one in particular, one who did me for A-level maths was yeah… I remember him, he was quite good”

</pSpeech>

<pbl startTime="4371" endTime="4376" type=”full” attack=”2” sustain=”0” decay=”4” />

<pem startTime="4401" endTime="4518">

<pems startIndex="1" startTime="4401" endTime="4403" angle="40" distance="0.1" />

<pems startIndex="2" startTime="4469" endTime="4472" angle="60" distance="0.1" />

<pems startIndex="3" startTime="4482" endTime="4484" angle="240" distance="0.1" />

<pems startIndex="4" startTime="4514" endTime="4518" angle="0" distance="0" />

</pem>

<pbl startTime="4406" endTime="4412” type=”full” attack=”3” sustain=”0” decay=”4” />

<pbl startTime="4440" endTime="4449” type=”full” attack=”3” sustain=”0” decay=”7” />

<phg startTime="4485" endTime="4632">

<phgs startIndex="1" startTime="4485" endTime="4488" direction="180" distance="0.1" endAngle="3" />

<phgs startIndex="2" startTime="4489" endTime="4492" direction="5" distance="0.1" endAngle="3" />

<phgs startIndex="3" startTime="4493" endTime="4496" direction="170" distance="0.1" endAngle="4" />

<phgs startIndex="4" startTime="4497" endTime="4500" direction="0" distance="0.2" endAngle="4" />

<phgs startIndex="5" startTime="4501" endTime="4504" direction="180" distance="0.1" endAngle="4" />

<phgs startIndex="6" startTime="4505" endTime="4508" direction="0"

distance="0.1" endAngle="4" />

<phgs startIndex="7" startTime="4509" endTime="4510" direction="180" distance="0.1" endAngle="4" />

<phgs startIndex="8" startTime="4512" endTime="4513" direction="5" distance="0.1" endAngle="4" />

<phgs startIndex="9" startTime="4514" endTime="4518" direction="135" distance="0.5" endAngle="3" />

<phgs startIndex="10" startTime="4519" endTime="4523" direction="0" distance="0.1" endAngle="3" />

<phgs startIndex="11" startTime="4524" endTime="4527" direction="180" distance="0.3" endAngle="3" />

<phgs startIndex="12" startTime="4528" endTime="4531" direction="15" distance="0.2" endAngle="3" />

<phgs startIndex="13" startTime="4532" endTime="4532" direction="185" distance="0.1" endAngle="4" />

<phgs startIndex="14" startTime="4533" endTime="4538" direction="5" distance="0.1" endAngle="3" />

<phgs startIndex="15" startTime="4539" endTime="4542" direction="185" distance="0.2" endAngle="3" />

<phgs startIndex="16" startTime="4543" endTime="4546" direction="5" distance="0.2" endAngle="3" />

<phgs startIndex="17" startTime="4547" endTime="4550" direction="195" distance="0.2" endAngle="3" />

<phgs startIndex="18" startTime="4551" endTime="4554" direction="355" distance="0.2" endAngle="2" />

<phgs startIndex="19" startTime="4555" endTime="4557" direction="175" distance="0.1" endAngle="2" />

<phgs startIndex="20" startTime="4558" endTime="4562" direction="10" distance="0.2" endAngle="2" />

<phgs startIndex="21" startTime="4563" endTime="4566" direction="185" distance="0.4" endAngle="3" />

<phgs startIndex="22" startTime="4567" endTime="4570" direction="20" distance="0.2" endAngle="3" />

<phgs startIndex="23" startTime="4571" endTime="4578" direction="105" distance="0.3" endAngle="3" />

<phgs startIndex="24" startTime="4579" endTime="4581" direction="5"

distance="0.1" endAngle="3" />

<phgs startIndex="25" startTime="4582" endTime="4587" direction="270" distance="0.1" endAngle="2" />

<phgs startIndex="26" startTime="4588" endTime="4592" direction="230" distance="0.2" endAngle="3" />

<phgs startIndex="27" startTime="4593" endTime="4598" direction="290" distance="0.02" endAngle="2" />

<phgs startIndex="28" startTime="4599" endTime="4600" direction="0" distance="0.1" endAngle="3" />

<phgs startIndex="29" startTime="4601" endTime="4605" direction="`135" distance="0.1" endAngle="3" />

<phgs startIndex="30" startTime="4606" endTime="4607" direction="90" distance="0.05" endAngle="3" />

<phgs startIndex="31" startTime="4608" endTime="4611" direction="170" distance="0.2" endAngle="4" />

<phgs startIndex="32" startTime="4612" endTime="4614" direction="0" distance="0.05" endAngle="4" />

<phgs startIndex="33" startTime="4615" endTime="4617" direction="180" distance="0.05" endAngle="4" />

<phgs startIndex="34" startTime="4618" endTime="4621" direction="0" distance="0.1" endAngle="4" />

<phgs startIndex="35" startTime="4622" endTime="4624" direction="180" distance="0.1" endAngle="4" />

<phgs startIndex="36" startTime="4625" endTime="4628" direction="355" distance="0.05" endAngle="4" />

<phgs startIndex="37" startTime="4629" endTime="4632" direction="175" distance="0.05" endAngle="4" />

</phg>

<cState startTime="4536" endTime=”4626" state=”understanding” />

<pbl startTime="4513" endTime="4542” type=”full” attack=”3” sustain=”17” decay=”10” />

<peg startTime="4537" endTime="4652" looking=”atFace” />

<pbl startTime="4565" endTime="4572” type=”full” attack=”2” sustain=”1” decay=”5” />

<pbl startTime="4579" endTime="4586” type=”full” attack=”2” sustain=”0” decay=”6” />

<sSpeech startTime="4615" endTime="4718">

“Right, so you remember them for being good as opposed to me remembering them for being bad!”

</sSpeech>

<pbl startTime="4622" endTime="4630” type=”full” attack=”2” sustain=”0” decay=”7” />

<cState startTime="4627" endTime=”4688" state=”thought” />

<pem startTime="4652" endTime="4658">

<pems startIndex="1" startTime="4652" endTime="4654" angle="270" distance="0.3" />

<pems startIndex="2" startTime="4657" endTime="4658" angle="0" distance="0" />

</pem>

<peg startTime="4653" endTime="4657" looking=”awayFace” />

<peg startTime="4658" endTime="4754" looking=”atFace” />

<pfe startTime="4676" endTime="4823" expression=”smile” />

<cState startTime="4689" endTime=”4754" state=”understanding” />

<pbl startTime="4719" endTime="4741” type=”full” attack=”2” sustain=”16” decay=”5” />

<pSpeech startTime="4719" endTime="4725">

“Yeah!”

</pSpeech>

<phg startTime="4720" endTime="4782">

<phgs startIndex="1" startTime="4720" endTime="4724" direction="350" distance="0.3" endAngle="3" />

<phgs startIndex="2" startTime="4725" endTime="4730" direction="190" distance="0.7" endAngle="3" />

<phgs startIndex="3" startTime="4732" endTime="4735" direction="0" distance="0.7" endAngle="3" />

<phgs startIndex="4" startTime="4736" endTime="4740"

direction="180" distance="0.3" endAngle="3" />

<phgs startIndex="5" startTime="4741" endTime="4743" direction="5" distance="0.1" endAngle="3" />

<phgs startIndex="5" startTime="4744" endTime="4747" direction="185" distance="0.1" endAngle="3" />

<phgs startIndex="7" startTime="4748" endTime="4751" direction="5" distance="0.05" endAngle="3" />

<phgs startIndex="8" startTime="4752" endTime="4760" direction="185" distance="0.1" endAngle="3" />

<phgs startIndex="9" startTime="4761" endTime="4763" direction="5" distance="0.02" endAngle="3" />

<phgs startIndex="10" startTime="4764" endTime="4766" direction="185" distance="0.01" endAngle="3" />

<phgs startIndex="11" startTime="4767" endTime="4777" direction="10" distance="0.1" endAngle="3" />

<phgs startIndex="12" startTime="4778" endTime="4782" direction="135" distance="0.02" endAngle="3" />

</phg>

<sSpeech startTime="4734" endTime="4764">

“Very good. Ok”

</sSpeech>

<pbl startTime="4747" endTime="4754” type=”full” attack=”2” sustain=”0” decay=”6” />

<pem startTime="4754" endTime="4768">

<pems startIndex="1" startTime="4754" endTime="4756" angle="240" distance="0.3" />

<pems startIndex="2" startTime="4767" endTime="4768" angle="0" distance="0" />

</pem>

<peg startTime="4755" endTime="4767" looking=”awayFace” />

<cState startTime="4755" endTime=”4895" state=”thought” />

<peg startTime="4768" endTime="5019" looking=”atFace” />

<pbl startTime="4770" endTime="4778” type=”full” attack=”3” sustain=”0” decay=”6” />

<sSpeech startTime="4776" endTime="4892">

“Alright, well this is going to be easy for you I am sure, but let’s do a bit of a mathematical test on you”

</sSpeech>

<pbl startTime="4788" endTime="4796” type=”half” attack=”4” sustain=”0” decay=”5” />

<pst startTime="4815" endTime="4870" />

<pbl startTime="4819" endTime="4827” type=”full” attack=”2” sustain=”0” decay=”7” />

<phg startTime="4828" endTime="4910">

<phgs startIndex="1" startTime="4828" endTime="4831" direction="180" distance="0.01" endAngle="3" />

<phgs startIndex="2" startTime="4832" endTime="4835" direction="0" distance="0.01" endAngle="3" />

<phgs startIndex="3" startTime="4836" endTime="4839" direction="180" distance="0.02" endAngle="3" />

<phgs startIndex="4" startTime="4840" endTime="4844" direction="0" distance="0.01" endAngle="3" />

<phgs startIndex="5" startTime="4845" endTime="4847" direction="180" distance="0.01" endAngle="3" />

<phgs startIndex="6" startTime="4848" endTime="4851" direction="0" distance="0.01" endAngle="3" />

<phgs startIndex="7" startTime="4852" endTime="4856" direction="180" distance="0.01" endAngle="3" />

<phgs startIndex="8" startTime="4857" endTime="4860" direction="5" distance="0.01" endAngle="3" />

<phgs startIndex="9" startTime="4861" endTime="4864" direction="185" distance="0.01" endAngle="3" />

<phgs startIndex="10" startTime="4865" endTime="4867" direction="315" distance="0.01" endAngle="3" />

<phgs startIndex="11" startTime="4868" endTime="4871" direction="185" distance="0.01" endAngle="3" />

<phgs startIndex="12" startTime="4872" endTime="4875"

direction="45" distance="0.01" endAngle="3" />

<phgs startIndex="13" startTime="4876" endTime="4880" direction="180" distance="0.01" endAngle="3" />

<phgs startIndex="14" startTime="4881" endTime="4883" direction="0" distance="0.01" endAngle="3" />

<phgs startIndex="15" startTime="4884" endTime="4898" direction="180" distance="0.05" endAngle="3" />

<phgs startIndex="16" startTime="4899" endTime="4910" direction="5" distance="0.1" endAngle="3" />

</phg>

<pbl startTime="4862" endTime="4870" type="full" attack="2" sustain="0" decay="7" />

<pst startTime="4881" endTime="4894" />

<pbl startTime="4889" endTime="4893" type="full" attack="2" sustain="1" decay="2" />

<pSpeech startTime="4894" endTime="4902">

"Ok"

</pSpeech>

<pbl startTime="4896" endTime="4899" type="full" attack="1" sustain="0" decay="3" />

<cState startTime="4896" endTime="4905" state="understanding" />

<pbl startTime="4900" endTime="4908" type="full" attack="2" sustain="1" decay="6" />

<sSpeech startTime="4905" endTime="4937">

"What is the sum of 2 + 2?"

</sSpeech>

<cState startTime="4906" endTime="4942" state="thought" />

<phg startTime="4942" endTime="4979">

<phgs startIndex="1" startTime="4942" endTime="4945" direction="5" distance="0.15" endAngle="3" />

<phgs startIndex="2" startTime="4946" endTime="4951" direction="185" distance="0.1" endAngle="3" />

<phgs startIndex="3" startTime="4952" endTime="4955" direction="5" distance="0.05" endAngle="3" />

<phgs startIndex="4" startTime="4956" endTime="4962" direction="155" distance="0.05" endAngle="3" />

<phgs startIndex="5" startTime="4963" endTime="4966" direction="355" distance="0.02" endAngle="3" />

<phgs startIndex="6" startTime="4967" endTime="4979" direction="185" distance="0.05" endAngle="3" />

</phg>

<cState startTime="4943" endTime=”4954" state=”understanding” />

<pbl startTime="4944" endTime="4948” type=”full” attack=”2” sustain=”0” decay=”2” />

<pSpeech startTime="4946" endTime="4952">

“Four”

</pSpeech>

<pbl startTime="4949" endTime="4956” type=”full” attack=”2” sustain=”1” decay=”5” />

<cState startTime="4955" endTime=”5012" state=”thought” />

<sSpeech startTime="4971" endTime="5009">

“and the sum of 5 + 10?”

</sSpeech>

<pst startTime="4987" endTime="5012" />

<pbl startTime="5012" endTime="5017” type=”full” attack=”2” sustain=”0” decay=”4” />

<cState startTime="5013" endTime=”5063" state=”understanding” />

<phg startTime="5013" endTime="5039">

<phgs startIndex="1" startTime="5013" endTime="5018" direction="5" distance="0.02" endAngle="3" />

<phgs startIndex="2" startTime="5019" endTime="5026" direction="185" distance="0.2" endAngle="3" />

<phgs startIndex="3" startTime="5029" endTime="5039" direction="35" distance="0.15" endAngle="3" />

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</phg>

<pem startTime="5019" endTime="5025">

    <pems startIndex="1" startTime="5019" endTime="5020" angle="260"
distance="0.2" />

    <pems startIndex="2" startTime="5023" endTime="5025" angle="80"
distance="0.2" />

</pem>

<peg startTime="5020" endTime="5024" looking=”awayFace” />

<pSpeech startTime="5021" endTime="5033">

    “Fifteen”

</pSpeech>

<pbl startTime="5021" endTime="5031” type=”full” attack=”2” sustain=”0”
decay=”9” />

<peg startTime="5025" endTime="5094" looking=”atFace” />

<sSpeech startTime="5047" endTime="5086">

    “Sum of 1 + 0?”

</sSpeech>

<cState startTime="5064" endTime=”5094" state=”thought” />

<pst startTime="5064" endTime="5094" />

<pem startTime="5095" endTime="5104">

    <pems startIndex="1" startTime="5095" endTime="5096" angle="260"
distance="0.2" />

    <pems startIndex="2" startTime="5101" endTime="5104" angle="0"
distance="0" />

</pem>

<peg startTime="5095" endTime="5104" looking=”awayFace” />

<cState startTime="5095" endTime=”5134" state=”understanding” />

<phg startTime="5095" endTime="5139">

    <phgs startIndex="1" startTime="5095" endTime="5098" direction="0"
distance="0.1" endAngle="3" />

    <phgs startIndex="2" startTime="5099" endTime="5102"
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direction="185" distance="0.2" endAngle="3" />

<phgs startIndex="3" startTime="5103" endTime="5116" direction="35" distance="0.5" endAngle="5" />

<phgs startIndex="4" startTime="5117" endTime="5129" direction="180" distance="0.03" endAngle="5" />

<phgs startIndex="5" startTime="5133" endTime="5139" direction="180" distance="0.01" endAngle="5" />

</phg>

<pbl startTime="5099" endTime="5106" type="full" attack="3" sustain="0" decay="5" />

<pSpeech startTime="5099" endTime="5106">

"One"

</pSpeech>

<peg startTime="5105" endTime="5159" looking="atFace" />

<sSpeech startTime="5121" endTime="5148">

"Sum of a + b?"

</sSpeech>

<cState startTime="5135" endTime="5159" state="thought" />

<pst startTime="5135" endTime ="5159" />

<pem startTime="5159" endTime="5187">

<pems startIndex="1" startTime="5159" endTime="5161" angle="260" distance="0.3" />

<pems startIndex="2" startTime="5166" endTime="5169" angle="260" distance="0.2" />

<pems startIndex="3" startTime="5173" endTime="5174" angle="10" distance="0.3" />

<pems startIndex="4" startTime="5185" endTime="5187" angle="90" distance="0.3" />

</pem>

<peg startTime="5160" endTime="5186" looking="awayFace" />

<cState startTime="5160" endTime="5187" state="unsure understanding" />

<pfe startTime="5167" endTime="5337" expression="smile" />

<phg startTime="5178" endTime="5255">

<phgs startIndex="1" startTime="5178" endTime="5184" direction="260" distance="0.3" endAngle="5" />

<phgs startIndex="2" startTime="5185" endTime="5187" direction="95" distance="0.1" endAngle="5" />

<phgs startIndex="3" startTime="5188" endTime="5190" direction="0" distance="0.02" endAngle="5" />

<phgs startIndex="4" startTime="5191" endTime="5193" direction="100" distance="0.05" endAngle="5" />

<phgs startIndex="5" startTime="5194" endTime="5197" direction="180" distance="0.05" endAngle="5" />

<phgs startIndex="6" startTime="5198" endTime="5204" direction="10" distance="0.2" endAngle="3" />

<phgs startIndex="7" startTime="5205" endTime="5209" direction="210" distance="0.05" endAngle="4" />

<phgs startIndex="8" startTime="5210" endTime="5211" direction="95" distance="0.02" endAngle="4" />

<phgs startIndex="9" startTime="5212" endTime="5219" direction="175" distance="0.1" endAngle="4" />

<phgs startIndex="10" startTime="5223" endTime="5225" direction="185" distance="0.02" endAngle="4" />

<phgs startIndex="11" startTime="5226" endTime="5227" direction="280" distance="0.05" endAngle="4" />

<phgs startIndex="12" startTime="5228" endTime="5230" direction="235" distance="0.05" endAngle="4" />

<phgs startIndex="13" startTime="5231" endTime="5233" direction="5" distance="0.05" endAngle="4" />

<phgs startIndex="14" startTime="5234" endTime="5238" direction="155" distance="0.1" endAngle="4" />

<phgs startIndex="15" startTime="5239" endTime="5242" direction="325" distance="0.05" endAngle="4" />

<phgs startIndex="16" startTime="5243" endTime="5247" direction="180" distance="0.02" endAngle="4" />

<phgs startIndex="17" startTime="5248" endTime="5249" direction="45" distance="0.02" endAngle="4" />

<phgs startIndex="18" startTime="5250" endTime="5255"

direction="315" distance="0.02" endAngle="4" />

</phg>

<pbl startTime="5179" endTime="5183" type="half" attack="3" sustain="0" decay="2" />

<pSpeech startTime="5180" endTime="5214">

"Cant answer that. Don't know what a and b are"

</pSpeech>

<pbl startTime="5184" endTime="5190" type="full" attack="2" sustain="0" decay="5" />

<peg startTime="5187" endTime="5554" looking="atFace" />

<cState startTime="5188" endTime="5277" state="understanding" />

<sSpeech startTime="5249" endTime="5293">

"Ok. Well, that's enough engines for now"

</sSpeech>

<pbl startTime="5264" endTime="5273" type="full" attack="2" sustain="0" decay="8" />

<cState startTime="5278" endTime="5385" state="thought" />

<pbl startTime="5302" endTime="5308" type="full" attack="2" sustain="0" decay="5" />

<pst startTime="5309" endTime="5380" />

<sSpeech startTime="5314" endTime="5353">

"Did you experience the enjoy?"

</sSpeech>

<pem startTime="5371" endTime="5386">

<pems startIndex="1" startTime="5371" endTime="5374" angle="10" distance="0.4" />

<pems startIndex="2" startTime="5384" endTime="5386" angle="190" distance="0.4" />

</pem>

<phg startTime="5378" endTime="5429">

<phgs startIndex="1" startTime="5378" endTime="5385" direction="5"

distance="0.2" endAngle="3" />

<phgs startIndex="2" startTime="5386" endTime="5391" direction="300" distance="0.3" endAngle="2" />

<phgs startIndex="3" startTime="5392" endTime="5396" direction="260" distance="0.15" endAngle="1" />

<phgs startIndex="4" startTime="5399" endTime="5413" direction="180" distance="0.8" endAngle="1" />

<phgs startIndex="5" startTime="5415" endTime="5429" direction="5" distance="0.15" endAngle="1" />

</phg>

<pbl startTime="5380" endTime="5386" type="full" attack="4" sustain="0" decay="3" />

<cState startTime="5386" endTime="5444" state="misunderstanding" />

<pbl startTime="5387" endTime="5394" type="full" attack="2" sustain="1" decay="5" />

<pSpeech startTime="5387" endTime="5427">

"Did I experience any joy did you say?"

</pSpeech>

<cState startTime="5445" endTime="5523" state="thought" />

<sSpeech startTime="5450" endTime="5501">

"Did you experience the enjoy?"

</sSpeech>

<phg startTime="5452" endTime="5473">

<phgs startIndex="1" startTime="5452" endTime="5455" direction="0" distance="0.01" endAngle="1" />

<phgs startIndex="2" startTime="5456" endTime="5459" direction="180" distance="0.01" endAngle="1" />

<phgs startIndex="3" startTime="5460" endTime="5463" direction="0" distance="0.01" endAngle="1" />

<phgs startIndex="4" startTime="5464" endTime="5467" direction="180" distance="0.02" endAngle="1" />

<phgs startIndex="5" startTime="5468" endTime="5473" direction="355" distance="0.01" endAngle="1" />

</phg>

<pbl startTime="5462" endTime="5469” type=”full” attack=”3” sustain=”0” decay=”5” />

<pst startTime="5466" endTime="5523" />

<phg startTime="5519" endTime="5596">

<phgs startIndex="1" startTime="5519" endTime="5526" direction="0" distance="0.1" endAngle="1" />

<phgs startIndex="2" startTime="5527" endTime="5537" direction="0" distance="0.15" endAngle="1" />

<phgs startIndex="3" startTime="5538" endTime="5541" direction="340" distance="0.25" endAngle="0" />

<phgs startIndex="4" startTime="5542" endTime="5545" direction="180" distance="0.05" endAngle="0" />

<phgs startIndex="5" startTime="5546" endTime="5550" direction="90" distance="0.1" endAngle="0" />

<phgs startIndex="6" startTime="5551" endTime="5553" direction="0" distance="0.02" endAngle="0" />

<phgs startIndex="7" startTime="5554" endTime="5558" direction="185" distance="0.3" endAngle="0" />

<phgs startIndex="8" startTime="5559" endTime="5561" direction="355" distance="0.05" endAngle="0" />

<phgs startIndex="9" startTime="5562" endTime="5565" direction="175" distance="0.4" endAngle="0" />

<phgs startIndex="10" startTime="5567" endTime="5571" direction="325" distance="0.25" endAngle="359" />

<phgs startIndex="11" startTime="5572" endTime="5581" direction="45" distance="0.25" endAngle="359" />

<phgs startIndex="12" startTime="5582" endTime="5588" direction="225" distance="0.2" endAngle="359" />

<phgs startIndex="13" startTime="5589" endTime="5596" direction="125" distance="0.1" endAngle="359" />

</phg>

<pSpeech startTime="5520" endTime="5583">

“The enjoy … I can’t make sense of your sentence”

```
</pSpeech>

<cState startTime="5524" endTime=”5590" state=”misunderstanding” />

<pbl startTime="5546" endTime="5550” type=”full” attack=”2” sustain=”0” decay=”3” />

<peg startTime="5555" endTime="5572" looking=”awayFace” />

<pem startTime="5547" endTime="5573">

    <pems startIndex="1" startTime="5547" endTime="5549" angle="260" distance="0.2" />

    <pems startIndex="2" startTime="5553" endTime="5554" angle="315" distance="0.4" />

    <pems startIndex="3" startTime="5563" endTime="5573" angle="120" distance="0.7" />

</pem>

<pbl startTime="5552" endTime="5557” type=”full” attack=”2” sustain=”0” decay=”4” />

<pbl startTime="5559" endTime="5574” type=”full” attack=”3” sustain=”9” decay=”4” />

<peg startTime="5573" endTime="5815" looking=”atFace” />

<cState startTime="5591" endTime=”5665" state=”thought” />

<sSpeech startTime="5622" endTime="5663">

    “Did you enjoy the experience?”

</sSpeech>

<pst startTime="5630" endTime="5663" />

<phg startTime="5643" endTime="5688">

    <phgs startIndex="1" startTime="5643" endTime="5647" direction="180" distance="0.01" endAngle="359" />

    <phgs startIndex="2" startTime="5648" endTime="5651" direction="0" distance="0.01" endAngle="359" />

    <phgs startIndex="3" startTime="5652" endTime="5655" direction="180" distance="0.01" endAngle="359" />

    <phgs startIndex="4" startTime="5656" endTime="5660" direction="0" distance="0.01" endAngle="359" />
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<phgs startIndex="5" startTime="5661" endTime="5664" direction="180" distance="0.01" endAngle="359" />

<phgs startIndex="6" startTime="5665" endTime="5670" direction="0" distance="0.4" endAngle="0" />

<phgs startIndex="7" startTime="5671" endTime="5672" direction="180" distance="0.02" endAngle="359" />

<phgs startIndex="8" startTime="5674" endTime="5677" direction="0" distance="0.2" endAngle="0" />

<phgs startIndex="9" startTime="5678" endTime="5682" direction="180" distance="0.1" endAngle="0" />

<phgs startIndex="10" startTime="5684" endTime="5688" direction="215" distance="0.1" endAngle="0" />

</phg>

<cState startTime="5666" endTime=”5688" state=”understanding” />

<pbl startTime="5667" endTime="5673” type=”full” attack=”2” sustain=”0” decay=”5” />

<pSpeech startTime="5668" endTime="5674">

“Yes”

</pSpeech>

<cState startTime="5689" endTime=”5700" state=”thought” />

<sSpeech startTime="5689" endTime="5727">

“Good. Ok. Me too!”

</sSpeech>

<phg startTime="5696" endTime="5735">

<phgs startIndex="1" startTime="5696" endTime="5700" direction="200" distance="0.1" endAngle="0" />

<phgs startIndex="2" startTime="5708" endTime="5712" direction="160" distance="0.05" endAngle="0" />

<phgs startIndex="3" startTime="5728" endTime="5731" direction="340" distance="0.05" endAngle="0" />

<phgs startIndex="2" startTime="5732" endTime="5735" direction="180" distance="0.1" endAngle="0" />

</phg>

<pbl startTime="5697" endTime="5704” type=”full” attack=”3” sustain=”0” decay=”5” />

<pfe startTime="5698" endTime="5815" expression=”smile” />

<cState startTime="5701" endTime=”5815" state=”understanding” />

<sSpeech startTime="5739" endTime="5783">

“Alright. Thank you very much!”

</sSpeech>

<pbl startTime="5773" endTime="5779” type=”full” attack=”2” sustain=”0” decay=”5” />

<pbl startTime="5801" endTime="5808” type=”full” attack=”3” sustain=”0” decay=”5” />

</dialogue>