DEVELOPMENT OF A VERBAL AND NON-VERBAL COMMUNICATION MODEL BETWEEN LEARNING COMPANION HUMANOIDS AND THE ELDERLY

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ABSTRACT

As the number of elderly people in Malaysia increases, they might feel lonely as caregivers struggle to give care and provide companionship to the elders. Loneliness can lead to mental diseases like depression and dementia that can have a negative impact on the quality of life of both elderly people and their caregivers. Therefore, a solution to overcome this problem is by using humanoids as companions for the elders and to encourage them to gain knowledge at a later age. This study aimed to develop a model on verbal and non-verbal communication between learning companion humanoids and elderly humans who live alone. Design and Development Research Approach (DDR) was adopted which consists of three phases. Phase 1 is the needs analysis phase that utilized survey questionnaires on 100 respondents and interviews on 5 participants to investigate the need to develop a communication model between humanoids and the elderly. The data was analyzed through Statistical Package for the Social Sciences (SPSS) and interpreted based on the values of mean and standard deviation. In Phase 2, Nominal Group Technique (NGT) and Interpretive Structural Modeling (ISM) were used in developing the model with aid from 8 heterogeneous experts. Data for this phase was interpreted based on the communication model generated by the ISM software and the classifications and relationships of the elements. The final phase adopted a modified Fuzzy Delphi Method (FDM) to evaluate the developed model in its suitability to facilitate successful communication between learning companion humanoids and elders who live alone. 15 experts shared their views by responding to a seven-point linguistic scale survey questionnaire. Experts' consensus for all the questionnaire items were determined by the calculation of the threshold values (d) whereas the defuzzification

values (Amax) indicated the agreement of the experts. The findings from Phase 1 showed that there was a need to develop a communication model for humanoids and elders who live on their own. Results of Phase 2 constitute the development of the model which comprises of 32 elements determined through experts' views. In the reviewing of the communication model, the experts had divided the elements into four domains and four clusters to interpret and understand the roles of the elements better. Finally, the results of Phase 3 showed that all the items have met the requirements of the triangular fuzzy number and defuzzification process which indicated that all the experts consensually agreed with the questionnaire items. The model is expected to act as a guideline in facilitating successful communication between learning companion humanoids and elders who live alone. Therefore, the results of the study can benefit the fields of education, health and robotics at the same time and improve the quality of life of elders who live alone.

PEMBANGUNAN MODEL KOMUNIKASI LISAN DAN BUKAN LISAN ANTARA TEMAN PEMBELAJARAN 'HUMANOID' DAN WARGA EMAS

ABSTRAK

Dengan penambahan warga emas di Malaysia, mereka mungkin rasa kesunyian kerana penjaga-penjaga menghadapi kesukaran dalam memberi penjagaan dan menjadi teman kepada warga emas. Kesunyian boleh menyebabkan penyakit mental seperti depresi dan demensia yang boleh memberi impak yang negatif kepada kualiti hidup warga emas dan juga penjaga mereka. Maka, satu penyelesaian bagi menangani masalah ini adalah dengan menggunakan '*humanoids*' sebagai teman kepada warga emas sambil menggalakkan mereka menambah ilmu pada usia yang sudah lanjut. Tujuan kajian ini adalah untuk membangunkan model komunikasi lisan dan bukan lisan antara ;*humanoid*' teman pembelajaran dan warga emas yang tinggal seorang diri. Kaedah Penyelidikan Reka bentuk dan Pembangunan (DDR) telah digunakan untuk kajian ini dan terdiri daripada tiga fasa. Fasa 1 adalah fasa analisa keperluan yang menggunakan soal selidik kepada 100 warga emas serta menemubual 5 warga emas bagi menyiasat keperluan untuk membangunkan satu model komunikasi antara '*humanoids*' dan warga emas. Data telah dianalisa melalui '*Statistical Package for the Social Sciences'* (SPSS) dan diinterpretasi berdasarkan nilai-nilai min dan sisihan piawai. Dalam fasa kedua, *Nominal Group Technique* (NGT) dan *Interpretive Structural Modeling* (ISM) telah digunakan dalam pembangunan model dengan bantuan 8 pakar yang berlainan bidang. Interpretasi data bagi fasa ini adalah berdasarkan model komunikasi yang dijanakan oleh perisian ISM dan juga klasifikasi dan hubungan antara elemen. Fasa terakhir menggunakan *Fuzzy Delphi Method* (FDM) yang diubahsuai untuk menilai model yang

telah dibangunkan dari segi kesesuaiannya dalam memudahkan keberjayaan komunikasi antara '*humanoid*' teman pembelajaran dan warga emas yang tinggal seorang diri. 15 orang pakar berkongsi pendapat melalui respon mereka terhadap soal selidik yang terdiri daripada skala tujuh linguistik. Konsensus pakar bagi semua item soal selidik ditentukan melalui pengiraan nilai ambang (d) manakala nilai nyahfuzzi (Amax) menunjukkan persetujuan pakar. Dapatan kajian bagi fasa 1 menyatakan bahawa terdapat keperluan bagi membangunkan model komunikasi antara '*humanoids*' dan warga emas yang tinggal seorang diri. Dapatan kajian bagi fasa dua pula adalah pembangunan model tersebut yang terdiri daripada 32 elemen yang ditentukan oleh pandangan pakar. Semasa menyemak semula model komunikasi tersebut, pakar-pakar telah membahagikan elemen-elemen kepada empat kategori dan empat kluster untuk menginterpretasi serta memahami peranan elemen-elemen dengan lebih baik. Akhir sekali, dapatan kajian bagi fasa 3 menunjukkan bahawa semua item telah memenuhi syarat-syarat yang diperlukan oleh '*triangular fuzzy number'* dan proses nyahfuzzi yang menyatakan bahawa semua pakar bersetuju dengan item soal selidik. Model tersebut diharap dapat digunakan sebagai garis panduan dalam memudahkan keberjayaan komunikasi antara '*humanoid*' teman pembelajaran dan warga emas yang tinggal seorang diri. Oleh itu, hasil kajian ini dapat memberi manfaat kepada bidang-bidang pendidikan, kesihatan dan robotik serta menaiktaraf kualiti hidup warga emas yang tinggal seorang diri.

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CHAPTER 1

Introduction

In the year 2030, Malaysia is expected to become an ageing nation in which 15% of the population will be 60 years and above (Goh et al., 2013). This increase will lead Malaysia to become an ageing population in 2021 when the population aged 65 years and above reach 7.1 percent due to fertility decline and increased longevity (Department of Statistics Malaysia Official Portal, 2010). These statistics show that there will be more elderly people in Malaysia, as is happening in the rest of the world as well. With this increase, a few questions and problems will arise. Will the elderly be well taken care of? Will they be physically, mentally and emotionally healthy as the years go by? What will happen if they are not? Are we ready to care for the elderly and are we ourselves ready for our golden years? These questions just represent a few areas that we need to address to tackle the issues surrounding the ageing population.

As humans age, the expected dream is to have a family: a spouse, kids and grandchildren. In reality though, not everyone can achieve this dream and a few are not even interested in this dream. There are those who have loved and lost due to many reasons, be it death, separation etc (Van Assche et al., 2013). Elders who still live with their spouses or children are considered lucky, especially if the elders are physically or mentally ill. Senior citizens who have good attitude and good relationships with their family are usually taken care of without much fuss. This ideal situation does not always occur in a setting of an elder being cared for by a carer, whether by an informal carer or a formal carer. Even elders who are healthy fall sick when living with their children or other carers because they usually do not know

what to do at other people's houses. They are told to rest for their health and some children do not want their parents to mess with the things in the house so as not to disrupt the way things are or they just don't like the way their parents do things. These conflicts, among others, cause friction and a lack of stimulation for the elderly. It can cause boredom and negative thoughts (Korte et al., 2011). This is also how perfectly healthy elders can suddenly get mental or physical illness despite taking good care of their health all those years before.

The bad thing about being a carer to a senior citizen is that it can bring about anger. The anger can come from the carer who can't cope with the demands of caring for an elder, especially one who is sick (Anderson & White, 2018). It can also come from the elder who cannot accept their illness or lack of independence and think of themselves as burden. When the children were young, parents were the decision makers and head of the household. As the elderly parents move into their children's house, the shift of power is hard for them to understand or get used to. Even the children don't understand how their reliable parents can become slow and forgetful as they age and seem to just cause trouble when they forget to turn off the lights or spill food with or without trembling hands. They cannot accept that their parents have become weaker and that can bring out unexpected anger. As they lash out at each other because they are not even aware of where the anger comes from, their relationship becomes worse and their mental and even physical health deteriorates (Shirai & Koerner, 2018).

The situation is not so different in formal caregiving settings like in nursing homes and senior centres. Although there are some good carers who understand the needs and wants of the elders, and there are elders who prefer to stay in nursing homes where they can be independent and at the same time be surrounded by friends,

such is not always the case. Some senior citizens are unhappy that their children or relatives do not want to take care of them and that they are 'thrown' into the hands of strangers. They cannot accept that fact and refuse to be happy there while pining for their children. This could be worse if they have some sort of disability and need help from carers to bathe or eat for example. The shame of needing help, especially from strangers, could be unbearable for some elders who are used to being independent (De Witt Jansen et al., 2017). For the formal carers, refusal from these seniors would mean they can't do their job well or fast enough as they would need to coax or even force the elders to cooperate with them. The work that they do can be repetitive as they have to do it the next day as well and also to a number of people. It can also be considered 'dirty' because they might have to deal with problems regarding body functions like changing diapers or spilt food and vomit. This brings about caregiver stress to those who can't cope and have to deal with it in their own ways. An example given by Emilsson (2008) was that a caregiver did laundry in her workplace as compensation for dealing with "an impossible work situation". The lack of understanding and patience for each other can lead to depression for both parties and also violence or abuse can be inflicted by any of them (Steve M., 2016).

Quite a number of elders do choose to stay on their own. These independent elders are used to doing everything themselves and they like it that way. For those who have children and prefer to stay by themselves, this could also mean that they are fond of their homes and have a hard time leaving it and the memories it contains. Getting used to life in a new house and a new neighbourhood is not easy for everyone, especially at a later age. Some elders, who are more able in terms of income, even hire formal caregivers to give personal care to them at their homes (Cederbom et al., 2017). For senior citizens who have grandchildren, taking care of

toddlers or babies can be tiring if they live with their children. Most of them prefer a quiet life and having more time for themselves compared to their younger days, raising their own children while working. On the other hand, some of the elders staying alone do not have children and chose that way. They are usually in good health because they are able to concentrate on caring for their own health. However, as they retire from work, there is minimal need for outside contact and a lack of social interaction is feared to lead to mental illnesses, as shown in the example studies below.

In Japan, there have been reports on depression in community-dwelling elderly (Wada, Ishine et al., 2004). Depression was associated with both lower activities of daily living (ADL) and quality of life (QOL). Another study by Murata, Kondo et al. (2008) showed that depression was significantly associated with lower socio-economic status and residential area. They stated that depression can lead to various health problems including disability. A study in South Korea (Lee, 2008) showed that significant violence occurred in families that live with an older relative who has physical or cognitive disabilities. The stress of being a caregiver can lead to violence, especially if the elder has disabilities and makes things difficult for the caregiver without them being aware of it. In another Asian country, a systematic review was done on loneliness and social support of older people in China (Chen, Hicks et al., 2014). They found that loneliness is a serious problem for older people but it can be alleviated by social support, especially from family and friends. Support from family can improve subjective well-being and mental health but effects of support from friends were inconsistent. They also receive little support from neighbours, governmental or other social organisations. A study in Hong Kong (Ngan & Kwan, 2002) revealed that a high proportion of elderly respondents residing

in their own residences fell into the highly depressed category. This can lead to serious mental and physical problems if not prevented.

The situation is similar in the West. A study in the United Kingdom by Aboderin (2004) tried to explain the lack of family support for the elderly using modernisation and ageing theory. Young people are unwilling to provide for their older parents or relatives. German researchers (Diestel, Cosmar et al., 2013) even did a study on burnout among nursing home employees and found that high levels of emotional exhaustion were associated with more errors. Emotional exhaustion can lead to stress and ultimately depression if caregivers are not careful. A study in Italy (Albertini & Mencarini, 2014) researched on childlessness and support networks in later life and one of the results was that they are more likely to report emotional support as the most important help received. This shows the importance of emotional support in the life of the elderly.

Emotional support can come in the form of communication. Good communication or conversation is beneficial for mental and emotional health which can translate to good physical health. As the conversations stimulate cognitive function and positive feelings, it does help in preventing the early onset of mental diseases such as dementia and depression (Cai et al., 1998). Although, communication that encourages negative feelings like anger and sadness should be avoided because it contributes to mental illnesses. However, these feelings can't be helped at times. There are also issues concerning 'baby talk', or some would call it 'elderspeak', whereby younger adults would talk to elders with a simplified vocabulary in a high-pitched tone of voice and a relatively slow speech (Brown & Draper, 2003). This was shown to be disliked by cognitively alert elders but was preferred by cognitively confused, dependent elders (Ryan et al., 1994). Therefore,

the verbal content and non-verbal aspects of communication can have an impact on the well-being of our elders.

Problem Statement

As humans get older, we depend more on others (Johnson, Cuijpers et al., 2014). Most of us get weaker mentally and physically. The solution that we have today for the seniors are by using informal and formal caregivers. Informal caregivers are usually family members, relatives or even neighbours and friends who care for the elderly without profit. Formal caregivers are senior centres or old folks homes where the seniors pay to get care. These current solutions are being overwhelmed by the increasing number of elderly and also the stress of caregiving (Bolin, Lindgren et al., 2008).

However, our healthcare policies are getting better and people are also taking better care of themselves as they are getting more health-conscious. These factors contribute to the increased longevity and number of elders. These elders have a sense of independence and feel that they do not want to burden anyone while they can still care for themselves (Lai, 2009). The independent elders may have lost a spouse or have never been married. They may not have children, close relatives or friends that they can depend on without feeling guilty of being a burden. Some of them just refuse to live with others due to pride or ego and even because of their love for their home which can have sentimental value to them.

As the elders opt to stay alone rather than living with a caregiver, they are more prone to loneliness. With ageing, it gets harder to maintain relationships and they feel a loss of connection with the outside world. Loneliness is a dangerous thing

as it can lead to a lot of mental diseases like depression and dementia that can cause various psychiatric and behavioural disturbances such as hallucinations, aggression and wandering (Smith, 2012). Such disorders have a negative impact on the quality of life of both elderly people and even their caregivers (Shibata & Wada, 2010).

Animals or pets can be good companions but they require energy, care and expenses that the elderly might not have. Money must be put aside for the pets' food and visits to the veterinarian which can get expensive. Pets are living beings and therefore can be unpredictable. Some animals have fur or dander which might be detrimental to the elderly in terms of health and cleanliness. Allergies that they have may lead to serious health problems and caring for a sick pet is also not easy and sickness is bound to happen (Shibata & Wada, 2010). Going to the veterinarian is another hassle if the elder has problem with transportation. If the pet that they have is big or heavy, carrying the animal may harm the owner by breaking the owner's back, knees or other body parts. As the animals can move on their own accord and can be small, the seniors may trip on their pets while they are curled up on the floor or running around the place. Verbal communication will also be one-way as animals and humans do not share the same language. Animal lovers may beg to differ but it is not the same as hearing the same language being spoken back to you.

In Malaysia, there is not enough support for elders who live alone to achieve successful ageing. Therefore, alternative solutions are being sought to overcome this problem. One of the solutions is by using artificial intelligence or robots to aid humans in caring for the elderly (Cavallaro, Morin et al., 2012). Quite a number of research projects pertaining to robots cater to the physical aspects of what a robot can do (Louie et al., 2014; Montemerlo et al., 2002; Fischinger et al., 2016), a handful cater to the needs of the elderly (Torta et al., 2014; Mitzner et al., 2014; Harmo et al.,

2005) and an even smaller number focus on the verbal communication between elderly humans and robots (Yorita & Kubota, 2011; Sugiyama et al., 2005). There are quite a few studies in connection to robots or artificial intelligence that are done on space exploration (Brunner et al., 2015) and for children with learning disabilities (Robins et al., 2009). Other than that, advanced countries have conducted researches on social robots and using them in hotels (Pan et al., 2015) and are also working on making robots have the ability to learn (Asada et al., 2001). In Malaysia though, I have found no local literature on verbal and non-verbal communication between robots and elderly humans. Therefore, there is a lack of literature on verbal communication and non-verbal communication between robots and the elderly and also literature on robots as learning companions. The uniqueness of my study is to fill in these gaps.

As scientists and researchers develop robots or specifically humanoids to contribute to the betterment of quality of life of elders who live on their own, there is a need for a guideline to facilitate successful communication or conversation between robots and the elderly. Otherwise, the effort would just be a waste of time, energy and funds, and a lot more trial and error would have to be done compared to doing experiments regulated by guidelines approved by experts. If the humanoids were to be utilised in Malaysia, it would be best if the guidelines for the robots came from local experts. This is because the needs and wants of our elders may differ even slightly from elders in other countries. So far, there is no communication model focusing on verbal and non-verbal content between robots and the elderly with a local flavour. The verbal and non-verbal communication model in this study can act as that guideline and assist other researchers in developing companion robots that are capable and innovative in many ways.

Purpose of the Study

The general purpose of this study is to develop a model for verbal and non-verbal communication between learning companion humanoids and elderly humans in Malaysia. The model acts as a guideline to be used for humanoid robots when they are communicating with elders who live by themselves and are without a companion for a long period of time. Since independent elders are usually quite agile and can still move around on their own, communication or conversation is important for them to prevent mental diseases (Robinson, MacDonald et al., 2014). A panel of experts helped in developing the model by sharing their opinions in the development phase and decisions were made on the appropriate items to be put into the model. The relationships among the items were also determined. Another decision making tool using experts' views was used for the evaluation of the model. The procedure of developing the model incorporated three stages that were formed according to the design and development research (DDR) approach, which are the needs analysis phase, the development phase and the assessment phase.

Rationale of the Study

The study attempted to figure out what kind of companionship an elderly person who lives on their own would want in a humanoid robot. A lot of research has been done on the physical aspects of socially assistive robots (Salichs, Barber et al., 2006) like should the robots resemble humans or should they look more like machines and what size of robots are they comfortable with. In recent years, a lot of improvement and upgrades have been done on the robots so that they can do more

for the elderly like assisting them to another room or getting things for them (Pollack, Brown et al., 2002; Fischinger et al., 2016).

As some elders get older, they are still physically and mentally healthy but are not able to or are not allowed to work. In this fast-paced world that we live in, it is hard for them to find a companion who can just sit and listen and talk to them. They might not like to go outside too often as they feel that it is unsafe, or their friends may live too far away from them or might not be very healthy. Using the telephone often may put a strain on telephone bills as well. Whatever their reason may be, it is detrimental to the health of these elders to go without any kind of communication or social interaction every day (Smith, 2012). Even elders who do not like to be social, have to talk to someone for their mental health. Therefore, a humanoid companion is suitable for these elders.

Apart from being a companion, the humanoid can help the elders who are interested in gaining knowledge. It can help just by listening to the elders talk about what they learned or what they are interested in. It would be beneficial for the elderly to recite what they have learned as a form of mental training. The humanoid could give verbal cues when the elder is talking to show interest or acknowledgement of the information. Talking to another being would help with memory retention and understanding of the topic. Talking to oneself too often may make them feel like they have gone insane. Therefore, the act of having a conversation is crucial for the elder's mental health.

This study focuses on communication or more specifically, the type of companion that an elder would want to be with them. What type of 'personality' or specifications that the humanoid should have that they would not mind to talk to it

almost every day? The study aims to lessen, if not eliminate, loneliness among physically healthy elders. The three stages in the methodology will hopefully give the government an idea of what healthy Malaysian elders want in a companion and help them achieve successful ageing.

Objectives of Study

The main objective of the study is to design a model for a humanoid companion that can communicate verbally with Malaysian elders who are living alone. For independent elders, the humanoid can act as a friend when a friend is needed, which is more convenient and perhaps safer for them if there are no other alternatives in finding companionship due to their personal reasons. The humanoid can also help with the elders' learning activities and at the same time, encourage them to learn.

Sometimes, to improve on the quality of life for the elderly, all they need is a companion because they are still physically healthy albeit with some restrictions. This study will look at what elderly Malaysians require in a companion. The study consists of three phases and the objectives are as described below:

1. To find out the needs of elderly people regarding learning companionship.
2. To develop a model on verbal and non-verbal communication between learning companion humanoids and elderly humans.
3. To determine the usability of the model on verbal and non-verbal communication between learning companion humanoids and elderly humans.

Research Questions

The research questions for this study were formed according to the objectives, problem statement and rationale of the study. It was composed based on the three phases of the design and development research approach that is explained in chapter 3.

For Phase 1, the needs analysis phase sought to find answers to these research questions:

1.1 What physical type of humanoid robots do the elderly prefer?

1.2 What type of humanoid companion do the elderly prefer?

1.3 What are the elders' perception on communication between humanoids and humans?

For Phase 2, in developing the communication model between humanoids and elderly humans, a selected panel of experts were invited. The development phase seeks to find answers to these questions:

2.1 What are the experts' collective views on the elements that should be included in the development of the verbal and non-verbal communication model between learning companion humanoids and elderly humans?

2.2 Based on the experts' collective views, what are the relationships among the elements in the development of the verbal and non-verbal communication model between learning companion humanoids and elderly humans?

2.3 Based on the experts' collective views, how should the elements be classified in the interpretation of the verbal and non-verbal communication model between learning companion humanoids and elderly humans?

In Phase 3, the evaluation phase of the communication model between humanoids and elderly humans also utilises expert opinions and aims to find answers to these research questions:

3.1 What is the experts' consensus on the suitability of the elements proposed in the verbal and non-verbal communication model between learning companion humanoids and elderly humans?

3.2 What is the experts' consensus on the list of elements in the four clusters (Independent, Linkage, Dependent and Autonomous) as proposed in the verbal and non-verbal communication model between learning companion humanoids and elderly humans?

3.3 What is the experts' consensus on the relationships among the elements proposed in the verbal and non-verbal communication model between learning companion humanoids and elderly humans?

3.4 What is the experts' consensus on the usability of the verbal and non-verbal communication model between learning companion humanoids and elderly humans?

Limitations of the study

The development of the verbal and non-verbal communication model between humanoids and elderly humans was intended as a guideline or example for

robot scientists and manufacturers. An actual robot or software could not be made due to the lack of budget and expertise. Hence, this study is theoretical. It is also context specific as the model was produced for a targeted group of people with certain criteria.

In terms of methodology, the opinions of the elderly were sought after in order to determine their needs in the needs analysis phase of the development of the communication model. For the development phase, the study utilised the nominal group technique (NGT) to ascertain the elements of the model and interpretive structural modelling (ISM) in developing the model. In the final phase, fuzzy delphi method (FDM) was adopted in order to assess the model. All these methods and techniques mostly use experts' views. Therefore, the model was determined by the choices of experts and their viewpoints on the subject.

The sample for the needs analysis phase was chosen from Petaling Jaya area because the data collection was done under Malaysian Elders Longitudinal Research (MELoR) project which focused on the Petaling Jaya area. It is a research project catering to the needs and problems of the elderly and because of insufficient budget and transportation, the research assistants could only collect data in the areas surrounding University of Malaya. For clarification, this sample was only used for the needs analysis phase but elders who had worked as professionals were taken as the sample for the evaluation phase.

Significance of study

This study is significant as it contributes to the extention of knowledge in multiple fields, namely education, robotics and health. In the field of education, this

study shows that there is no limit in gaining knowledge, even at an old age and even if a person lives alone with minimal social contact. There are plenty of tools and technology that can aid in the pursuit of knowledge. It also shows that our senior citizens actually have a desire to continue gaining knowledge at that age. Furthermore, we could also find out the types of information that the elders are curious about and use those information for positive uses like prepare an event for the elderly according to things that they are most curious about or coming up with solutions for their problems so that it can benefit the youth when they get older as well. The contribution in the field of robotics is that most literature in that field are focused on the physical aspects of robots, very few literature have been done on communication. The contents of this study also challenges the advances in the world of robotics as the programming for the demands of an ideal humanoid companion can be quite difficult and revolutionary. Programmers can utilise this research as a guide in coming up with communication modules for humanoids and the elders. Other than that, this study is based on local context with Malaysian elders and Malaysian experts as local literature on robotics are very rare so this study contributes to the local domain as well. As for the contribution towards health, this study could provide an alternative solution towards preventing mental, emotional and physical illness of our elders which is becoming a concern, more so in recent times. As an extra benefit, it relieves the burden of the youth and the government in caring for sick elders before their time which could also lead to the carers' depression.

Operational Definition

Communication between humanoids and elderly humans: A socially intelligent robot should be able to communicate and interact with humans in similar ways humans interact with each other (Sekmen & Challa, 2013). Communication in this study is the exchange of words or information between the two parties.

Elderly humans: The age where a person is defined as an elderly may differ between countries due to functional abilities, social, political and economic situations (WHO, 2016). This study uses the age classification of elders in Malaysia which is 60 years old and above.

Face to face interaction: the reciprocal influence of individuals upon one another's actions when in one another's immediate physical presence (Erving Goffman, 1959).

Humanoid: According to Bennewitz et al. (2007), humanoids are complex machines with a human-like body plan and human-like senses. In this study, a humanoid is a type of robot that bears a resemblance to humans. Although the term humanoid can be used to explain anything that is human-like, it specifically refers to robots for this particular study.

Humanoid companion: Companion robots were made to satisfy social goals and to establish affective bonds (Heylen et al., 2012). In this study, it is a type of robot that acts as a companion to humans, usually at home. The robots interact with humans by talking, playing games or doing an activity.

Humanoid learning companion: According to Yorita and Kubota (2011), robotic conversation can activate the brain of the elderly and improve their concentration and memory. It is defined in this study as a type of robot that acts as a companion to humans while assisting them with their learning activities. The type of assistance depends on the ablities of the humanoids but for this study, it is in the form of encouragement in learning.

Non-verbal communication: It is defined as communication without words and includes gestures, facial expressions, body language, tone of voice etc (Kleckova, 2009). For this study, non-verbal communication consists of aspects related to speech like tone of voice, speed of speaking and voice pitch.

Paralanguage: a non-verbal element of communication and includes various acoustic properties of speech and vocal aspects of communication, such as pitch, intonation of speech and speed of speaking (George L. Trager, 1950).

Self-directed learning: a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes (Malcolm Knowles, 1975).

Verbal communication: Forms of verbal language between two persons characterize their relationship, including sounds, words, language, and speaking style (Kim et al. 2013). In this study, it is defined as the use of words in exchanging information between two or more parties. The exchange usually consists of a speaker and a listener.

Summary

This chapter consists of the reason this study was started and the rationale behind it. Those early sections aided in the formulation of the objectives and research questions of the study, which in turn systematically guided the development of the model. Limitations and benefits of the study was also mentioned. The operational definition of certain words were given to make things clearer as the use of the words could be unique to this particular research.

CHAPTER 2

LITERATURE REVIEW

Introduction

The general purpose of this study was to develop a verbal and non-verbal communication model between learning companion humanoids and elderly humans. It is aimed as a guideline for successful communication and interaction between the two parties, specifically at home. This chapter discusses important relevant theories and concepts that guide the selection of the elements to be integrated into the development of the model. Therefore, this chapter talks about these aspects:

1) Concept of communication.
2) Theoretical framework of the study:
    a. Paralanguage, a theory on the non-verbal aspect of language.
    b. Self-directed learning, which is a learning theory that will be used for the benefit of the elderly.
    c. Face to face interaction, which will explain the type of interaction that occurs between the humanoid and elderly involved.
3) Previous studies.
4) A conceptual framework for the development of the verbal and non-verbal communication model between humanoids and elderly humans.

Concept of Communication

Communication comes in verbal and non-verbal form. The verbal form includes the sounds, words, language and speaking style (Kim et al., 2013) that we use to convey information. Non-verbal communication consists of several categories like facial expressions, gaze, proxemics, paralanguage, etc. (Kleckova, 2009). It is mostly used to express our emotions. The combination of these two forms will enable better communication between two or more parties.

Humanoid communication is being researched on making it capable of intuitive multimodal communication with people (Bennewitz et al., 2007). It would enable the humanoids to be more efficient when communicating with humans and includes the use of multiple modalities like speech, facial expressions, gestures, body language, etc. A very recent study from Kumazaki et al. (2018) found that conversing with a simple humanoid robot promoted self-disclosure in adolescents with autism spectrum disorder compared to conversing with humans. The adolescents were also reported to share more personal experiences with the humanoid rather than an android that looks exactly like a human but is still essentially a robot or a machine. Brooks and Arkin (2007) did a study on body language for a humanoid robot to assist in verbal communication between humanoids and humans. A pilot study in Japan (Mitsunaga et al., 2008) was even researching on an adaptation mechanism based on reinforcement learning that reacts to body language in order to cater to individual preferences. Schurer et al. (2018) had tested a first prototype of a communication module that allows a humanoid to learn cultural meanings through a machine learning system in the form of the meaning of words and placement of objects. The interaction was achieved by non-verbal and natural language communication between humanoids and test persons. The experiment was

done in order to better understand how a spatial model of cultural meaning for humanoids could be developed so that the role of humanoid robots as human companions would be more successful. Furthermore, there is an interesting research by Kawato (2008) on brain controlled humanoid robots that can assist humans in a number of ways like being a nursing robot for disabled people in a natural way or substituting a human body that is far away at the time. Humanoids are also potentially being used as avatars for humans and used to portray the human's personality by replicating body movements (Bremner et al., 2017). Infantino et al. (2013) described an approach to robot introspection based on self-observation and communication so that the humanoid robot would be able to build, represent and understand its own internal state. This ability could improve communication and understanding between a humanoid robot and its human user. There is even a research whereby a life-supporting robot system can carry out tasks depending on the situation of the user which encompasses the user's emotions and task selection (Baek et al., 2006). Triggered by interactions between the robot and the user, the mechanism constructs and updates the association between the user's situation and tasks so that the robot can adapt to the user's behaviours related to the robot's tasks effectively. The system would then provide or suggest tasks according to the understanding of the situation.

As for communication between humanoids and the elders, the most important aspect for the elders is to gain a companion and a physical helper for difficult tasks (Zsiga et al., 2013). The humanoids should provide cognitive and physical support and also have perfect speech recognition and synthesis. Researchers are also incorporating emotion systems alongside cognitive systems of humanoid robots to improve on human-robot interaction because it can benefit the robots as well as the

humans (Breazeal, 2004). The study mentioned that a robot that cares for the elderly should be able to respond appropriately in times when the elder is showing signs of distress or anxiety, preferably without being annoying or upsetting. As learning companions for the elderly, it is said that robotic conversation can activate the brain of the elderly and improve their concentration and memory (Yorita & Kubota, 2011). Consequently, the conversational capability of a humanoid is applied to the prevention of dementia and other mental diseases in the elderly.

Paralanguage

Non-verbal communication consists of several categories like facial expressions, proxemics, paralanguage, gaze and haptics (Kleckova, 2009). It complements verbal communication in getting a point across and is also an important element towards successful communication. This study, however, will only take paralanguage as a focus in the study due to certain constraints.

Paralanguage is a non-verbal element of communication and includes various acoustic properties of speech and vocal aspects of communication, such as pitch, intonation of speech and speed of speaking (Shih, 2014). The term was coined by George L. Trager in the 1950s while he was working at the Department of State. These paralinguistic cues contribute to the emotional part of an utterance and can evoke different emotions from the listener as well (Campbell, 2007). For example, the phrase “Really? Tell me more about it.” in a high tone of voice can be perceived as interested whereas the same phrase in a low tone of voice can be perceived as bored. The listener would be more motivated to speak if the other party is perceived as interested.

Table 2.1

Paralanguage Aspects. Adapted from *Speech considered as modulated voice* by Traunmuller, 2005, Ms, University of Stockholm.

Paralanguage aspects	**Constituents**
Perspective	Acoustic and optics factors: place, distance, orientation
Organic	Larynx size, vocal tract length: age, sex
Expressive	Speaking rate, pitch dynamics, voice quality: emotion, attitude, environment
Linguistic	Words, speech sounds: message, accent, speech style

According to Traunmuller (2005), and as shown in the table above, paralanguage is divided into four aspects of the speech signal, which are the perspective aspects, organic aspects, expressive aspects and linguistic aspects. The perspective aspects of speech are more concerned with spatial relationships like distance, orientation and transition channel. These aspects have various impacts on communication. For example, listeners may identify the location of the speaker through sensing of distance and direction. On the other hand, organic aspects are modifications of speech caused by differences of the vocal tract. Every human being has their own unique vocal tract with a unique modification of speech. Based on these modifications, information like age, sex and pathology can be extracted. This aspect is usually used to differentiate between child and adult voices or male and female voices. Expressive aspects of paralanguage are transmitted by variations in speaking rate, pitch dynamics and voice quality (Schmitz & Berns, 2011). They contribute to the emotive or attitudinal quality of an utterance and strongly influence the communication process. For example, a speaker speaking at a fast rate may evoke a feeling of panic in the listener and they may end up finishing a task in a hurry.

Finally, the linguistic aspects transmit primarily the message itself. Other than the spoken words, dialect, accent and speech style are also transmitted. There is a huge influence on the communication process which is mainly based on the transmitted content. As an example, small vocalizers may be associated with being harmless or submissive whereas large vocalizers may come across as dangerous or dominant to others. This goes to show that paralinguistic properties of speech do play an important role in communication.

Self-Directed Learning

In 1973, Malcolm Knowles, an American Adult Educator who was famous for the theory of andragogy, had proposed a set of assumptions about adult learners. These assumptions differentiate andragogy from pedagogy or in other words, adult learners from young learners. With these assumptions, he later came up with the steps that self-directed learners could use to learn on their own. The assumptions are (Noor et al., 2014; Choy & Delahaye, 2002):

- The need to know – adults like to relate their learning to their lives. They need to know why something is important before learning it.
- The learner's self-concept – adult learners are responsible for their own decisions. They believe that they are capable of making decisions for themselves and not be led or manipulated by others.
- The role of the learner's experience – adults have a lot of life experiences that can have an impact on their learning. The experiences are used to express their self-identity and form valuable learning resources.

- Readiness to learn – adults are ready to learn when they realize that there is a need to learn. This realization can come when they see content that is relevant to their lives.
- Orientation to learning – adult learners expect life-centered content. They are motivated to learn as they realise the value of learning in enhancing their abilities in addressing issues and problems in their daily lives.
- Motivation – Most adults are intrinsically motivated to learn whereas some adults are also extrinsically motivated.

Then, in the year 1975, he published a book on self-directed learning titled 'Self-Directed Learning: A guide for learners and teachers'. He defined self-directed learning (SDL) as a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes (Knowles, 1975). These steps were useful in aiding those who wanted to learn on their own and for educators to teach this skill to their students and even for the educators to improve themselves.

The figure below sums up the learning steps a self-directed learner should take in order to learn successfully. The learning goals should be set first and planning of the learning strategies and resources should be in accordance to the goals. Then, the learning process takes place. After that, the learner can show what they have learned in however way and to whomever they want and reflect on what they have

learned. They can use that reflection to come up with new learning goals or set unrelated new ones.

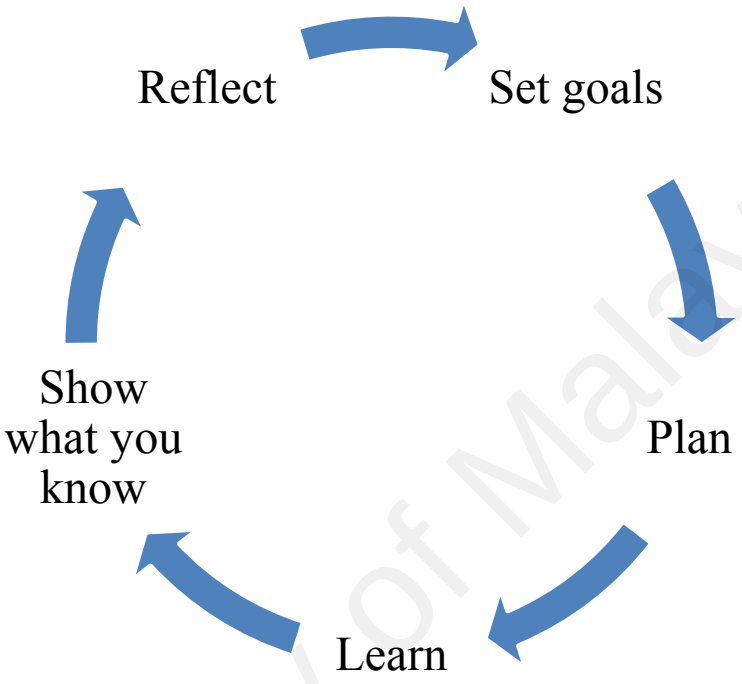


Figure 2.1. Learning Steps by a Self-Directed Learner. Adapted from http://www.slideshare.net/maheswarijaikumar/self-directed-learning-38965472

Face to Face Interaction

One of the most influential sociologists in America, Erving Goffman, defined face to face interaction as "the reciprocal influence of individuals upon one another's actions when in one another's immediate physical presence" in his 1959 book 'The Presentation of Self in Everyday Life'. It is a concept describing social interaction carried out without any mediating technology.

According to Duncan and Fiske (2015), there is a broad spectrum of acts that potentially contribute to face to face interaction and these acts have been subdivided in a variety of ways. A representative set of categories and terms are shown in seven major categories of action, which are:

a) Paralanguage: all information transmitted on top of speech signals but not directly related to the content of the spoken words.
b) Kinesics: any type of body motion including head, facials, trunk, hands and so on.
c) Proxemics: the perception of distance zones, spatial arrangements and sensory capabilities.
d) Artifacts: artifacts in the environment and even the environment itself influence a communication process.
e) Olfactory: the scent of interaction partners can also influence communication.
f) Haptics: related to specific situations like hand shaking, beating, grabbing or any kind of body contact between persons.
g) Language: although non-verbal aspects are considered important, most of the conversational content is transferred through the speech.

These categories were chosen by the researchers based on relatively specific, immediately observable behaviours for the sake of convenience. They stated that when there is less usage of abstracts in the characterization of human conduct, judges will not have to do a lot of inferring and they will not need to summarize their judgements over time.

Previous Studies on Paralanguage

Quite a number of studies found on paralanguage were done on children, whether it has to do with their emotions or learning abilities (Morton & Trehub, 2001; Rothman & Nowicki, 2004; Veenendaal, 2014). Some research even compared children and adults on their abilities pertaining to paralanguage (Hupp & Jungers, 2013) and found that adults were better than children in detecting paralanguage. It has even been studied in association with the service industry (Jung & Yoon, 2011) and romantic emotions (Farley et.al, 2013). Paralanguage is not a new theory but most of the studies found were recent and the number of research on this topic was not high.

In the field of technology, a study was done on computer-mediated communication (Shih, 2014) and part of the findings was that paralanguage does play a role in learning a new language. Communication that employs both verbal and non-verbal were able to sustain communication between two or more parties. Another study by Gupta et al. (2016) was on detecting non-verbal vocalizations as they are often associated with several aspects of human behaviour like depression, emotions and as a marker of the overall quality of interaction. Therefore, early detection of negative emotions may be beneficial for the future of healthcare. In Japan, a few researchers attempted to design a mutual adaptive speech interface that adopts the cognitive features humans use for communication and induces and exploits users' adaptations (Komatsu et al., 2005). They found that when interactive agents like robots or adaptive speech interface systems were required to form a mutual adaptation process with users, the agents should be equipped with two competences: the ability to recognize the reward information expressed in human paralanguage information and the possession of a system for learning about humans by using

reward information. The researchers came up with a meaning-acquisition model but there were still unresolved issues that were aimed to be resolved in subsequent studies.

Another study proposes to enhance the experience of humans with computers or robots by making it easier, more natural and effective (Kleckova, 2009). The researcher compared different methods to combine the results of both paralanguage and facial expressions to enhance the proposed dialog system. Researchers are also trying to make paralanguage computational (Schuller, 2012; Sundberg et al. 2011), in that machines are able to interpret paralanguage and identify traits and emotions like gender, depression or even sleepiness. Wang et al. (2014) had associated paralanguage, or specifically prosody, to the emotion intelligence of humanoid robots. They provided a new approach to design and evaluate the vocal emotion of humanoids based on the brain mechanism of human beings. As shown by these studies, research on paralanguage are scattered and few because there are a lot of sub criteria under the theory of paralanguage. Most researchers prefer to focus on a few aspects of paralanguage so as not to overwhelm themselves and readers with too much information or to make it too complicated and difficult to understand.

Previous Studies on Self-Directed Learning

A lot of literature on self-directed learning was written in the field of nursing or medicine (Williams, 1999; Fredholm, 2015; Applin et al., 2011; Hasan et al., 1997). They use this theory to ensure that nurses and clinicians are learning independently without the need for constant tutoring and that they are up to date on recent developments. They promote self-directed learning as a way to improve

themselves in a challenging and competitive field. The incorporation of self-directed learning during ward rounds proved to give better results than the traditional method among medical students (Prado et al., 2011). Another study connected self-directed learning to the level of confidence for newly qualified doctors (Whitehouse et al., 2002). Surprisingly enough, there is even a study on self-directed learning of women with breast cancer (Rager, 2003). The study examined the self-directed learning experiences of women with breast cancer and found that the efforts were beneficial to them in a number of ways, especially in a crisis situation. A self-directed learning program was used to provide introductory training in pivotal response treatment to parents of children with autism (Nefdt et al., 2010). The data proved to be promising and suggested the efficacy and effectiveness of a self-directed learning program to serve as an initial step toward providing intervention for parents of children with autism.

In education, studies were done on adult learners' informal learning experiences while in a formal education setting, usually set in a university (Peeters et al., 2014; Kicken et al., 2009; Suh et al., 2015; Stockdale & Brockett, 2011). This theory was also researched on student teachers (Tillema, 2000; Washbourne, 2014) to test the benefits of the theory on their improvement. There is even a discussion on the role of self-directed learning in teachers' professional development (Benson & Huang, 2008), in the form of teacher autonomy. Other than that, online learning is also being known as a self-directed learning tool (Hong et al., 2016; Ulrich & Karvonen, 2011; Kim et al., 2014). A lot of material and resources can be found on the internet and the process of online learning fits the criteria of self-directed learning. A blended learning model, incorporating self-directed learning through face to face and e-learning (Banyen et al., 2016), proved to be more successful than

traditional learning. The undergraduate students in the study were also satisfied with the outcome. However, a case study on an online graduate level course (Gilbert & Driscoll, 2002) did mention that some scaffolds should be provided to accommodate the freedom and learning orientation of students in a self-directed learning environment. This is because some students are not oriented towards this type of learning but the support should just guide and not drive the learning process of the students.

As we go deeper into education, in the aspects of andragogy or adult learning, there are the elders who are defined as 60 years old and above. They too have a desire to learn, even in their old age. An investigation on the SDL efforts of 10 adults (Danis & Tremblay, 1987, 1988) was done and they found that their participants used multiple approaches in their learning process. Seemingly random events were viewed as opportunities to further their personal learning. Another interesting study on SDL, done in a rural setting on older adults, reported that SDL occurs in overlooked ways like in the activities of everyday life, when a person is alone, and through individual thought processes and impressions (Leean, 1981). This goes to show that learning doesn't have to be in a classroom or with a tutor and it is a continuous process throughout life.

A study on the learning process of the elderly (Roberson & Merriam, 2005) linked the SDL process to three main changes in late life. The changes include more time due to retirement, the transitions in family life, and the experiences of social and physical loss. Due to these changes, some elders choose to stay at home while others choose to go out. Some can't go out because of health, safety or even social reasons that are personal to them. Roberson and Merriam (2005) also reported that an increasing number of elders enjoy using the computer and the Internet for their

learning purposes. This is a good sign of the open-mindedness of the elders and their readiness in accepting and learning new things.

Every adult would have their own purpose or direction in life and have their own personalities and preferences. This uniqueness means that they have their own set of assumptions about their life purposes. A study done by Kroth and Boverie (2000) stated that adults may re-evaluate and uncover their purposes by examining their assumptions about them through new learning experiences. These learning experiences may agree or disagree with their life purposes and it is up to them on what to do about the knowledge. This allows them to improve their quality of life at their own pace and on their own terms. A study by Kop (2011) discussed about the role and benefit of self-directed learning of adults during a massive online course. About half of the participants of the study were 55 years old and above and found that people need to have the ability to direct their own learning although some people do prefer more coordination or assignments to give their learning a direction.

In 1961, Houle suggested that adult learners are motivated to participate in learning activities because they are a means to accomplishing specific goals and are personally and socially gratifying. These learning activities could be accomplished alone with a number of resources to choose from but it would be nice if an elder had someone to talk to about what they learned that day and it would be good for memory retention to talk about it. Social isolation is unhealthy and to at least have one being to talk to is hugely beneficial in the long run.

As adult learners, the elders are self-directed and their learning is optimized when their experiences are recognized and utilized in the learning process (Chen, 2014). Their life experiences could become a medium in learning new content and in

redefining new goals to achieve (Merriam, 2001). Their environment and even conflicts that happen can trigger an interest on learning a particular subject. At a later age, health is usually a subject of particular interest to them. Every pain, sickness and prescription promoted individual efforts of learning (Roberson & Merriam, 2005).

Previous Studies on Face to Face Interaction

Many fields have done research on this theory, especially sociology. In the field of medicine, a study done by Eggenberger et al. (2013) showed that communication skills training by means of face to face interaction with the aim of improving basic communicative skills of people with dementia significantly improved their quality of life and wellbeing and also increased positive interactions in various care settings. Another study found that senior doctors in Australia thought that continuing medical education involving face to face interaction was superior to electronic forms of continuing medical education (Stewart & Khadra, 2009). They prefer face to face workshops than online material because they did not believe more modern, technology dependent forms were the best mode of delivery. There is even a research paper dedicated to improving face to face interaction among different communities of clinicians in hospitals by manipulating the spatial and structure of hospitals (Rashid, 2009). The paper explained the advantages of face to face interaction among clinicians especially in learning and for the benefit of their patients. In the world of computers, data from Wang and Chen (2012) indicates that collaborative learning can be effectively facilitated, cultured and enhanced in a cyber face to face environment. It is like a classroom with whiteboards and students but it

is done online so they are still able to pick up on visual cues even if they are not in the same room.

A study (Freitag, 2003) mentioned that face to face contact is a key ingredient for the development of trust. This makes sense as there is a saying that goes 'seeing is believing'. There is a difference in the amount of trust you can put into someone or something that is in front of you rather than a voice on the phone or a faceless person online. Results from research done by Van Zant and Kray (2014) revealed that people were more honest when communicating face to face rather than through an intermediary. They suggest that even the briefest of face to face interactions may activate moral interest that prevents individuals from lying to others. Apart from that, a study by Hampton and Parker (2011) reported that collaborations among institutions that meet face to face regularly are more productive in their research and publications. The number of meetings that they have affects the working group productivity and scientific impact. In a study on leadership (Kelly & Kelloway, 2012), it was found that managers or leaders who frequently have face to face interaction with their followers have better relationships than remote management, wherein the managers lead from afar and rarely meet their followers. They said that more face to face communication actually encourages higher communication frequency using other channels as well, like email and telephone. According to a study in the financial and business services sector in Manchester (Britton et al., 2004), researchers found that their respondents believe in the importance of face to face contact as a means of extending and consolidating trust relations between members of the business community despite the introduction and benefits of information technology.

Chan and Cheng (2004) found that, in a Chinese sample, higher degrees of understanding, interdependence and commitment among others were found in offline friendships than online friendships. Even when it comes to things that aren't alive, a person can feel a bond with a car or a teddy bear that is face to face rather than a person online or on the phone. In a study by Sessions (2010), online friends who meet face to face have better relationships than with friends who just interact online. They get to know each other better and non-verbal communication between them also plays a role in getting to know the other person. Another study (Lee et al., 2011) reported that socially isolated and disadvantaged people were less likely to use the Internet for interpersonal communication. This is said to be because of the lack of non-verbal cues, emotional information, and interactive rigor compared to face to face interaction. A social science study by Cohn (2010) even attempted to detect a person's emotions through facial expressions, specifically on pain detection and severity of depression. He tried to make it automated which would benefit the fields of computer science, health and psychology.

Recent research has shown that just by being present, another person's responses can be modified (Golland et al., 2015). The presence of another individual can automatically activate the mechanisms targeted to share information with others. Apart from that, it was also found that the presence of more than one individual can decrease actual self-disclosure, the willingness to self-disclose and the level of intimacy (Knop et al., 2016). A study by Waksler (2005) determined that face to face interaction is presented by co-presence and reciprocity, regardless of it being human or not. The author talked about the divine, the retarded, animals and even imaginary friends of children.

In 2016, Friedman wrote a paper on Berger and Luckman's *The Social Construction of Reality* that was published in 1966. It was stated that when a person can see with whom they are interacting with, they are 'available' in a way that makes them seem more 'fully real'. This emphasises the significance of face to face interaction in our daily lives. They also claim that conversation is the most important vehicle of reality maintenance. A study by Sacco and Ismail (2014) reported that although both virtual and face to face interactions reduced negative mood compared to no social interaction, only face to face interactions enhanced the participants' social belongingness needs and positive mood. This is further supported by a study from Vlahovic et al. (2012) that mentioned that face to face interaction positively predicted happiness compared to other modes of communication like Skype, telephone and instant messages. Face to face interaction plays an important role in building and maintaining emotionally intense relationships and that real and symbolic laughter can both mediate social interaction. They explained that laughter is systematically connected to elevated positive affect and prosocial behaviour, therefore bolstering human relationships through infusing communication with the positive affect. Even neuroscience (Watanabe et al., 2016) found proof that face to face interaction during work breaks significantly improved mood state and also observed that the verbal working memory task performance of participants who did not have face to face interaction during breaks decreased significantly.

Theoretical Framework of the Study

This section explains the variables and theories used in the study and their relationships. Figure 2.2 below maps out the theoretical framework for this study,

utilizing 3 theories which are the theories of paralanguage, face to face interaction and self-directed learning.

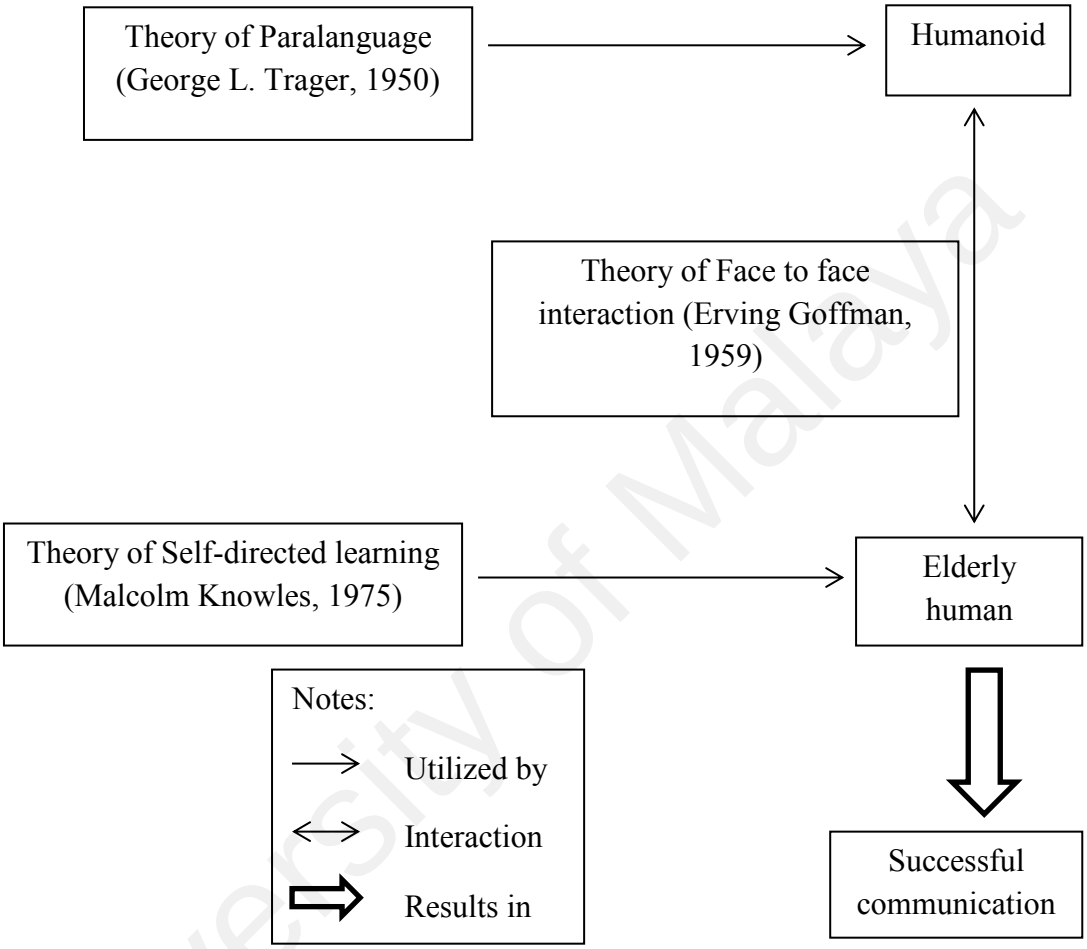


Figure 2.2. Theoretical framework of the verbal and non-verbal communication model between learning companion humanoids and elderly humans

The humanoid robot uses the theory of paralanguage to determine the most suitable aspects of verbal and non-verbal communication that can be used to have a conversation with elderly humans who live on their own. The aspects chosen should be able to mimic normal conversation and also able to motivate the elders to learn.

Therefore, the elements of the verbal and non-verbal communication model were based on the four aspects of the paralanguage theory which are perspective, organic, expressive and linguistic.

Self-directed learning is a learning theory that the elders can use to gain knowledge that is of interest to them as it can occupy their time and prevent mental diseases which in turn can cause physical diseases. This theory is beneficial to elders who live alone because they are in control of their learning objectives, procedures and outcomes. It validates their independence and they will not be bored or be at a loss on what to do with their spare time. Based on the learning steps of a self-directed learner portrayed in the theory (set goals, plan, learn, show what you know and reflect), the elders are in full control of the first, second and fifth steps but are aided by the humanoid robot in the third and fourth learning steps. Elements in the model were chosen with emphasis on these two steps out of the five steps of self-directed learning.

In order to link these two variables and theories together, face to face interaction is utilized. This theory works in the way that humanoids and the elders they are with should be in the same room so that the theories of paralanguage and self-directed learning can be used as well. One may argue that self-directed learning can be by itself as it is only used by the elders but bear in mind that the humanoid robot is supposed to aid the elders in their learning. Therefore, the two parties should be in the immediate presence of each other for these theories to work together. Elements of the communication model were categorized and narrowed down utilizing the seven categories of action mentioned in the theory. With the three theories successfully working together, the elderly and the humanoid would be able to achieve successful communication. As a consequence of good communication or

conversation between the two parties, mental diseases can be prevented and the elders' quality of life can also improve.

Conceptual Framework of the Study

This section talks about the conceptual framework of this research to emphasize on the key concepts and major variables in the development of the verbal and non-verbal communication model between learning companion humanoids and elderly humans. The framework involves these aspects:

a) The objective of the study.

b) The major variables in relation to the development of the model.

c) The theories supporting the variables and the way the variables are related to each other in accordance to the purpose of the study.

d) The way the variables are positioned during the development process of the model.

e) The theories and models involved in directing the development process of the model.

f) The way the theories, models and development process are linked to each other resulting in the end purpose of the study.

Described in detail, the conceptual framework in Figure 2.3 explains on:

a) Generally, the intention of this study is to help elders who live alone achieve successful ageing. Based on the problem statement, the main objective of the

study is to develop a verbal and non-verbal communication model between learning companion humanoids and elderly humans. This serves to contribute to the body of knowledge as a guideline in helping elders who live by themselves to achieve successful ageing with minimal help from other humans. This guideline is also aimed at preventing mental diseases and motivating the elderly to learn.

b) The main variables of the study would be the elderly human and the humanoid robot. Verbal and non-verbal communication would be incorporated in the model as a guideline for the interaction between the two parties.

c) There are three theories used in this study which are paralanguage, face to face interaction and self-directed learning. Paralanguage focuses the elements of the communication model to verbal and non-verbal aspects to be applied for the humanoid robot. Self-directed learning guides the elderly in taking control of their own learning process with aid from the humanoid robot. Face to face interaction links the two variables and theories so that the relationship of the three theories will result in successful communication between the learning companion humanoids and elders who live on their own. A model of perception systems for naturally interacting humanoid robots acts as a framework for the verbal and non-verbal communication model between learning companion humanoids and elderly humans. It is based on face to face interaction theory but in the context of HRI (Human Robot Interaction).

d) The variables are related to the development process of the model via the theories and model linked to them as portrayed in the framework based on the phases of the methodology (Design and Development Research Approach).

e) The conceptual framework also comprises of the models and approaches used in every phase of the methodology to lead the development of the communication model. For example, all the three theories with a model of perception systems for naturally interacting humanoid robots were utilized in leading the needs analysis phase. The interpretive structural modelling (ISM) technique is related to the second phase of the methodology as the major tool in developing the communication model. Then, the model is assessed using fuzzy Delphi method (FDM) as demonstrated in the framework.

f) The three theories and model were used as references throughout the research but especially in the design phase of the model. Generally, the conceptual framework was intended to demonstrate how the purpose of the research is accomplished via linking of the variables, theories, framework and model in developing the verbal and non-verbal communication model between learning companion humanoids and the elderly. The model serves as a guide in facilitating successful communication between learning companion humanoids and elderly humans who live alone.

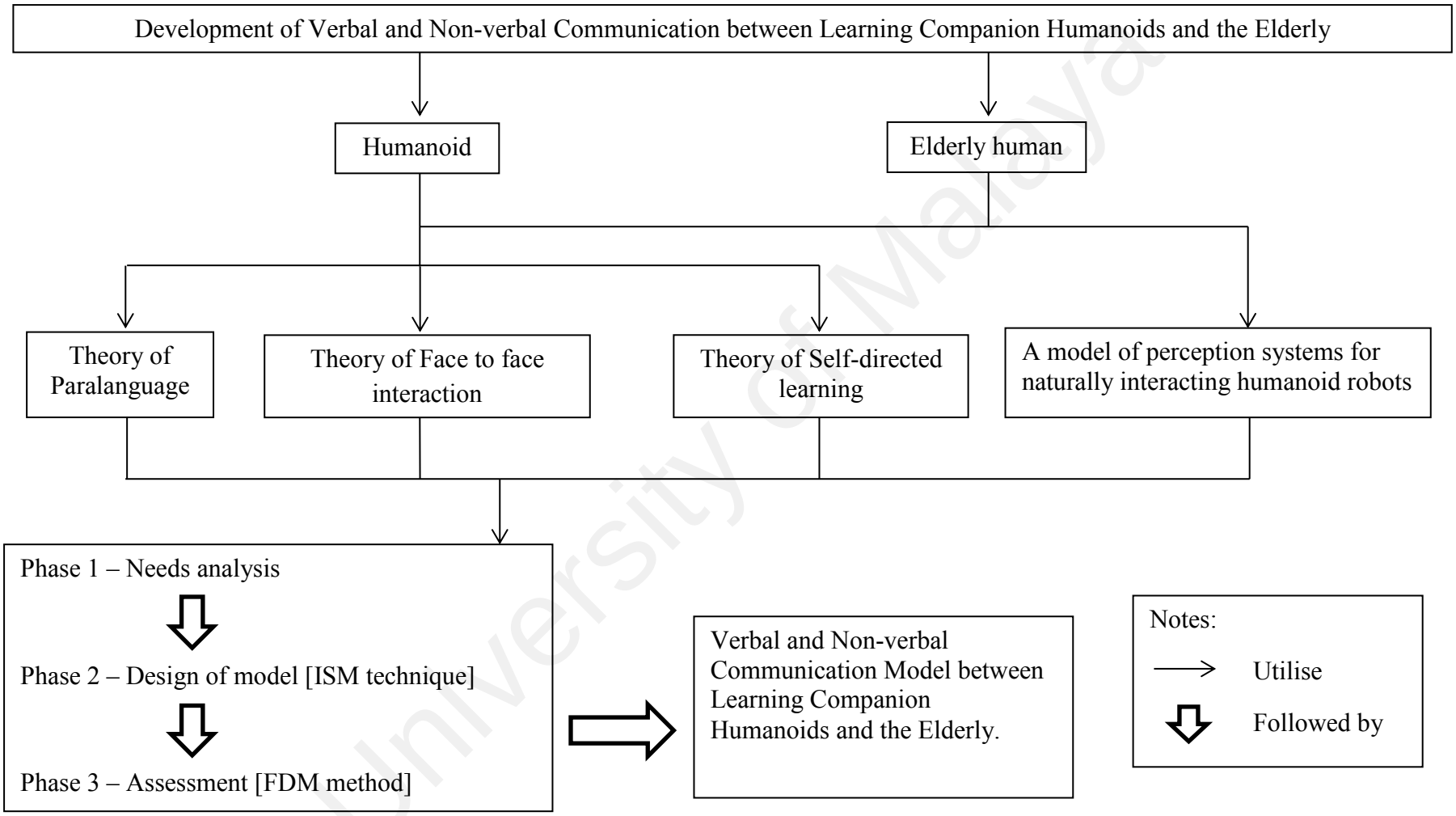


Figure 2.3. Conceptual framework of the verbal and non-verbal communication model between humanoids and elderly humans

Summary

The major purpose of this chapter was to show appropriate concepts and theories that would play a crucial role in leading the development of the verbal and non-verbal communication model between learning companion humanoids and the elderly. The theories were explained one by one and were linked to each other in the theoretical framework as well as to the variables and methodology of the study as shown in the conceptual framework.

CHAPTER 3

METHODOLOGY

Introduction

This chapter goes on to explain the methodology and procedures involved in the development process of the communication model between humanoid robots and the elderly. A major part of the methodology centers on a panel of experts' cooperation during the interpretive structural modeling session to aid in developing the model. Other than that, the discussion and literature on the past and present use of the interpretive structural modeling and fuzzy Delphi method as the assessment part of the methodology are also reported.

Method of the study

The study's goal is to develop a communication model to be used between humanoids and elderly humans. The development of this model was dependent on the collective opinions of a panel of selected experts. This research utilized paralanguage, face to face interaction, self-directed learning and a model of perception systems for naturally interacting humanoid robots as theoretical framework for the development of the communication model as reported in chapter 2. According to the study's intention, the objectives, as mentioned in chapter 1, are as follows:

1. To find out the needs of elderly people regarding learning companionship.
2. To develop a model on verbal and non-verbal communication between learning companion humanoids and the elderly.

3. To determine the usability of the model on verbal and non-verbal communication between learning companion humanoids and the elderly.

This study utilized the design and development research approach (Siraj et al., 2013) to develop the communication model. This method used to be known as developmental research (Richey et al., 2004). There are two essential aspects when defining the characteristics of design and development research: this method results in the production of some form of artifact, and the process is indeed research, not to be confused with product development (Ellis & Levy, 2010). The artifacts may include the development of a new tool, product, theory, model or even process. This chosen method has two types and this study is based on Type 2 which focuses more on model research as opposed to Type 1 which leans towards product and tool research (Richey et al., 2004).

This method has been simplified to contain 3 phases: needs analysis, design and development, and the assessment phase (Siraj et al., 2013). In the first phase, the needs of the elderly were investigated, in terms of companionship. This stage was also important to see whether they were ready to accept robots into their daily lives. The findings for this phase will act as the basis for the next phase of the methodology. The second phase was the design and development phase for the model. This stage required the participation of a selected panel of experts. The panel discussed and identified the suitable elements for the communication model. In the last phase, which was the assessment phase, the model was assessed by a modified mathematical method.

One of the strengths of design and development research (DDR) is that it can be used to solve problems in specific contexts. It addresses problems specific to the practice of instructional design and its processes. Therefore, DDR is very helpful to instructional designers to develop theories in this field. Other than that, DDR is also useful for research that uses new techniques or tools and does not have much reference and literature in the field (Siraj et al., 2013). This is suitable when the problem is related to new technology. In organizing research such as this, research questions are required instead of hypotheses because these emerging technologies need to be explored in specific contexts. As the contexts are specific and authentic to the participants, the credibility of the research is enhanced because of the original context although it may take more time and effort. Another strength of DDR is that the data collection is a combination of rich experiences from different perspectives as the participants in each phase of DDR may not be the same people.

On the other hand, there are a few limitations to this method (Siraj et al., 2013). The specific contexts require the methods used to be reliable so the data collected needs to be triangulated for validity and reliability. Other than that, the researcher is often the participant in DDR. The internal validity of the research is ensured by being as objective as possible to reduce any bias the researcher may have. As a participant observer or facilitator for the implementation of a model, objectivity can be made sure through systematic data collection during each phase of the research, and triangulation of data collection.

Table 3.1

Research Metrics

Research Questions	Method	Target/Data Analysis
Phase 1: Needs analysis 1.1 What physical type of humanoid robots do the elderly prefer? 1.2 What type of humanoid companion do the elderly prefer?	Questionnaire survey	100 respondents (SPSS)
1.3 What are the elders' perception on communication between humanoids and humans?	Interview (semi-structured)	5 participants (using Microsoft Word thematically)
Phase 2: Development of Communication Model between Humanoids and Elderly Humans. 2.1 What are the experts' collective views on the criteria that should be included in the development of the verbal and non-verbal communication model between learning companion humanoids and elderly humans? 2.2 Based on the experts' collective views, what are the relationships among the criteria in the development of the verbal and non-verbal communication model between learning companion humanoids and elderly humans? 2.3 Based on the experts' collective views, how should the elements be classified in the interpretation of the verbal and non-verbal communication model between learning companion humanoids and elderly humans?	Nominal Group Technique (NGT), Interpretive Structural Modeling (ISM) and MICMAC analysis	8 experts
Phase 3: The assessment of the Communication Model between Humanoids and Elderly Humans. 3.1 What is the experts' consensus on the suitability of the elements proposed in the verbal and non-verbal communication model between learning companion humanoids and elderly humans? 3.2 What is the experts' consensus on the		

list of elements in the four clusters (Independent, Linkage, Dependent and Autonomous) as proposed in the verbal and non-verbal communication model between learning companion humanoids and elderly humans? 3.3 What is the experts' consensus on the relationships among the elements proposed in the verbal and non-verbal communication model between learning companion humanoids and elderly humans? 3.4 What is the experts' agreement on the usability of the verbal and non-verbal communication model between learning companion humanoids and elderly humans?	Fuzzy Delphi Method (FDM)	15 experts

Phase 1 – Needs Analysis.

Purpose. The aim of this phase was to find out the needs of the elderly people in terms of companionship and whether or not there is a need for the development of this model according to their opinions. For the purpose of fulfilling this aim, the needs analysis phase tried to answer these research questions:

1. What physical type of humanoid robots do the elderly prefer?
2. What type of humanoid companion do the elderly prefer?
3. What are the elders' perception on communication between humanoids and humans?

Answers to these questions are crucial to justify whether there is a need to implement the communication model between humanoids and elderly humans in order to prevent loneliness. The model could also be used to assist the elderly in any desire to gain knowledge.

Interviews. Interview is a data collection tool that has been utilized in a majority of researches across education and social sciences discipline. It refers to a situation when an interviewer tries to obtain information from one or more participants by asking questions and recording their answers (Siraj et al., 2013). The most common categories of interviews used by researchers are structured interview, semi-structured interview, in-depth interview and focus group interview.

Compared to other research methods, this method is easier to manage and more flexible. There is a higher chance of response from the chosen sample and it can be used to investigate sensitive issues that can be difficult to identify using other methods. Interviews explore an individuals' manner of thinking and perception about a topic and there is always room for change in the early stages of interview. Other than that, interviews are more personal than other types of data collection methods so it makes the research more in-depth with complete information, provided the researcher is skilled at it.

On the other hand, this method can be time consuming with the amount of work that has to be done like setting up of the interviews, transcribing and analyzing the interviews. Interviewer bias is applicable too and must be careful of because the interviewer may get too involved in personal questions and it may affect the outcome of the research. Furthermore, it is not really practical if there are too many participants in the study and it may seem intrusive to some respondents. Therefore, anonymity should be assured by the interviewer so that the respondents will be more willing to share information.

Table 3.2

Common Forms of Interview Categorisation. Adapted from *Design and Developmental Research: Emergent Trends in Educational Research.* by Siraj et al., 2013, Kuala Lumpur: Pearson Malaysia Sdn Bhd. Print.

Type of interview	Aim of interview	Question form	Objective of analysis
Structured	• Face to face or using phone • Using a standard set of questions	• Fixed • Have order • Standardised	• Combine the data from different participants and apply the data from the sample to the population
Semi-structured	• Gaining a deep understanding based on information obtained • The level of understanding and depth identify this type of interview	• Flexible • Different level of standard • Open framework	• A lesser rigid type of answer that can be coded later by the researcher to fit a proper theme • Describe the event • Explore the similarities and differences among the respondents' replies
In-depth (unstructured interview)	• Face to face • Goal is to expose the participants' dominant structure	• Flexible • Different level of standard	• To obtain rich data • To obtain in-depth data
Focus group	• To initiate with an existing theory rather than generating a new theory	• Predetermined • Free flow of discussion	• To obtain impression, perception and thinking manner of the potential users/experts on a given topic

Sample and instrumentation of the study. This phase of the study involved 100 elderly people who were 60 years old and above and they were selected through purposive sampling (Guarte & Barrios, 2006). The participants were given a set of needs analysis questionnaire (Appendix A) and were asked to answer a number of questions that satisfied the first two research questions. It consists of 7 items and data was analysed via Statistical Package for the Social Sciences (SPSS) and interpreted based on the values of mean and standard deviation. The third question of Phase 1 was answered by interviews done on 5 elders (Appendix B). Semi-structured interview was used for this part of the phase with open-ended questions. This type of interview was chosen because the balance between structured and flexibility was most suitable to come up with the themes pertaining to this study. The responses from the participants were analyzed according to themes and summed up to meet the requirements of this phase. Then, it would be used as a basis for the next stage.

According to Merriam et al. (2002), both producers and consumers of research want to be assured that the findings of an investigation are to be believed and trusted. In research, this is represented by establishing the validity and reliability of a study. A survey has content validity built into it by careful selection of which items to include (Anastasi & Urbina, 1997). Items are chosen so that they comply with the survey specification which is drawn up through a thorough examination of the subject domain. Foxcroft, Paterson, le Roux & Herbst (2004) note that by using a panel of experts to review the survey specifications and the selection of items, the content validity of a survey can be improved. The experts will be able to review the items and comment on whether the items cover a representative sample of the behavior domain. Therefore, this study used content validity by recruiting 3 experts who reviewed and suggested a few improvements to the items in the survey.

Reliability test was also conducted on all the items in the questionnaire and it registered a Cronbach Alpha coefficient of 8.30. The validity and reliability of this stage is strengthened by the triangulation of data, as can be seen through the use of questionnaires and interviews. Other than that, peer review was done through discussions with colleagues about the raw data; and maximum variation was also done in that there is diversity in the selection of the sample.

Phase 2 – Development of Communication Model between Humanoids and Elderly Humans.

Purpose. In this phase, the development process of the communication model takes place. It seeks answers to these research questions:

1. What are the experts' collective views on the criteria that should be included in the development of the verbal and non-verbal communication model between learning companion humanoids and elderly humans?
2. Based on the experts' collective views, what are the relationships among the criteria in the development of the verbal and non-verbal communication model between learning companion humanoids and elderly humans?
3. Based on the experts' collective views, how should the elements be classified in the interpretation of the verbal and non-verbal communication model between learning companion humanoids and elderly humans?

This model was intended to make communication better and more beneficial for the elderly. The criteria should also be able to encourage the elders to learn through the humanoid. A number of experts were invited to discuss and choose the

criteria suitable for the model. Identifying the criteria is not enough without determining the relationship among these criteria in order to guide the makers of the humanoids more efficiently. However, discussing the criteria one by one took a lot of time and commitment before they could be selected. After that, the process became more complicated as the connections among the criteria needed to be investigated to form a meaningful and practical guide for the implementers of the model.

Interpretive Structural Modeling (ISM). This particular method was chosen for this phase because it could assist examination of the connections between the criteria involved and also an overall structural model could be brought out according to the connections of the criteria for the expected model. ISM was first proposed by John N. Warfield (1976) to analyze a complex socioeconomic system. It is a well-recognized methodology for identifying relationships among specific items, which define a problem or an issue (Attri et al., 2013). It is computer-aided to develop a graphical representation of system composition and structure.

ISM provides plenty of benefits over other methods utilised for analysis and decision making (Lee, 1999). It addresses a lot of communication issues related to problem solving in a group setting like the absence of a shared language. When a few people are grouped together, the pair-wise analysis of ideas promotes input from those who comprehend the issues being examined, but they might not comprehend every issue connected to the problem. Other than that, a lot of management tools that are accessible happen to be dichotic processes in which they break a problem down into smaller parts. ISM is a synthetic process and constructs a higher-level concept from a cluster of ideas that appear disconnected. The process of ISM also pressures decisions to be made. The end result is in fact the outcome of many smaller decisions that are formed during the construction of the model. An ISM computer tool can

methodically assist when handling hundreds of ideas. Furthermore, it is not difficult to learn and use ISM. It is formed on the concepts of pair-wise comparison and transitive logic, which a lot of people already utilize in their lives.

The ISM Process. There are a few steps involved in ISM (Attri et al., 2013). The first step is to determine the elements that are related to the problem. A survey or a group problem solving technique can be utilized for this purpose. Then, a contextual relationship between the elements is identified by experts that are knowledgeable about the problem. Based on the relationship, a Structural Self-Interaction Matrix (SSIM) is developed. This matrix indicates the pair-wise relationship among the elements. After that, a reachability matrix is developed by substituting symbols in SSIM to the numbers 1 or 0 in the reachability matrix. Then, the matrix is partitioned into different levels and converted to conical form. A digraph is drawn based on the relationship given in the reachability matrix and transitive links are removed. The digraph is then converted into an ISM model by replacing nodes of the factors with statements.

The model produced can be explained and judged by the experts to come up with an answer or even to just have a deeper comprehension of the issue or problem. This process will be discussed more in the procedure section. The section also indicates that ISM can be utilized in collaboration with different methodologies in research studies like brain storming, nominal group technique (Delbecq & Van de Ven, 1971) and Delphi technique (Adler & Ziglio, 1996). This study adopts the nominal group technique (NGT) to generate the variables that will be in discussion by the experts during the ISM session. The two methods form the bulk of the design and development process of the model.

Participants of the study. The participants for this phase were a panel of heterogeneous experts carefully chosen for the purpose of the study. The same panel was used for the NGT process and ISM session as ISM is a continuation of NGT in this research study. Jairath and Weinstein (1994) suggested that study participants should be experts who are knowledgeable about current information and perceptions regarding the subject of discussion but are open-minded to the findings. According to Adler and Ziglio (1996), there are certain criteria in selecting appropriate experts. The first component is having knowledge and practical engagement with the issues under investigation. Another criterion is the capacity and willingness of the experts to contribute to the exploration of a particular problem. Other than that, the experts should give assurance that a sufficient amount of time will be dedicated towards the process. The experts should also have skills in written communication and in expressing priorities through voting procedures.

This study chose experts in their selected areas to come together and give their input on those subjects as this research touches on a few areas at the same time. Therefore, the panel of experts was selected from these fields:

- Caregivers, either formal or informal caregivers to elders
- Geriatricians
- Professors and PhD holders in a variety of fields: Artificial Intelligence, Communication and Language.

Another major concern is the size of the panel of experts. The size of the group should be restricted to a total of about 8 people at most (Janes, 1988). This is because as the number of experts increase to more than 8 people, the quality of

discussion becomes worse. As every member of the group can talk with every other person, the number of possible communications between different individuals in a group of n people is n(n-1). Therefore, if the number of experts in the panel is 10 people, then the count of likely communications would amount to 10(10-1) = 90 likely communications. This would result in a decline of individual participation, involvement in the process and a lack of interest. Therefore, it could affect the quality of ISM results in a negative way.

In this study, the experts for both NGT and ISM sessions were made up of two geriatricians, two experts in Artificial Intelligence, 3 experts in Communication and Language and one formal caregiver. These total up to 8 experts in multiple fields. One of the experts, besides the formal caregiver, was a formal caregiver herself and a few experts are informal caregivers in which they take care of one elderly parent or both parents. Each of them has more than 5 years of experience in their respective fields. The profile of experts is shown in Table 3.3:

Table 3.3

Profile of Experts

Ex	Designation	Field of Expertise	Years of Experience
1	Associate Professor	Geriatrician- • Medical And Health Sciences (Falls, Syncope, Autonomic Dysfunction) • Autonomic Nervous System, Medical And Health Sciences (Syncope, Orthostatic Intolerance)	15
2	Doctor	Geriatrician- Medical And Health Sciences (Stroke)	14

3	Senior Lecturer	Artificial Intelligence- • Information, Computer And Communication Technology (ict) (Autonomous Robot, Cognitive Mapping, Cognitive Slam) • Biomedical Imaging/Modelling Information, Computer And Communication Technology (ict) (Cardiac Imaging/modelling, Craniofacial Imaging/modelling) • Motion/Action Recognition/Modelling Information, Computer And Communication Technology (ict) (Arm Flapping In Autistic Detection, Exoskeleton In Harvesting Activities)	8
4	Senior Lecturer	Artificial Intelligence- • Artificial Intelligence In Education Information, Computer And Communication Technology (ict) (Summarization, Summary Sentence Decomposition, Heuristic Rules, Understanding & Categorization, Essay Grading System) • Natural Language Information, Computer And Communication Technology (ict) (Malay Text Processing, Text Normalization, Stemming Algorithm)	15
5	Senior Lecturer	Communication & Language- English, head of management and administration at Institut Perguruan Bahasa	20

		Antarabangsa	
6	Senior Lecturer	Communication & Language- English, co-ordinator of English, has experience in organizing English-related events	14
7	Teacher	Communication & Language- Head of English Department, organized a lot of English-related activities	20
8	Director	Elderly Caregiving- has experience in company set-up, deals with elders from all races in Malaysia	7

Note. Ex = Expert

Instruments. Three instruments were used in this phase. Two instruments were used during the NGT session whereby there was an initial list of elements and a final list of elements. The initial list consisted of elements for the communication model that were generated from literature review and interview of 5 experts from different fields (Pre-NGT). They consisted of two experts from Language, one from Artificial Intelligence, one from Engineering and one from Communication. These experts were different than the experts in the NGT and ISM sessions. It assisted and guided the experts during NGT in determining the relevant elements for the verbal and non-verbal communication model. They could either agree or disagree to include or omit the elements and could even add other elements that they think are suitable. Then, the elements that were agreed upon were concluded in the final list. The experts had to designate a ranking number that shows their degree of preference for every element.

Another instrument was the interpretive structural modeling software that was produced by Sorach Incorporation and is known as Concept Star. The software was utilized to ease the process of discussion and decision making among the panel of

experts which was done in a closed session in order to ascertain the connection of the elements that had been put into the software. The NGT and ISM sessions were carried out in one day. An example of the program session can be seen in Appendix C. The execution of the sessions is discussed more in the next section.

Procedure of NGT and ISM. There are seven steps involved in Phase 2 of developing a verbal and non-verbal communication model between learning companion humanoids and elderly humans. The steps are described as follows:

1. Identification of elements that are in accordance to the problem or issues.

In order to identify the elements for this study, the researcher used a modified nominal group technique (NGT) as it is more efficient and complementary to be paired with interpretive structural modeling (ISM). NGT is an established method to generate ideas or variables that are related to an issue, problem or situation. Both of these techniques are similar in that they involve participants who have knowledge and interest about an issue (Kapelouzos, 2016). However, as NGT talks about the elements one-by-one, ISM takes it a step further by using mathematical algorithm and the aid of a computer to organize the elements and their relationships into a structure. Therefore, the two techniques do complement each other.

The classic NGT, according to Van de Ven & Delbecq (1972), is a structured meeting which seeks to provide an orderly procedure for obtaining qualitative information from target groups who are most closely associated with a problem area. It has been associated with five basic steps (Potter et al., 2004):

1) An introduction and explanation on the purpose and procedure of the meeting;
2) Silent generation of ideas that is done individually;

3) Sharing of ideas with the group;
4) Group discussion where explanations on the ideas can be asked for; and
5) Voting and ranking of the ideas.

In this study, instead of the experts generating ideas individually, they were given an initial list of elements that were compiled from literature review and interview of 5 experts. This helps to guide them in coming up with ideas related to the issue and it shortens the process of NGT to about two hours as the experts are very busy people and some of them had expressed their time constraints. Some researchers conduct the processes of NGT and ISM in more than one day so as not to stress the participants too much but in this case, the participants preferred to dedicate one whole day for the two processes. In this list, the experts could choose to agree or disagree with the elements proposed and they could add other elements that they thought were relevant. Then, after the group discussion, a final list was given to each expert for them to give a ranking number to each element. The ranking was in a scale of one to seven in which one signifies the least favourable and seven is the most favourable element to be a part of the model. The scale is interpreted as seen below:

1 = Least favourable 7 = Most favourable

2 = Slightly favourable

3 = Moderately favourable

4 = Favourable

5 = Very favourable

6 = Highly favourable

The ranking numbers assigned from the experts were added up to allocate priority values to each element. Finally, the NGT process ended with the elements being prioritized based on the priority values where the highest number would be the most important on the list.

2. As the process of ISM starts, the contextual relationship and relation phrase for the elements should be determined. The contextual relationship refers to the objective or end result of this exercise. It provides the focus on the way the elements need to be linked during the construction of the ISM model. The objectives of this study were utilized to decide the context of the relationship. The relation phrase shows how the relationships between the elements are analyzed during ISM. The contextual relationship and relation phrase were decided through the consensus of the experts.

3. Development of a Structural Self-Interaction Matrix (SSIM) of the elements that indicate the relation between them. This step was carried out with the assistance of ISM software that was developed by Concept Star of Sorach Incorporation. The software displays the elements in pairs so that the experts can decide the relationship of the pairs through voting procedure. The action of pairing and voting was done repeatedly until all the elements had been paired.

4. Generation of the ISM model. After the voting session and all the elements had been effectively paired, the software generates the model according to the concept of pair wise comparison and transitive logic. Transitive logic states that for any 3 elements (A, B, C) with a given relation:
   - When A has a relation to B (written A → B),

- And B has a relation to C (written B → C),
- Then A has a relation to C (written A → C or A → B → C).

5. The model is then shown to the experts to inspect for any conceptual inconsistencies or necessary modifications. Any amendments that are crucial and minor will be done through the software again for the final model. After the amendments were made, the model is presented to the experts. The next steps (6 and 7) are to interpret the final model further.

6. As the model is generated, it has to be interpreted correctly in order to understand it. Therefore, the reachability matrix has to be partitioned to classify the elements into different levels. Generally, the reachability matrix was achieved by substituting V, A, X and O to 1 and 0 based on the SSIM. The symbols V, A, X and O actually indicate the relationships between the pairs of elements:

V – Element 'i' influences element 'j'.

A – Element 'j' influences element 'i'.

X – Elements 'i' and 'j' influences each other.

O – Elements 'i' and 'j' are unrelated.

The substitution of the symbols with 1s and 0s follow these conditions:

- If the (i, j) entry in SSIM is V, then (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.
- If the (i, j) entry in SSIM is A, then (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.

- If the (i, j) entry in SSIM is X, then (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1.
- If the (i, j) entry in SSIM is O, then (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

7. As the elements were put into different levels, with the highest number being the most important, they were also put into clusters based on their driving powers and dependency. This was further analysed using MICMAC analysis.

MICMAC analysis. The factors in the model are then analysed using MICMAC (Cross-Impact Matrix Multiplication Applied to the Classification) analysis. It is usually used to classify the factors into four different categories (Tiwari, 2013), which are:

- **Independent factors**: They have strong drive power but weak dependence power. A factor with a very strong drive power, called the 'key factor', falls into the category of independent or linkage factors.
- **Linkage factors**: They have strong drive power and strong dependence power. These factors are unstable in the fact that any action on these factors will have an effect on others and also a feedback effect on themselves.
- **Dependent factors**: They have weak drive power but strong dependence power.
- **Autonomous factors**: They have weak drive power and weak dependence power. They are relatively disengaged from the system but they have a few links, which may be very strong.

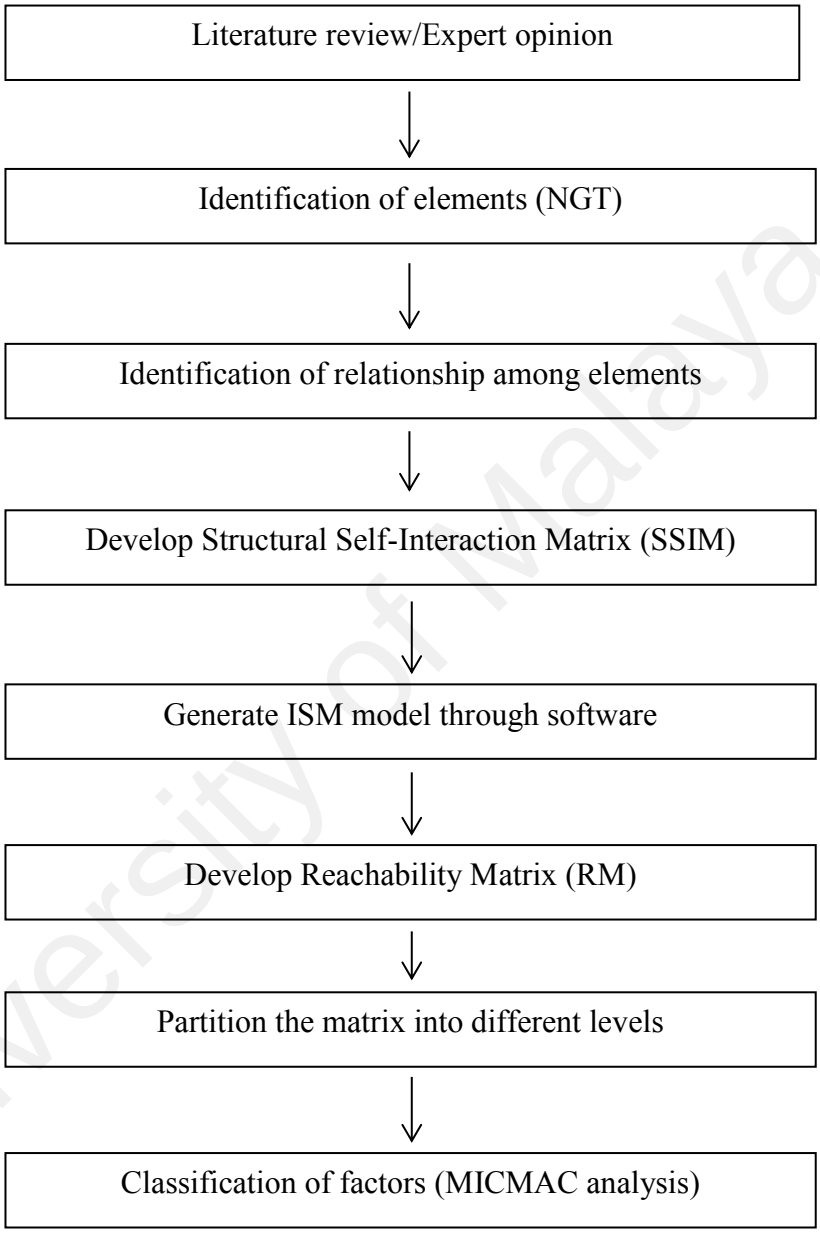


Figure 3.1. Flowchart for developing ISM

Phase 3 – The Assessment of the Communication Model between Humanoids and Elderly Humans.

Purpose. The aim of this phase was to verify if the communication model is applicable in guiding verbal and non-verbal communication between humanoids and elderly humans. The assessment was done using a decision making method to establish the suitability of the model and its elements. It attempts to provide answers to these research questions:

1. What is the experts' consensus on the suitability of the elements proposed in the verbal and non-verbal communication model between learning companion humanoids and elderly humans?
2. What is the experts' consensus on the list of elements in the four clusters (Independent, Linkage, Dependent and Autonomous) as proposed in the verbal and non-verbal communication model between learning companion humanoids and elderly humans?
3. What is the experts' consensus on the relationships among the elements proposed in the verbal and non-verbal communication model between learning companion humanoids and elderly humans?
4. What is the experts' consensus on the usability of the verbal and non-verbal communication model between learning companion humanoids and elderly humans?

The opinions of experts were used in the second phase of the DDR method. The third phase also utilized expert opinions but the selection of experts was of different criteria. They assessed the model in terms of its suitability and the

relationships between the elements of the model. In order to do this, the study adopted the Fuzzy Delphi method. More details on the application of the method, the election of experts, the instruments used, the process of the assessment and analysis of data are reported in the next sections.

Fuzzy Delphi Method (FDM). Fuzzy Delphi is a fusion of fuzzy set theory and Delphi method, introduced by Kaufman and Gupta in 1988. It is an analytical method for decision making, an upgrade from the traditional Delphi method. The Delphi method was commonly used for decision making, where the opinions of experts would be surveyed through questionnaires (Wu & Fang, 2011). This method requires multiple rounds of questionnaires if there is no consensus between the experts in the first round. Therefore, a few problems with Delphi technique is that the repetition of rounds is time-consuming and can get expensive as more rounds are added. This could also bore the experts and result in a decrease of response rate (Siraj et al., 2013). So, taking these problems into consideration, the mathematics of Fuzzy theory by Lotfi Zadeh was incorporated into Delphi technique to eliminate them and guarantee consistency of group opinion.

FDM was chosen for the evaluation phase of DDR as it is a well-received decision making tool. Another reason for this is because the model was developed through expert opinion, it is only fitting to evaluate the model using experts' views as well. However, a modified FDM was used to suit the evaluation process of the communication model, as described below:

1) Usually, in traditional Delphi technique, experts are used to determine variables before development of a model or product. In this research study, generation of the variables is not needed although the session involves

decision making. Fuzzy Delphi method considers the collective views of experts through consensus. It addresses the fuzziness that is always present in the survey process.

2) Another modification is in the usage of defuzzification process and rankings in FDM. In the traditional sense of FDM, defuzzification and rankings are utilized to figure out the variables of a research study. In this particular research, they are utilized to find out the consensual agreement among experts on elements assessed in the model according to a range of defuzzification values that was determined beforehand. The procedure for the modified FDM will be further elaborated in the coming sections.

Participants of the study. For this phase of the study, purposive sampling was utilized to choose a panel of experts for evaluation of the communication model. According to Adler and Ziglio (1996), the criteria for expert selection may vary between situations but there are a few key requirements when choosing an appropriate panel:

1. The most important criterion in choosing experts is the knowledge and experience that they have with the issues being discussed.
2. The experts should also be willing to share that knowledge towards the exploration of a particular problem.
3. Other than that, they should be willing to allocate sufficient time for this FDM commitment.
4. A minor requirement would be to have skills in written communication and expressing priorities through voting procedures.

This study chose experts that were considered end-users of the product, elderly people who live alone and worked as professionals before retirement. Those who were still working were also accepted. The reason for choosing professionals is that they would have more experience with technology and seem more willing to accept humanoids into their daily lives. This was seen during the needs analysis process. They would also better understand the nature of the research and questionnaire as it can get quite complicated for elders to fully grasp the concept.

As for the number of experts suitable for the study, there are still multiple opinions on this subject ranging from less than 10 to more than 50 experts. However, the most suitable and practical number would be around a small panel of 10-15 people (Adler & Ziglio, 1996) or 10-18 individuals (Okoli & Pawlowski, 2004). A total of 15 experts were selected for this phase.

Instrument. This phase of the study used a set of evaluation survey questionnaire (refer to Appendix D). The questionnaire contained 13 questions that were split into 4 sections, which are: 1) Suitability of elements of the verbal and non-verbal communication model between learning companion humanoids and elderly humans; 2) views on the cluster classification of elements of the verbal and non-verbal communication model between learning companion humanoids and elderly humans; 3) views on the relationships of elements of the verbal and non-verbal communication model between learning companion humanoids and elderly humans; and 4) views on the overall usability of the model.

Procedure and data analysis. Fuzzy Delphi method was chosen to assess the model developed in the previous phase and the steps involved in this procedure are:

1. Choosing of suitable experts to assess the developed model. The selection procedure was elaborated in the previous section.
2. FDM differs from the traditional Delphi method because of the addressing of fuzziness issue. In order to do this, a linguistic scale was utilized to outline the response from the experts. The scale is very much alike to the Likert scale but there is an addition of fuzzy numbers to the scale of feedback in reference to a triangular fuzzy number (as shown in Figure 3.2). For each feedback, three fuzzy values were given to consider the fuzziness of experts' views. Those values consist of three levels of fuzzy value: minimum value (m_1), most plausible value (m_2) and maximum value (m_3).

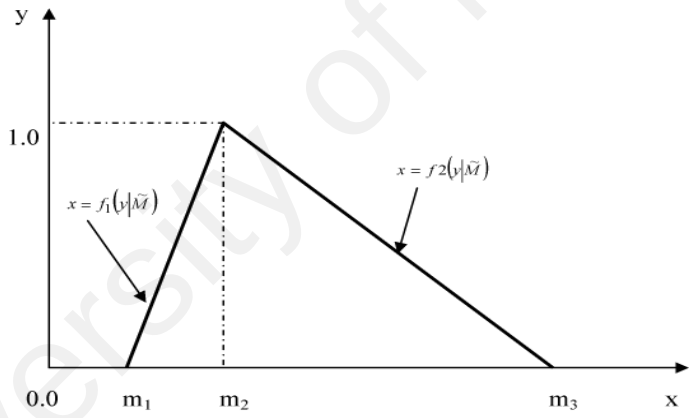


Figure 3.2. Triangular fuzzy number

The linguistic scale is utilized to change the linguistic variable to fuzzy numbers. The level of agreement scale should be in odd numbers, usually in 3, 5 or 7 point linguistic scale. A higher scale would make the response analysis more accurate. Table 3.4 shows an example of a 5-point linguistic scale.

Table 3.4

5-point Linguistic Scale

Linguistic variable	**Fuzzy scale**		
Strongly disagree	0.0	0.1	0.2
Disagree	0.1	0.2	0.4
Not sure	0.2	0.4	0.6
Agree	0.4	0.6	0.8
Strongly agree	0.6	0.8	1.0

Based on the example scale above, we can see that the fuzzy numbers are in a range of 0 to 1. This study utilizes the 7-point scale, as shown in Table 3.5 below.

Table 3.5

7-point Linguistic Scale

Linguistic variable	**Fuzzy scale**		
Strongly disagree	0.0	0.0	0.1
Disagree	0.0	0.1	0.3
Slightly disagree	0.1	0.3	0.5
Slightly agree	0.3	0.5	0.7
Moderately agree	0.5	0.7	0.9
Agree	0.7	0.9	1.0
Strongly agree	0.9	1.0	1.0

3. Responses from the experts for each questionnaire item and their correspondent fuzzy number scales were then inserted into an excel spreadsheet. The purpose of this is to get the average for m_1, m_2 and m_3.
4. Next, the difference between the experts' evaluation data and the average value of every item were calculated to determine the threshold value 'd' utilizing this formula:

$$d(\tilde{m},\tilde{n}) = \sqrt{\frac{1}{3}\left[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2\right]}.$$

In reference to the formula above, m_1, m_2 and m_3 are the average values for all the experts' opinions while n_1, n_2 and n_3 are fuzzy values for all three values for every user. The threshold value is essential in determining the consensus level among the experts. Cheng and Lin (2002) had stated that all the experts are considered to have reached a consensus when the threshold value is less than or equal to 0.2. Some experts in a study will have a threshold value that is more than 0.2 but the most important aspect is the overall consensus for all the items. The overall group consensus should exceed 75%. If it is less than that, a second round of fuzzy Delphi will have to be carried out.

5. When group consensus has been actualized, the fuzzy numbers for every item are added to get the aggregate fuzzy evaluation. This action is crucial for the last step of this phase.
6. Finally, this step is identified as the defuzzification process. The defuzzification value for every questionnaire item was determined according to the formula: $A = 1/3 * (m_1 + m_2 + m_3)$. Generally, in Fuzzy Delphi, this process is used to categorize the variables acknowledged by expert consensus via ranking of the variables. The variable with the highest defuzzification value is ranked as the highest in priority to be accepted as an output variable. Although, in this study, the ranking of elements acknowledged by the experts was not utilized to select the variables for the study.

The determination of defuzzification value and the rankings were utilized to determine whether the questionnaire items had been acknowledged in assessing the verbal and non-verbal communication model. The formula used in the calculation utilizes the average of fuzzy number or Fuzzy score (A). α-cut is defined as the median score for 0 and 1, whereby α-cut is (0 + 1) / 2 = 0.5 (Bodjanova, 2006; Tang & Wu, 2010). To show that consensus of the experts has been reached, the value of A must be equal to or higher than the value of α-cut which is 0.5. A score of less than 0.5 as the threshold value indicates that no consensus was reached for that particular item and has to be rejected. An example showing the defuzzification process is portrayed in Table 3.6 below.

Table 3.6

Example of Defuzzification Process

Expert	**Item**					
	1			**2**		
1	0.6	0.8	1	0	0.2	0.4
2	0.6	0.8	1	0	0.2	0.4
3	0.4	0.6	0.8	0.4	0.6	0.8
4	0.6	0.8	1	0	0.2	0.4
5	0.4	0.6	0.8	0.4	0.6	0.8
6	0.4	0.6	0.8	0.4	0.6	0.8
7	0.4	0.6	0.8	0.4	0.6	0.8
8	0.4	0.6	0.8	0.4	0.6	0.8
9	0.6	0.8	1	0.6	0.8	1
10	0.4	0.6	0.8	0	0.2	0.4
Defuzzification process						
Sum of every element	4.80	6.80	8.80	2.60	4.60	6.60
	m_1	m_2	m_3	m_1	m_2	m_3
Fuzzy evaluation	6.800			4.600		
Ranking	1			9		
Average of every element	0.480	0.680	0.880	0.260	0.460	0.660
	m_1	m_2	m_3	m_1	m_2	m_3
Average of fuzzy number (A)	0.680			0.460		
Ranking	1			9		

According to the example above, a value of more than 0.5 for average of fuzzy number shows consensus among the experts whereas a value lower than that shows no consensus. Therefore, the item with an A value of 0.460 has to be rejected. Hence, the method used to validate the verbal and non-verbal communication model is a modified fuzzy Delphi method in the way that the defuzzification value and rankings are used. The process flow for this phase can be seen in Figure 3.3 below.

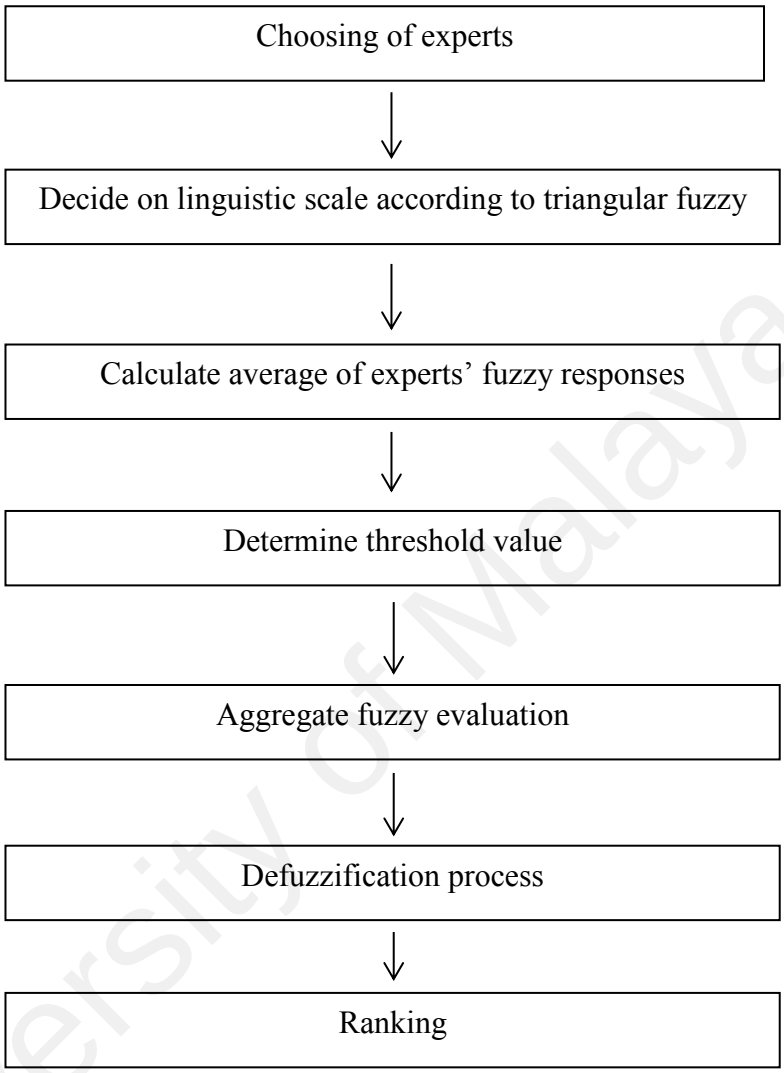


Figure 3.3. Flowchart of fuzzy Delphi method procedure

Summary

The study adopted the design and development research (DDR) approach to develop the communication model between humanoids and elderly humans. This method separated the execution of this study into three phases: 1) the needs analysis phase to find out the needs of elderly people pertaining to companionship; 2) the

development of the model itself; and 3) the assessment of the model. The needs analysis phase was carried out with questionnaires and interviews to find out the needs of the elderly pertaining to companionship and to gauge their willingness to accept robots in their daily lives.

The second phase of the method was the development of the communication model. The criteria of the model were already determined in the first phase of the methodology. Then, the model was developed with the help of experts by using the interpretive structural modeling method and software. In the third phase, a decision making tool known as a modified fuzzy Delphi method was utilized to evaluate the developed model. An evaluation survey questionnaire was the instrument in this method, using a seven-point linguistic scale. The final calculation of the values showed the consensus among the experts on evaluating the verbal and non-verbal communication model between learning companion humanoids and elderly humans.

In this study, the needs analysis phase, which is the first phase of DDR, will be reported in chapter 4. This is followed by phase two, which is the development phase, in chapter 5. The final phase of DDR is the assessment phase and will be reported in chapter 6. Discussions of all three phases as well as the implications and recommendations of the study will commence in chapter 7.

CHAPTER 4

FINDINGS OF PHASE 1: NEEDS ANALYSIS

Introduction

The next chapters 4, 5, and 6 will report on the results of the study. The findings would be reported in three chapters which are in accordance to the three phases of the methodology of this study. The presentation of the results is also in line with the research questions that expanded on the focus of the research. The results for every phase of the methodology are presented according to the research questions and objectives of every phase. The format of the presentation is also in line with the design and development research method (Siraj et al., 2013) to describe the findings for development of verbal and non-verbal communication model between humanoid learning companion and elderly humans, starting with the need to develop the model, the development process and ending with the results for the assessment of the communication model.

This chapter reports on the results of the first phase which is the needs analysis phase. It contains only the findings of the needs analysis and the discussion would be reported in chapter 7, along with the discussions for chapters 5 and 6, which are the second phase findings and the third phase findings respectively.

Results of Needs Analysis

Background of Participants

The main objective of the first phase of the methodology was to establish the need for a learning companion among the elderly, especially for those who live alone. This phase was carried out by employing a questionnaire survey given out to the elderly people in Malaysia. The sample consisted of 44 male elders and 56 female elders as shown in Table 4.1. Concerning the distribution of race, Table 4.2 indicates that out of 100 respondents, 39 participants were Chinese, followed by 33 Malay elders and finally 28 Indian participants.

Table 4.1

Participants' Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	44	44.0	44.0	44.0
	Female	56	56.0	56.0	100.0
	Total	100	100.0	100.0	

Table 4.2

Race of Participants

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Malay	33	33.0	33.0	33.0
	Chinese	39	39.0	39.0	72.0
	Indian	28	28.0	28.0	100.0
	Total	100	100.0	100.0	

The following findings report on the elders' preferences and opinions on robots in general and as companions as well as the necessity of robots in their lives especially for lonely elders. The data is then triangulated with results from interviews done on 5 participants. The reports conclude with the need to incorporate

communication and learning between humanoid companions and elderly humans. In this report, the terms respondents and elderly are utilized in turns.

Elderly's Opinions and Preferences on Humanoid Robots

The first part of the needs analysis aimed to find out the preferences and opinions of Malaysian elders on humanoid robots in general. The questions were not in-depth and acted as an introduction to robotics in the future lives of the elders. The questionnaire answered the first two research questions:

1.4 What physical type of humanoid robots do the elderly prefer?

1.5 What type of humanoid companion do the elderly prefer?

The first question was on the size of humanoid that the elderly preferred and they were given three choices. 43% of the respondents chose the size of a small child whereas 33% preferred the size of a small animal. The remaining percentage, 24% chose the robot size of an average adult.

Table 4.3
Size of Robot

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	small animal	33	33.0	33.0	33.0
	small child	43	43.0	43.0	76.0
	average adult	24	24.0	24.0	100.0
	Total	100	100.0	100.0	
	Mean	1.91			
	SD	.753			

This is followed by a question on whether they think a communication model between humanoids and elderly humans is necessary. 68% of the elders supported the notion of a communication model but 32% of them did not see the need for it.

Table 4.4
Necessity of Communication Model

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	68	68.0	68.0	68.0
	no	32	32.0	32.0	100.0
	Total	100	100.0	100.0	
	Mean	1.32			
	SD	.469			

The succeeding question asked about their preference on the initiator of communication between the two parties. A majority of 83% said they would prefer to start communication whereas 17% of the respondents would rather the initiator of communication be the humanoid.

Table 4.5
Initiator of Communication

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Humanoid	17	17.0	17.0	17.0
	Human	83	83.0	83.0	100.0
	Total	100	100.0	100.0	
	Mean	1.83			
	SD	.378			

The next question referred to the type of companion the elders' prefer in terms of communication. From 100 respondents, 36% chose a companion that could give them facts like the weather report, television programmes or the latest news. Then, 25% preferred a more playful companion, one that could tell jokes to them and

make them laugh. A polite companion was chosen by 19% of the respondents and 16% preferred a good listener. Only 4% of the elders had no preference.

Table 4.6
Type of Companion

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no preference	4	4.0	4.0	4.0
	facts	36	36.0	36.0	40.0
	polite	19	19.0	19.0	59.0
	playful	25	25.0	25.0	84.0
	listener	16	16.0	16.0	100.0
	Total	100	100.0	100.0	
	Mean	2.13			
	SD	1.186			

This was followed by a question on the preferred voice type of a humanoid companion. 68% of the respondents opted for a female voice whereas 30% went for a male voice. 2% of them had no preference on the type of voice that would be heard from a humanoid companion.

Table 4.7
Type of Voice

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no preference	2	2.0	2.0	2.0
	male	30	30.0	30.0	32.0
	female	68	68.0	68.0	100.0
	Total	100	100.0	100.0	
	Mean	1.66			
	SD	.517			

The next question asked the elders' opinion on whether an elder who lives alone would benefit from a humanoid companion. 81% of the respondents agreed that there would be benefits to lonely elders. On the other hand, 19% of them saw no benefits in using a humanoid companion.

Table 4.8
Benefit for Lonely Elders

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	81	81.0	81.0	81.0
	no	19	19.0	19.0	100.0
	Total	100	100.0	100.0	
	Mean	1.19			
	SD	.394			

The final question in the questionnaire was on the extent of necessity of robotics in the lives of the elderly. Out of 100 respondents, 60% thought that it is necessary but 31% of them deemed it unnecessary. 9% thought that robotics is very necessary and nobody chose the option of very unnecessary.

Table 4.9
Necessity of Robotics

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very necessary	9	9.0	9.0	9.0
	necessary	60	60.0	60.0	69.0
	unnecessary	31	31.0	31.0	100.0
	Total	100	100.0	100.0	
	Mean	2.22			
	SD	.596			

Conclusion. The findings for this part of the needs analysis indicate the general acceptance of the elderly in our country in accepting humanoid robots in their daily lives. They each have their own preferences but it can be generalized to a certain extent. A majority of the respondents find it necessary to have robots in their lives and believe in the benefit it has for elders who live alone and are prone to loneliness.

Elderly's Opinions and Perceptions on Communication

The questionnaire revealed only a part of the elders' opinions on their interaction with robots in general. The second part was a semi-structured interview to understand deeper their perceptions and opinions on communication generally and with humanoids. Therefore, the next part of the needs analysis answered the next research question:

1.6 What are the elders' perception on communication between humanoids and humans?

The interviews resulted in 9 themes pertaining to communication and learning. The themes are as follows, in no particular order:

1. **Natural conversation** – Most of them agree that humanoids can mimic human conversation but only to a certain extent. Although they are confident of the advanced technology that we have, they feel that emotions and opinions are still lacking from the humanoids. Participant 1 mentioned that "It's more of a question and answer" whereas participant 3 showed confidence by saying that "In terms of natural, in terms of casualness, in normal conditions, impromptu, there should be no problem. Yes, technology can modify the conditions."

2. **Listening aid** – The participants agree that communication between humanoids and humans should be both ways. A few of them prefer to ask questions and the humanoid will answer them so the humanoid would be more useful for facts rather than discussions. Talking to a listening humanoid helps the memory, as stated by participant 2 "Helps our memory, to get good ideas" but an interesting quote from Participant 3 was that he said "Only, the

sophistication would be how it can respond accurately and how it does it". This indicates the knowledge and expertise he has on machines and robots and partly agrees with this notion albeit with major improvements.

3. **Humanoid companions** – Most of the participants agree that humanoids may accompany humans in the future but they must also assist them in doing chores besides talking to them. They may change the environment just by singing or talking. Participant 3 also added that "Now we already know, robots can do work, can clean houses and it's not 'remote-controlled' but it works by verbal instruction. So to some extent, yes." One participant (Participant 4) still prefers human companionship and says he is never lonely because he finds his own companionship, as can be seen in this statement "I find my companionship, I'm never lonely. Because this one, to me, I'm always conscious it's a machine and you can do very good like a painting to make it you know.. it's all plastic."

4. **Different companion** – A few participants preferred the pets at first but when talking about taking care of the pets and when their health causes limitations to what they can do, they opt for the humanoids but the humanoids must be useful to them like doing chores or reminding them of medications. Participant 2 said that the humanoids will listen to their owners if told not to do something whereas pets might not listen as they have a mind of their own. Participant 5 preferred a talking robot because it takes less care and when asked about the maintenance of the robot, she said that "Maintenance is easier than looking after a pet which needs to be walked, it needs to be cleaned, all these things."

5. **Mental health** – Most of the participants strongly agree that having daily conversations are important for their mental health. Even short conversations would be enough as they need to connect to someone or something everyday. Participant 2 said that if she does not talk for a day or two, she would feel like something is wrong, "We will definitely feel unhealthy. We will feel something is wrong and turn the robot back on. Yeah, there's a bad feeling." A male participant (Participant 3) was quoted as saying "So it is very, very necessary for individuals to be having somebody or something for interaction and keep away from being alone and quiet. If not, they will be worried, think a lot. Rather than think a lot on your own, get worried, it's better to talk right". This shows that he is aware of the consequences of being lonely.

6. **Non-verbal aspects** – The participants agree that non-verbal aspects of communication carry a great deal of importance to daily conversations. A high pitch may grate on their nerves and hurt their feelings and talking too fast might prevent them from understanding. Participant 3 stated that "Definitely, yes. Your punctuation, your intonation, where you stop, where you stress, all that makes a difference right? Sometimes it's the opposite right? So there could be misunderstandings. So very important." They also said that these aspects are important to convey emotions and to avoid misunderstandings. It was quoted that "Yes, because the pitch denotes or can convey emotion and also the way you say things, it is all connected to emotion." from participant 5.

7. **Benefit** – The participants agree that the humanoid must be able to do things like chores for them. Most of them believe that it could be a talking companion but that is not enough, the humanoids must be useful in assisting

them physically. Participant 1 even added that "Yeah, and maybe like, instead of browsing on the internet for factual information, I can just ask, yeah. There might come a time when I might not be able to…(browse the internet)" One participant (Participant 3) said that the humanoid can listen to them and give responses and proceeds to ask the researcher for a humanoid of his own, "Well, like I've said just now, firstly is to be robotically active to help you in your job, physically. Secondly, to have another party, to listen to you. First stage, just for you to be confident that you are talking to something, it can be recorded, you can listen back. The second stage, if it is more developed, then you can even have feedback, responses, so it's more interactive. So it can lah! Give me one! (laughing)"

8. **Learning** – Most of the participants don't mind if the humanoids stimulate them to learn but it would be better if it is scheduled as it gives them discipline and a participant (Participant 2) said that it is interesting that a thing that is not alive can speak to them and makes learning more interesting for her, "I think at this age, it would be better to get the robot's help. Let it remind me, yes. So it's interesting that a thing that is not alive can speak right. So we feel "Even a thing that is not alive can give us an idea". So it would be interesting and fun to talk to it." A male participant chose both ways as he likes time factors to be in his control and scheduled sessions would be better but the humanoid must be able to back down if he says he is not ready to learn yet. This means that the humanoid should be flexible to the needs of its owner. Participant 5 was quoted as saying "Yeah, if the humanoid can play scrabble with me, that is a learning thing also. It would be good, or play cards or, you know.'

9. **Talking preference** – Most of the participants chose face to face situation because they believe that non-verbal aspects like body language and facial expression matter as well. It is better to avoid misunderstandings and to convey emotions better, as stated by participant 2 "I prefer to talk face to face. Because we can see their reaction and explain better. If we are on the phone, sometimes we say the wrong thing or we can't hear. I prefer face to face. It's safer, yes. No misunderstandings." Talking on the phone relies heavily on verbal aspects and certain aspects of non-verbal communication but most of this applies to human-human interaction. Participant 5 explained that "Because you can, it's not only verbal communication, it's non-verbal communication, emotions, all these things. Over the phone, you can express emotions but you can't see the…(expressions)".

Conclusion. Most of the respondents agree that humanoids can be good companions to the elderly if they are able to do chores as well as have a conversation with them. Some still preferred pets unless their health prevents them from taking care of the pets well. They believe that daily conversations are crucial for good mental health and like the idea that the humanoids can assist them in gaining knowledge. The respondents recognize the importance of non-verbal aspects of communication and prefer a face to face interaction rather than talking on the phone.

Summary of Findings of Phase 1

This chapter has reported on the results of the needs analysis, which is the first phase of a three-phase methodology adopted for the development of the verbal and non-verbal communication model between humanoid learning companion and

elderly humans. Based on the research questions, the first part of the results showed the elders' preferences on the physical aspects of a humanoid robot and the type of humanoid companion. Other than that, it also showed their opinions on a few general aspects related to communication and robotics. The findings indicate the general acceptance of the elderly in accepting humanoid robots in their daily lives. Their personal preferences may be generalized to a certain extent according to majority. Most of them believe in the necessity to have robots in their lives especially for lonely elders.

The second part of the findings aimed to find out the elders' perceptions and opinions on communication in general and between humanoids and humans. The second part is important for triangulation of data and to have more in-depth information on the need for a communication model between the two parties. The results show that the elderly would prefer a humanoid companion that can have a conversation with them and do chores for them. They believe in the benefits of having daily conversations on their mental health and like the idea of the humanoids assisting them in gaining knowledge. The respondents also recognize the importance of non-verbal aspects of communication and prefer face to face interaction rather than talking on the telephone.

Therefore, based on the findings above, the results of the first phase support the need to develop a verbal and non-verbal communication model between humanoids and elderly humans. The next chapter reports on the results for the development phase of the model.

CHAPTER 5

FINDINGS OF PHASE 2: DESIGN AND DEVELOPMENT OF MODEL

Introduction

This chapter reports on the results of the second phase of the study which is the design and development of the communication model. It contains the findings of this phase and the discussion will ensue in chapter 7. The second phase of the methodology is the most crucial part of the three phases as this is the part that the verbal and non-verbal communication model was developed. The development was based on the results of the needs analysis phase of the study. As there was a need to support lonely elders to achieve successful ageing in Malaysia, the communication model was suggested as an answer. The model focuses on verbal and non-verbal (paralinguistic) aspects of communication between humanoids and the elderly. The findings reported in this phase consist of the result of the collection of experts' opinions on the elements and the connections of the elements, which were incorporated into the model.

Findings of the Development Phase

Before the commencing of the first step of the second phase, elements for the verbal and non-verbal communication model had to be listed first. The list was done through the readings of literature review. It will then be discussed in the first step which utilises nominal group technique. The elaborations and research studies that support each element are shown in Table 5.1 below:

Table 5.1

Element Description and Research Studies

No	Element	Description	Research studies
1	Body motion that is non-threatening to elders should be incorporated into the model e.g. slow movements, hand not raised too high.	Some elders may fear or be uncomfortable with something that they are not familiar with. If they feel physically threatened by the humanoid, then communication cannot happen and the humanoid will fail as successful companions.	Mavridis (2015); Nomura & Nakao (2010); Breazeal (2003)
2	The humanoid should have a friendly tone of voice.	This tone may encourage the elders to talk or uplift a foul mood.	Campbell (2007)
3	Responses as verbal content such as "Wow, that's amazing!", "That's nice" and "Well done" should be incorporated into the model.	These responses validate the elders' achievements and may encourage them to learn or do more and maintain positive feelings. Generally, humans like to be complimented.	Mavridis (2015)
4	Humanoid should detect emotion of elders through tone of voice and respond accordingly.	The humanoid should cater to the emotional needs of the elders' at the moment to be a successful companion.	Yorita & Kubota (2011); Mower et al. (2009)
5	If the elder does not respond to the humanoid, the humanoid should wait for a response and prompt the elder until a response is heard.	The elders should not be allowed to dwell on negative feelings for too long as it could be mentally unhealthy. No response could also mean that something is wrong and further action should be implemented.	Shi et al. (2015)
6	The humanoid should have a happy or encouraging tone of voice.	This tone may encourage the elders to share happy emotions and stories and prevent them from negative thoughts.	Campbell (2007)
7	Questions as verbal content such as "How are you?", "What do you mean?" and "Is it interesting?" should	These questions may prompt the elders to share their feelings, stories or what they learned that day as it shows interest in the elders. They would feel like someone cares about their	Mavridis (2015); Nakano et al. (2006); Johnson et al. (2016)

	be incorporated into the model.	feelings and opinions. It can also be seen as exercise for the brain as they come up with answers to the questions.	
8	If sadness is detected from the elder, the humanoid should listen and respond accordingly.	Sadness may dissipate as the elders let it all out by telling the humanoid what made them sad. Changing of topic could make them feel like nobody cares about their feelings.	Zhang et al. (2013)
9	The humanoid should have a moderate pitch of voice.	Some elders may prefer or be able to hear a moderate pitch of voice.	Traunmuller (2005)
10	Comfortable distance and orientation between elders and humanoids should be incorporated into the model.	Personal space is important to elders as well. If the elders are uncomfortable with the humanoid, it will be difficult for them to communicate.	Lee et al. (2014); Nakadai et al. (2004); Shi et al. (2015)
11	The humanoid should have a moderate rate of speech.	Some elders may prefer or be able to understand a moderate rate of speech.	Traunmuller (2005)
12	News as verbal content should be incorporated into the model.	Some elders may like to be updated on current news and not just the headlines but a multitude of sections like economics, sports and entertainment. Being updated on news could be like a hobby for some, and it could make them feel connected to the rest of the world.	Mavridis (2015); Hilt & Lipschultz (2004)
13	If anger is detected from the elder, the humanoid should listen and respond accordingly.	Anger may dissipate as the elders let it all out by telling the humanoid what angers them. A change of topic may anger them more and feel like no one wants to listen to them.	Zhang et al. (2013)
14	The humanoid should have a female voice.	Elders might prefer to talk to a woman. It could remind them of someone dear to them like a family member, caregiver or relative.	Traunmuller (2005); Komatsu et al. (2005)
15	Facts as verbal content such as medical content, television programmes, and	Some elders may want a routine update on something they care about, or like to be updated on health issues or current situations. It can also serve as a conversation	Zhang et al. (2013); Mavridis (2015); Hilt & Lipschultz (2004)

	weather report should be incorporated into the model.	starter. As the facts are of interest to them, the humanoid can search more information on it.	
16	If anger is detected from the elder, the humanoid should change the topic.	The elders should not dwell on the anger and should forget about it by talking about or doing something else. Focusing on the anger could make them become violent.	Zhang et al. (2013)
17	The humanoid should have an empathetic tone of voice.	This tone may encourage the elders to talk and show emotion as it portrays an understanding of the elders' emotions. It reflects the feelings of the elders e.g. if the elder uses a happy tone, the humanoid uses a happy tone as well. If the elder is sad, the humanoid is sad too.	Campbell (2007); Moridis & Economides (2012)
18	The humanoid should use a happy tone when reminding of medication.	Since a lot of elders take medication and don't like to take it, a happy tone should be used to associate the taking of medication with positive feelings.	Zhang et al. (2013); Sober et al. (2016)
19	When anger is detected, the humanoid should use a curious tone.	This is to counter the feeling of anger by showing concern. It demonstrates a willingness to listen.	Zhang et al. (2013); Moridis & Economides (2012)
20	When sadness is detected, the humanoid should use a curious tone.	This is to counter the feeling of sadness by showing concern. It demonstrates a willingness to listen.	Zhang et al. (2013); Moridis & Economides (2012)
21	A happy tone should be the default tone.	The humanoid should always have a happy tone to maintain a positive vibe.	Kienast & Sendlmeier (2000); Davidson et al. (2006)
22	Inspirational quotes as verbal content should be incorporated into the model.	Some elders may like to be inspired by quotes to avoid negative thoughts and be inspired to do something. Positive words from famous figures could feel like someone giving advice to them.	Craig & Strivens (2016); Yagcioglu (2014)
23	The humanoid should start communication with the elders first.	The humanoid could prompt the elders to have a conversation, for those who have difficulty starting a conversation. This helps prevent the elders from getting used to the silence.	Yorita & Kubota (2011); Shi et al. (2015); Mavridis (2015)

24	Jokes as verbal content should be incorporated into the model.	Some elders may like to hear jokes often to have a good laugh and be kept in a good mood. This is one way to ward off feelings of depression.	Shammi & Stuss (2003); Hilt & Lipschultz (2004); Richman (2006)
25	The humanoid should have a curious tone of voice.	This tone may encourage the elders to talk as it shows an act of concern and interest.	Campbell (2007)
26	When sadness is detected, the humanoid should use a happy tone.	This is to counter the negative feeling that is sadness. Whether the humanoid gives out a statement or a question, the happy tone would influence the elders' feelings in a positive way.	Zhang et al. (2013); Moridis & Economides (2012)
27	A neutral tone should be the default tone.	The humanoid should be neutral unless needed to avoid provoking unwanted or unnecessary feelings.	Kienast & Sendlmeier (2000); Davidson et al. (2006)
28	Elders should start communication with the humanoid first.	Some elders prefer to talk when they are good and ready and don't like to be forced to talk. It could also make them feel in control of the situation as they speak when they want to.	Ma et al. (2016); Shi et al. (2015); Mavridis (2015)
29	The humanoid should have a slow rate of speech.	Some elders may prefer or be able to understand a slow rate of speech.	Traunmuller (2005)
30	The humanoid should use a serious tone when reminding of medication.	Since a lot of elders take medication and don't like to take it, a serious tone should be used to remind them of the seriousness of the matter.	Zhang et al. (2013); Sober et al. (2016)
31	When anger is detected, the humanoid should use a happy tone.	This is to counter the negative feeling that is anger. Whether the humanoid gives out a statement or a question, the happy tone would influence the elders' feelings in a positive way.	Zhang et al. (2013); Moridis & Economides (2012)
32	The humanoid should have a male voice.	Elders might prefer to talk to a man. It could remind them of someone dear to them like a family member, caregiver or relative.	Traunmuller (2005); Komatsu et al. (2005)

Findings from Step 1: Results of Modified Nominal Group Technique

The findings of the modified nominal group technique (NGT) decided the elements that would be incorporated into the communication model. As the NGT session ended, the experts had proposed and collectively agreed on the final list of elements to develop the verbal and non-verbal communication model. Table 5.2 indicates the ranking and priority values of the elements according to the experts' individual voting decision. The purpose of this exercise was to rank the elements in the final list based on the experts' individual preferences on a scale of 1 to 7.

Table 5.2

Ranking and Priority Values of Elements for NGT

	Elements	EP1	EP2	EP3	EP4	EP5	EP6	EP7	EP8	Total	Priority
1	The humanoid should have a female voice.	5	6	7	6	4	7	6	5	46	14
2	The humanoid should have a male voice.	3	6	4	2	4	4	2	5	30	32
3	The humanoid should start communication with the elders first.	5	7	7	6	2	6	1	6	40	23
4	Elders should start communication with the humanoid first.	5	4	5	2	5	5	7	1	34	28
5	Comfortable distance and orientation between elders and humanoids should be incorporated into the model.	5	7	7	6	6	6	7	4	48	10
6	Body motion that is non-threatening to elders should be incorporated into the model e.g. slow movements, hand not raised too high.	7	7	7	7	7	7	7	5	54	1
7	The humanoid should have a moderate pitch of voice.	3	6	7	6	7	7	7	6	49	9
8	The humanoid should have a friendly tone of voice.	5	7	7	6	7	7	7	7	53	2
9	The humanoid should have a curious tone of voice.	3	7	6	5	5	4	2	5	37	25
10	The humanoid should have an empathetic tone of voice.	4	6	7	6	7	5	6	3	44	17
11	The humanoid should have a happy or encouraging tone of voice.	6	7	7	6	7	5	7	6	51	6
12	The humanoid should have a slow rate of speech.	5	5	5	5	2	5	2	3	32	29
13	The humanoid should have a moderate rate of speech.	3	6	7	6	7	6	7	6	48	11
14	Facts as verbal content such as medical content, television programmes, and weather report should be incorporated into the model.	3	7	7	6	6	6	7	4	46	15
15	Jokes as verbal content should be incorporated into the model.	2	7	7	3	3	6	7	4	39	24

16	Inspirational quotes as verbal content should be incorporated into the model.	1	7	7	3	6	6	7	5	42	22
17	Questions as verbal content such as "How are you?", "What do you mean?" and "Is it interesting?" should be incorporated into the model.	5	7	7	5	6	7	7	6	50	7
18	News as verbal content should be incorporated into the model.	3	7	7	5	6	6	7	6	47	12
19	Responses as verbal content such as "Wow, that's amazing!", "That's nice" and "Well done" should be incorporated into the model.	6	7	7	6	5	7	7	7	52	3
20	Humanoid should detect emotion of elders through tone of voice and respond accordingly.	6	7	7	6	6	7	7	6	52	4
21	If the elder does not respond to the humanoid, the humanoid should wait for a response and prompt the elder until a response is heard.	7	6	7	6	6	7	6	7	52	5
22	If anger is detected from the elder, the humanoid should listen and respond accordingly.	3	6	7	6	6	7	7	5	47	13
23	If anger is detected from the elder, the humanoid should change the topic.	6	5	7	3	6	5	6	7	45	16
24	If sadness is detected from the elder, the humanoid should listen and respond accordingly.	6	6	7	6	6	7	7	5	50	8
25	The humanoid should use a serious tone when reminding of medication.	3	6	2	1	5	6	6	3	32	30
26	The humanoid should use a happy tone when reminding of medication.	6	6	7	6	3	7	6	3	44	18
27	When anger is detected, the humanoid should use a happy tone.	2	5	1	3	3	6	6	5	31	31
28	When sadness is detected, the humanoid should use a happy tone.	2	5	1	6	3	6	7	6	36	26
29	When anger is detected, the humanoid should use a curious tone.	2	7	7	5	4	6	6	7	44	19
30	When sadness is detected, the humanoid should use a curious tone.	3	7	7	5	4	6	6	6	44	20
31	A neutral tone should be the default tone.	6	3	7	1	3	7	6	3	36	27

32	A happy tone should be the default tone.	4	5	4	6	5	5	7	7	43	21

Note. EP = Expert

Table 5.2 indicates the results of NGT where 32 elements were agreed upon to be included in the verbal and non-verbal communication model. It also displays the ranking numbers that were given by each expert to the elements according to the scale of 1 indicating 'least favourable' until 7 that indicates 'most favourable' element to be put into the model. These ranking numbers were then added up to reveal the priority value of every element. Based on the priority values, the elements can be arranged as shown below:

1. Body motion that is non-threatening to elders should be incorporated into the model e.g. slow movements, hand not raised too high.
2. The humanoid should have a friendly tone of voice.
3. Responses as verbal content such as "Wow, that's amazing!", "That's nice" and "Well done" should be incorporated into the model.
4. Humanoid should detect emotion of elders through tone of voice and respond accordingly.
5. If the elder does not respond to the humanoid, the humanoid should wait for a response and prompt the elder until a response is heard.
6. The humanoid should have a happy or encouraging tone of voice.
7. Questions as verbal content such as "How are you?", "What do you mean?" and "Is it interesting?" should be incorporated into the model.
8. If sadness is detected from the elder, the humanoid should listen and respond accordingly.
9. The humanoid should have a moderate pitch of voice.
10. Comfortable distance and orientation between elders and humanoids should be incorporated into the model.
11. The humanoid should have a moderate rate of speech.

12. News as verbal content should be incorporated into the model.
13. If anger is detected from the elder, the humanoid should listen and respond accordingly.
14. The humanoid should have a female voice.
15. Facts as verbal content such as medical content, television programmes, and weather report should be incorporated into the model.
16. If anger is detected from the elder, the humanoid should change the topic.
17. The humanoid should have an empathetic tone of voice.
18. The humanoid should use a happy tone when reminding of medication.
19. When anger is detected, the humanoid should use a curious tone.
20. When sadness is detected, the humanoid should use a curious tone.
21. A happy tone should be the default tone.
22. Inspirational quotes as verbal content should be incorporated into the model.
23. The humanoid should start communication with the elders first.
24. Jokes as verbal content should be incorporated into the model.
25. The humanoid should have a curious tone of voice.
26. When sadness is detected, the humanoid should use a happy tone.
27. A neutral tone should be the default tone.
28. Elders should start communication with the humanoid first.
29. The humanoid should have a slow rate of speech.
30. The humanoid should use a serious tone when reminding of medication.
31. When anger is detected, the humanoid should use a happy tone.
32. The humanoid should have a male voice.

During the ISM session, the elements were placed into the ISM computer software in accordance to the priority list shown above.

Findings from Step 2: Contextual Relationship Phrase and Relation Phrase

According to the objectives of the study, the experts identified 'In order to promote effective companionship between learning companion humanoids and elderly humans' as the contextual relationship phrase and 'is more important than' as the relation phrase for the elements during the construction of SSIM. An example of a phrase that will be shown on the computer software is 'In order to promote effective companionship between learning companion humanoids and elderly humans, element 'i' is more important than element 'j''.

Findings from Step 3 and 4: Development of the Model

These steps were aimed at developing the verbal and non-verbal communication model via experts' decisions on the connections of the elements utilizing pairwise technique with the help of ISM software as mentioned before in the methodology section. The model is intended to serve as a guide for robot makers who want to focus on companionship for the elderly. In order to be a successful companion that can prevent loneliness and mental degradation, the humanoid should possess certain criteria and help the elders to learn in their golden age. According to the elements that were decided through nominal group technique in Step 1, and the 'contextual phrase' and 'relation phrase' in Step 2, the ISM model was generated by computer software through expert consensus and is shown in Figure 5.1.

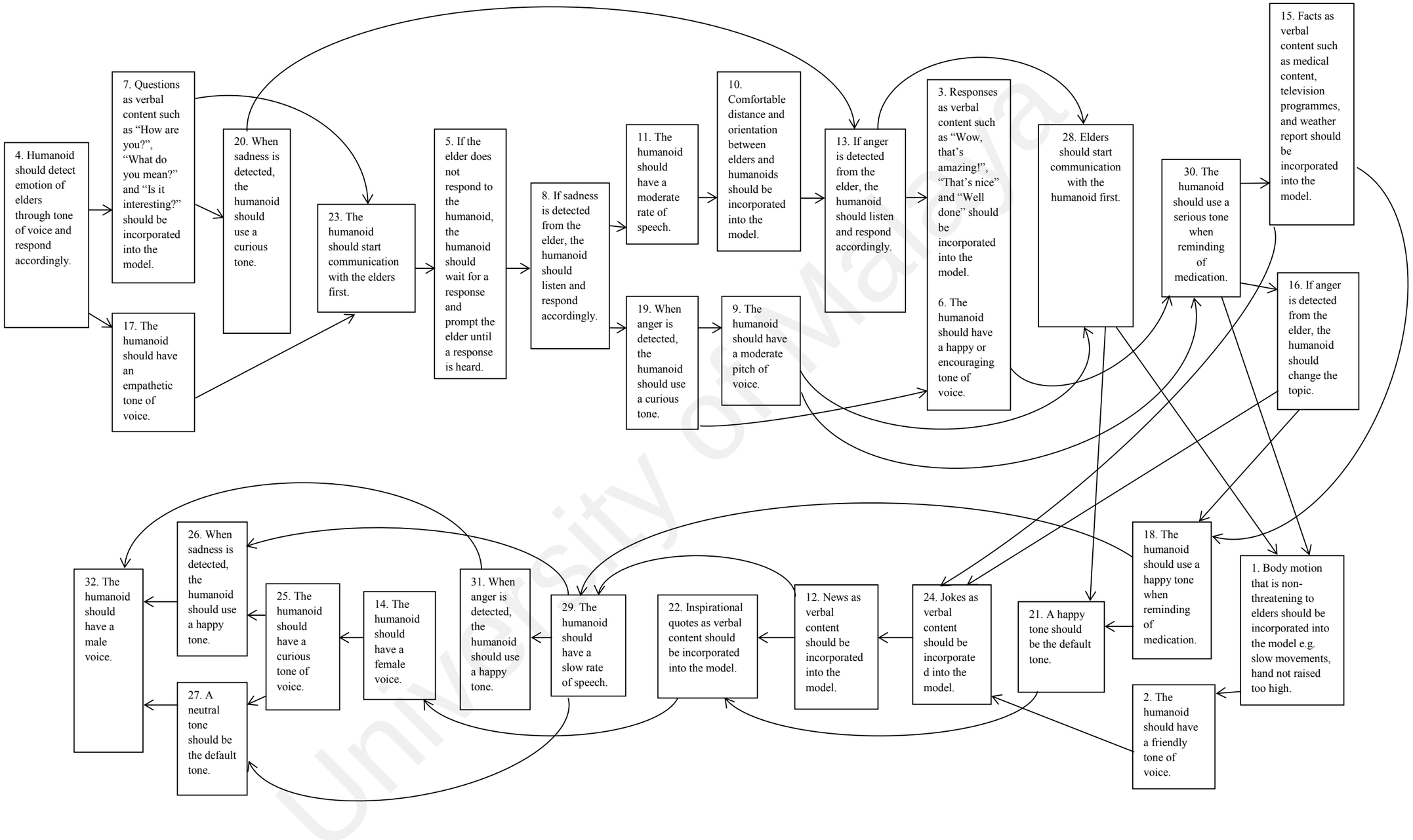


Figure 5.1. ISM model for verbal and non-verbal communication model between learning companion humanoids and elderly humans

Findings from Step 5: Review and Presentation of the Model

As the model was presented to the experts, they reviewed the elements and their relationships in the model. They agreed that element 4 (Humanoid should detect emotion of elders through tone of voice and respond accordingly) is the most important element and should be addressed first before other elements. They also consensually agreed that element 3 (Responses as verbal content such as "Wow, that's amazing!", "That's nice" and "Well done" should be incorporated into the model) and element 6 (The humanoid should have a happy or encouraging tone of voice) belong in the same box as these elements are equally important and work well together. When the reviewing process was done, the panel of experts agreed to maintain the developed model and no amendments were needed. Therefore, the regeneration of the model utilizing the ISM software once again was not conducted.

After that, the experts suggested for the model to be split into four domains, which are Responsiveness, Motivating, Healthcare and Personal Preferences. The Responsiveness domain consists of elements 4, 17, 7, 20, 23, 5, 8 and 19 which are mostly associated with response, whether to the elder or to the humanoid. The domain of Motivating (elements 11, 10, 9, 13, 6 and 3) mostly contains elements that encourage the elders in their self-directed learning but these elements can still be used for other purposes. Healthcare is the domain that is associated with health-related or medical elements which are from elements 28, 30, 16, 15, 1 to 18. Finally, in Personal Preferences, the elements (2, 21, 24, 12, 22, 29, 31, 14, 25, 27, 26 and 32) are considered as choices the elderly can choose if they prefer these elements in the settings of the humanoid. Therefore, according to importance, the experts had found the ability to detect the emotion of elders and responding to their emotions as the most crucial aspect of the verbal and non-verbal communication model through

the aid of ISM process. Then, motivating the elders to learn is also important for their mental health, followed by healthcare issues as the elderly are most concerned about their health at that stage of life. Finally, individual preferences of the elders should also be looked at to make it easier to sustain a relationship with the humanoid.

Figure 5.2 below shows the final model for verbal and non-verbal communication between learning companion humanoids and elderly humans. The arrows indicate the flow from one element to another as groups of elements in sequence. This is based on the contextual and the relation phrase, which in this case means that one is more important than the other in aiding successful communication between the two parties, although all the elements are important. The four domains represent the important elements in the form of an overall structure for the communication model. In order to explain how the model could be interpreted further, the reachability matrix of the elements must be formed to categorize the elements as shown in steps 6 and 7.

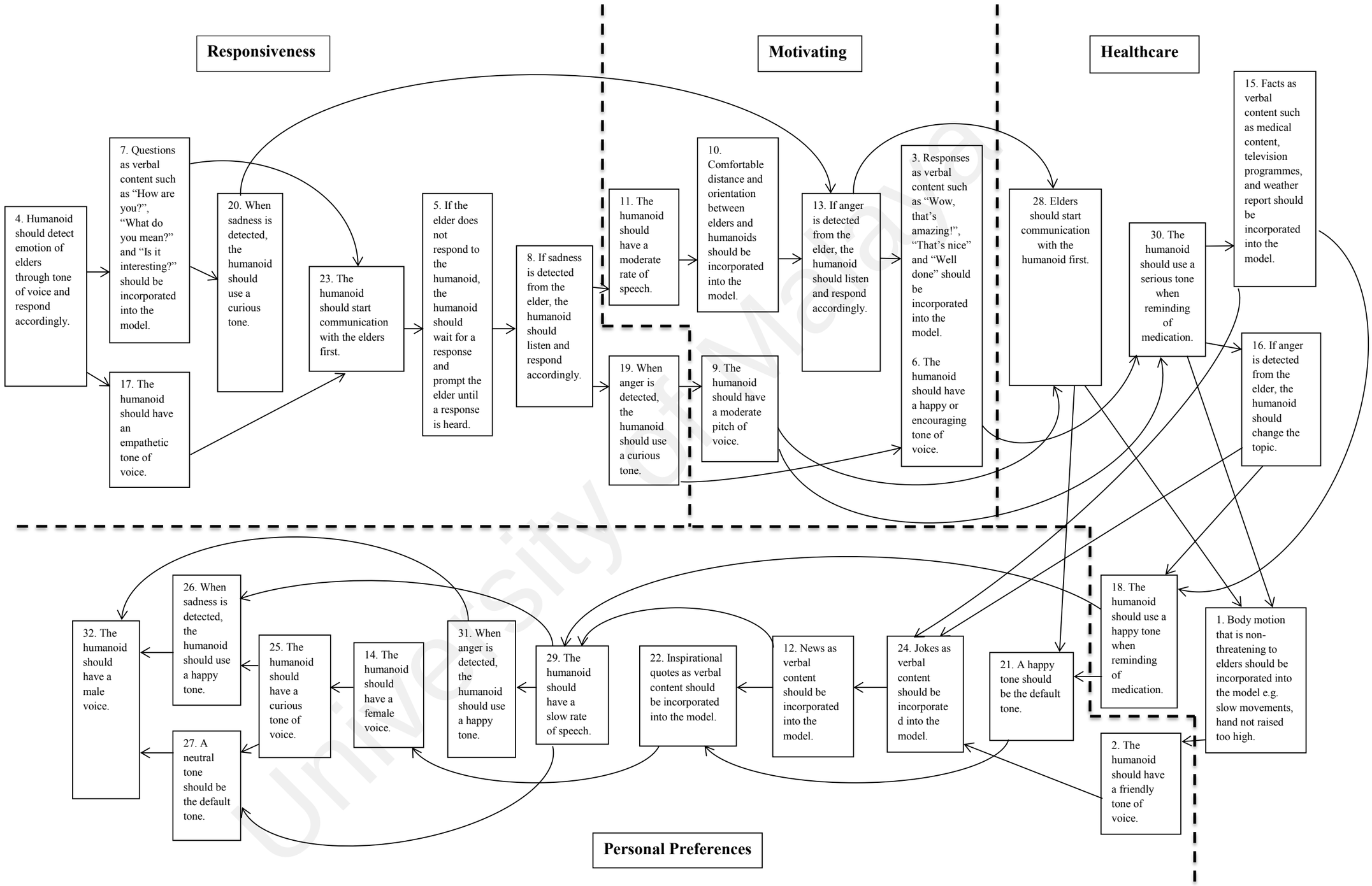


Figure 5.2. Verbal and non-verbal communication model between learning companion humanoids and elderly humans

Findings from Step 6: Classification of Elements Based on Model

According to the ISM model in Figure 5.2, the reachability matrix was formed as portrayed in Table 5.3 below:

Table 5.3

Final Reachability Matrix

Ele	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	DP
1	1	1	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	1	0	0	1	1	0	1	1	1	1	0	1	0	1	1	16
2	0	1	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	1	0	0	1	1	0	1	1	1	1	0	1	0	1	1	15
3	1	1	1	0	0	1	0	0	1	0	0	1	0	1	1	1	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	21
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	32
5	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	28
6	1	1	1	0	0	1	0	0	1	0	0	1	0	1	1	1	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	21
7	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	31
8	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	27
9	1	1	1	0	0	1	0	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	25
10	1	1	1	0	0	1	0	0	1	1	0	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	25
11	1	1	1	0	0	1	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	26
12	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	1	1	0	0	1	1	1	0	1	0	1	1	11
13	1	1	1	0	0	1	0	0	1	0	0	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	23
14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	1	1	7
15	1	1	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	1	0	0	1	1	0	1	1	1	1	1	1	0	1	1	17
16	1	1	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	1	0	0	1	1	0	1	1	1	1	1	1	0	1	1	17
17	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	31
18	1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	1	1	0	1	1	1	1	1	1	0	1	1	15

19	1	1	1	0	0	1	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	26
20	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	30
21	1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	1	0	1	1	1	1	0	1	0	1	1	13
22	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1	0	0	1	1	1	0	1	0	1	1	10
23	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	29
24	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	1	1	0	1	1	1	1	0	1	0	1	1	12
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	1	1	6
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	4
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	4
28	1	1	1	0	0	1	0	0	0	0	0	1	0	1	1	1	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	20
29	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	1	1	1	0	1	0	1	1	9
30	1	1	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	18
31	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	1	1	8
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
DEP	21	22	15	1	6	15	3	7	14	11	10	24	12	28	20	20	4	24	11	11	27	27	5	23	29	31	31	19	28	16	31	32	

Note. Ele - Element; DP - Driving Power; DEP - Dependent Power

The reachability matrix as presented in Table 5.3 indicates the driving power and dependence power of every element in the model. Horizontally, the totaled numbers on the right hand side of the table are the driving power of the elements. It is the total number of all elements that the element may impact including it. Vertically, the dependence power is the total number of elements that may impact it including the element itself. For example, element 1 – 'Body motion that is non-threatening to elders should be incorporated into the model e.g. slow movements, hand not raised too high' has a driving power of 16, which means that this element must be addressed before other elements except for elements 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 17, 19, 20, 23, 28 and 30 which are not related to it. The dependence power of element 1 is 21 which shows that it is dependent on the rest of the elements except element 2, 12, 14, 22, 24, 25, 26, 27, 29, 31 and 32.

Then, the elements were further partitioned into levels of influence according to the reachability matrix. The partitioning is formed from the reachability set and antecedent set for every element as can be seen in Table 5.4. The reachability set contains the element itself and other elements that it may impact but the antecedent set contains the element itself and other elements that may impact it. When ISM is conducted manually without the use of the software, the partitioning of the reachability matrix is important in developing the model by arranging the elements according to the levels. However, for this study, the partition levels of the elements were developed to better understand the model produced by the software.

Table 5.4

Partitioning of Reachability Matrix

Elements	Reachability Set	Antecedent Set	Intersection	Level
1	1,2,12,14,15,16,18,21,22,24,25,26,27,29,31,32	1,3,4,5,6,7,8,9,10,11,13,15,16,17,18,19,20,21,23,28,30	1,15,16	12
2	2,12,14,15,16,18,21,22,24,25,26,27,29,31,32	1,2,3,4,5,6,7,8,9,10,11,13,15,16,17,18,19,20,21,23,28,30	2,15,16,18	11
3	1,2,3,6,9,12,14,15,16,18,21,22,24,25,26,27,28,29,30,31,32	3,4,5,6,7,8,9,10,11,13,17,19,20,23,28	3,6,9	16
4	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32	4	4	25
5	1,2,3,5,6,8,9,10,11,12,13,14,15,16,18,19,20,21,22,24,25,26,27,28,29,30,31,32	4,5,7,17,20,23	5,20	21
6	1,2,3,6,9,12,14,15,16,18,21,22,24,25,26,27,28,29,30,31,32	3,4,5,6,7,8,9,10,11,13,17,19,20,23,28	3,6,9	16
7	1,2,3,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32	4,7,17	7,17	24
8	1,2,3,6,8,9,10,11,12,13,14,15,16,18,19,20,21,22,24,25,26,27,28,29,30,31,32	4,5,7,8,17,20,23	8,20	20
9	1,2,3,6,9,10,11,12,13,14,15,16,18,20,21,22,24,25,26,27,28,29,30,31,32	3,4,5,6,7,8,9,10,11,13,17,19,20,23	9,10,11,20	18
10	1,2,3,6,9,10,12,13,14,15,16,18,19,20,21,22,24,25,26,27,28,29,30,31,32	4,5,7,8,9,10,11,17,19,20,23	9,10,19,20	18
11	1,2,3,6,9,10,11,12,13,14,15,16,18,19,20,21,22,24,25,26,27,28,29,30,31,32	4,5,7,8,9,11,17,19,20,23	11,19,20	19
12	12,14,18,21,22,25,26,27,29,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,15,16,17,18,19,20,21,23,24,28,30	12,18,21	8
13	1,2,3,6,9,12,13,14,15,16,18,19,21,22,24,25,26,27,28,29,30,31,32	4,5,7,8,9,10,11,13,17,19,20,23	9,13,19	17
14	14,25,26,27,29,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,28,29,30,31	14,29,31	4
15	1,2,12,14,15,16,18,21,22,24,25,26,27,28,29,31,32	1,2,3,4,5,6,7,8,9,10,11,13,15,16,17,19,20,23,28,30	15,16,28	13
16	1,2,12,14,15,16,18,21,22,24,25,26,27,28,29,31,32	1,2,3,4,5,6,7,8,9,10,11,13,15,16,17,19,20,23,28,30	15,16,28	13
17	1,2,3,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32	4,7,17,20	7,17	24
18	1,2,12,14,18,21,22,24,25,26,27,28,29,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,15,16,17,18,19,20,22,23,24,28,30	1,2,18,28	11
19	1,2,3,6,9,10,11,12,13,14,15,16,18,19,20,21,22,24,25,2	4,5,7,8,10,11,13,17,19,20,23	11,19,20	19

	6,27,28,29,30,31,32			
20	1,2,3,5,6,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32	4,5,7,8,9,10,11,17,19,20,23	17,20	23
21	1,2,12,14,21,22,24,25,26,27,29,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,15,16,17,18,19,20,21,22,23,24,28,29,30,31	1,2,21	10
22	14,18,21,22,25,26,27,29,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,15,16,17,18,19,20,21,22,23,24,28,29,30,31	18,21,22	7
23	1,2,3,5,6,8,9,10,11,12,13,14,15,16,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32	4,7,17,20,23	20,23	22
24	12,14,18,21,22,24,25,26,27,29,31,32	1,2,3,4,5,6,7,8,9,10,11,13,15,16,17,18,19,20,21,23,24,28,30	18,21,24	9
25	25,26,27,29,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,28,29,30,31	25,29,31	3
26	26,27,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31	26,27,31	2
27	26,27,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31	26,27,31	2
28	1,2,3,6,12,14,15,16,18,21,22,24,25,26,27,28,29,30,31,32	3,4,5,6,7,8,9,10,11,13,15,16,17,18,19,20,23,28,30	3,6,28	15
29	14,21,22,25,26,27,29,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,28,29,30	21,22,29	6
30	1,2,12,14,15,16,18,21,22,24,25,26,27,28,29,30,31,32	3,4,5,6,7,8,9,10,11,13,17,19,20,23,28,30	28,30	14
31	14,21,22,25,26,27,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31	21,22,31	5
32	32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32	32	1

As shown in Table 5.4 above, the influence level of every element is according to the reachability set, antecedent set and the intersection between them. There are 25 levels of elements with element 32 being at level 1 and element 4 at level 25. Level 1 is the lowest level whereas level 25 is the highest. Mapping against the ISM model in Figure 5.2, the elements were arranged using top down sequence with elements 4, 7, 17, 20 and 23 at the top running down to elements 26, 27 and 32 at the bottom of the model. In order to clearly see the position of the elements

according to the level partitions, the elements are rearranged as can be seen in Table 5.5 below.

Table 5.5

Level Partition of Reachability Matrix

No	Elements	Level
32	The humanoid should have a male voice.	1
26	When sadness is detected, the humanoid should use a happy tone.	2
27	A neutral tone should be the default tone.	2
25	The humanoid should have a curious tone of voice.	3
14	The humanoid should have a female voice.	4
31	When anger is detected, the humanoid should use a happy tone.	5
29	The humanoid should have a slow rate of speech.	6
22	Inspirational quotes as verbal content should be incorporated into the model.	7
12	News as verbal content should be incorporated into the model.	8
24	Jokes as verbal content should be incorporated into the model.	9
21	A happy tone should be the default tone.	10
2	The humanoid should have a friendly tone of voice.	11
18	The humanoid should use a happy tone when reminding of medication.	11
1	Body motion that is non-threatening to elders should be incorporated into the model e.g. slow movements, hand not raised too high.	12
15	Facts as verbal content such as medical content, television programmes, and weather report should be incorporated into the model.	13
16	If anger is detected from the elder, the humanoid should change the topic.	13
30	The humanoid should use a serious tone when reminding of medication.	14
28	Elders should start communication with the humanoid first.	15
3	Responses as verbal content such as “Wow, that’s amazing!”, “That’s	16

	nice" and "Well done" should be incorporated into the model.	
6	The humanoid should have a happy or encouraging tone of voice.	16
13	If anger is detected from the elder, the humanoid should listen and respond accordingly.	17
9	The humanoid should have a moderate pitch of voice.	18
10	Comfortable distance and orientation between elders and humanoids should be incorporated into the model.	18
11	The humanoid should have a moderate rate of speech.	19
19	When anger is detected, the humanoid should use a curious tone.	19
8	If sadness is detected from the elder, the humanoid should listen and respond accordingly.	20
5	If the elder does not respond to the humanoid, the humanoid should wait for a response and prompt the elder until a response is heard.	21
23	The humanoid should start communication with the elders first.	22
20	When sadness is detected, the humanoid should use a curious tone.	23
7	Questions as verbal content such as "How are you?", "What do you mean?" and "Is it interesting?" should be incorporated into the model.	24
17	The humanoid should have an empathetic tone of voice.	24
4	Humanoid should detect emotion of elders through tone of voice and respond accordingly.	25

Findings from Step 7: Analysis and Interpretation of Model

As the final step for phase 2, the elements were then categorized according to clusters based on their driving power and dependence power utilizing MICMAC (Cross-impact multiplication applied to classification) analysis. The classification is divided into four categories, as elaborated in the methodology section: independent elements, linkage elements, dependent elements and autonomous elements; as illustrated in Figure 5.3.

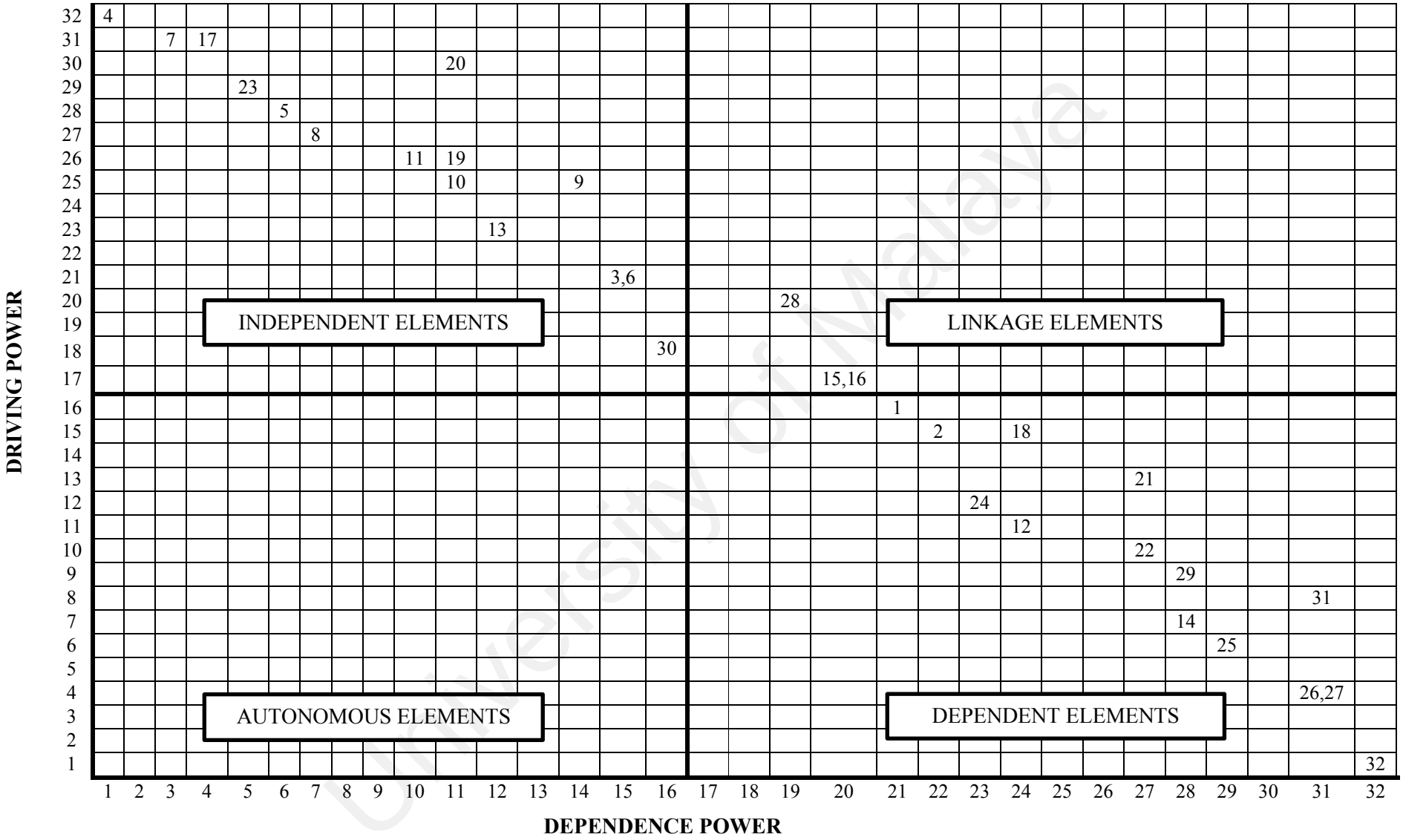


Figure 5.3. MICMAC analysis matrix for verbal and non-verbal communication model

Based on Figure 5.3, there are four clusters related to driving power and dependence power. The first cluster consists of the independent elements. These elements have strong driving power but weak dependence power. Elements 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 17, 19, 20, 23 and 30 fall under this category and they need to be addressed first before other elements. Element 4 (Humanoid should detect emotion of elders through tone of voice and respond accordingly) was found to have the strongest driving power and is not affected by the rest of the elements. The second cluster shows linkage elements that have strong driving and dependence power. Elements 15, 16 and 28 are under this category. They are known to be important links between dependent and independent elements. If these elements are implemented in the right way, the communication model will definitely be successful.

The dependent elements 1, 2, 12, 14, 18, 21, 22, 24, 25, 26, 27, 29, 31 and 32 are in the third cluster that has weak driving power but strong dependence power. These elements are not strong enough to be implemented on its own without the elements in the independent and linkage clusters. The final cluster is the autonomous elements cluster whereby the elements plotted here have weak driving and dependence power. This indicates that the elements under this cluster are relatively disengaged from the model and the presence of those elements does not really have a major impact on the model. However, as can be seen in Figure 5.3, there are no elements under this cluster for this particular study. Table 5.6 below shows all the elements in their respective clusters. The interpretations of these results will be explained in chapter 7.

Table 5.6

Elements According to Clusters

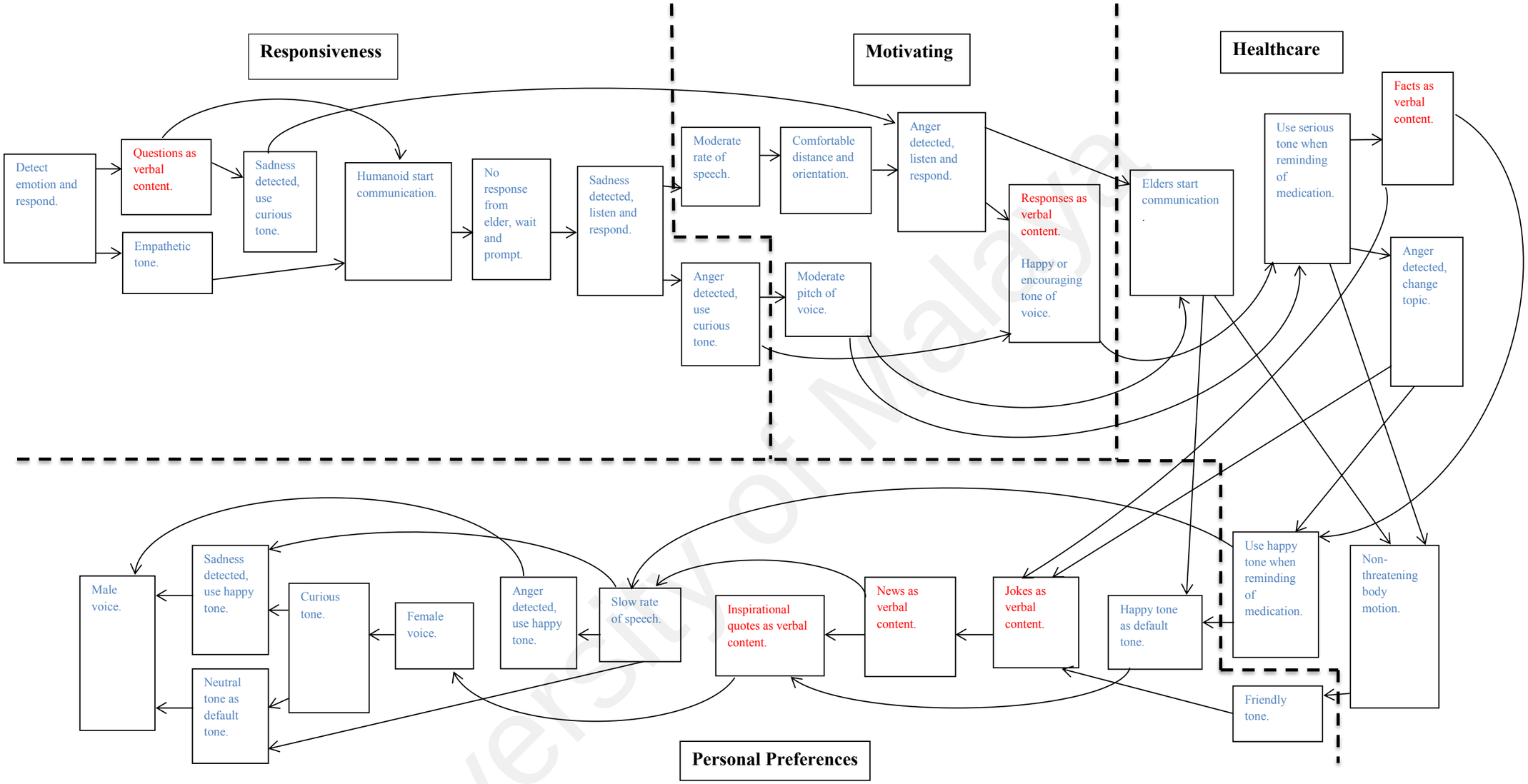
Clusters		Elements
Independent	4	Humanoid should detect emotion of elders through tone of voice and respond accordingly.
	7	Questions as verbal content such as "How are you?", "What do you mean?" and "Is it interesting?" should be incorporated into the model.
	17	The humanoid should have an empathetic tone of voice.
	20	When sadness is detected, the humanoid should use a curious tone.
	23	The humanoid should start communication with the elders first.
	5	If the elder does not respond to the humanoid, the humanoid should wait for a response and prompt the elder until a response is heard.
	8	If sadness is detected from the elder, the humanoid should listen and respond accordingly.
	11	The humanoid should have a moderate rate of speech.
	19	When anger is detected, the humanoid should use a curious tone.
	10	Comfortable distance and orientation between elders and humanoids should be incorporated into the model.
	9	The humanoid should have a moderate pitch of voice.
	13	If anger is detected from the elder, the humanoid should listen and respond accordingly.
	3	Responses as verbal content such as "Wow, that's amazing!", "That's nice" and "Well done" should be incorporated into the model.
	6	The humanoid should have a happy or encouraging tone of voice.
	30	The humanoid should use a serious tone when reminding of medication.
Linkage	28	Elders should start communication with the humanoid first.
	15	Facts as verbal content such as medical content, television

		programmes, and weather report should be incorporated into the model.
	16	If anger is detected from the elder, the humanoid should change the topic.
Dependent	1	Body motion that is non-threatening to elders should be incorporated into the model e.g. slow movements, hand not raised too high.
	2	The humanoid should have a friendly tone of voice.
	18	The humanoid should use a happy tone when reminding of medication.
	21	A happy tone should be the default tone.
	24	Jokes as verbal content should be incorporated into the model.
	12	News as verbal content should be incorporated into the model.
	22	Inspirational quotes as verbal content should be incorporated into the model.
	29	The humanoid should have a slow rate of speech.
	31	When anger is detected, the humanoid should use a happy tone.
	14	The humanoid should have a female voice.
	25	The humanoid should have a curious tone of voice.
	26	When sadness is detected, the humanoid should use a happy tone.
	27	A neutral tone should be the default tone.
	32	The humanoid should have a male voice.

Simplified Models

In order to make it easier to understand the final communication model, a simplified version of the final model is shown in Figure 5.4. The elements are condensed into important points and are colour coded according to verbal and non-verbal elements. Other than that, the final model is further broken down into the four domains which are Responsiveness (Figure 5.5), Motivating (Figure 5.6), Healthcare (Figure 5.7)

and also Personal Preferences (Figure 5.8). The relationship of the elements in each domain will be discussed in Chapter 7. The separated models enable the relationships of the elements in each domain to be seen better.



Notes:
Words in red = verbal element
Words in blue = non-verbal element

Figure 5.4. Simplified verbal and non-verbal communication model between learning companion humanoids and elderly humans

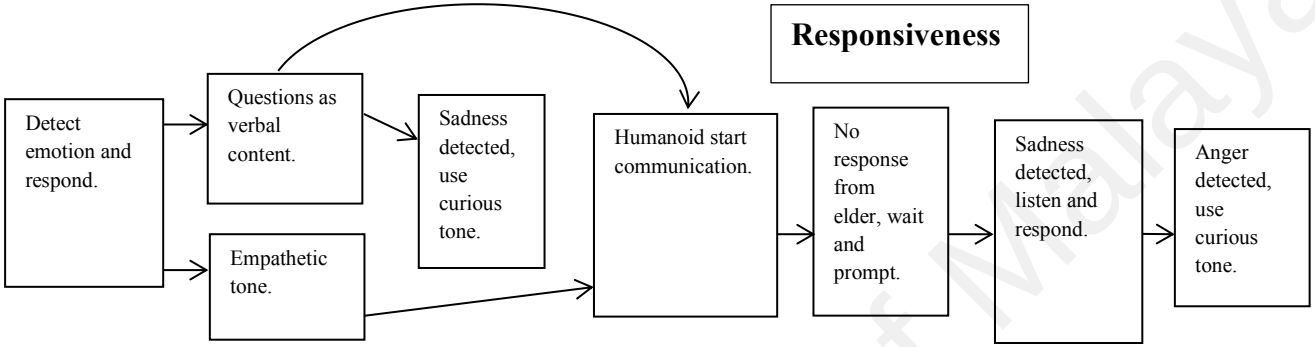


Figure 5.5. Responsiveness domain of communication model

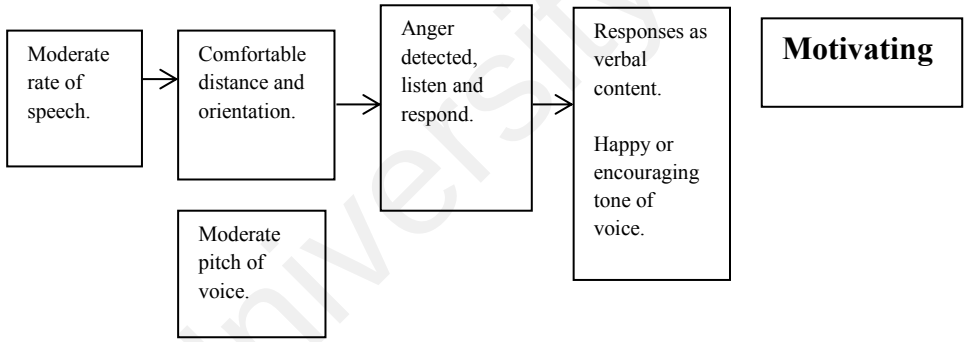


Figure 5.6. Motivating domain of communication model

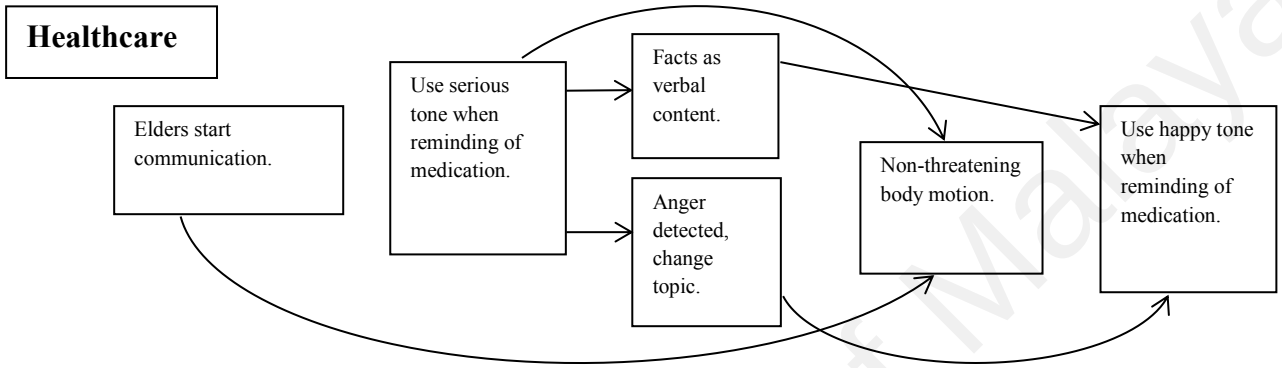


Figure 5.7. Healthcare domain of communication model

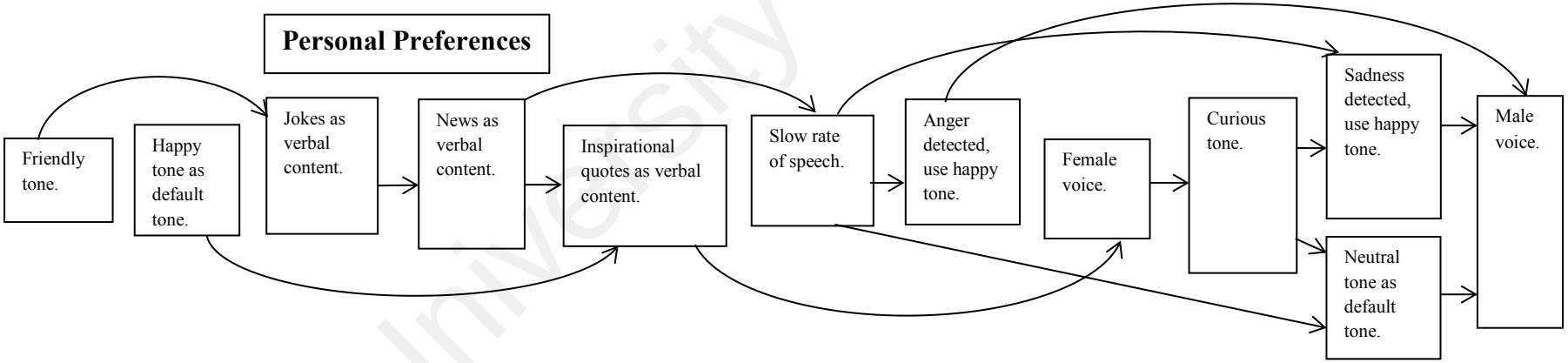


Figure 5.8. Personal Preferences domain of communication model

Summary of Findings for Phase 2

This phase resulted in the verbal and non-verbal communication model between learning companion humanoids and elderly humans as can be seen in Figure 5.2. The model was developed utilizing expert's opinions through interpretive structural modeling technique, which is a powerful decision-making tool used in multiple sectors. The model consists of 32 elements that are related to each other in a hierarchical manner through pairwise technique. It was then divided into four domains that show the critical areas that the verbal and non-verbal communication model focuses on. The elements were further analyzed using MICMAC analysis to decide the clusters for every element according to their driving and dependence powers. The four clusters could determine the elements that need to be addressed before other elements and the combination of elements that could enhance the effectiveness of the humanoid in being a successful companion to the elderly. The model is then condensed and simplified into a colour-coded model and four domain models. The output of the study is a guideline on the elements needed by a humanoid to be a successful companion to elders as it eliminates loneliness and deter mental illnesses.

CHAPTER 6

FINDINGS OF PHASE 3: EVALUATE USABILITY OF THE MODEL

Introduction

This chapter reports on the results of phase 3 of the study which is the assessment of the communication model. It contains the results for the third phase which is a continuation of the second phase. Discussions for this phase will be reported in chapter 7, along with the discussions for phase 1 and 2 which are chapters 4 and 5 respectively. The final phase of this study intends to evaluate the verbal and non-verbal communication model between learning companion humanoids and elderly humans that was developed in phase 2. This phase is crucial in determining the suitability of the developed model in assisting in successful communication between humanoids and elders who live alone. This study uses fuzzy Delphi method to evaluate the model that incorporates views from experts. The evaluation was conducted on 15 experts who are considered end-users of the product. The criteria for the expert selection in this phase were described in chapter 3.

Findings of the evaluation of Verbal and Non-verbal Communication Model between Learning Companion Humanoids and Elderly Humans

The responses from the experts were obtained through survey questionnaires that utilized the seven-point linguistic scale. The threshold value,'d' was estimated for all the questionnaire items according to feedback from the participants to ascertain the level of consensus among the experts for every item. The threshold values are displayed in Table 6.1 whereby the values in bold are items that exceeded

the threshold value of 0.2. This shows the opinion of an individual participant that differs or not in consensus with other participants for a particular questionnaire item (Cheng & Lin, 2002). However, the purpose of calculating the threshold value is to determine the threshold values for the overall questionnaire items.

Table 6.1

Threshold Value, d, for Survey Questionnaire Items

Expert	1.1	2.1	2.2	2.3	2.4	3.1	4.1	4.2	4.3	4.4	4.5	4.6	4.7
1	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.2	0.1
2	0.0	0.0	0.1	0.2	0.2	0.2	0.0	0.2	**0.3**	0.0	0.0	0.1	0.0
3	0.0	0.2	0.1	0.0	0.2	0.2	0.0	0.2	0.0	0.0	**0.3**	0.1	0.0
4	0.1	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.2	0.1
5	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.1	0.2	0.0	0.2	0.0
6	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.1	0.0	0.0	**0.5**	0.0
7	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.1	0.2	0.1	0.2	0.0
8	**0.5**	**0.5**	**0.3**	**0.5**	0.1	0.2	0.2	**0.4**	**0.5**	0.2	**0.3**	0.2	**0.3**
9	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
10	0.1	0.2	0.1	0.2	0.1	0.2	0.2	0.2	0.1	0.2	0.1	0.2	0.1
11	0.0	0.2	**0.3**	0.0	0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.2	0.1
12	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.0	0.2	0.0	0.1	0.0
13	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.0	0.2	0.0	0.1	0.0
14	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.0	0.2	0.0	0.1	0.0
15	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.0	0.2	0.0	0.1	0.0
d value for each item	0.091	0.106	0.102	0.106	0.177	0.147	0.154	0.182	0.125	0.147	0.084	0.151	0.070
d construct value							0.13						

In accordance to Table 6.1, the overall threshold value,'d', was estimated as [195 (total experts' responses) – 12 (total responses exceeding 0.2) ÷ 195] x 100 = 94%. This shows that the threshold value is more than the necessary percentage of 75% which means that the experts had achieved group consensus in their opinions for all the questionnaire items of the evaluation survey questionnaire in the evaluation of the verbal and non-verbal communication model between learning companion humanoids and elderly humans. A threshold value of less than 75% would require a second round of fuzzy Delphi questionnaire to reevaluate their opinions. More rounds of FDM may be done until group consensus is achieved. Table 6.2 below shows the consensus percentage for every item and the overall items and the consensus achieved among the experts is very high.

Table 6.2

Consensus Percentage for Every Item and Overall Items

	Item												
	1.1	2.1	2.2	2.3	2.4	3.1	4.1	4.2	4.3	4.4	4.5	4.6	4.7
No. of items $d \leq 0.2$	14	14	13	14	15	15	15	14	13	15	13	14	14
% of items $d \leq 0.2$	93	93	87	93	100	100	100	93	87	100	87	93	93
% overall items $d \leq 0.2$	94%												

For this study, since group consensus has already been acquired, the following step is to report on the findings of the experts' collective opinions on the assessment of the model regarding their agreement on these aspects:

1) Suitability of elements of the verbal and non-verbal communication model between learning companion humanoids and elderly humans.

2) Views on the cluster classification of elements of the verbal and non-verbal communication model between learning companion humanoids and elderly humans.
3) Views on the relationships of elements of the verbal and non-verbal communication model between learning companion humanoids and elderly humans.
4) Views on the overall usability of the verbal and non-verbal communication model between learning companion humanoids and elderly humans.

Aspects 1, 2 and 3 are aspects that represent the elements and the connections of the elements, which form the major components of the structure of the model. The suitability of the model as a clear guide in implementing successful communication depends on the structure of the model. Aspect 4 evaluated the purpose and clarity of the model.

The aspects mentioned above are in accordance with the research questions for this phase, which are:

a. What is the experts' consensus on the suitability of the elements proposed in the verbal and non-verbal communication model between learning companion humanoids and elderly humans? (Aspect 1)
b. What is the experts' consensus on the list of elements in the four clusters (Independent, Linkage, Dependant and Autonomous) as proposed in the verbal and non-verbal communication model between learning companion humanoids and elderly humans? (Aspect 2)

c. What is the experts' consensus on the relationships among the elements proposed in the verbal and non-verbal communication model between learning companion humanoids and elderly humans? (Aspect 3)
d. What is the experts' consensus on the usability of the verbal and non-verbal communication model between learning companion humanoids and elderly humans? (Aspect 4)

Therefore, the report of the findings is as follows:

The requirements for triangular fuzzy numbers and defuzzification process were already explained in Chapter 3 but here is a brief reminder of the requirements involved in this section:

a) Triangular fuzzy numbers:
    1) Threshold value (d) ≤ 0.2
    2) Percentage of experts' consensus ≥ 75%
b) Defuzzification process:
    1) Fuzzy score (A) ≥ α-cut value = 0.5

Aspect 1: Suitability of elements of the verbal and non-verbal communication model. For this questionnaire item, the experts had to answer the following question: 'Do you agree with the elements proposed in the model in connection to the research outcome?' (Item 1.1).

Table 6.3

Experts' Views on Elements Proposed in the Model

Item	Triangular Fuzzy Numbers		Defuzzification Process			
	Threshold value for each item	Percentage of consensus	m_1	m_2	m_3	Fuzzy Score (A)
1.1	0.091	93%	0.727	0.900	0.980	0.869

According to Table 6.3, the threshold value for this item is less than 0.2 and has a consensus percentage of more than 75%. Therefore, this item is accepted and there is no need for another round of questionnaire. Fuzzy score is more than the α-cut of 0.5 and shows high consensus between the experts involved in the study. The results of aspect 1 show that the experts do agree with most of the elements proposed in the verbal and non-verbal communication model in regards to the outcome of the research which is to eliminate loneliness among elders who live alone and to encourage them to learn in their old age.

Aspect 2: Views on the cluster classification of elements in the verbal and non-verbal communication model. In order to find out the participants' views on the four cluster classification of elements (Independent, Linkage, Dependent and Autonomous), they were asked to answer these questions:

2.1 Do you agree with the classification of elements in the independent cluster?

2.2 Do you agree with the classification of elements in the linkage cluster?

2.3 Do you agree with the classification of elements in the dependent cluster?

2.4 Do you agree with the classification of elements in the autonomous cluster?

Table 6.4

Experts' Views on Cluster Classification of Elements

Item	Triangular Fuzzy Numbers		Defuzzification Process			
	Threshold value for each item	Percentage of consensus	m_1	m_2	m_3	Fuzzy Score (A)
2.1	0.106	93%	0.700	0.880	0.973	0.851
2.2	0.102	87%	0.753	0.913	0.987	0.884
2.3	0.106	93%	0.700	0.880	0.973	0.851
2.4	0.177	100%	0.647	0.813	0.940	0.800

As can be seen in Table 6.4 above, the threshold values for every item in aspect 2 are below 0.2 with consensus percentages of more than 75% which indicates no need for a second round of questionnaire. The consensus percentage of 100% means that no expert had a totally different answer from the other experts and most of their answers were near to each other. For example, all the experts could have chosen numbers 5, 6 and 7 in the 7-point Linguistic Scale which are close to each other. Item 2.2 has a fuzzy score of 0.884 which is the highest in aspect 2 and shows high consensus among experts compared to items 2.1 and 2.3 with fuzzy scores of 0.851 respectively followed by item 2.4 with a score of 0.800. Item 2.4 has a low fuzzy score due to some experts choosing lower numbers in the linguistic scale although it has a consensus percentage of 100%.

The results for aspect 2 indicate that the participants of the research do agree with the classification of the elements based on clusters with a higher agreement on elements in the linkage cluster (elements with strong driving power and strong dependence power). They also have quite strong consensus on elements in the independent (elements with strong driving power and weak dependence power) and

dependent (elements with weak driving power and strong dependence power) clusters. Although agreement on classification in the autonomous (elements with weak driving power and weak dependence power) cluster has the lowest score, it is still a strong consensus for elements in that cluster. The lower score could be because some experts thought that a few elements could be eliminated from the cluster as they were not very important elements.

Aspect 3: Views on the relationships of elements in the verbal and non-verbal communication model. For this questionnaire item, the experts were asked to answer this particular question: 'Do you agree with the overall relationships among the elements as shown in the model to aid in successful communication between humanoids and elders who live alone?' (Item 3.1).

Table 6.5

Experts' Views on Element Relationships in the Model

Item	Triangular Fuzzy Numbers		Defuzzification Process			
	Threshold value for each item	Percentage of consensus	m_1	m_2	m_3	Fuzzy Score (A)
3.1	0.147	100%	0.700	0.867	0.967	0.844

Table 6.5 shows that item 3.1 has a threshold value, 'd' of 0.147 and consensus percentage of 100% which indicates that the item is accepted as the d-value is less than 0.2 and the consensus percentage is more than 75%. The fuzzy score for this item is 0.844 which exceeds the α-cut value of 0.5 and shows high consensus among the experts involved. The results for aspect 3 show that the participants of the research do agree quite strongly with all the relationships

portrayed in the model in the context of aiding in successful communication between humanoids and elders who live alone.

Aspect 4: Views on the overall usability of the model. The last aspect of the assessment of the model involves the participants' opinions on the suitability of the model in the context of humanoids and elderly humans who live alone. In order to elicit these views, they had to respond to the following questions:

4.1 The model shows a clear guide on what elements should be given attention to have successful communication between humanoids and elders who live alone.

4.2 It is practical to use a network of interrelationship of elements in developing a verbal and non-verbal communication model to aid in effective communication between humanoids and elders who live alone.

4.3 The model clearly shows how and which verbal elements and non-verbal elements can work together to eliminate loneliness and mental illnesses.

4.4 The model clearly shows how and which verbal and non-verbal elements can work together to aid and motivate elders who live alone to learn.

4.5 The model clearly shows how one element connects to other elements in aiding elders who live alone to learn and subsequently prevent loneliness and mental illnesses.

4.6 The model could be used to guide planning of communication between humanoids and elders who live alone for robot manufacturers and scientists.

4.7 The model could be used as an example to develop other communication models between humanoids and the elderly.

Table 6.6

Experts' Views on Usability of Model

Item	Triangular Fuzzy Numbers		Defuzzification Process			
	Threshold value for each item	Percentage of consensus	m_1	m_2	m_3	Fuzzy Score (A)
4.1	0.154	100%	0.713	0.873	0.967	0.851
4.2	0.182	93%	0.647	0.820	0.940	0.802
4.3	0.125	87%	0.740	0.900	0.973	0.871
4.4	0.147	100%	0.700	0.867	0.967	0.844
4.5	0.084	87%	0.727	0.900	0.987	0.871
4.6	0.151	93%	0.687	0.860	0.960	0.836
4.7	0.070	93%	0.740	0.913	0.993	0.882

According to table 6.6, all the items in aspect 4 have threshold values that are lower than 0.2 and consensus percentages of more than 75%. This means that the items are accepted and another round of questionnaire is not needed. Items 4.1 and 4.4 have consensus percentages of 100% which means that the answers from the experts do not differ that much from each other. For the values of fuzzy score (A), all the items exceed the α-cut value of 0.5 with the highest value being item 4.7 with a fuzzy score of 0.882. This is followed by items 4.3 and 4.5 with values of 0.871 respectively, item 4.1 with 0.851, item 4.4 with 0.844, item 4.6 with 0.836 and item 4.2 with 0.802. These values are not that far apart and show high consensus between the experts.

Results for aspect 4 indicate that the experts do believe in the usability of the verbal and non-verbal communication model in aiding communication between humanoids and elderly humans who live on their own. The item with the highest fuzzy score which is item 4.7 shows that most experts gave high scores to the notion that the developed model could be used as an example in developing other communication models between humanoids and the elderly. Two items with the second highest fuzzy scores are items 4.3 and 4.5 and they mean that the experts do agree that the model clearly shows how and which verbal and non-verbal elements can work together to aid and motivate elders who live alone to learn and how one element connects to other elements in aiding elders who live alone to learn and subsequently prevent loneliness and mental illnesses. This is followed by item 4.1 that shows quite strong agreement from the experts on the model being a clear guide on what elements should be given attention to have successful communication between humanoids and elders who live alone. Then, item 4.4 indicates that the model clearly shows how and which verbal and non-verbal elements can work together to aid and motivate elders who live alone to learn. Item 4.6 shows that the experts agree that the verbal and non-verbal communication model could be used to guide planning of communication between humanoids and elders who live alone for robot manufacturers and scientists. Finally, the lowest fuzzy score in aspect 4 is item 4.2 but still shows consensus on the practicality of using a network of interrelationship of elements in developing a verbal and non-verbal communication model to aid in effective communication between humanoids and elders who live alone.

Summary

The overall findings for all four aspects in assessing the communication model can be concluded in Table 6.7. This table indicates the defuzzification values and ranking of the questionnaire items. The purpose of the ranking is to indicate the way an item compares to other items in the degree of consensus among the participants of the study. Ranking number one is taken as the highest rank in line with the highest defuzzification value for that particular item.

Table 6.7

Threshold Value, Defuzzification Value and Ranking of Items

Item	**1.1**	**2.1**	**2.2**	**2.3**	**2.4**	**3.1**	**4.1**	**4.2**
d value	0.091	0.106	0.102	0.106	0.177	0.147	0.154	0.182
A value	0.869	0.851	0.884	0.851	0.800	0.844	0.851	0.802
Ranking	4	5	1	5	9	6	5	8

Item	**4.3**	**4.4**	**4.5**	**4.6**	**4.7**
d value	0.125	0.147	0.084	0.151	0.070
A value	0.871	0.844	0.871	0.836	0.882
Ranking	3	6	3	7	2

Note. 'd' value: threshold value; A value: Fuzzy score

In conventional Fuzzy Delphi, as explained in chapter 3, the ranking of items were used to determine the variables for a particular research study. Items with higher ranks could be chosen as a variable in result of that study. However, in this

study, the ranks are used to compare the level of consensus among the experts for the questionnaire items. As can be seen in table 6.7, item 2.2 (agreement on classification of elements in the linkage cluster) is ranked as first in the level of consensus among experts whereas item 2.4 (agreement on classification of elements in the autonomous cluster) received the lowest rank.

Although, the most crucial results of Phase 3 for this study are the defuzzification values for the questionnaire items in the experts' assessment of the verbal and non-verbal communication model between learning companion humanoids and elderly humans. From those findings, the defuzzification values for all the items exceed the α-cut value of 0.5 and show high agreement as the values range between 0.8 and 0.9. This conclusively suggests that the participants of the study consensually agree with all the four aspects of the assessment of the model. Therefore, according to the experts, the model is suitable to act as a guideline in implementing successful communication between humanoids and elderly humans who live alone to prevent loneliness and mental illnesses.

CHAPTER 7

DISCUSSION AND IMPLICATIONS

Introduction

To summarize on the findings, chapters 4, 5 and 6 reported on the results of the study in three phases: Phase 1- Needs analysis, Phase 2- Development of the verbal and non-verbal communication model between learning companion humanoids and elderly humans, and Phase 3- Evaluation of the model. In short, the needs analysis phase established the need for a solution to prevent loneliness in healthy elders who live alone and who lack support in achieving successful ageing. In response to this need, the development phase focused on developing the verbal and non-verbal communication model between learning companion humanoids and elderly humans to aid in successful communication between the two parties. Then, the evaluation phase dealt with the assessment of the developed model by utilizing experts' opinions on the suitability of the model in guiding successful communication between humanoids and the elders. The next sections add details on the results for every phase followed by discussions on the model pertaining to the elements of the model and the relationships among them in facilitating how elders who live by themselves can learn and prevent loneliness as well as mental illnesses.

The discussion on the findings in chapters 4, 5 and 6 end with a summary of findings before moving on to a brief summary of the whole study. This is then followed by the implications and recommendations of the study. That section will contain the practical implications, theoretical implications and methodology implications. The chapter ends with suggestions for future possible directions of the study.

Discussion of findings from Phase 1: Needs Analysis.

Initially, the communication model was proposed to bridge the gap of verbal communication between humanoids and elders who live alone. The model would act as a guide for robot makers and scientists to use when they plan to make robots or humanoids for the benefit of our elders. A lot of research has been done on the physical aspects or what a humanoid can do for elders but research on communication between humanoids and elders are rare, especially on local terms. However, before the proposal can be accepted, the need to have a communication support for the elders must be determined first. The needs analysis was carried out utilizing a set of needs analysis survey questionnaire, which contained 7 questions and also interview sessions with 5 elders. The questionnaires were given to the elders and the major purpose was to evaluate the need for a communication support between humanoids and elders who live alone and to evaluate their level of acceptance of humanoid robots in their everyday lives. The questions for the survey were constructed based on previous researches and conducted on 100 elders selected randomly. The interview sessions were aimed at gaining a deeper understanding of the elders' perceptions and opinions on communication generally and with humanoids. The interviews consisted of 9 questions and resulted in 9 themes. Data from this phase were analyzed utilizing descriptive statistics through the Statistical Package for Social Science (SPSS) and thematically. The analysis of mean scores and themes for this phase were proposed to decide whether there is a need for a verbal and non-verbal communication model between humanoids and elders based on the elders' views. In identifying this need, the needs analysis phase had the purpose of answering these research questions:

1.1 What physical type of humanoid robots do the elderly prefer?

1.2 What type of humanoid companion do the elderly prefer?

1.3 What are the elders' perception on communication between humanoids and humans?

The findings for research questions 1.1 and 1.2 justified the need to have a communication support between humanoids and elderly humans (refer to Tables 4.3 to 4.9, pp. 78-81). Firstly, a majority of the elders (43%) chose the size of a small child as the preferred size for a humanoid robot that is required to live with them. This could be because the smaller size is less intimidating to them but the size of a small animal is too small for their convenience. The size of a toddler could even make the humanoid seem more endearing to them as it reminds them of children or grandchildren rather than an adult-sized humanoid that can seem threatening at times. Then, when the elders were asked whether they think a communication model between humanoids and the elders is necessary, 68% of them agreed to this notion because they are aware of how lonely some of the elders can feel even if there are people around them. Any effort made in terms of communication is much appreciated by the senior citizens, especially when dealing with robots or things unfamiliar to them. The respondents who answered no to this question probably felt that human interaction is still the best and found no need for a model to be developed for communication purposes.

The next item in the questionnaire survey was on the initiator of conversation between humanoids and the elders. Most of them (83%) preferred to start the conversation first. The reason is because they would like to be in control of the conversation, and want to talk only when they feel like it. The minority of the

respondents did not really care about control, and preferred to be greeted by the humanoid as they thought they might need the prompt. In finding out the type of companion that the elders preferred in terms of communication, a majority of 36% chose a companion that could give them facts like weather reports, television programmes or the latest news. In their old age, these are the things that they are interested in, apart from medical facts that are related to their own symptoms or illnesses. Apart from that, 25% of the respondents picked a more playful companion that could tell jokes and make them laugh. These elders believe that 'laughter is the best medicine' and trust that this is the key to a happier and healthier life. 19% of the elders selected a polite companion wherein the tone of voice and words that the humanoid uses are considered polite to them. For example, the tone of voice would be deep and the humanoid would use polite terms like using the words 'sir' or 'madam' in their sentences when addressing people. Another choice of answer for this question was a good listener and 16% chose this answer. These elders want to be heard and have a lot of stories to tell, some of them probably have a lot of negative feelings stacked up inside but have nobody willing to listen to them. This could lead to depression, which is one of the things that this study is trying to prevent. Although only a minority of respondents chose this kind of companion, they are aware that an elder who lives alone does need a good listener who can prompt the elder into pouring out negative feelings.

This question is followed by an inquiry on the preferred voice type of a humanoid companion. 68% of the 100 respondents opted for female voice whereas 30% chose to hear a male voice. The reason for a majority of the elders, regardless of their gender, choosing female voice is probably because a female voice is higher pitched and thus can be heard better. It could even remind them of their mother,

spouse, children or someone who cared for them. For those who chose male voice, some women said that they would like to hear the voice of the opposite gender and some men just prefer to hear a male voice from the humanoid. 2% of the elders just didn't mind what kind of voice comes out from the humanoid. When the respondents were asked whether an elderly person who lives alone would benefit from a humanoid companion, 81% of them gave a positive response. They agreed that if all human resources have been exhausted, this would be a good effort as a last resort. Some elders do not like to deal with other humans because of the emotional uncertainty and think that it is a pain to deal with other people's antics. A minority of 19% saw no benefits in utilizing humanoids as they still believe that human interaction is the best and will always be available somehow.

The final question in the survey was on the extent of necessity of robotics in the lives of the elderly. 60% of the respondents thought that it is necessary as time and technology are moving forward and they are bound to need the help of technology in the form of robotics in their lives. On the other hand, 31% deemed it unnecessary because they do not see yet how they would need robotics in the future. 9% of them thought that robotics is very necessary and that it is inevitable that they would need this kind of technology in the near future, some of them even talk about the interesting innovations that technologically-advanced countries like Japan have done in regards to robotics.

The findings for research question 1.3 justified the use of a communication model between humanoids and elders for communication and learning as a solution in preventing loneliness and mental illnesses (refer to list of themes, pp. 82-86). The findings from the interview sessions resulted in a list of 9 themes: natural conversation, listening aid, humanoid companions, different companion, mental

health, non-verbal aspects, benefit, learning and talking preference. These themes indicate that the elders do see the need for a humanoid as a companion for elders who live alone but a communication model must be done in order for the communication to be successful. Although the humanoid must not be made only for talking and should be able to do chores as well, the role of the humanoid as a talking and listening companion is agreed upon by the elders. The opportunity of learning with the help of a humanoid does intrigue the elders and they agree that it is hugely beneficial for their mental health rather than just talking to the humanoids. This supports Roberson and Merriam (2005) who stated that an increasing number of elders enjoy using the computer and Internet for their learning purposes. The desire to learn is already there, only that the medium of learning is different. The respondents seemed happy when talking about improving or preserving their mental health because it is an important issue for them at their age and they do not want to be a burden to themselves or anyone else.

As a whole, the respondents did have differing preferences but those preferences could be changed individually on the humanoid itself as possible options for their individual owners. Then again, finding out what the majority wants is useful as the information could be used as the default setting or even for marketing purposes. In view of incorporating communication as support in preventing loneliness and mental illnesses, the study focused on the development of verbal and non-verbal communication model between learning companion humanoids and elderly humans who live alone. The next section adds details on the discussion of the results for development of the model.

Discussion of findings from Phase 2: Development Phase.

In the development of the verbal and non-verbal communication model between learning companion humanoids and elderly humans, the development phase attempted to seek answers to these research questions:

2.1 What are the experts' collective views on the elements that should be included in the development of the verbal and non-verbal communication model between learning companion humanoids and elderly humans?

2.2 Based on the experts' collective views, what are the relationships among the elements in the development of the verbal and non-verbal communication model between learning companion humanoids and elderly humans?

2.3 Based on the experts' collective views, how should the elements be classified in the interpretation of the verbal and non-verbal communication model between learning companion humanoids and elderly humans?

For the purpose of answering research question 2.1, the elements for the intended communication model were decided via experts' opinions using nominal group technique (NGT). The model was developed to assist in successful communication between learning companion humanoids and elders who lived by themselves. The next procedure for this phase, which seeks to answer research question 2.2, was the development of the verbal and non-verbal communication model using experts' opinions as well but with the aid of interpretive structural modeling technique (ISM). ISM is a well-recognized methodology for identifying relationships among specific items, which define a problem or an issue (Attri et al., 2013). The result of the process was the verbal and non-verbal communication model between learning companion humanoids and elderly humans as shown in Figure 5.2

(pp. 103). The model finally contains 32 elements that focus on verbal and non-verbal (paralinguistic) aspects of communication between humanoids and the elderly. The elements were linked to each other in a hierarchical manner decided by the experts according to the pairwise technique of ISM. The elements were also split into four domains to understand the focus of the communication model better. Then, in response to research question 2.3, the elements were categorized into four clusters using a driver-dependence matrix based on their respective driving power and dependence power (Figure 5.3, pp.111). The four clusters were independent cluster, linkage cluster, dependent cluster and autonomous cluster. The clusters signify the way the elements were connected to each other in regards to the flow and priority of the elements in the implementation to aid successful communication between humanoids and elders who lived alone to prevent loneliness and mental illnesses. More explanations on the way the model could be utilized to guide successful communication between the two parties is presented in section 7.4. In the discussion, the results were utilized to explain more on the model with regards to the elements and the connections they have, and in relation to past studies and theories or models, which were adopted as both theoretical and conceptual framework of the study.

Discussion of findings from Phase 3: Evaluate usability of the model.

The last phase of the study was the assessment of the verbal and non-verbal communication model between learning companion humanoids and elderly humans that was developed in the second phase of the study. The assessment phase attempted to seek answers to these research questions:

3.1 What is the experts' consensus on the suitability of the elements proposed in the verbal and non-verbal communication model between learning companion humanoids and elderly humans?

3.2 What is the experts' consensus on the list of elements in the four clusters (Independent, Linkage, Dependent and Autonomous) as proposed in the verbal and non-verbal communication model between learning companion humanoids and elderly humans?

3.3 What is the experts' consensus on the relationships among the elements proposed in the verbal and non-verbal communication model between learning companion humanoids and elderly humans?

3.4 What is the experts' consensus on the usability of the verbal and non-verbal communication model between learning companion humanoids and elderly humans?

According to the research questions mentioned above, the model was assessed based on four aspects:

1) Suitability of elements of the verbal and non-verbal communication model between learning companion humanoids and elderly humans.
2) Views on the cluster classification of elements of the verbal and non-verbal communication model between learning companion humanoids and elderly humans.
3) Views on the relationships of elements of the verbal and non-verbal communication model between learning companion humanoids and elderly humans.

4) Views on the overall usability of the verbal and non-verbal communication model between learning companion humanoids and elderly humans.

The assessment was carried out on 15 experts utilizing a modified Fuzzy Delphi method. They were asked to give feedback through a set of survey questionnaire, consisting of 13 questions. According to the threshold values, 'd' (Table 6.1, pp. 122) and the defuzzification values (Table 6.7, pp. 132), the results indicated that the experts have consensually agreed to all four assessment aspects of the communication model. Therefore, it is concluded that the respondents of this phase consensually agree that the model is suitable to be used as a guide in aiding successful communication between learning companion humanoids and elders who live alone to prevent loneliness and mental illnesses. The next sections explain more on the way the elements of the model and their connections could assist in the implementation of successful communication and learning.

Role of Elements in the Verbal and Non-verbal Communication Model.

As mentioned in chapter 3's methodology section, the elements were selected and decided by a panel of experts. This study adopted the theories of paralanguage (Trager, 1950), face to face interaction (Goffman, 1959), self-directed learning (Knowles, 1975) and a model of perception systems for naturally interacting humanoid robots (Schmitz & Berns, 2011) to guide in the selection of elements in the communication model.

As a result of the development phase, the panel of experts had identified 32 elements of the model. According to Schmitz and Berns (2011), a communication

model based on face to face interaction processes consist of seven major categories of action, which are:

a) Paralanguage: all information transmitted on top of speech signals but not directly related to the content of the spoken words.
b) Kinesics: any type of body motion including head, facials, trunk, hands and so on.
c) Proxemics: the perception of distance zones, spatial arrangements and sensory capabilities.
d) Artifacts: artifacts in the environment and even the environment itself influence a communication process.
e) Olfactory: the scent of interaction partners can also influence communication.
f) Haptics: related to specific situations like hand shaking, beating or grabbing and requires an embodied agent and direct feedback of the robot.
g) Language: although non-verbal aspects are considered important, most of the conversational content is transferred through the speech.

Even though there are seven categories in the model mentioned above, this study focuses on the verbal and non-verbal aspects of communication. This is because the other categories that are related to the physical and technical aspects have been explored a lot in other studies, especially in the fields of engineering and technological sciences. Based on the model of perception systems for naturally interacting humanoid robots and the findings of the study, the elements could be sorted into three categories as portrayed in Table 7.1 below.

Table 7.1

Distribution of Elements Based on a Model of Perception Systems for Naturally Interacting Humanoid Robots

Categories		Elements
Paralanguage	2	The humanoid should have a friendly tone of voice.
	4	Humanoid should detect emotion of elders through tone of voice and respond accordingly.
	5	If the elder does not respond to the humanoid, the humanoid should wait for a response and prompt the elder until a response is heard.
	6	The humanoid should have a happy or encouraging tone of voice.
	8	If sadness is detected from the elder, the humanoid should listen and respond accordingly.
	9	The humanoid should have a moderate pitch of voice.
	10	Comfortable distance and orientation between elders and humanoids should be incorporated into the model.
	11	The humanoid should have a moderate rate of speech.
	13	If anger is detected from the elder, the humanoid should listen and respond accordingly.
	14	The humanoid should have a female voice.
	16	If anger is detected from the elder, the humanoid should change the topic.
	17	The humanoid should have an empathetic tone of voice.
	18	The humanoid should use a happy tone when reminding of medication.
	19	When anger is detected, the humanoid should use a curious tone.
	20	When sadness is detected, the humanoid should use a curious tone.
	21	A happy tone should be the default tone.

	23	The humanoid should start communication with the elders first.
	25	The humanoid should have a curious tone of voice.
	26	When sadness is detected, the humanoid should use a happy tone.
	27	A neutral tone should be the default tone.
	28	Elders should start communication with the humanoid first.
	29	The humanoid should have a slow rate of speech.
	30	The humanoid should use a serious tone when reminding of medication.
	31	When anger is detected, the humanoid should use a happy tone.
	32	The humanoid should have a male voice.
Language	3	Responses as verbal content such as "Wow, that's amazing!", "That's nice" and "Well done" should be incorporated into the model.
	7	Questions as verbal content such as "How are you?", "What do you mean?" and "Is it interesting?" should be incorporated into the model.
	12	News as verbal content should be incorporated into the model.
	15	Facts as verbal content such as medical content, television programmes, and weather report should be incorporated into the model.
	22	Inspirational quotes as verbal content should be incorporated into the model.
	24	Jokes as verbal content should be incorporated into the model.
Kinesics	1	Body motion that is non-threatening to elders should be incorporated into the model e.g. slow movements, hand not raised too high.

As can be seen in Table 7.1, a majority of the elements fall under the category of paralanguage. These elements are variations on the aspects of gender of voice, tone of voice, rate of speech, pitch of voice, initiator of conversation and response from elders or humanoids in the form of vocalization. Elements 14 (the humanoid should have a female voice) and 32 (the humanoid should have a male voice) give the elders a choice on the gender of the voice they would like to hear from the humanoids as these personal choices could expedite the feeling of closeness between the two parties. Element 4 which is 'humanoid should detect emotion of elders through tone of voice and respond accordingly' shows that the humanoid is naturally interacting with a human and that it can be a good partner for an elder who lives on their own. The default tone to be used by the humanoid or the 'go to' setting for the tone of voice is given in two choices which are elements 21 (a happy tone should be the default tone) and 27 (a neutral tone should be the default tone). The difference between these two choices is that a happy tone may spread the feeling of happiness and a neutral tone may be calming. Other variations on tone of voice come in the form of elements 17 (the humanoid should have an empathetic tone of voice), 6 (the humanoid should have a happy or encouraging tone of voice), 2 (the humanoid should have a friendly tone of voice) and element 25 which is 'the humanoid should have a curious tone of voice'. The variety of these voice tones aim to match the feelings of the elders at the time and to evoke certain emotions or actions from them. For example, using a curious tone of voice when asking a question makes the humanoid seem more human and genuinely interested to know the opinion of the elder, therefore the elderly would be more willing to share their feelings with the humanoid. This shows how adaptable artificial intelligence can be and that it is the best substitute for a human. Other than that, elements 30 (the humanoid should use a

serious tone when reminding of medication) and 18 (the humanoid should use a happy tone when reminding of medication) indicates how important medication is at that age and that the right tone of voice can encourage the elders to take their medication at the right time. Some elders do just forget to take their medicine and just needs reminding but some of them do not like that routine and need some coaxing to take their medicine, even if it's just in the form of voice tones because it can affect them psychologically. This is in line with a study by Sober et al. (2016) where they talk about the importance of tone of voice when delivering health-related messages.

For the rate of speech, two elements were accepted which are element 11 (the humanoid should have a moderate rate of speech) and element 29 (the humanoid should have a slow rate of speech). These rates of speech were considered most suitable when speaking to the elders to avoid misunderstanding. Only one pitch of voice was accepted in the model and that is element 9 which is 'the humanoid should have a moderate pitch of voice' because a high pitch can be annoying and a low pitch may be hard to hear however romantic that can be. The elements for initiator of conversation are elements 23 (the humanoid should start communication with the elders first) and 28 (elders should start communication with the humanoid first). Some elders prefer to be in control of when they want to speak while others prefer to be greeted. For elements associated with responses, three criteria were chosen, which are when sadness or anger is detected and if there is no response from the elders. When sadness is detected from the tone of voice of the elder, there are three choices accepted in the model, which are elements 20 (when sadness is detected, the humanoid should use a curious tone), 8 (if sadness is detected from the elder, the humanoid should listen and respond accordingly) and 26 which is 'when sadness is

detected, the humanoid should use a happy tone'. Elements 20 and 8 were chosen with the purpose of letting the elders talk about their sadness so that they will feel better whereas element 26 was intended to prevent the elders from dwelling on negative feelings. For anger, four choices were accepted and they are elements 19 (when anger is detected, the humanoid should use a curious tone), 13 (if anger is detected from the elder, the humanoid should listen and respond accordingly), 16 (if anger is detected from the elder, the humanoid should change the topic) and 31 which is 'when anger is detected, the humanoid should use a happy tone'. Elements 19 and 13 were chosen so that the elders would talk about their anger in a healthy way and not be destructive whereas elements 16 and 31 aim to prevent the elders from dwelling on that feeling. Another element associated with responses is element 5 which is 'if the elder does not respond to the humanoid, the humanoid should wait for a response and prompt the elder until a response is heard'. Experts chose this element because they were worried for the safety of the elders and if something were to happen to them, this could be a trigger for the humanoid to alert certain people or authorities as a safety measure.

In the category of language, element 7 (questions as verbal content such as "how are you?", "what do you mean?" and "is it interesting?" should be incorporated into the model) was intended to encourage the elders to share their feelings or what they have learned through asking questions. By talking, the elderly would feel less lonely and their brains could get a bit of a workout as well as they come up with words to explain things and to search their memories. This element is supported by a study (Johnson et al., 2016) that stated that the action of the robot in the study asking direct questions to the human appeared to encourage the human to interact with the robot. Another element in this category is 'responses as verbal content such as "wow,

that's amazing!", "that's nice" and "well done" should be incorporated into the model' (element 3) and suitable responses were chosen to motivate the elders to continue what they were doing or saying and also to make them feel good about themselves which is very important when you are old and alone and could easily fall into depression. Element 15 (facts as verbal content such as medical content, television programmes and weather report should be incorporated into the model) deals with information that the older generation enjoy finding out on a daily basis. This keeps their minds occupied and usually having a somewhat fixed schedule gives them a sense of discipline and familiarity. 'Jokes as verbal content should be incorporated into the model' is element 24 and it is meant to bring laughter into the daily lives of the senior citizens. Laughter is known as 'the best medicine' as it reduces stress hormones and releases endorphins or 'feel-good' hormones with some health benefits like strengthening the immunity system. Element 12 which is 'news as verbal content should be incorporated into the model' was chosen because although the elders can't really venture out into the world as often as they would like to but they are still interested to know what is going on around the world. News covers a majority of things and the elderly can choose their favourite subjects like economics, politics and even their favourite celebrities or public figures. The final element in this category is 'inspirational quotes as verbal content should be incorporated into the model' (element 22) and it is intended to bring about a positive atmosphere for the senior citizens. A daily quote could even motivate them to try new things or think about something from a new perspective.

The only element associated with kinesics is element 1 which is 'body motion that is non-threatening to elders should be incorporated into the model e.g. slow movements, hand not raised too high' and it was chosen to be in the model because

the elders are the generation that is most unfamiliar with robots. Therefore, the humanoids have to seem as unthreatening as possible for the elders to accept them more easily into their daily lives as constant companions.

Relationship of elements in domains. In reference to the final communication model in Figure 5.2 (pp. 103) and also the four simplified models in domains (Figure 5.5, Figure 5.6, Figure 5.7 and Figure 5.8, pp. 117-118), the elements were sorted into different levels and then four domains. The four domains are Responsiveness, Motivating, Healthcare and Personal Preferences. The domain of Responsiveness consists of the top elements in the model which are elements 4, 17, 7, 20, 23, 5, 8 and 19. A majority of these elements are related to responding to the other party. For example, element 4 is about the humanoid detecting the emotions of elders through their tone of voice and respond according to that emotion. This element is backed by elements 20, 5, 8 and 19 that suggest appropriate responses when sadness, anger and even no response are detected from the elders. Element 7 talks about questions as verbal content and as questions need answers as responses, it is to elicit conversation from elders. Element 17 indicates the humanoid having an empathetic tone of voice in response to communication from the elder and empathetic in this sense means mirroring the emotions that the elders have at that time, happiness evokes a happy tone and sadness evokes a sad tone of voice. Element 23 states that the humanoid should start communication with the elders first and wait for their response.

The second domain is Motivating and 6 elements are in it (elements 11, 10, 9, 13, 6 and 3). The elements in this domain are meant to motivate the elders in their self-directed learning although it is not exclusive to that purpose. A moderate rate of speech, moderate pitch of voice and a happy or encouraging tone of voice are

portrayed in elements 11, 9 and 6 respectively. They are found to be the most suitable non-verbal aspects in assisting elders with their learning. Elements 3 and 6 are in one box which means that responses as verbal content should be said with a happy or encouraging tone of voice to promote positive emotions while learning. Element 10 talks about comfortable distance and orientation between humanoids and elders so that the humanoid doesn't seem intimidating to the elderly and element 13 indicates that if the elder gets angry while learning, the preferred response is for the humanoid to listen and respond accordingly. For example, the elder might think the information given is too much or they might get tired and express anger in their voices. The humanoid will listen and respond, perhaps whether to stop or continue.

The next domain is Healthcare and contains elements 28, 30, 16, 15, 1 and 18. Element 28 indicates that the elderly should start communication with the humanoid first pertaining to healthcare. This could mean that the elders could ask the humanoid about symptoms that they have or new updates on medical technology. Element 15 talks about factual content especially medical content being of interest to the elderly and non-threatening body motion is stated in element 1 so that the elders are not too surprised or scared while explanations are going on. Element 30 states that the humanoid should use a serious tone when reminding elders about their medication but if that does not work, element 18 can be used which is the use of a happy tone when reminding elders to take their medicine. In element 16, it is said that if anger is detected from the elders, usually when reminding them of their medication, the humanoid should change the topic first and then use a happy tone to remind them again to take their medicine.

The final domain is called Personal Preferences and consists of 12 elements (elements 2, 21, 24, 12, 22, 29, 31, 14, 25, 27, 26 and 32). The elements in this

domain are considered as choices the elderly can make and they are not as important as elements in other domains but are necessary to aid humanoids in having successful communication with the elderly in Malaysia. For example, element 2 (the humanoid should have a friendly tone of voice) can be used if the elder prefers this tone of voice over an empathetic tone of voice (element 17) which is in the Responsiveness domain. Although, element 2 is at a higher level than element 25 (the humanoid should have a curious tone of voice) which is a bit odd because elements in higher levels preferred the use of a curious tone of voice. A possible explanation for this is that as that tone of voice has been used specifically for other elements, there is no strong importance to put this tone of voice on its own at a high level of importance. This explanation was discussed during the reviewing of the model in ISM session by the experts of phase 2 of the study. Two elements to be considered as choices in this domain are element 21 (a happy tone should be the default tone) and element 27 (a neutral tone should be the default tone). If the elders do not want to make a choice, then element 21 will be chosen because it is at a higher level. Elements 24, 12 and 22 are about jokes, news and inspirational quotes as verbal content respectively. They are elements that were made to suit different elders' personalities and also to promote positivity in their daily lives. Element 29 states that the humanoid should have a slow rate of speech and this option was accepted into the model by the experts because some elders might prefer this element over a moderate rate of speech (element 11) or there might be days that an elder can only handle words spoken at a slow rate. Elements 31 and 26 say that when anger or sadness is detected from the elderly, a happy tone should be used by the humanoid when communicating back. However, these elements are not top priority when anger or sadness are detected and remain second choices if elements at higher levels fail for some reason. The final two

elements that can be considered as choices are elements 14 (the humanoid should have a female voice) and 32 (the humanoid should have a male voice). If the elders do not mind either one, element 14 at the higher level will be chosen and the humanoid will have a female voice.

Relationship of elements to theories of face to face interaction, paralanguage and self-directed learning. In relation to the theory of face to face interaction (Goffman, 1959), the elements of the model adhered to the seven major categories of action listed in the theory, although as the study focused on spoken communication, the categories were narrowed down to three. The three categories are paralanguage, language and kinesics (body motion). A majority of the elements talked about detection of emotions through tone of voice and other non-verbal aspects like pitch of voice and rate of speech. This supports the category of paralanguage in the seven categories of action. The language category is backed by the verbal contents present in the communication model such as questions, responses and jokes. Even though body motion is not spoken communication, it is considered important for communication between humanoids and the elderly and it supports one of the major categories in the theory which is kinesics. All the elements were chosen without the need for any mediating technology between the humanoids and the elders, which defines the theory.

For the theory of paralanguage (Trager, 1950), all the elements in the verbal and non-verbal communication model adhere to the four aspects of paralanguage which are the perspective aspects, organic aspects, expressive aspects and linguistic aspects (refer to Table 2.1, pp. 23). Although paralanguage is a theory of non-verbal communication, there is still a linguistic aspect in the theory. Table 7.2 below shows

how the verbal and non-verbal elements can be categorized according to the four aspects of the paralanguage theory.

Table 7.2

Category of Verbal and Non-verbal Communication Model Elements based on Paralanguage Aspects

Paralanguage aspects		**Elements of the verbal and non-verbal communication model**
Perspective	23	The humanoid should start communication with the elders first.
	10	Comfortable distance and orientation between elders and humanoids should be incorporated into the model.
	28	Elders should start communication with the humanoid first.
	1	Body motion that is non-threatening to elders should be incorporated into the model e.g. slow movements, hand not raised too high.
Organic	14	The humanoid should have a female voice.
	32	The humanoid should have a male voice.
Expressive	4	Humanoid should detect emotion of elders through tone of voice and respond accordingly.
	17	The humanoid should have an empathetic tone of voice.
	20	When sadness is detected, the humanoid should use a curious tone.
	5	If the elder does not respond to the humanoid, the humanoid should wait for a response and prompt the elder until a response is heard.
	8	If sadness is detected from the elder, the humanoid should listen and respond accordingly.
	11	The humanoid should have a moderate rate of speech.
	19	When anger is detected, the humanoid should use a curious tone.
	9	The humanoid should have a moderate pitch of voice.

	13	If anger is detected from the elder, the humanoid should listen and respond accordingly.
	6	The humanoid should have a happy or encouraging tone of voice.
	30	The humanoid should use a serious tone when reminding of medication.
	16	If anger is detected from the elder, the humanoid should change the topic.
	2	The humanoid should have a friendly tone of voice.
	18	The humanoid should use a happy tone when reminding of medication.
	21	A happy tone should be the default tone.
	29	The humanoid should have a slow rate of speech.
	31	When anger is detected, the humanoid should use a happy tone.
	25	The humanoid should have a curious tone of voice.
	26	When sadness is detected, the humanoid should use a happy tone.
	27	A neutral tone should be the default tone.
Linguistic	7	Questions as verbal content such as "How are you?", "What do you mean?" and "Is it interesting?" should be incorporated into the model.
	3	Responses as verbal content such as "Wow, that's amazing!", "That's nice" and "Well done" should be incorporated into the model.
	15	Facts as verbal content such as medical content, television programmes, and weather report should be incorporated into the model.
	24	Jokes as verbal content should be incorporated into the model.
	12	News as verbal content should be incorporated into the model.
	22	Inspirational quotes as verbal content should be incorporated into the model.

In the theory of self-directed learning (Knowles, 1975), there are five steps for a self-directed learner to follow, which are to set goals, plan, learn, show what you know and reflect (Figure 2.1, pp. 26). One of the purposes of the humanoid companion is to aid the elders in their self-directed learning and the elements support this theory in the third and fourth steps which are 'learn' and 'show what you know' respectively. When the elders have set their own learning goals and plan their learning strategies and resources, the humanoid can be their main source of information as it is connected to the internet. Then, the elderly can learn and show what they have learned with assistance from the humanoid and finally reflect on what they have learned. After that, they can use that reflection to come up with new learning goals or set unrelated new ones. For example, questions like "Is there anything you are curious about today?" or "Did you find anything interesting today?" (element 7) can prompt the elders to learn and share what they have learned to help in their understanding and memory. Other than that, with the construct of the four domains, the Motivating domain also supports the theory of self-directed learning as the elements in this domain are catered to motivating the elderly to learn. Between the four domains, Motivating is the second most important domain and it shows that self-directed learning is crucial for the well-being of elders who live on their own. The elements in this domain consist of the ideal aspects when motivating the elders to learn, although the elements are not exclusive for that purpose. However, this does not mean that other elements do not support self-directed learning. As an example, element 15 that talks about facts as verbal content also supports this theory although it is in the Healthcare domain because the elders learn something when asking about these facts. Even asking about television programmes can be seen as learning because the elders would have to plan their schedule for the day, which promotes

discipline, and can learn something from the programmes that they watch and talk about it later.

Role of relationships among elements.

To understand the role of relationships among the elements of the communication model, the level partition (Table 5.5, pp. 109-110) and cluster classification (Figure 5.3, pp. 111) are important sections. The driving power and dependence power as shown in the driver-dependence matrix diagram in Figure 5.3 provides valuable insights into the importance and interrelationship among elements. For example, without the aid of the matrix diagram and just referring solely to the model after the ISM procedure, nobody would understand the significance of the model because there were too many arrows and the elements were not nicely aligned. However, with the level partitioning and cluster classification, element 4 (humanoid should detect emotion of elders through tone of voice and respond accordingly) was determined as the most important element because of its position at the highest level of 25 with a high driving power and low dependence power among all the elements in the verbal and non-verbal communication model. Therefore, this element should be addressed first before other elements in the model because successful implementation of this element will affect other elements below it.

In the independent cluster, these elements have strong driving power and weak dependence power and should be dealt with according to their respective levels. There are 15 elements in this cluster and these independent elements consist of elements in the Responsiveness domain, Motivating domain and one from the Healthcare domain. These elements are important factors in ensuring the success of the verbal and non-verbal communication model between learning companion

humanoids and the elderly. They are also important because it influences other elements in other clusters. Elements that are on the same level like elements 7 (questions as verbal content such as "how are you?", "what do you mean?" and "is it interesting?" should be incorporated into the model) and 17 (the humanoid should have an empathetic tone of voice) are equally important and should be addressed first before elements in the next level although they do not influence each other as there are no arrows connecting them in the ISM model. In other words, after the humanoid has the ability to detect the emotion of elders through their tone of voice (element 4) perfected, the humanoid must have questions as verbal content (element 7) and an empathetic tone of voice (element 17) before moving on to having the ability to use a curious tone when sadness is detected from the elderly (element 20). Although element 30 (the humanoid should use a serious tone when reminding of medication) is at a lower level than element 28 (elders should start communication with the humanoid first), it is still considered an independent element because it is a crucial element in the successful implementation of the model and has an impact on elements in other clusters.

The linkage cluster contains 3 elements which are elements 28 (elders should start communication with the humanoid first), 15 (facts as verbal content such as medical content, television programmes, and weather report should be incorporated into the model) and 16 (if anger is detected from the elder, the humanoid should change the topic). Elements in this cluster play an important role in linking the upper elements (independent elements) to the lower elements in the communication model as they have strong driving power as well as strong dependence power. These elements are said to be unstable as any action on these elements will have an effect on other elements and to each other (Tiwari, 2013). For example, element 28 is

influenced by elements 13 and 9. If anger is detected from the elderly, the humanoid should listen and respond accordingly (element 13), this affects element 28 in that the elder is starting the communication in anger or in other words, the elder is starting to show anger. This will in turn affect the body motion of the humanoid (element 1) and happy tone as the default tone of the humanoid (element 21). Element 9 (the humanoid should have a moderate pitch of voice) affects element 28 in the way that when the elderly starts communication with the humanoid, the humanoid should have a moderate pitch of voice and this influences the body motion of the humanoid (element 1) and the happy tone as the default tone (element 21) because this time, the starting of communication is not associated with feelings of anger or sadness. As mentioned before, linkage factors can influence each other. An example of this action in the context of this model is that when the elder starts communication with the humanoid (element 28) and asks about medical issues, this would affect elements 15 and 16 which are all situated in the Healthcare domain. This action would go on to influence other elements connected to them, which are in the dependent cluster.

Elements in the dependent cluster have weak driving power but strong dependence power. They are influenced by other elements that they are linked to, as shown by the arrows in the model. They should also be dealt with carefully because these elements are affected by other elements, as explained by an example in the linkage cluster. Coincidentally, most elements in this cluster fall under the Personal Preferences domain with two elements from the Healthcare domain. Autonomous elements are elements with weak driving power and weak dependence power. They do not have a strong influence on the implementation of the communication model and fortunately, no elements fall under that cluster. Therefore, in reference to the role

of elements in their respective clusters, all the 32 elements should be given attention as they individually and connectedly have influence on the implementation of the verbal and non-verbal communication model.

Summary of findings

This chapter begins with the discussion of findings in three phases which are: Phase 1- Needs analysis, Phase 2- Development of the verbal and non-verbal communication model between learning companion humanoids and elderly humans, and Phase 3- Evaluation of the model. In the needs analysis phase, it was reported that elders who lived alone were prone to loneliness and mental diseases like depression and dementia due to lack of companionship and challenges for the brain. Most of the elders agreed that a humanoid robot that can communicate well with these elders would be a great solution in preventing these problems. They also agreed that verbal and non-verbal aspects of communication are equally important for successful communication. Apart from being a constant companion, the humanoid would also motivate the senior citizens to learn using self-directed learning.

Findings from phase 2 comprise of the major findings of this study with the result of the model. The model was generated using ISM software with the aid of experts' views and it will be used as a guideline on the elements needed by a humanoid to be a successful companion to elders as it eliminates loneliness and deter mental illnesses. The third phase involved the assessment of the model utilizing experts' opinions. The assessment was carried out utilizing fuzzy Delphi technique. The results showed that the model received high level of consensual agreement on all the four aspects being used as instrument to assess the model. This concludes that the

verbal and non-verbal communication model between learning companion humanoids and elderly humans is suitable to serve as a guide in incorporating successful communication between humanoids and elders who live alone.

Brief summary of the study

The study's purpose was to develop a verbal and non-verbal communication model between learning companion humanoids and elders who lived by themselves. The model would act as a guideline to be used for humanoids when communicating with the elders. This is to aid in successful communication between the two parties to prevent loneliness and mental illnesses like depression and dementia for the elderly. The communication model (Figure 5.2) was developed because there was a need for a communication support as can be seen in the findings of phase one. In the second phase of the study, the development of the model was according to experts' opinions facilitated through interpretive structural modeling technique (ISM). The elements of the model were decided using nominal group technique before the ISM session. Based on the ISM technique, a MICMAC analysis matrix (Figure 5.3) was used to analyze the role and importance of the elements in supporting successful communication between humanoids and the senior citizens living alone. Then, the model was assessed for its suitability to be utilized as a guide for successful communication in the final phase. The assessment was carried out with the help of a panel of experts through fuzzy Delphi technique. The result of the assessment showed experts' consensual agreement on all the suitability criteria, which meant that the model is acceptable to be utilized as a guideline. Furthermore, the findings of the study do have implications on three fields, which are discussed in the next

section. This is followed by the theoretical implications of the study and the implications to the research methodology.

Practical implications of the study

As the number of elders in our country increases and they are still in good health, their quality of life matters too. Any preventable diseases that they get will affect themselves and the people around them. The result of this study contributes to prevention of mental diseases and to three fields at the same time, namely in the fields of education, robotics and health. This is exemplified through the development of the verbal and non-verbal communication model between learning companion humanoids and elderly humans. It was specifically designed as a communication support between humanoid robots and elders who live on their own in Malaysia.

In the field of education, the model incorporates elements that cater to learning like 'facts as verbal content such as medical content, television programmes, and weather report should be incorporated into the model' (element 15) and 'the humanoid should have a moderate pitch of voice' (element 9) that are ideal for the experience of learning for the elders. The purpose of learning at a later age is to 'train the brain' for mental health but it can also give other positive effects like personal satisfaction and a sense of achievement if they give themselves a learning goal and achieving it. This provides the elderly with a feeling of happiness and it could enhance their quality of life, even though they live alone. Other than that, researchers could also find out what the elderly in our country like to learn about or what kind of information is beneficial to them at that age through data from the humanoid, with the elders' permission. For example, if the senior citizens talk about or search a lot of

information about how to prevent Alzheimers, then an event on Alzheimers prevention can be set up and all the interested seniors could be invited and they can meet and talk with each other. The sharing of information and having a reason to go out of the house would hopefully be enjoyable for the elders.

The implication for the field of robotics is the challenge that it poses and also the help it provides. The communication model deals a lot with paralanguage and 'action and reaction' and the technicality of it all is quite difficult, as explained by experts in phase 2 of the study. The model guides researchers or scientists who actually utilize humanoids in communicating with elders so that they would know where to start and improve from there. Another big challenge is to make it sound as natural as possible. Technology is a big part of our lives now and the advancements are both fun and inspiring. To pair robots, the most advanced of technologies, with the elderly, who are the generation that are the least familiar with the machines, is truly a feat to achieve. On that note, in order to fix a problem, there are usually a few solutions to choose from. Why not prepare robots or humanoids as alternative solutions for the future? The capabilities of these machines for the future are endless.

For the field of medicine or health, the implications are huge. The elements of the model were carefully selected by experts to slow the deterioration of the elders' mental health and to keep their emotions stable. There is even a Healthcare domain in the model that consists of elements that promote the care of the elders' health. With the delayed onset of mental diseases, which in turn could affect the physical body, the elders in our country would not be seen as burdens to their caregivers and to the youth of the country. In other words, as the communication model aids in preventing loneliness and mental diseases among senior citizens who live on their own, there will be less sick elders for caregivers to care for and consequently, there

will be lesser reports of caregiver stress and also abuse from both sides. Therefore, this study does not only benefit the elderly, but the advantages also affect other parties in positive ways.

Other than that, as the humanoids are mechanical, there will be no need for daily care from the elders as opposed to having pets as companions. There might be monthly or yearly maintenance required, which is up to the manufacturers of the humanoids. With all the benefits of the verbal and non-verbal communication model mentioned above, elders who live on their own in Malaysia will be able to achieve successful ageing even without daily human contact and assistance.

Theoretical implications of the study

The model in this study was made with the intention of incorporating communication and learning in the relationship between two parties, specifically humanoids and the elderly. In guiding the development of the model, the theoretical framework of the study contains three theories: face to face interaction, paralanguage and self-directed learning. A model of perception systems for naturally interacting humanoid robots was utilised as an example model for the study. The combination of these three theories show that a social theory, a language theory and a learning theory can work together to facilitate successful communication. The communication model portrays a nice integration of suitable aspects from these three different theories, namely the seven categories of action in face to face interaction, the four aspects in paralanguage theory and the five learning steps of self-directed learning. The theories mentioned were originally meant to describe concepts relating to humans but this study indicates that the theories can be adapted for communication between robots

and humans. The model of perception systems for naturally interacting humanoid robots helped to frame the elements based on the theories in accordance with the context of the study which is communication between a humanoid robot and the elderly. The model of perception systems was chosen because it was derived from the theory of face to face interaction but in the context of Human Robot Interaction (HRI).

Based on the communication model, the elements showed that verbal and non-verbal components of communication can be utilised to aid in learning as well. In the Motivating domain of the model, a moderate rate of speech (element 11) and a moderate pitch of voice (element 9) were found to be some of the most suitable elements in facilitating the elders in their self-directed learning. The study enforces the impact of language and communication on learning and mental health. As stated before, the combination of these theories actually benefit three fields at the same time, which are the fields of education, robotics and health. A learning theory and a language theory, linked by a social theory, can be used to prevent loneliness and mental illnesses via conversation and learning with the help of a humanoid robot. This goes to show that the elderly in Malaysia can still achieve successful ageing and good quality of life even though they live alone and have minimal contact with other people and the outside world. Other than that, the study also indicates that past theories can still be relevant for future studies. They can be adopted and adapted for futuristic and innovative researches. Studies involving technology does not mean that only technology-related theories should be used and the use of a few theories shows creativity and an ability to adapt.

Methodology implications of the study

In the field of education, this study does contribute in terms of research methodology. Design and Development Research (DDR) was employed in developing the verbal and non-verbal communication model between learning companion humanoids and elderly humans. This method involves three phases which are needs analysis phase, design and development phase and finally, the assessment phase. In the needs analysis phase, problems relating to the context of the study were investigated in order to justify the need to develop a communication model. Questionnaires and interviews were utilized for this phase and the results were analyzed via mean scores and themes. In the next phase, elements were listed and validated through nominal group technique (NGT) and then, interpretive structural modeling (ISM) was employed to prioritize the elements in developing the model. The use of ISM in the field of education is still rare although it is a popular method in business or organization related fields. ISM is a powerful decision making tool and it could be used to solve plenty of specific learning and teaching problems. As studies using ISM as a method is scarce, even fewer studies use ISM with NGT, which is a technique utilized to generate the elements as reported in the study. The final phase of DDR utilized fuzzy Delphi method (FDM) to evaluate the elements of the developed model and the overall usability of the model in facilitating successful communication between humanoids and the elderly in order to prevent loneliness and mental illnesses. This method is starting to gain popularity in the field of education with many researchers showing interest in using FDM for their studies. These three methods are compatible with each other because all three techniques utilize experts' decisions. Since studies combining education and robotics are new and rare, the use of experts' opinions is employed in this study. The combination of NGT and ISM

allowed the cooperation of heterogeneous experts from medical, robotics, education and even caregiving backgrounds. These experts were brought together in phase 2 of the study and made use of the voting system of ISM to save time and energy on otherwise lengthy discussions.

Although the methods utilized in this study are not new, not many studies integrate these methods to come up with a solution to a problem, especially in the field of education. Therefore, the integration of ISM with NGT and FDM in the development of the verbal and non-verbal communication model could be seen as an example for other studies looking to use these methods. The methods used in developing the model could be replicated or adapted to suit other model developments.

Recommendations

According to the results of the study, a few recommendations could be made. Firstly, natural and successful communication should be incorporated into the interaction between robots or humanoids with the elderly. A lot of the studies found on robots and humanoids with the senior citizens focused on the physical things that they can do like playing games and bringing things to them. These machines have a lot of potential and can do so much more. Apart from helping the elders with their physical limitations, the humanoids can help ease their mental and emotional burdens. Advanced technology should be beneficial to all walks of life, not only to the youth or to the working community.

Another recommendation is that the quality of life of our elders should be given attention. The fact that they are just alive is not enough, they deserve to be

happy near the end of their lives as well. The number of elders who are on their own is increasing and to prevent them from becoming burdens to themselves and to others, preventive steps must be taken. The use of technology for this purpose is most welcome and should be incorporated. This brings us to the next recommendation which is the cooperation of different fields for the betterment of the future. This study can be an example of a good outcome if a few fields could work together, in this context, the cooperation of the fields of education, robotics and health. The benefits of different fields sharing ideas are plenty and the methods used in this study can also serve as a guide to realize and organize those ideas. Collaborations between differing fields could result in surprising solutions. The final recommendation is on further research that could be carried out according to the outcome of the study. This is explained in the next section.

Further research of the study

The final product of this study is the verbal and non-verbal communication model between learning companion humanoids and elderly humans. Based on this model, communication modules or learning modules can be developed for the elderly. The effectiveness of the model can be evaluated this way, as to whether the model really supports successful communication and learning of the elders. The model can also be refined or upgraded according to the assessment of the implemented modules. Other than that, experiments or case studies could be done based on the model. Researchers could use a humanoid to test out the model on senior citizens who live on their own and report the results. This requires a lot of

technical knowledge and expertise from the engineering and artificial intelligence department that could not be included in this study.

Further research could also be done based on this study in other settings like in old folks homes, senior centres or even on elders with physical or mental disabilities. For example, communication with elders suffering from dementia would be different from communication with elders who are bedridden, but learning or brain-based activities could hopefully improve both these situations. Therefore, these studies are important for the well-being of elders and also the caregivers to guide them if they are suddenly thrown into that situation.

Apart from that, comparison studies on communication models between humanoids and elders who live alone can be done according to countries. The similarities and differences of the models can be recorded and from there, the factors contributing to the similarities or differences can be identified. For example, the needs and wants of these elders could differ according to culture or social norms in their country. Even in this country itself, there are different races and cultures that can contribute as factors in further research of the study.

Closing Statement

A lot of researches pertaining to robots and the elderly have to do with the physical aspects or what the robots can do for and with the elders. Very little literature is found on communication aspects between these two parties, especially local studies. Even those few studies are mostly technical aspects related to communication. This study sought to find a solution for senior citizens who lived on their own in preventing loneliness and mental illnesses with the aid of robots or

specifically humanoids. The elders just need a companion to talk to as they are usually still in good health. By incorporating advanced technology in the daily lives of these elders, a guide or standard must be available for the humanoid manufacturers to follow so that the initiative of using humanoids as companions would be successful.

As shown by the needs analysis of the study, the elders agreed on the benefits of a humanoid companion for elders who lived alone. To add to the benefits of these companions, the humanoids can also help the elders in their self-directed learning which prevents the early onset of mental diseases like dementia and depression that can also lead to physical illnesses. Therefore, the development of the verbal and non-verbal communication model between learning companion humanoids and elderly humans was proposed. This model would act as a guideline for the manufacturers or programmers so that the communication is successful and the objective of the initiative is realized.

References

Aboderin, I. (2004). Modernisation and ageing theory revisited: Current explanations of recent developing world and historical Western shifts in material family support for older people. *Ageing and Society, 24*, 29-50. doi:10.1017/s0144686x03001521

Adler, M., & Ziglio, E. (1996). *Gazing into the oracle: The Delphi method and its application to social policy and public health*: Jessica Kingsley Publishers.

Albertini, M., & Mencarini, L. (2014). Childlessness and Support Networks in Later Life: New Pressures on Familistic Welfare States? *Journal of Family Issues, 35*(3), 331-357. doi:10.1177/0192513x12462537

Anastasi, A., & Urbina, S. (1997). Validity: basic concepts. *Psychological testing*, *7*, 113-139.

Anderson, E. W., & White, K. M. (2018). "This Is What Family Does": The Family Experience of Caring for Serious Illness. *American Journal of Hospice and Palliative Medicine®, 35*(2), 348-354. doi:10.1177/1049909117709251

Applin, H., Williams, B., Day, R., & Buro, K. (2011). A comparison of competencies between problem-based learning and non-problem-based graduate nurses. *Nurse Education Today, 31*(2), 129-134. doi:10.1016/j.nedt.2010.05.003

Asada, M., MacDorman, K. F., Ishiguro, H., & Kuniyoshi, Y. (2001). Cognitive developmental robotics as a new paradigm for the design of humanoid robots. *Robotics and Autonomous Systems, 37*(2), 185-193.

Attri, R., Dev, N., & Sharma, V. (2013). Interpretive structural modelling (ISM) approach: an overview. *Research Journal of Management Sciences, 2*(2), 3-8.

Baek, S. M., Tachibana, D., Arai, F., Fukuda, T., & Matsuno, T. (2006). The task selection mechanism for interactive robots: Application to the intelligent life supporting system. *International Journal of Intelligent Systems, 21*(9), 973-1004. doi:10.1002/int.20172

Banyen, W., Viriyavejakul, C., & Ratanaolarn, T. (2016). A Blended Learning Model for Learning Achievement Enhancement of Thai Undergraduate Students. *International Journal of Emerging Technologies in Learning, 11*(4), 48-55. doi:10.3991/ijet.v11i04.5325

Bennewitz, M., Faber, F., Joho, D., Behnke, S., & Ieee. (2007). *Fritz - A humanoid communication robot*. New York: Ieee.

Benson, P., & Huang, J. (2008). Autonomy in the transition from foreign language learning to foreign language teaching. [Autonomia na transição da aprendizagem de língua estrangeira para o ensino de língua estrangeira]. *DELTA: Documentação de Estudos em Lingüística Teórica e Aplicada, 24*(spe), 421-439. doi:10.1590/s0102-44502008000300003

Berns, K., & Schmitz, N. (2009). Perception System for Naturally Interacting Humanoid Robots. *KI, 23*(1), 56-59.

Berry, R. S. (1999). "Collecting data by in-depth interviewing." Paper presented at the British Educational Research Association Annual Conference, University of Sussex at Brighton, September 2 - 5 1999. From http://www.leeds.ac.uk/educol/documents/000001172.htm

Bodjanova, S. (2006). Median alpha-levels of a fuzzy number. *Fuzzy Sets and Systems, 157*(7), 879-891.

Bolin, K., Lindgren, B., & Lundborg, P. (2008). Informal and formal care among single-living elderly in Europe. *Health Economics, 17*(3), 393-409. doi:10.1002/hec.1275

Breazeal, C. (2004). Function meets style: Insights from emotion theory applied to HRI. *Ieee Transactions on Systems Man and Cybernetics Part C-Applications and Reviews, 34*(2), 187-194. doi:10.1109/tsmcc.2004.826270

Bremner, P. A., Celiktutan, O., & Gunes, H. (2017). Personality Perception of robot avatar Teleoperators in solo and Dyadic Tasks. *Frontiers in Robotics and Ai, 4*. doi:10.3389/frobt.2017.00016

Britton, N. J., Halfpenny, P., Devine, F., & Mellor, R. (2004). The future of regional cities in the information age: The impact of information technology on Manchester's financial and business services sector. *Sociology-the Journal of the British Sociological Association, 38*(4), 795-814. doi:10.1177/0038038504045865

Brooks, A. G., & Arkin, R. C. (2007). Behavioral overlays for non-verbal communication expression on a humanoid robot. *Autonomous Robots, 22*(1), 55-74. doi:10.1007/s10514-006-9005-8

Brown, A., & Draper, P. (2003). Accommodative speech and terms of endearment: elements of a language mode often experienced by older adults. *Journal of Advanced Nursing, 41*(1), 15-21. doi:10.1046/j.1365-2648.2003.02500.x

Brunner, M., Fiolka, T., Schulz, D., & Schlick, C. M. (2015). Design and comparative evaluation of an iterative contact point estimation method for static stability estimation of mobile actively reconfigurable robots. *Robotics and Autonomous Systems, 63*, 89-107.

Cai, D., Giles, H., & Noels, K. (1998). Elderly perceptions of communication with older and younger adults in China: Implications for mental health.

Campbell, N. (2007). On the Use of NonVerbal Speech Sounds in Human Communication. In A. Esposito, M. Faundez-Zanuy, E. Keller, & M. Marinaro (Eds.), *Verbal and Nonverbal Communication Behaviours: COST Action 2102 International Workshop, Vietri sul Mare, Italy, March 29-31, 2007, Revised Selected and Invited Papers* (pp. 117-128). Berlin, Heidelberg: Springer Berlin Heidelberg.

Cavallaro, F. I., Morin, F. O., Garzo, A., Remazeilles, A., Renteria, A., & Gaminde, G. (2012). Growing Older together: when a robot becomes the best ally for ageing well.

Cederbom, S., Thunborg, C., Denison, E., Söderlund, A., & Wågert, P. v. H. (2017). Home Help Service Staffs' Descriptions of Their Role in Promoting Everyday Activities Among Older People in Sweden Who Are Dependent on Formal Care. *Journal of Applied Gerontology, 36*(8), 971-992. doi:10.1177/0733464815595511

Chan, D. K. S., & Cheng, G. H. L. (2004). A comparison of offline and online friendship qualities at different stages of relationship development. *Journal of Social and Personal Relationships, 21*(3), 305-320. doi:10.1177/0265407504042834

Chen, J. C. (2014). Teaching nontraditional adult students: adult learning theories in practice. *Teaching in Higher Education, 19*(4), 406-418. doi:10.1080/13562517.2013.860101

Chen, Y., Hicks, A., & While, A. E. (2014). Loneliness and social support of older people in China: a systematic literature review. *Health & Social Care in the Community, 22*(2), 113-123. doi:10.1111/hsc.12051

Cheng, C. H., & Lin, Y. (2002). Evaluating the best main battle tank using fuzzy decision theory with linguistic criteria evaluation. *European journal of operational research, 142*(1), 174-186. doi:10.1016/s0377-2217(01)00280-6

Choy, S. C., & Delahaye, B. L. (2002). Andragogy in vocational education and training: Learners' perspective.

Cohn, J. F. (2010). Advances in Behavioral Science Using Automated Facial Image Analysis and Synthesis. *Ieee Signal Processing Magazine, 27*(6), 128-133. doi:10.1109/msp.2010.938102

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches*: Sage publications.

Danis, C., & Tremblay, N. (1988). Autodidactic learning experiences: Questioning established adult learning principles. *Self-directed learning: Application and theory*, 171-197.

Danis, C., & Tremblay, N. A. (1987). Propositions regarding Autodidactic Learning and Their Implications for Teaching. *Lifelong Learning, 10*(7), 4-7.

Delbecq, A. L., & Van de Ven, A. H. (1971). A group process model for problem identification and program planning. *The Journal of Applied Behavioral Science, 7*(4), 466-492.

Department of Statistics Malaysia Official Portal; statistics.gov.my. (2010)

Diestel, S., Cosmar, M., & Schmidt, K.-H. (2013). Burnout and impaired cognitive functioning: The role of executive control in the performance of cognitive tasks. *Work and Stress, 27*(2), 164-180. doi:10.1080/02678373.2013.790243

Duncan, S., & Fiske, D. W. (2015). *Face-to-face interaction: Research, methods, and theory* (Vol. 3): Routledge.

Eggenberger, E., Heimerl, K., & Bennett, M. I. (2013). Communication skills training in dementia care: a systematic review of effectiveness, training content, and didactic methods in different care settings. *International Psychogeriatrics, 25*(3), 345-358. doi:10.1017/s1041610212001664

Ellis, T. J., & Levy, Y. (2010). *A guide for novice researchers: Design and development research methods.* Paper presented at the Proceedings of Informing Science & IT Education Conference, InSITE.

Emilsson, U. M. (2008). IDENTITY AND RELATIONSHIPS: ON UNDERSTANDING SOCIAL WORK WITH OLDER PEOPLE SUFFERING FROM DEMENTIA. *Journal of Social Work Practice, 22*(3), 317-328. doi:10.1080/02650530802396650

Farley, S. D., Hughes, S. M., & LaFayette, J. N. (2013). People Will Know We Are in Love: Evidence of Differences Between Vocal Samples Directed Toward Lovers and Friends. *Journal of Nonverbal Behavior, 37*(3), 123-138. doi:10.1007/s10919-013-0151-3

Fischinger, D., Einramhof, P., Papoutsakis, K., Wohlkinger, W., Mayer, P., Panek, P., . . . Vincze, M. (2016). Hobbit, a care robot supporting independent living at home: First prototype and lessons learned. *Robotics and Autonomous Systems, 75*, 60-78. doi:10.1016/j.robot.2014.09.029

Foxcroft, C., Paterson, H., Le Roux, N., & Herbst, D. (2004). Psychological assessment in South Africa: a needs analysis: the test use patterns and needs of psychological assessment practitioners: final report. July.

Fredholm, A., Savin-Baden, M., Henningsohn, L., & Silen, C. (2015). Autonomy as both challenge and development in clinical education. *Learning Culture and Social Interaction, 5*, 20-27. doi:10.1016/j.lcsi.2014.08.003

Freitag, M. (2003). Beyond Tocqueville: The origins of social capital in Switzerland. *European Sociological Review, 19*(2), 217-232. doi:10.1093/esr/19.2.217

Friedman, A. M. (2016). Perceptual Construction: Rereading The Social Construction of Reality Through the Sociology of the Senses. *Cultural Sociology, 10*(1), 77-92. doi:10.1177/1749975515615149

Gilbert, N. J., & Driscoll, M. P. (2002). Collaborative knowledge building: A case study. *Etr&D-Educational Technology Research and Development, 50*(1), 59-79. doi:10.1007/bf02504961

Goh, Z.-Y., Lai, M.-M., Lau, S.-H., & Ahmad, N. (2013). The Formal and Informal Long-Term Caregiving for the Elderly: The Malaysian Experience. *Asian Social Science, 9*(4), 174-184.

Golland, Y., Arzouan, Y., & Levit-Binnun, N. (2015). The Mere Co-Presence: Synchronization of Autonomic Signals and Emotional Responses across Co-Present Individuals Not Engaged in Direct Interaction. *Plos One, 10*(5). doi:10.1371/journal.pone.0125804

Guarte, J. M., & Barrios, E. B. (2006). Estimation Under Purposive Sampling. *Communications in Statistics - Simulation and Computation, 35*(2), 277-284. doi:10.1080/03610910600591610

Gupta, R., Audhkhasi, K., Lee, S., & Narayanan, S. (2016). Detecting paralinguistic events in audio stream using context in features and probabilistic decisions. *Computer Speech and Language, 36*, 72-92. doi:10.1016/j.csl.2015.08.003

Hampton, S. E., & Parker, J. N. (2011). Collaboration and Productivity in Scientific Synthesis. *Bioscience, 61*(11), 900-910. doi:10.1525/bio.2011.61.11.9

Harmo, P., Taipalus, T., Knuuttila, J., Vallet, J., & Halme, A. (2005). Needs and Solutions - Home Automation and Service Robots for the Elderly and Disabled.

Hasan, M., Meara, R. J., Bhowmick, B. K., & Woodhouse, K. W. (1997). Continuing medical education in Wales: A survey of geriatricians. *Age and Ageing, 26*(4), 309-313. doi:10.1093/ageing/26.4.309

Heylen, D., van Dijk, B., & Nijholt, A. (2012). Robotic Rabbit Companions: amusing or a nuisance? *Journal on Multimodal User Interfaces, 5*(1-2), 53-59. doi:10.1007/s12193-011-0083-3

Hong, J.-C., Hwang, M.-Y., Szeto, E., Tsai, C.-R., Kuo, Y.-C., & Hsu, W.-Y. (2016). Internet cognitive failure relevant to self-efficacy, learning interest, and satisfaction with social media learning. *Computers in Human Behavior, 55*, 214-222. doi:10.1016/j.chb.2015.09.010

Houle, C. (1961). The inquiring mind: A study of the adult learner who continues to participate to learn: Madison, WI: University of Wisconsin Press.

Hupp, J. M., & Jungers, M. K. (2013). Beyond words: Comprehension and production of pragmatic prosody in adults and children. *Journal of Experimental Child Psychology, 115*(3), 536-551. doi:10.1016/j.jecp.2012.12.012

Infantino, I., Pilato, G., Rizzo, R., & Vella, F. (2013). Humanoid Introspection: A Practical Approach. *International Journal of Advanced Robotic Systems, 10*. doi:10.5772/55919

Jairath N. & Weinstein J. (1994) The Delphi methodology: a useful administrative approach. *Canadian Journal of Nursing Administration 7,* 29–42.

Janes, F. (1988). Interpretive structural modelling: a methodology for structuring complex issues. *Transactions of the Institute of Measurement and Control, 10*(3), 145-154.

Johnson, D. O., Cuijpers, R. H., Juola, J. F., Torta, E., Simonov, M., Frisiello, A., . . . Beck, C. (2014). Socially Assistive Robots: A Comprehensive Approach to Extending Independent Living. *International Journal of Social Robotics, 6*(2), 195-211. doi:10.1007/s12369-013-0217-8

Johnson, D. O., Cuijpers, R. H., Pollmann, K., & van de Ven, A. A. J. (2016). Exploring the Entertainment Value of Playing Games with a Humanoid Robot. *International Journal of Social Robotics, 8*(2), 247-269. doi:10.1007/s12369-015-0331-x

Jung, H. S., & Yoon, H. H. (2011). The effects of nonverbal communication of employees in the family restaurant upon customers' emotional responses and customer satisfaction. *International Journal of Hospitality Management, 30*(3), 542-550. doi:10.1016/j.ijhm.2010.09.005

Kapelouzos, I. (2016). The impact of structural modeling on the creation of new perspectives in problem solving situations.

Kawato, M. (2008). Brain controlled robots. *Hfsp Journal, 2*(3), 136-142. doi:10.2976/1.2931144

Kelley, E., & Kelloway, E. K. (2012). Context Matters: Testing a Model of Remote Leadership. *Journal of Leadership & Organizational Studies, 19*(4), 437-449. doi:10.1177/1548051812454173

Kicken, W., Brand-Gruwel, S., van Merrienboer, J., & Slot, W. (2009). Design and evaluation of a development portfolio: how to improve students' self-directed learning skills. *Instructional Science, 37*(5), 453-473. doi:10.1007/s11251-008-9058-5

Kim, R., Olfman, L., Ryan, T., & Eryilmaz, E. (2014). Leveraging a personalized system to improve self-directed learning in online educational environments. *Computers & Education, 70*, 150-160. doi:10.1016/j.compedu.2013.08.006

Kim, Y., Kwak, S. S., & Kim, M.-s. (2013). Am I acceptable to you? Effect of a robot's verbal language forms on people's social distance from robots. *Computers in Human Behavior, 29*(3), 1091-1101. doi:10.1016/j.chb.2012.10.001

Kleckova, J. (2009). *Important Nonverbal Attributes for Spontaneous Speech Recognition*.

Knop, K., Oncu, J. S., Penzel, J., Abele, T. S., Brunner, T., Vorderer, P., & Wessler, H. (2016). Offline time is quality time. Comparing within-group self-disclosure in mobile messaging applications and face-to-face interactions. *Computers in Human Behavior, 55*, 1076-1084. doi:10.1016/j.chb.2015.11.004

Knowles, M. (1975). *Self-directed learning: A guide for learners and teachers.* Chicago, IL: Follett Publishing.

Komatsu, T., Ustunomiya, A., Suzuki, K., Ueda, K., Hiraki, K., & Oka, N. (2005). Experiments toward a mutual adaptive speech interface that adopts the cognitive features humans use for communication and induces and exploits users' adaptations. *International Journal of Human-Computer Interaction, 18*(3), 243-268. doi:10.1207/s15327590ijhc1803_1

Kop, R. (2011). The Challenges to Connectivist Learning on Open Online Networks: Learning Experiences during a Massive Open Online Course. *International Review of Research in Open and Distance Learning, 12*(3), 19-38. doi:10.19173/irrodl.v12i3.882

Korte, J., Bohlmeijer, E. T., Westerhof, G. J., & Pot, A. M. (2011). Reminiscence and adaptation to critical life events in older adults with mild to moderate depressive symptoms. *Aging & Mental Health, 15*(5), 638-646. doi:10.1080/13607863.2010.551338

Kroth, M., & Boverie, P. (2000). Life mission and adult learning. *Adult Education Quarterly, 50*(2), 134-149. doi:10.1177/07417130022086955

Kumazaki, H., Warren, Z., Swanson, A., Yoshikawa, Y., Matsumoto, Y., Takahashi, H., . . . Kikuchi, M. (2018). Can Robotic Systems Promote Self-Disclosure in adolescents with Autism Spectrum Disorder A pilot Study. *Frontiers in Psychiatry, 9*. doi:10.3389/fpsyt.2018.00036

Lai, D. W. L. (2009). From Burden to Depressive Symptoms: The Case of Chinese-Canadian Family Caregivers for the Elderly. *Social Work in Health Care, 48*(4), 432-449. doi:10.1080/00981380802591759

Learning Steps by Self-Directed Learner. http://www.slideshare.net/maheswarijaikumar/self-directed-learning-38965472 (2014)

Lee, Donna M. (1999) *Structured Decision Making with Interpretive Structural Modeling (ISM): An analysis and decision-making method and tool for individuals and groups.* Ontario: Sorach Inc. Print.

Lee, M. (2008). Caregiver stress and elder abuse among Korean family caregivers of older adults with disabilities. *Journal of Family Violence, 23*(8), 707-712. doi:10.1007/s10896-008-9195-2

Lee, P. S. N., Leung, L., Lo, V., Xiong, C., & Wu, T. (2011). Internet Communication Versus Face-to-face Interaction in Quality of Life. *Social Indicators Research, 100*(3), 375-389. doi:10.1007/s11205-010-9618-3

Leean, C. (1981). Learning Projects and Self-Planned Learning Efforts among Undereducated Adults in Rural Vermont. NIE Adult Learning Project. Final Report.

Louie, W.-Y. G., McColl, D., & Nejat, G. (2014). Acceptance and Attitudes Toward a Human-like Socially Assistive Robot by Older Adults. *Assistive Technology, 26*(3), 140-150. doi:10.1080/10400435.2013.869703

Merriam S. B., et al. (2002) *Qualitative Research in Practice: Examples for Discussion and Analysis.* San Francisco, CA: Jossey-Bass. Print.

Merriam, S. B. (2001). Andragogy and Self-Directed Learning: Pillars of Adult Learning Theory. *New directions for adult and continuing education, 2001*(89), 3-14. doi:10.1002/ace.3

Mitsunaga, N., Smith, C., Kanda, T., Ishiguro, H., & Hagita, N. (2008). Adapting robot behavior for human-robot interaction. *Ieee Transactions on Robotics, 24*(4), 911-916. doi:10.1109/tro.2008.926867

Mitzner, T. L., Chen, T. L., Kemp, C. C., & Rogers, W. A. (2014). Identifying the Potential for Robotics to Assist Older Adults in Different Living Environments. *International Journal of Social Robotics, 6*(2), 213-227. doi:10.1007/s12369-013-0218-7

Montemerlo, M., Pineau, J., Roy, N., Thrun, S., & Verma, V. (2002). Experiences with a Mobile Robotic Guide for the Elderly. *American Association for Artificial Intelligence Proceedings*, 587-592.

Morton, J. B., & Trehub, S. E. (2001). Children's understanding of emotion in speech. *Child Development, 72*(3), 834-843. doi:10.1111/1467-8624.00318

Murata, C., Kondo, K., Hirai, H., Ichida, Y., & Ojima, T. (2008). Association between depression and socio-economic status among community-dwelling elderly in Japan: the Aichi Gerontological Evaluation Study (AGES). *Health & place, 14*(3), 406-414.

Nefdt, N., Koegel, R., Singer, G., & Gerber, M. (2010). The Use of a Self-Directed Learning Program to Provide Introductory Training in Pivotal Response Treatment to Parents of Children With Autism. *Journal of Positive Behavior Interventions, 12*(1), 23-32. doi:10.1177/1098300709334796

Ngan, R., & Kwan, A. (2002). The mental health status and long term care needs of the chinese elderly in Hong Kong. *Social Work in Health Care, 35*(1-2), 461-476. doi:10.1300/J010v35n01_07

Noor, N. M., Harun, J., Aris, B., & Ieee. (2014). Application of the Pedagogical and Andragogical Model in Web-Based Learning Instruction among Non-Major Computer Science Students Learning Programming *2014 International Conference on Teaching and Learning in Computing and Engineering* (pp. 106-111).

Okoli, C., & Pawlowski, S. D. (2004). The Delphi method as a research tool: an example, design considerations and applications. *Information & Management, 42*(1), 15-29.

Pan, Y. D., Okada, H., Uchiyama, T., & Suzuki, K. (2015). On the Reaction to Robot's Speech in a Hotel Public Space. *International Journal of Social Robotics, 7*(5), 911-920. doi:10.1007/s12369-015-0320-0

Peeters, J., De Backer, F., Buffel, T., Kindekens, A., Struyven, K., Zhu, C., & Lombaerts, K. (2014). Adult Learners' Informal Learning Experiences in Formal Education Setting. *Journal of Adult Development, 21*(3), 181-192. doi:10.1007/s10804-014-9190-1

Pollack, M. E., Brown, L., Colbry, D., Orosz, C., Peintner, B., Ramakrishnan, S., . . . Roy, N. (2002). Pearl: A Mobile Robotic Assistant for the Elderly. *AAAI Technical Report*.

Potter, M., Gordon, S., & Hamer, P. (2004). The nominal group technique: a useful consensus methodology in physiotherapy research. *New Zealand Journal of Physiotherapy, 32*, 126-130.

Prado, H. M., Falbo, G. H., Falbo, A. R., & Figueiroa, J. N. (2011). Active learning on the ward: outcomes from a comparative trial with traditional methods. *Medical Education, 45*(3), 273-279. doi:10.1111/j.1365-2923.2010.03846.x

Rager, K. B. (2003). The self-directed learning of women with breast cancer. *Adult Education Quarterly, 53*(4), 277-293. doi:10.1177/0741713603254030

Rashid, M. (2009). Hospital Design and Face-to-Face Interaction Among Clinicians: A Theoretical Model. *Herd-Health Environments Research & Design Journal, 2*(4), 62-84. doi:10.1177/193758670900200404

Richey, R. C., & Klein, J. D. (2005). Developmental research methods: Creating knowledge from instructional design and development practice. *Journal of Computing in higher Education, 16*(2), 23-38.

Richey, R. C., Klein, J. D., & Nelson, W. A. (2004). Developmental research: Studies of instructional design and development. *Handbook of research for educational communications and technology, 2*, 1099-1130.

Roberson, D. N., & Merriam, S. B. (2005). The self-directed learning process of older, rural adults. *Adult Education Quarterly, 55*(4), 269-287. doi:10.1177/0741713605277372

Robertson, J. (2014). HUMAN RIGHTS VS. ROBOT RIGHTS: Forecasts from Japan. *Critical Asian Studies, 46*(4), 571-598. doi:10.1080/14672715.2014.960707

Robins, B., Dautenhahn, K., & Dickerson, P. (2009). *From isolation to communication: a case study evaluation of robot assisted play for children with autism with a minimally expressive humanoid robot.* Paper presented at the Advances in Computer-Human Interactions, 2009. ACHI'09.

Robinson, H., MacDonald, B., & Broadbent, E. (2014). The Role of Healthcare Robots for Older People at Home: A Review. *International Journal of Social Robotics, 6*(4), 575-591. doi:10.1007/s12369-014-0242-2

Rothman, A. D., & Nowicki, S. (2004). A measure of the ability to identify emotion in children's tone of voice. *Journal of Nonverbal Behavior, 28*(2), 67-92. doi:10.1023/b:jonb.0000023653.13943.31

Ryan, E. B., Hamilton, J. M., & See, S. K. (1994). PATRONIZING THE OLD - HOW DO YOUNGER AND OLDER ADULTS RESPOND TO BABY TALK IN THE NURSING-HOME. *International Journal of Aging & Human Development, 39*(1), 21-32. doi:10.2190/m52c-m2d2-r6c2-3pbm

Sacco, D. F., & Ismail, M. M. (2014). Social belongingness satisfaction as a function of interaction medium: Face-to-face interactions facilitate greater social belonging and interaction enjoyment compared to instant messaging. *Computers in Human Behavior, 36*, 359-364. doi:10.1016/j.chb.2014.04.004

Salichs, M. A., Barber, R., Khamis, A. M., Malfaz, M., Gorostiza, J. F., Pacheco, R., . . . Garcia, D. (2006). Maggie: A Robotic Platform for Human-Robot Social Interaction. *IEEE*.

Schmitz, N., & Berns, K. (2011). *Perception systems for naturally interacting humanoid robots.* Paper presented at the RO-MAN, 2011 IEEE.

Schuller, B. W. (2012). The Computational Paralinguistics Challenge. *Ieee Signal Processing Magazine, 29*(4), 97-101. doi:10.1109/msp.2012.2192211

Schurer, O., Stangl, B., Hubatschke, C., & Muller, C. (2018). Experiments with a First Prototype of a Spatial Model of Cultural Meaning through Natural-Language Human-Robot Interaction. *Technologies, 6*(1). doi:10.3390/technologies6010006

Sekmen, A., & Challa, P. (2013). Assessment of adaptive human-robot interactions. *Knowledge-Based Systems, 42*, 49-59. doi:10.1016/j.knosys.2013.01.003

Sessions, L. F. (2010). HOW OFFLINE GATHERINGS AFFECT ONLINE COMMUNITIES When virtual community members 'meetup'. *Information Communication & Society, 13*(3), 375-395. doi:10.1080/13691180903468954

Shibata, T., & Wada, K. (2010). Robot Therapy: A New Approach for Mental Healthcare of the Elderly. *Gerontology, 57*, 378-386.

Shih, Y.-C. (2014). Communication strategies in a multimodal virtual communication context. *System, 42*, 34-47. doi:10.1016/j.system.2013.10.016

Shirai, Y., & Koerner, S. S. (2018). Examining the Influence of Care-Recipient Resistance on Family Caregiver Emotional and Physical Well-Being: Average Frequency Versus Daily Fluctuation. *Journal of Applied Gerontology, 37*(2), 203-227. doi:10.1177/0733464816631594

Siraj, Saedah, et al. (2013) *Design and Developmental Research: Emergent Trends in Educational Research.* Kuala Lumpur: Pearson Malaysia Sdn Bhd. Print.

Smith, J. M. (2012). Toward a Better Understanding of Loneliness In Community-Dwelling Older Adults. *Journal of Psychology, 146*(3), 293-311. doi:10.1080/00223980.2011.602132

Sober, J. D., VanWormer, L. A., & Arruda, J. E. (2016). Age-related differences in recall for words using semantics and prosody. *Journal of General Psychology, 143*(1), 67-77. doi:10.1080/00221309.2015.1079138

Steve, M. (2016). Safeguarding vulnerable older people: a job for life? *The Journal of Adult Protection, 18*(4), 214-228. doi:doi:10.1108/JAP-02-2016-0001

Stewart, G. D., & Khadra, M. H. (2009). The continuing medical education activities and attitudes of Australian doctors working in different clinical specialties and practice locations. *Australian Health Review, 33*(1), 47-56.

Stockdale, S. L., & Brockett, R. G. (2011). Development of the PRO-SDLS: A Measure of Self-Direction in Learning Based on the Personal Responsibility Orientation Model. *Adult Education Quarterly, 61*(2), 161-180. doi:10.1177/0741713610380447

Sugiyama, O., Kanda, T., Imai, M., Ishiguro, H., Hagita, N., & Ieee. (2005). *Three-layered draw-attention model for humanoid robots with gestures and verbal cues*.

Suh, H. N., Wang, K. T., & Arterberry, B. J. (2015). Development and Initial Validation of the Self-Directed Learning Inventory With Korean College Students. *Journal of Psychoeducational Assessment, 33*(7), 687-697. doi:10.1177/0734282914557728

Sundberg, J., Patel, S., Bjorkner, E., & Scherer, K. R. (2011). Interdependencies among Voice Source Parameters in Emotional Speech. *Ieee Transactions on Affective Computing, 2*(3), 162-174. doi:10.1109/t-affc.2011.14

Tang, C.-W., & Wu, C.-T. (2010). Obtaining a picture of undergraduate education quality: A voice from inside the university. *Higher Education, 60*(3), 269-286.

Tillema, H. H. (2000). Belief change towards self-directed learning in student teachers: immersion in practice or reflection on action. *Teaching and Teacher Education, 16*(5-6), 575-591. doi:10.1016/s0742-051x(00)00016-0

Tiwari, R. (2013). Identification of factors affecting reverse chain performance in relation to customer satisfaction using ISM Modelling & MICMAC Analysis. *Uncertain Supply Chain Management, 1*(4), 237-252.

Torta, E., Werner, F., Johnson, D. O., Juola, J. F., Cuijpers, R. H., Bazzani, M., . . . Bregman, J. (2014). Evaluation of a Small Socially-Assistive Humanoid Robot in Intelligent Homes for the Care of the Elderly. *Journal of Intelligent & Robotic Systems, 76*(1), 57-71. doi:10.1007/s10846-013-0019-0

Traunmüller, H. (2005). Speech considered as modulated voice. *Ms, University of Stockholm*.

Ulrich, J., & Karvonen, M. (2011). Faculty instructional attitudes, interest, and intention: Predictors of Web 2.0 use in online courses. *Internet and Higher Education, 14*(4), 207-216. doi:10.1016/j.iheduc.2011.07.001

Van Assche, L., Luyten, P., Bruffaerts, R., Persoons, P., van de Ven, L., & Vandenbulcke, M. (2013). Attachment in old age: Theoretical assumptions, empirical findings and implications for clinical practice. *Clinical Psychology Review, 33*(1), 67-81. doi:10.1016/j.cpr.2012.10.003

Van de Ven, A. H., & Delbecq, A. L. (1972). The nominal group as a research instrument for exploratory health studies. *American Journal of Public Health, 62*(3), 337-342.

Van Zant, A. B., & Kray, L. J. (2014). "I can't lie to your face": Minimal face-to-face interaction promotes honesty. *Journal of Experimental Social Psychology, 55*, 234-238. doi:10.1016/j.jesp.2014.07.014

Veenendaal, N. J., Groen, M. A., & Verhoeven, L. (2014). The role of speech prosody and text reading prosody in children's reading comprehension. *British Journal of Educational Psychology, 84*(4), 521-536. doi:10.1111/bjep.12036

Vlahovic, T. A., Roberts, S., & Dunbar, R. (2012). Effects of Duration and Laughter on Subjective Happiness Within Different Modes of Communication. *Journal of Computer-Mediated Communication, 17*(4), 436-450. doi:10.1111/j.1083-6101.2012.01584.x

Wada, T., Ishine, M., Sakagami, T., Okumiya, K., Fujisawa, M., Murakami, S., . . . Matsubayashi, K. (2004). Depression in Japanese community-dwelling elderly—prevalence and association with ADL and QOL. *Archives of Gerontology and Geriatrics, 39*(1), 15-23. doi:http://dx.doi.org/10.1016/j.archger.2003.12.003

Waksler, F. C. (2005). Analogues of ourselves: Who counts as an other? *Human Studies, 28*(4), 417-429. doi:10.1007/s10746-005-9007-0

Wang, Y. H., Hu, X. H., Dai, W. H., Zhou, J., & Kuo, T. Z. (2014). Vocal Emotion of Humanoid Robots: A Study from Brain Mechanism. *Scientific World Journal*. doi:10.1155/2014/216341

Wang, Y., & Chen, N.-S. (2012). The collaborative language learning attributes of cyber face-to-face interaction: the perspectives of the learner. *Interactive Learning Environments, 20*(4), 311-330. doi:10.1080/10494821003769081

Warfield, J. N. (1976). *Societal systems: Planning, policy, and complexity*: World Scientific.

Washbourne, K. (2014). The self-directed learner: intentionality in translator training and education. *Perspectives-Studies in Translatology, 22*(3), 373-387. doi:10.1080/0907676x.2013.827225

Watanabe, J.-i., Atsumori, H., & Kiguchi, M. (2016). Informal Face-to-Face Interaction Improves Mood State Reflected in Prefrontal Cortex Activity. *Frontiers in Human Neuroscience, 10*. doi:10.3389/fnhum.2016.00194

Whitehouse, C. R., O'Neill, P., & Dornan, T. (2002). Building confidence for work as house officers: student experience in the final year of a new problem-based curriculum. *Medical Education, 36*(8), 718-727. doi:10.1046/j.1365-2923.2002.01287.x

Williams, A. F. (1999). An Antipodean evaluation of problem-based learning by clinical educators. *Nurse Education Today, 19*(8), 659-667. doi:10.1054/nedt.1999.0369

World Health Organization; http://www.who.int/healthinfo/survey/ageingdefnolder/en/ (2016)

Wu, C. H., & Fang, W. C. (2011). Combining the Fuzzy Analytic Hierarchy Process and the fuzzy Delphi method for developing critical competences of electronic commerce professional managers. *Quality & Quantity, 45*(4), 751-768. doi:10.1007/s11135-010-9425-6

Yorita, A., & Kubota, N. (2011). Cognitive Development in Partner Robots for Information Support to Elderly People. *Ieee Transactions on Autonomous Mental Development, 3*(1), 64-73. doi:10.1109/tamd.2011.2105868

Zsiga, K., Edelmayer, G., Rumeau, P., Peter, O., Toth, A., & Fazekas, G. (2013). Home care robot for socially supporting the elderly: focus group studies in three European countries to screen user attitudes and requirements. *International Journal of Rehabilitation Research, 36*(4), 375-378. doi:10.1097/MRR.0b013e3283643d26