A THEORETICAL AND PRACTICAL APPROACH TO A PERSUASIVE AGENT MODEL FOR CHANGE BEHAVIOUR IN ORAL CARE AND HYGIENE

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Terdapat peningkatan penggunaan agen pemujuk dalam intervensi perubahan tingkah laku kerana agen mempunyai ciri peramah, reaktif, autonomi, dan proaktif. Walau bagaimanapun, banyak intervensi menemui kegagalan, khususnya dalam domain penjagaan oral. Tindak balas psikologi telah dikenal pasti sebagai salah satu penyebab utama kegagalan intervensi perubahan tingkah laku. Kajian ini mencadangkan satu model agen pemujuk yang formal yang membolehkan pengurangan tindak balas psikologi untuk intervensi perubahan tingkah laku yang lebih baik dalam penjagaan dan kebersihan oral. Metodologi simulasi berasaskan agen telah diguna pakai dalam pembangunan model yang dicadangkan. Penilaian model dijalankan dalam dua fasa yang merangkumi penentusahan dan pengesahsahihan. Proses penentusahan melibatkan analisis simulasi surihan dan kestabilan. Sebaliknya, pengesahsahihan telah dijalankan dengan menggunakan pendekatan berpusatkan pengguna yang melibatkan pembangunan aplikasi berasaskan agen berdasarkan seni bina kepercayaan- keinginan-niat. Kajian ini menyumbang satu model agen yang terdiri daripada faktor kognitif dan tingkah laku yang saling berkaitan. Tambahan pula, simulasi surih memberi pemahaman tentang interaksi antara faktor-faktor yang telah dikenal pasti bagi mengetahui peranannya dalam intervensi perubahan tingkah laku. Hasil simulasi menunjukkan apabila masa meningkat, tindak balas psikologi akan menurun ke arah sifar. Secara yang serupa, hasil pengesahsahihan model menunjukkan peratusan responden yang mengalami tindak balas psikologi bagi perubahan tingkah laku dalam kebersihan dan penjagaan oral telah menurun daripada 100 peratus kepada 3 peratus. Sumbangan yang telah dibuat dalam tesis ini membolehkan pereka aplikasi agen dan intervensi perubahan tingkah laku untuk membuat penaakulan saintifik dan peramalan. Begitu juga, ia menyediakan satu garis panduan untuk pereka perisian membangunkan aplikasi berasaskan agen yang berkemungkinan tidak menghadapi tindak balas psikologi.

Kata kunci: Agen pemujuk, Simulasi berasaskan agen, Tindak balas psikologi, Intervensi perubahan tingkah laku, Kebersihan dan penjagaan oral.

Abstract

There is an increased use of the persuasive agent in behaviour change interventions due to the agent's features of sociable, reactive, autonomy, and proactive. However, many interventions have been unsuccessful, particularly in the domain of oral care. The psychological reactance has been identified as one of the major reasons for these unsuccessful behaviour change interventions. This study proposes a formal persuasive agent model that leads to psychological reactance reduction in order to achieve an improved behaviour change intervention in oral care and hygiene. Agent-based simulation methodology is adopted for the development of the proposed model. Evaluation of the model was conducted in two phases that include verification and validation. The verification process involves simulation trace and stability analysis. On the other hand, the validation was carried out using user-centred approach by developing an agent-based application based on belief-desire-intention architecture. This study contributes an agent model which is made up of interrelated cognitive and behavioural factors. Furthermore, the simulation traces provide some insights on the interactions among the identified factors in order to comprehend their roles in behaviour change intervention. The simulation result showed that as time increases, the psychological reactance decreases towards zero. Similarly, the model validation result showed that the percentage of respondents' who experienced psychological reactance towards behaviour change in oral care and hygiene was reduced from 100 percent to 3 percent. The contribution made in this thesis would enable agent application and behaviour change intervention designers to make scientific reasoning and predictions. Likewise, it provides a guideline for software designers on the development of agent-based applications that may not have psychological reactance.

Keywords: Persuasive agent, Agent-based simulation, Psychological reactance, Behaviour change intervention, Oral care and hygiene.

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CHAPTER ONE
INTRODUCTION

1.1 Overview

In recent time, notions about humanoids, androids, cyborgs robots and science fiction creatures permeate our society. This is evident in the current trend whereby people are fascinated with the idea of non-human agencies in movies (Heyck, 2011). This has formed the unconscious backdrop against which software agents are perceived. It is becoming a reality that human beings can be persuaded by computer or software agent to perform a target action or behaviour (Fogg, 2002). This target behaviour or action might not be singularly achievable previously by the human. The manifestation of such behaviour or action can be seen in many agents' applications like computer graphic and games (Wang, Lee, Wu, Cheng & Teytaud, 2010), mobile technology (Chen, Cheng & Palen, 2009), health interventions (Kafalı, Bromuri, Sindlar, Weide, Pelaez, Schaechtle & Stathis, 2013), learning environment (Gladun, Rogushina, Martínez-Béjar, & Fernández-Breis, 2009), advertisement campaigns (Kazienko & Adamski, 2007) and others; where agents are providing assistance to humans in accomplishing a defined objective.

An agent is an entity or computer system that can be located in a particular environment and capable of autonomous action, takes initiative, responds to its immediate needs and relates to its environment in order to meet its design objectives (Wooldridge, 2009). It is a system that facilitates and supports solutions to critical and complex tasks under a dynamic environment. It also has the ability to react to the unstable environment and automatically execute specific tasks according to its pre-defined objective(s). Agents can be classified into five, namely; collaborative agents, interface agents, mobile agents, information agents and persuasive agents (Pipattanasomporn, Feroze & Rahman, 2009).

Collaborative agents use sophisticated notions of responsiveness, autonomy and proactiveness to accomplish negotiation. They usually emerge in coarse-grained multi-agent systems, and most of the time, they are static. They may or may not possess a mentalistic attribute that governs their predefined objectives. Interface agents, on the other hand, are used in learning, education and informatics activities. These agents make use of responsiveness and autonomy attributes to achieve their predefined goal. For instance, interface agents can interact with other agents for the purpose of learning by imitation, or direct feedback to accomplish their predefined objectives. However, interface agents abilities in negotiation are limited compared to collaborative agents (Nwana & Ndumu, 1997).

Another classification of agents is the mobile agent. This agent has the capability to move around networks by interacting with the remote host-base (home), collecting information on behalf of their users and consequently returning to their host. It demonstrates sophisticated proactiveness, social ability and autonomy. The fourth in the classification is the information agents. These agents are designed to coordinate important processes in retrieval, management, selection and manipulation of information within their environment. They may be mobile or collaborative, and possibly they can demonstrate many of the properties of interface agents (especially the learning ones). Several past studies tend to focus more on collaborative, interface, mobile and information agents whereas in recent time more attention has been given to persuasive agents too (Lim, Miao & Shen, 2013; Ogawa, Bartneck, Sakamoto, Kanda, Ono & Ishiguro, 2009). The reason behind this might be due to the complex nature of behavioural theories which has an immersed root in psychology domain (Schmidt, 2000). Persuasive agent design is militated by human behaviour, and human behaviour is a

complex phenomenon which cannot be easily predicted (Jawdat, Obeidat & Aljanaby, 2011; Luck, McBurney & Preist, 2003; Wood, 1988).

Persuasive agents are designed to support and maintain audiences' behaviour change. The agent's main aim is to enhance change in behaviour by the act of persuasion. Such agent makes use of voluntary actions such as embodied posture, body movement and gesture in order to modify and influence audience behaviour change processes. Nowadays, there is a growing interest in the application of persuasive agents in many interventions especially the healthcare intervention (Midden, Ham & Baten, 2015; Ham, Cuijpers & Cabibihan, 2015; Ham & Spahn, 2015; Khan & Sutcliffe, 2014). Many healthcare intervention programs make use of a persuasive agent to motivate target audience to follow their interventions. For example, a persuasive agent was designed to motivate a diabetic patient's change in food and insulin intake when blood sugar crosses the pre-defined level (Zhang, 2008). In addition, there is the AGALZ, an autonomous agent for monitoring Alzheimer patients to support the residence for healthy living (Corchado, Bajo, De Paz, & Tapia, 2008). These aforementioned two examples depict the usefulness of persuasive agents in behaviour change interventions.

Although the use of persuasive agents in behaviour change interventions have become increasingly popular in recent years, yet many interventions have been unsuccessful and psychological reactance has been identified as one of the major reasons for these unsuccessful behaviour change interventions (Graton, Ric & Gonzalez, 2016; Miller, 2015; Richards & Banas, 2015; Murtagh, Gatersleben & Uzzell, 2014). Psychological reactance is the state that an audience reflects or reacts to persuasive messages as directed by an agent. It is an experience that takes place whenever an audience's free behaviour is limited and produces sentimental responses like anger, annoyance, irritation and frustration (Burgoon, Alvaro, Grandpre and Voulodakis, 2002). This occurs when

audience tries to modify their behaviour in accordance with the agent instructions which is contrary to the initial intention and desire of the audience. It makes the audience form a resilient to the agent instructions.

Despite the fact that the hampering effect of psychological reactance on behaviour change interventions has been widely studied such as in Sinclair, Felmlee, Sprecher and Wright (2015), Greenberg (2015), Borland et al (2009), Ford, Ford and D'Amelio (2008), Matthews (1982), Clee, and Wicklund (1980) and Miller (1976), the interaction between behavioural factors to generate psychological reactance during behaviour change processes has not been clearly understood. Likewise, none of these existing studies explored formal analysis to explicitly understand how psychological reactance hampers agent's behaviour change processes. Hence, a formal model is desirable for this study because it can depict an agent's mental stance in behaviour change processes. This formal model will explicitly portray agent factor mechanisms and how these factors can interact in order to achieve successful agent behaviour change. Thus, this study seeks to develop a formal model of a persuasive agent which clearly explains how persuasive agents will deflect psychological reactance during the behaviour change process.

1.2 Problem Statement

Recently, research and design efforts within the agent community have increasingly embraced the concept of persuasive agents (Hanus & Fox, 2015; Ham, Cuijpers, & Cabibihan, 2015; Midden, Ham, & Baten, 2015; Khan, & Sutcliffe, 2014; Yoshii & Nakajima, 2014). One key reason is that the idea of a persuasive agent as an autonomous system, capable of interacting with human beings (and other agents) in order to achieve predefined objectives like behaviour change, is scientifically appealing to software designers (Sumi & Nagata, 2013). This is the reason why the persuasive agent is being incorporated in healthcare interventions so that audience's decision and behaviour can be

supported by the persuasive agent (Aziz, Klein & Treur, 2010; Rodríguez, & Favela, 2005). However, the persuasive agent designs (Hachisu & Kajimoto, 2012; Vladimirov, Park & Kim, 2011; Kirman, et al., 2010; Soler, Zacarías & Lucero, 2009; Al Mahmud, et al., 2007; Hasbro, 2007; Swartz, 2003; Valle & Opalach, 2005) are still found to be hampered by the effect of psychological reactance which is preventing audience to achieve intended and successful predefined behaviours (Rains, 2013; Beale & Creed, 2009; Roubroeks, Ham & Midden, 2009, 2010, 2011).

Psychological reactance is activated because persuasive agents did not possess adequate factors to reduce audiences' threat on the targeted behaviour (Mattiske, 2012; Kim, Hong & Magerko, 2010). During persuasive interaction, the audience feels that their autonomy is threatened by the intention of the agent to support their behaviour which causes them to experience psychological reactance (Roubroeks, Ham & Midden, 2010). Psychological reactance results in anger, irritation, and annoyance that threaten the autonomy of the audience which then cause deflection towards behaviour change. Despite the fact that many studies have proposed models and understanding on the effect of psychological reactance on behaviours like Borland et al (2009), Ford, Ford and D'Amelio (2008), Rains and Turner (2007), Dillard and Shen (2005), Matthews (1982), Clee and Wicklund (1980), Miller (1976) and Brehm (1966) however how behaviour factors interact to generate psychological reactance and how reactance can be reduced to obtained an improved behaviour outcome have not been well studied.

In addition, many of the persuasive agents (Valle & Opalach, 2005; Hasbro, 2007; Al Mahmud, et al., 2007; Chang, et al., 2008; Soler, Zacarías & Lucero, 2009; Hachisu & Kajimoto, 2012) are rarely based on formal models of behaviour. Existing models do not provide scientific reasoning which ensure the correctness of the theorized behaviour with the actual behaviour (Farrell & Lewandowsky, 2010). These models do not ensure

explicit understanding of the interacting factors mechanism which will enable proper application of the model knowledge on designs. Formal model helps in ensuring reproducibility in scientific thinking which allow persuasive agent designers to make predictions and reproduction of various scenarios based on agent's predefined objectives. Even though, there are very few examples of persuasive agent formal models such as Computerized Behaviour Intervention COMBI (Klein et al., 2011) that formally describes factors influencing behaviours. The model was based on six psychological theories (Social Cognitive Theory, Transtheoretical Model, Theory of Planned Behaviour, Self-Regulation Theory, Relapse Prevention Model and Health Belief Model). Thirteen factors were identified based on these theories and were divided into external and internal factors. These external factors include susceptibility, severity, pros/cons, social norms, barriers, skills and high-risk situation, whereas internal factors are cues, threat, attitude, self-efficacy, coping strategies and mood, nevertheless, the model does not capture some major factors of behaviour especially persuasive factors like motivation, ability, trigger and time (Klein et al., 2013; 2011; Fogg, 2009). Hence, the model does not fully acknowledge evident expression of persuasive influence. In addition, the model only presents a formal representation of factors, whereas detail and in-depth formal analysis were not carried out on the model. Hence, the precision and correction of the model are yet to be proven and established.

Moreover, to achieve successful behaviour change, persuasive agents should depend on psychological perspective in which persuasion takes places (Petty, 2013). This is because persuasive agents with low persuasive influence rarely achieve successful predefined behaviour while the ones with extremely high persuasive influence usually experience psychological reactance (Roubroeks, Ham & Midden, 2010). Thus, this study

will propose a formal model of a persuasive agent that explicates agent persuasive influence to reduce psychological reactance and lead to change behaviours.

1.3 Research Questions

Based on the above discussion, this study will answer the following research questions:

I. How should the persuasive factors for behaviour change be organized to produce the interactions that reduced psychological reactance?
II. How can a formal persuasive agent model for behaviour change be developed?
III. How can the developed model for behaviour change process be evaluated?

1.4 Research Objectives

Generally, this study aims at the development of a formal persuasive agent model and in order to answer the three study questions above, the general objective can be segmented into:

I. To study the organization of the persuasive factors that reduced psychological reactance for behaviour change process.
II. To develop a formal persuasive agent model for behaviour change process.
III. To evaluate the developed model for behaviour change process.

1.5 Scope of the Study

The study focuses on formal model of persuasive agent which was implemented in oral healthcare domain particularly in teeth brushing behaviour. It only covers the persuasion attribution of an agent within the aforementioned domain. Similarly, this study is centred on behaviour change as defined by Abraham and Michie (2008) and Hardeman, et al. (2002). Specifically, the study employs children within the age of 7 to 11 years as respondents. This group of children had been identified to have poor oral hygiene due to

their inabilities to achieve proper teeth brushing behaviour (Edelstein, 2002; Saddki, Yusoff, & Hwang, 2010; Gao, Hsu, Xu, Loh, Koh & Hwarng, 2010; Sharma & Yeluri, 2012). The study exclusively focuses on persuasive agent used for behaviour change in oral healthcare hygiene. The agent was designed to give motivational instruction, on how children can achieve proper teeth brushing behaviours.

1.6 Significance of the Study

The study proposes a formal model of persuasive agent that explicates agent persuasive influence to reduce psychological reactance in order to achieve successful behaviour change. Specifically, the significance of this study could be viewed from two perspectives; theoretical and practical.

1.6.1. Theoretical Perspectives

The theoretical contribution of this study can be seen from three distinct contributions. The first theoretical contribution is the determination of agent persuasion factors that reduced psychological reactance and enable successful change in behaviour. This will enlightening agents' designer to identify important factors that are needed for reduction of psychological reactance in order to achieve change in behaviour. The second theoretical contribution is the conceptual model that shows the interaction of these factors in achieving behaviour changes. This will aid agents and behavioural change interventions designers to comprehend the position of these factors in the process of successful behaviour change outcome. Finally, the third contribution is the formal model of the persuasive agent which will enable designers to make predictions and scientific reasoning for furturistic scenarios'.

1.6.2. Practical Perspectives

This study contributes a persuasive agent simulator which shows how persuasive agent factors influence audience behaviour change process. The persuasive agent simulator is based on the developed persuasive model. In addition, it further broadens the understanding of how persuasive agent employs the act of persuasion to support behaviour change processes which will serve as core components in scientific reasoning for both artefact and digital persuasion. The simulator provides basic comprehensions on factors that influence behaviour change in artefact and digital persuasion which will enhance the design of reduced psychological reactance applications.

1.7 Outline of the Study

The organization of this thesis is divided into seven chapters; given below:

Chapter 1: Introduction

This chapter establishes the concept and fundamentals of the study. It started with a brief background of the study and states the research questions and objectives of the study.

Chapter 2: Literature Review

This chapter presents a detailed discussion of important concepts in persuasive technology, developmental psychology, and agent system technology. A detailed discussion of persuasive models is covered which are based on underlying psychology principles and theories. Also other models in psychology and persuasive technology are compared with existing work done in the domain of agent system.

Chapter 3: Research Methodology

This chapter explores the rationale behind the usage of a computational model for a persuasive interactive agent. Details of the research methodology were discussed in line with activities to be followed during the study. Each phase is discussed with a method to be used.

Chapter 4: Agent Model Development

Chapter Four contains details of developmental phases involved in the proposed model. The chapter is divided into three sub-sections namely the agent-based model development, the support model development and application development. The application implementation based on the proposed model is discussed.

Chapter 5: Simulation Results and Verification

This chapter gives full details on the simulation environment for the agent. The simulation results were in two categories namely agent-based model and support based model results. The chapter presents two verification analysis namely mathematical and automated verifications that are carried out on the model.

Chapter 6: Evaluation

This chapter presents the result of the validation of the proposed model based on the developed application. The application validation made use of user-centred approach where Malaysian children within 7 to 11 years were used as study respondents. This is to validate the proposed model in real life scenario by making use of real data.

Chapter 7: Conclusion

This chapter gives the implication of the study by stating how specifically the study can be useful for the development of persuasive agents in behaviour change interventions

generally. The chapter also highlights limitations of the study with suggestions on further work that can be done to improve the study.

1.8 Summary

This chapter introduced the study, stating the core problem and objectives of the study. A detailed background of the work had also been laid, which is further discussed in the next chapter. Chapter Two covers literature reviews within the domain of proposed study. This provided a theoretical foundation for the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter begins with the exploration of an agent concept in Section 2.2. The section examines the concept of agent, notions of agency, applications, architectures and communication language. Section 2.3 reviewed studies on agent-based modelling which is the core implementation of the agent with focus on persuasive agent modelling and its design concept with elements of persuasive expression which enables the agent to achieve its predefined objectives. Also, existing models in behaviour and psychology domains were examined to fully comprehend the design of the persuasive agent in Section 2.4. Issues on how an agent can provide support in order to achieve or maintain behavioural change were reviewed in Section 2.5.Furthermore; the main aim of this study is to develop a persuasive agent, formal model. Hence, Section 2.6 and Section 2.7 both provide detailed explanations on computational modelling and techniques used in computational modelling. Section 2.8 concludes this chapter with a brief chapter summary.

2.2 Agent Concept

One of the earlier definitions of agent was given by Russel and Norvig (1994) which describes agent relative to its situated environment. It was stated that an agent is a predefined entity which resides in a specific environment in order to achieve some set of goals which is only known by the agent itself. Later, Jennings and Wooldridge (1996) defined an agent as a self-contained program capable of controlling its own predefined objective and acting based on its perception of its environment which is in pursuit of one or more goals or objectives. Jennings and Wooldridge (1996) argued that for an agent to

be situated within an environment then such an agent has a predefined objective to accomplish within that particular environment. This implies that the agent must possess an intention to achieve or pursue the predefined goal or objective which is normally known to the agent alone. Similarly, Hayes (1999) supported Jennings and Wooldridge (1996) definition that an agent can be an autonomously controlled entity that can perceive its own operations as well as that of the surrounding environment, compile the predefined rules to make operational decisions, and act based on these decisions.

The definition and concept of agent became richer when Wooldridge (2009) introduced four new agent concepts namely; autonomy, reactivity, proactiveness and social abilities. Firstly, autonomy concept defines when agent functionality is not directly controlled by humans or another agent. This means that an agent has full functionality operation over its own action and mental state. Social ability is the second concept and it explains the nature of agent cooperation and negotiation with other agents or human to realize its predefined objective or goal. The third concept is the reactivity concept and it is defined as the nature of agent interaction with its environment by perception and responding in a timely manner to changes which occur in it. The fourth and last concept is pro-activeness which defines the nature of agent possessing initiatives and planning abilities to enhance the achievement of its objective and goal (Kulesza, Stumpf, Burnett & Kwan, 2012). For this study, the operational definition of agent is based on the combination of Hayes (1999) and Wooldridge (2009) which is summarized that an agent is a system (software) that is situated in a specific environment and capable of autonomous action, pro-activeness, reactivity and has social abilities in such environments in order to meet its predesigned objectives. The next subsection will further discuss the concept of agent and its notion of agency within situated environment.

2.2.1 Notion of Agency

The term agency defined the capacity of an agent to achieve a predefined objective within its situated environment. This aids the assignment of agent in order to define nature of the agent and behaviour predictions. The importance of this is that an agent with well definition and predictable behaviour outcome can be used for successful interventions. Based on Wooldridge (2009) classification of agency, there are two classes' namely weak and strong notions. These two classes are used in describing agents' nature and actions. The weak notion agency is denoted when an agent either in form of hardware (robot and computer systems) or software-based agent (avatar and animation) possess the six properties namely autonomy (control over their actions and internal state), social ability (interact with other agents), reactivity (perceive their environment), proactivity (act in response to their environment), temporal continuity (continuously running processes) and goal orientedness (capable of handling complex and high-level tasks). On the other hand, the strong notion of agency has been used in term of mentalistic concepts. These mentalistic concepts include agents with knowledge, intention, belief, emotion and obligation. This notion define agents that possess the five properties namely mobility (movable agents), benevolence (conflicting goals), rationality (achieve its goals), adaptively (adjust itself) and collaboration (work with other agents). This present study is focus on strong notion of agency where agent is define in term of its intention, belief, desire and performed action. This kind of agent is found to possess autonomy, reside within a specific environment in order to carry out action and analytic counterfactual future intervention. The next subsection will examine appropriate usage of both notions of agency whereas more attention will be given to strong agency due to it wider usage in interventions.

2.2.2 Application of Agent

The agent technology is increasingly becoming as part of our daily life by gaining more persuasiveness, being more interactive in nature and autonomy (Looije, Neerincx & Cnossen, 2010). Agent technology concept has provided advancement in many domains like healthcare (Rodríguez, & Favela, 2005; Aziz, Klein & Treur, 2010), political campaigns (D'Errico, Poggi, & Vincze, 2012), environmental campaigns (Wissen & Gal, 2011), and e-commerce (Reitano, 2007). As humans daily interact with digital artefacts, it is becoming a reality that human being can form a team with computer agent to achieve defined objectives that cannot be singularly achieved by humans alone (Dowling, 2000; Elfayoumy, & Patel, 2012; Mes, van der Heijden, & Schuur, 2013).

In addition, agent is proven to provide a solution to critical, complex and dynamic real-world environments situations (Hardhienata, Merrick & Ugrinovskii, 2012). The usage of agent technology in simulation environments provides solutions to complex and problematic real-world domains, for example, the modelling of human, system or economic behaviour (Treur & Wissen, 2012). Such agent-based simulations can assist system designers with complex and complicated systems. Most importantly, it will provide support and guidance to enhance the operational control of these complex systems.

There are many applications of agent in vast literature. For instance, Rodríguez and Favela (2005) proposed the usage of ambient intelligence agent for healthcare. They designed an ambient intelligence (AmI) system which is able to access patients' clinical records through medical devices distributed throughout the hospital premises. The intelligent agent system is capable of collaboration with other medical agents (possibly human medical agent) in ensuring easier hospital management system. Equally, Aziz, Klein and Treur (2010) designed an ambient intelligent agent which can be used in

treating depression. The ambient intelligent agent is able to monitor and manage individuals' condition in case of prior depression and it can provide suitable suggestions to avert relapse of such individuals.

Looije, Neerincx, and Cnossen (2010) designed an agent to support and manage obesity and diabetics in the older adult. The agent employs persuasion by influencing good healthy lifestyle in older adults to prevent against obesity and diabetic cases. Further application of agent-based system was pointed out by the study of Klein, Mogles, Treur, and Wissen (2011) which showed how an agent can be used to support the promotion of human healthy lifestyle habits. Similarly, Hoogendoorn, Klein, Memon and Treur (2013) proposed an ambient intelligent agent in a smart home environment to support medication monitoring and reminding management system. The agent is capable of examining whether the patient intends to take his medicine too early or too late, and can take measures to prevent this. It has the ability to explicitly represent patients' estimation of medicine intake by simulation means. Table 2.1 shows more examples of agent systems concepts and applications.

Table 2.1
Summary of Agent Systems Concept and Application

S/N	Author	Description	Concept	Application
1	Hoogendoorn, Klein, Memon and Treur (2013)	Ambient intelligent agent in a smart home environment	Autonomous, Proactivity, Reactivity and Social abilities	Reminding system and managing patients' medication
2	Elfayoumy and Patel, (2012).	Intelligent agent to enhance and support fast and efficient database management	Autonomous, Proactivity and Reactivity	Performance monitoring and fast error detection in database management
3	Klein, Mogles, Treur, and Wissen (2011)	Computational agent to support healthy lifestyle.	Autonomous, Proactivity, Reactivity and Social abilities	Agent designed to promote and support human healthy lifestyle habits
4	Aziz, Klein and Treur (2010)	Ambient intelligent agent which can be used in depression therapy	Autonomous, Proactivity, Reactivity and Social abilities	Monitoring and managing depression cases and relapse

Table 2.1 (Con't)
Summary of Agent Systems Concept and Application

5	Ji, et al., (2010)	Intelligent agent to promote safety proactive drug surveillance.	Autonomous, Proactivity, Reactivity and Social abilities	A proactive monitoring and detecting of adverse drug reactions (ADRs) system
6	Looije, Neerincx, and Cnossen (2010)	Persuasive agent to support and manage obesity and diabetics	Autonomous, Proactivity, Reactivity and Social abilities	Monitoring and managing obesity and diabetics in old adults
7	Gao and Xu, (2009)	Intelligent agent model to assist in limiting money laundering activities	Autonomous, Proactivity and Reactivity	Monitoring system to survey money laundering activities
8	Rodríguez and Favela (2005)	Ambient intelligent agent for smart clinical environment	Autonomous, Proactivity and Reactivity	Smart hospital management system
9	Slotznick, (1999)	Intelligent agent learning modules which execute and store information	Autonomous, Proactivity and Reactivity	Intelligent agent to promote a smart learning environment.
10	Voss and Kreifelts (1997)	Information sourcing agent	Autonomous, Proactivity, Reactivity and Social abilities	Communication agent that aid information sharing on the web

2.2.3 Architecture of Agent

Previous subsection has introduced various applications of agents within the vast literature while this subsection will explore various agent architectures used in these applications. Agent architectures are based on theories and models which aid the practical construction of agents into to satisfy properties within literature. The major aim of agent architecture is to provide understanding on how incoming information on an agent with the current state of the agent is used to determine the actions and the next agent's state (Wooldridge, 2009). Based on Chin et al (2014) agent architecture depicts the blueprint for the arrangement of agent's components whereas when cognitive attributes are added the architecture will define an intelligent agent. According to Chin et al (2014) and Wooldridge (2009) agent architecture can be summarize into five namely logic-based, reactive, BDI, layered and cognitive agent architectures.

The logic-based agent architecture is likewise called the deliberative or the symbolic-based agent architecture which is the oldest known architecture. This agent architecture was introduced by Newell and Simon (1976) has the physical-symbol systems hypothesis which model agent and agent's behaviour within its situated environment with symbolic representation. The agent symbolic representations allow manipulations of the agent behaviour within that environment. This approach is regarded as a deduction process whereas agents are based on logical theory using specifications by reducing predefined agent's objective to a solution in a theorem proving manners. This concept is better illustrated in Amir and Maynard-Reid (2004) and Amir and Maynard-Reid (2000) studies where it implementation made used of Brooks' subsumption and First-Order Logic (FOL) respectfully. In summary, this architecture shows that agents' complex tasks can be implemented using simple theories.

On the other hand, the reactive agent architecture does not make use of central symbolic world model and complex symbolic reasoning. The agent architecture is designed to response to agent's environmental changes in stimulus-response manners. In summary, the agent is directly mapped to act based on its receiving situation or needs from the environment which can be through effector or sensor (these are used to perceptual input from the environment). This concept has been implemented by Steels (1990) and Brooks (1986). This architecture is found to be computationally tractable and less complicated in implementation and design than the logic-based architecture. However Togelius (2003) pointed out that this architecture has insufficient information about agent's current state, difficulty learning state and undefined prediction of agent futuristic behaviour. These limitations made it impossible to build task-specific agents which are one of the needs for intelligent agents.

In order to improve on these limitations mentioned about reactive agent architecture and to design more intelligent agents, the BDI agent architecture was introduced. The agent architecture is based on reasoning using intentional stance in order to aid sufficient information on agent's state, enhance learning and futuristic predictions of behaviours. The architecture is made up of three parts known as mental states/mental attitudes which are beliefs (information on agent environment), desires (motivation or possible options to act on) and intentions (agent's commitments on beliefs and desires). This architecture has clear and intuitive formal logic properties however; Wooldridge and Parsons (1998) pointed out that agent's functionality in achieving balance during its commitment and reconsiderations are not well defined. There is need to define the point that an agent stop to reconsider its intention with the environment in order to act promptly to achieve its set goals.

Furthermore, the layered architecture known as hybrid agent architecture was introduced which combined both logic-based and reactive agent architectures. However, the limitations from both architectures were alleviated where the gent systems are breakdown into layer of hierarchical parts. Although, this architecture has been implemented in many studies such as Muller and Pischel (1993) and Ferguson (1992) however, its robustness is a major disadvantage whereas if one of its layers should fail then the whole system will fail. In view of this, studies have focus on cognitive agent architecture in order to build intelligent agents that will model human actions. This is done by assigning formal specification to agent predefine objective, knowledge acquisition and mental action (Wooldridge, 2009). This architecture is still in its embryonic stage and it is important in the developing of agent with memory and learning components.

Out of the five mentioned agent architectures, the cognitive architecture is found to be the most suitable for an intelligent agent that provides reasoning abilities. This agent is underpinned with many theories from psychology and cognitive sciences domains such as Franklin, Kelemen and McCauley (1998) study which was based on Unified Theories of Cognition by Newell (1990). The agent will be able to process and manipulate information in a meaningful manner that will in turn affect change in behaviour of other agents or environment which closely mimics the human reasoning process. Thus, the present study will define agent as a form of cognitive architectural agent which is designed to mimic human reasoning process.

2.2.4 Agent Communication Language

The main purpose of an agent is to achieve predefined objective within a specified environment whereas most times in order for an agent to achieve these objectives there are need for interactions or communications with other agents (or possibly human). Thus, it can be seen that there are two types of agent communications namely agent-agent communication and agent-user communication. The first type of agent communication is mostly used in multi-agent communication. An Agent communicates with other agents in order to exchange messages and to be able to comprehend each other which are very important for the achievements of their predefined objectives. In order to make agents comprehend each other they must share same language and ontology. This is very important because it will define agent's knowledge base and description on the kind of things they can deal with and how they are able to achieve their objectives. Agents understanding and comprehension of each other's within their situated environment formed the bases of agent communication language (ACL). The two popularly known ACL are the agent standard language proposed by the Foundation for Intelligent Physical (FIPA) Agent (Poslad, Buckle & Hadingham, 2000) and the

Knowledge Query and Manipulation Language (KQML) (Finin, Fritzson, McKay & McEntire, 1994).

FIPA and KQML are both based on speech act theory as developed by Searle (1960). The KQML is one of the earliest ACL in the literature which specifies agent interactions and communications by protocol based. This concept has been implemented in studies such as Thirunavukkarasu, Finin and Mayfield (1995) and Finin and Weber (1992) however, this type of ACL does not reflects a true de facto standard because it does not have a consensus on its specification (either single or sets). This implies that there is no common agreement on agent specifications among members which result to many variations of KQML. This leads to agents that are not interoperated in specification. This development led to FIPA which gives generic agent specifications in order to achieve interoperability among agents and its applications. The interoperable of this FIPA-ACL has made it implementable in many studies such as Gibbins, Harris and Shadbolt (2004) and Poslad and Calisti (2000). However, the main focus of this study is on agent-user communication (agent-human). This type of communicate is usually implemented to provide support or intervention to human being (users) whereby the agent is used to interacts in order to enhance users' quests. This type of agent communication is widely implemented in studies such as Wargnier et al (2016), Howley et al (2013), Poggi et al (2005), and Ball and Breese (2000) hence; this present study focuses on agent-user communication.

2.3 Agent-based Modelling (ABM)

Previous section has been able to point to Russel and Norvig (1994) study has one of the earliest to opened the minds of the computer science community to the reality of agent concept, however, agent-based modelling can be traced back to the studies by Von Neumann, Ulam and Schelling on autonomous entities interaction within a shared

environment with an emergent behavioural outcome which was revealed as cellular automata (Macy & Willer, 2002). Figure 2.1 depicts cellular automata which reflect how cells either singular or group behave in a given states and the changes that occur based on differences in history and interaction with others (von Neumann 1966).

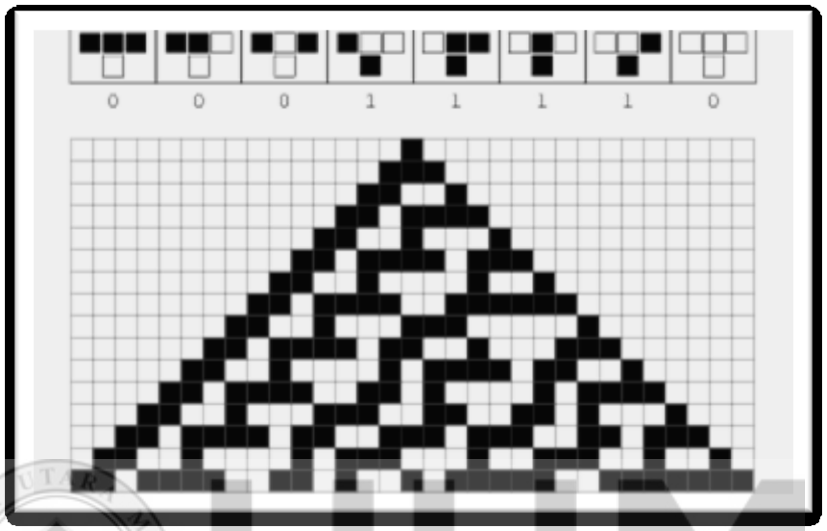

Figure 2.1. A diamond-shaped neighbourhood Cellular Automata

Source: Sahin, Uguz, Akın and Siap (2015)

This concept gained popularity with the innovation of Game of Life (Gardner 1970) which explained how simple interaction rules generate complex emergence global behavioural outcomes. However, agent-based modelling is different from cellular automata because ABM does not only examine the history and location of agents but more on their heterogeneity behaviour within the defined environment and changes that occur or affect that behaviour (Helbing, 2012). ABM depicts the interactions and actions of individual or group of autonomous agents within a situated environment on an emergence pattern or behavioural outcome (Page, 2005). Figure 2.2 illustrates ABM while reflects that each self-directed agents have the ability to make decisions that will

enable it to achieve its defined objective in the environment whereas the completive interaction behavioural pattern between the agents is of major importance in ABM.

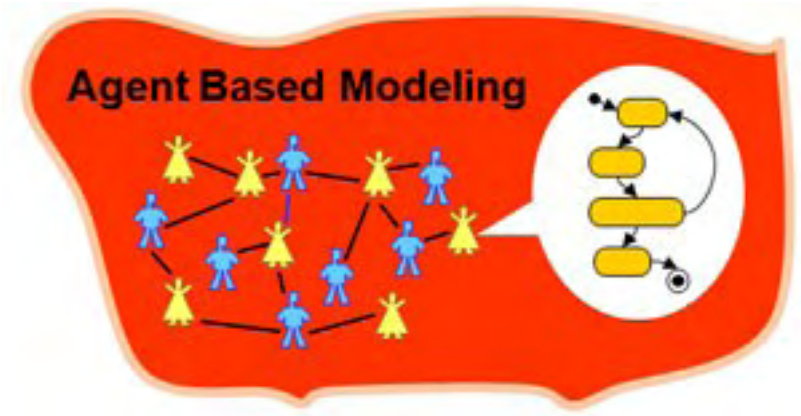

Figure 2.2. Agent Based Modelling

Source: Barnes and Chu (2015)

In term of practical application of ABM, it is used because of the decentralized and individual focus methodology. In this case, agent can be defined as a virtual, person, people, organization and entities whereas their actions and reactions can be investigated within a defined situation or event which is known as the environment (Getchell, 2008; Gilbert, 2008). The behaviour depicted can be revealed in a simulation which implies the global behaviour based on the interactions of the agents (Macal & North, 2005).

There is much application of ABM both in pure sciences and applied sciences, for instance, in pure sciences; it has been widely used in physics and biology. Its application in biology includes analysis of population dynamic (Caplat, Anand & Bauch, 2008), analysis of spread of epidemics, forced migration and displacement (Edwards, 2009), bio-warfare analysis, civilization growth analysis (Caplat, Anand & Bauch, 2008), ecology vegetation (Ch'ng, 2009), inflammation, dynamic of language (Hadzibeganovic,

Stauffer, & Schulze, 2009), breast cancer analysis (Tang et al 2011; Amnah et al 2009) and immune system of human (Tang & Hunt, 2010).

ABM is considered suitable for these studies because of its unique characteristics which include the ability to generate populations of entities and simulates their relationship and interactions in a virtual environment (An, Dutta-Moscato & Vodovotz, 2009). The agent-based model allows addition or modification of existing agents without change defies the entire model. Agents interaction based on localized set of rules behaviour can lead to a higher level of synergy between within the environment which is what most biological and nature science studies are interested (Politopoulos, 2007). Also, this type of modelling simulate random or probability behaviour which is an exhibited by most biological application and system (Madey & Nikolai, 2009). These were the rationale for using ABM to develop decision support systems such as for breast cancer in biological studies (Amnah et al, 2009).

Similarly, the method is widely used for solving issues in the applied sciences like economic, criminology, military and social sciences. For instance, agent-based models are used in economic and social sciences because these domains do not believe in the equilibrium of entities and variable which is also shared by ABM concept (Page, 2008). Agents are used to depicting the dynamic, diverse and interdependent variables and entities which follow a bottom-up perspective to give a futuristic understanding into any investigation (Testfatsion & Judd, 2006). Likewise, ABM depicts the interaction between unstable entities which reflect the nature of crashes and boom based on non-linear and probability outcome due to any small change in the interaction (The Economist, 2011). One recent study that applied this concept was by Stefan and Atman (2015) which show the correlation between the stock market index using agent-based modelling to analyse the three unique financial market profiles namely anti-imitating,

imitating and indifferent variable. Magliocca, Safirova, McConnell and Walls (2011) study made used of an economic agent-based model to investigate issues around coupled housing and land markets. These studies depict that ABM is gaining wider popularity especially in the deployment of architecture and urban planning in order to evaluate the design and to simulate pedestrian flow in the urban environment.

Furthermore, ABM has been applied to solve various business management and technological application issues like traffic congestion (Erol, Levy, & Wentworth, 2000; Kutluhan, Levy & Wentworth, 1998), consumer behaviour analysis (Guttman, Moukas & Maes, 1998), optimization of supply chain (Fox, Barbuceanu & Teigen, 2000), team working and building (Gaston & des Jardins, 2005) and organizational cognition and behaviour (Macal & North, 2005). Likewise, it is used in information and network to simulate peer-to-peer, ad-hoc, complex and self-organizing issues. Generally, ABM is widely used in complex, dynamic environment where issues of interactions and behavioural pattern are considered for understanding and predicting the fundamental phenomenon. These points made ABM to be suitable for dynamic investigations in insurance (Haer, Botzen, de Moel & Aerts, 2015), healthcare (Kruzikas et al 2014; Nealon & Moreno, 2003), leasing (Crooks & Castle, 2012; Mathevet, Bousquet, Le Page & Antona, 2003) and telecommunication (Lodhi, Dhamdhere & Dovrolis, 2012; Di Caro, 2004) where consumer make chang in behaviour is defined by characteristics of the consumers themselves with other relevant factors which can best be captured using agent-based modelling paradigm. This is also featured in epidemiology domain where agent-based model depict how people can be susceptible, infectious, recovered, or immune to a disease. ABM allows explicit capturing of social networks and contacts between target people which can aid in better prediction and control of the spread of diseases. Table 2.2 summarized some applications of ABM in healthcare domains.

Table 2.2
Selected ABM Applications in Healthcare Domain

Author	Year	Description	Model
Kalton et al	2016	Agent-Based Simulation that modelled the introduction of care coordination capabilities into a complex system of care for patients with Serious and Persistent Mental Illness.	Mental Health Care Model
Bielskis et al	2015	An intelligent e-health care environment by modelling of an adaptive multi-based e-health and e-social care system for people with movement disabilities.	Model of Intelligent Multi-Agent Based E-Health and E-Social Care System for People with Movement Disabilities
Silverman et al	2015	Agent-based modelling and simulation can help healthcare administrators discover interventions that increase population wellness and quality of care	Model of healthcare well-being
Collier, Ozik, and Macal	2015	Parallelizing a large-scale epidemiologic ABM developed with Repast HPC. Study centered on transmission dynamics and infection in Chicago USA	CA-MRSA model
Rigotti and Wallace	2015	Health-related wicked problem computational models which explain how individual elements of the system behave as a function of individual characteristics or interactions with each other and with the environment to for a severe health problem	Health wicked problem simulator
Kaushal et al	2015	An agent-based simulation tool is proposed in this research to evaluate fast track treatment (FTT) in an emergency department (ED)	Emergency FTT Model
Kumar et al	2015	Simulations to probe the causes of observed inequalities in influenza disease patterns	Poverty-related influenza rate Model
Schryver, Nutaro and Shankar	2015	Agent-based simulation model hierarchy emulating disease states and behaviours critical to progression of diabetes type 2	Computation Model for treatment of Diabetes type 2
Kruzikas et al	2014	Agent-based model to simulate development of region population, disease burden, health care infrastructure and estimate the impact of resource investment decisions on population health and health care costs	Model of Healthcare decision resources
Marshall	2014	Emotion evaluation on high-level abstractions of digital media design projects	Model of digital media emotion
Taboada, Cabrera, Epelde, Iglesias and Luque	2012	ABM to analyse the level of activity in the emergency department with different derivation policies.	Model of Health Emergency department policies

Despite the usefulness, benefits and wide applications of ABM, there have been some criticisms on its implementation in research. Kirman (1992) argued on the line of homogeneity representation of agents and identical representation of agent's utility functions. Likewise, Hoover (2006) pointed out that the greatest menace in ABM agent representation is taking a nonlocal property to be a local property which was termed local supervenience or locality fallacy. It was argued further that the reason this is a fallacy is that many social properties in fact ontologically depend on nonlocal factors; hence there may be the mistake of declaring nonlocal properties to be local properties. Furthermore, DeMarchi et al (2005) discredit ABM as a mere computer programming that generates simulation traces as output. These simulation traces are considered to be general and permit different interpretation.

However, there were many counter-arguments on these raised issues; for instance, Epstein (2012) maintained that the heterogeneous representation of agents in ABM is the most advantage it has over any other analytic models which are limited in representing characteristics. Thus, the heterogeneous nature of agent representation is what made the model to be dynamic and tractable. On local supervenience or locality fallacy, Epstein (2012) similarly pointed out that to avoid this pitfall then it is better to target the group social properties rather than individual properties because the group properties are easy to be identitied. In addition, Page (2005) responded to these claims that ABM simulation traces output allows research to gain virtual environment on the behaviour of agents. Thus, the agent-based models are not mere programming because it is pivoted by proves mathematical theories which are logically coherent. All these arguments and counter-arguments have strengthened ABM as a suitable method for investigating and analysing dynamic behavioural characteristics hence, the method was implemented in this study.

Thus, the study will focus on modelling of persuasive agent which will be further discussed in the three following subsections.

2.3.1 Persuasive Agent Modelling

The study of Nass, Fogg and Moon (1996) was the first to picture the concept of the persuasive agent in the community. According to Nass, Fogg, and Moon (1996), agents (software agent or robot) can employ persuasion to influence people's behaviour or attitudes, just as in human-to-human interaction. Agents that possess this ability could relate with another agent (possibly human too) as a team and collaborate to achieve delegated assignment, goal or objective. This argument was supported by many scholars like Fogg (1998, 2002 & 2009) and Biggs, Gunn and Smith (2012) that for an agent or any artefact to effectively carry-out motivation then the principles of persuasion should be incorporated in the agent or artefact design.

The sole aim of the persuasive agent is to facilitate audience in behaviour change without force or coercion. The presence of social cue or signal was suggested by Fogg (1998) to cause persuasion, which he defined as a trick of gaining support or achieving a target objective or goal. The trick was explained as an attempt to shape, reinforce, or change belief, faith, behaviours, feeling, or thoughts about an issue, object, or action (Fogg, 2002). In addition Miller (2002) has suggested that persuasion relies primarily on symbolic strategies that trigger the emotions. The author referred to persuasion as the power of verbal and non-verbal symbols which allows people to voluntarily participate in a persuasive or behaviour change process. The persuader only triggers the emotions of the persuadee using symbolic strategies which lead to the change in behaviour process of the persuadee. Later, Perloff (2003) defined persuasion as a symbolic process in which the persuader tries to induce others to change their belief or faith regarding an issue by exchanging messages in an atmosphere of free choice. This implies that it is a free choice

(freedom) of the persuadee to make the decision based on the exchange of symbolic messages from the persuader (Miller, Cousino, Leek & Kodish, 2014).

Therefore, the operational definition of persuasion for this study is given as the act of performing a willing action as a result of external influence where the power for the change behaviour is given to the audience only (Fogg, 1998; Miller, 2002). The action is carried out in an atmosphere of friendliness and self-will without force or coercion. This implies that an agent engages in persuasion for enhancement of behaviour of its audience while the decision to undertake the action is only given to the audience and not to be determined by the agent. Moreover, persuasive agent interacts with its audience (either fellow agents or human) by modifying its mental state rule to achieve its defined objective of behaviour change. Several studies have explored the use of persuasion as it follows the social rule on agents (software agent and robotic agent) examples of such agent and studies were SOAP by Voss and Kreifelts (1997), Microsoft Clippy by Xiao, Stasko and Catrambone (2004), Chick Clique by Toscos, Faber, An and Gandhi (2006), iParrot by Al Mahmud et al (2007), Persuasive Recommendation Agent (PRA) by Yu (2012) and Persuasive Teachable Agent (PTA) by Lim, Chan, Miao and Shen (2013). All these persuasive agents employ motivation to influence the audience in their behaviour change intervention. Table 2.3 shows the summary of persuasive systems in oral healthcare domain with their corresponding strength and weakness. These persuasive agents aimed to systematically influence their audience beliefs and behaviour by providing assistance to support behaviour change process.

Table 2.3
A Summary of Persuasive Agent in Oral Healthcare

Author	Description	Model	Strength	Weakness
Valle and Opalach (2005)	The Persuasive Mirror: computerized persuasion for healthy living	Based on principles of attractiveness, similarity, reciprocity and authority visual suggestions, and simulation media	Create a visual image that is expected to motivate audience's reactions in achieving behaviour change.	Low in persuasion and engagement of target behaviour.
Hasbro (2007)	Designed a persuasive system called Tooth Tune. The system has a sensor in the toothbrush area that triggers song for three minutes to motivate children to brush for that amount of time.	Persuasive design principles using Praise principle as unpinning theory	It allows children to stick to toothbrush behaviour in a friendly manner.	The engagement period is short and does not explicitly motivate on thorough and proper brushing e.g. brushing strokes etc.
Chang, Lo, Huang, Hsu, Chu, Wang, Chi & Hsieh (2008)	The toothbrush is made up of a vision-based motion tracker that recognises different tooth brushing strokes and a tooth brushing game in which the child cleans a virtual, mirror picture of his/her dirty teeth by physically brushing his/her own teeth.	Principles of Paediatric Occupational Therapy integrated with Learning and Teaching Model	Motivate kindergarten children to learn brushing skills.	Low in persuasion and engagement of target behaviour
Soler, Zacarías and Lucero (2009)	Developed a mobile persuasive game called Molarcropolis to persuade children of the importance of teeth brushing and the creation of awareness on different oral illness.	Persuasive design principle using cause-and-effect stimulation, suggestion and attractiveness theories.	It creates awareness of oral diseases.	Does not clearly show how the audience can be persuaded in overcoming these oral diseases.
Salam, Yahaya and Ali (2010)	A motivational multimedia interactive environment in persuading children on dental anxiety.	Persuasive design principles	It motivates children to be able to attend the dental clinic.	Does not support self-management
Hachisu and Kajimoto (2012)	Developed a persuasive toothbrush system. It augments the tooth brushing experience by modulating the brushing sounds to make tooth brushing entertaining in an intuitive manner.	It integrated the principles of persuasive design and haptic-auditory sensation	It attracts the attention of children for the target behaviour or action	Low in persuasion.

In addition, a study conducted by Kaplan, Farzanfar and Friedman (2003) on a persuasive intelligent system developed to monitor and counsel patient toward healthy lifestyle revealed that human beings form a teammate with computer agent when they perceived it as an expert. Equally, Skylogiannis, Antoniou, Bassiliades, Governatori and Bikakis (2007) proposed a system known as Doctor Negotiate; an agent based persuasive system which is based on the principles of negotiation to influence its audience. This system was based on a formal and executable approach to capture the behaviour of the audience involved in the negotiation process. Likewise, Arteaga, Kudeki and Woodworth (2009) integrated human-like persuasive agents into their mobile system to enhance reduction of obesity among teenagers. The agents were introduced to increase audience motivation with the technology. Therefore, these studies show that persuasive agent employs the act of persuasion to motivate their target audience in order to influence their change in behaviour.

Furthermore, the Microsoft Clippy popularly known as Office Assistant is another example of a persuasive agent. It was designed to assist and motivate users as an animated character, which interfaced with Microsoft-office help content by offering advice based on Bayesian algorithms (Xiao, Stasko & Catrambone, 2004. It pops up when the agent detects that the user could be needing assistant with Microsoft-office word application. The agent is integrated with office wizard and search help. Its major design objective is to persuade Microsoft word office users' on effective usage of Microsoft office features by giving motivational suggestions to the user. However, most users disliked this agent which was the reason for its termination by Microsoft cooperation due to strong negative response from many users (Xiao, Stasko & Catrambone, 2004). This dislike was referred to as a product of psychological reactant by Roubroeks, Ham and Midden (2011) when exploring the occurrence of psychological

reactant on artificial agents. Hence, it creates a gap in this study to investigate why a persuasive agent that is purposefully designed to support predefined behaviour resulted in psychological reactance and rejection.

2.3.2 Persuasive Agent Architecture

Many agent designs (Beer, Alboul, Norling & Wallis, 2013; Jiang, Vidal & Huhns, 2007; Biswas & Leeawong, 2005; Pokahr, Braubach, & Lamersdorf, 2005; Howden, Rönnquist, Hodgson & Lucas, 2001) are based on BDI (Beliefs, Desires and Intentions) architectures. BDI agent designs are predefined to situate in a changing environment, receive constant perceptual input, and take actions influenced on their immediate changing environment. The BDI is captured in their internal mental state. Beliefs, desires, and intentions are the three main mental attitudes of the agent. These mental attitudes represent the informational, motivational, and decisional components of an agent respectively. Similarly to attitudes, other concept such as commitments, capabilities, knowhow and others have been investigated. Sophisticated, multi-modal, action, temporal and dynamic logics have been used to create many of these notions (Guerra-Hernández, El Fallah-Seghrouchni & Soldano, 2005; Rao, 1996). However, there is dearth of studies in the literature that explicitly describe persuasive agent design. There are three exceptional studies that depict persuasion characteristics in an agent namely JAM by Huber (1999), Persuasive Agent Design (PAD) by Liu, Helfenstein and Wahlstedt (2008) and Persuasive Teacherable Agent (PTA) by Lim, Miao and Shen (2013).

In a major research, Huber (1999) presented a simple agent architecture known as JAM which was based on theories of Procedural Reasoning System (PRS) by Ingrand, Georgeff and Rao (1992), Structured Circuit Semantics (SCS) by Lee and Durfee, (1994) and Act Plan Interlingua by Levin, Gates, Lavie and Waibel (1998). JAM is a hybrid

intelligent agent architecture that evolved from pragmatic BDI-based agent architectures. It is made up of five major components namely world model, plan library, interpreter, intention structure and observer as illustrate in Figure 2.3.

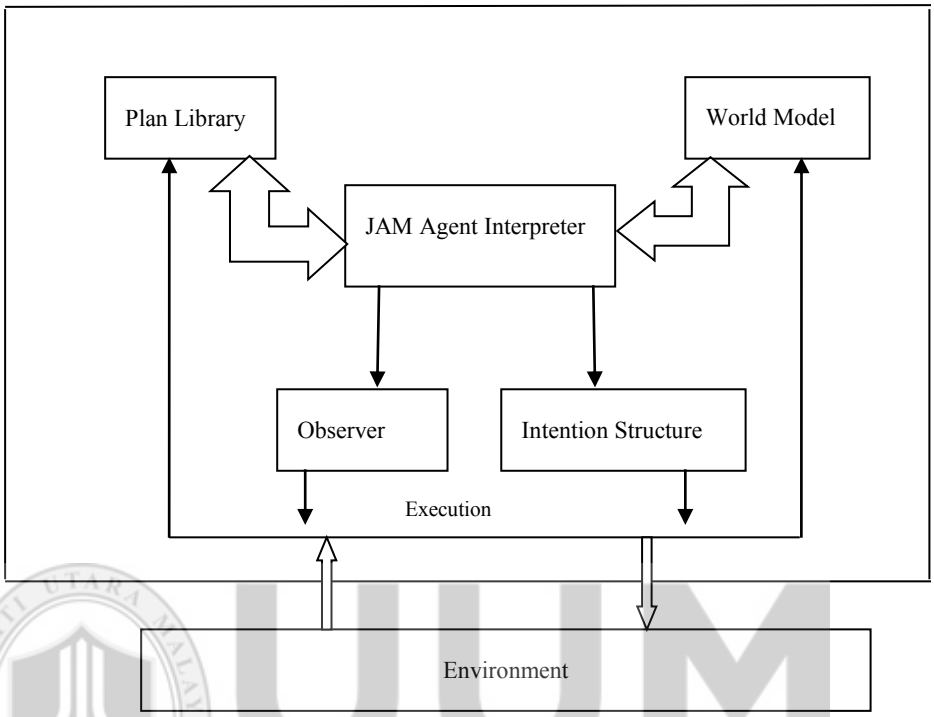

Figure 2.3. The JAM Intelligent Agent Architecture (Huber, 1999)

The world model is the agent database that symbolizes the beliefs while the plan is a compilation of different strategies that the agent uses to achieve its goals. The interpreter represents the agent's brain that aid reasoning and autonomy. It enables the agent to think about what to do and when and how to achieve its predefined objective and goal. The observer is a declarative procedure that interconnects agent's interpreter and its immediate environment. It aids the agent to perform functionality outside its normal goal/plan reasoning activities.

In another study, Liu, Helfenstein and Wahlstedt (2008) proposed a persuasive agent design based on Rao and Georgeff (1992) BDI (Beliefs, Desires, Intentions) architectural model which focuses on mental notion of encapsulation of hidden complex inner

functioning agent system. Rao and Georgeff (1992) BDI architectural model was later developed into a Procedure Reasoning System (PRS) by Ingrand, Georgeff and Rao (1992). Many studies (Brazier, Jonker & Treur, 2002; Georgeff, Pell, Pollack, Tambe, & Wooldridge, 1998; Huhns & Singh 1998; Ingrand, Chatila, Alami, & Robert, 1996; Maes, 1994) have studied the cognitive BDI agent and its PRS application. One of such application of BDI and PRS was Liu, Helfenstein and Wahlstedt (2008) as shown in the Figure 2.4.

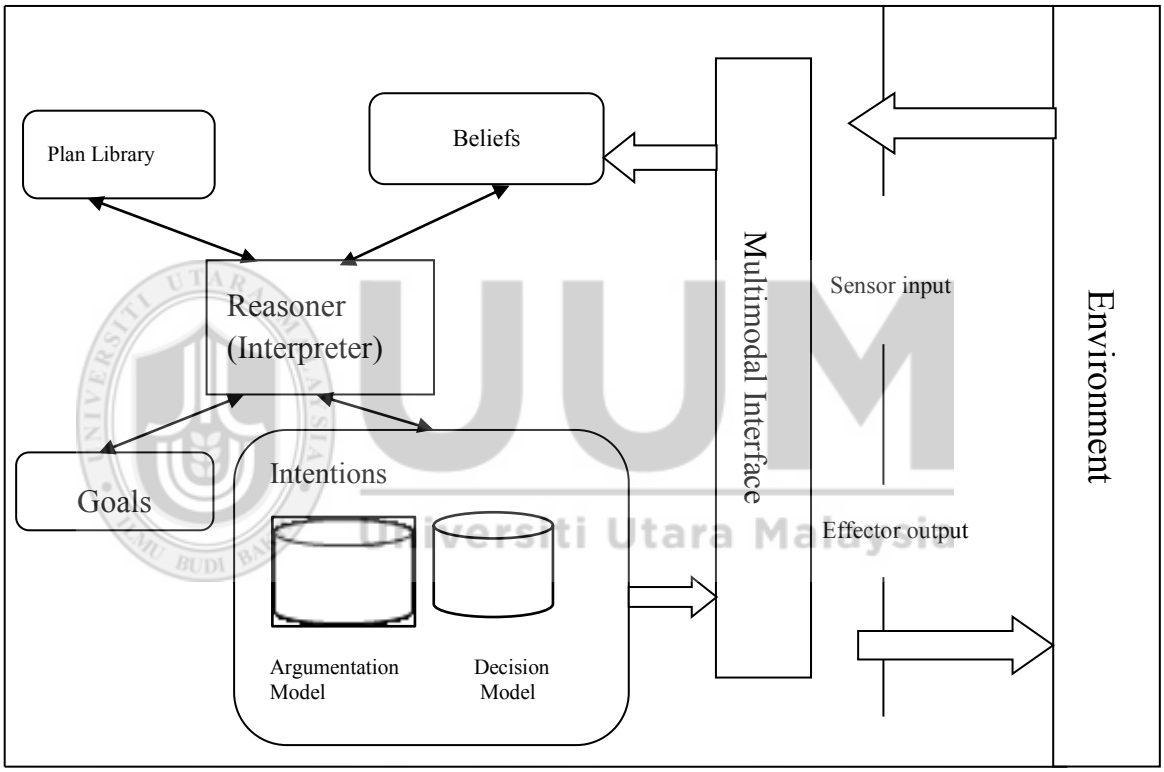

Figure 2.4. Persuasive Agent Design (Liu, Helfenstein & Wahlstedt, 2008)

In the design, the plan library is the decision making house because it holds the rule which is based on the input received and coordination from the belief and goal components. The intention component is made up of decision and argumentation modals and responsible for the formulation of agent decisions. The argumentation modal is added to enable the agent interact with its immediate environment in a predefined manner via multimodal interface.

The persuasive agent was designed to engage its immediate environment in argumentative behaviour change process that will be persuasive in nature. The argumentation model was based on heuristic model of persuasion (Chaiken, 1980; Petty & Cacioppo, 1986; 1984) by exploring the central and peripheral routes framework. Liu, Helfenstein and Wahlstedt (2008) concluded by suggesting five communication skill-relevant dimensions to persuasive agent which are namely agreeableness, anthropomorphism, informativity, persuasiveness, and adaptivity.

Similarly and more recently, Lim, Miao and Shen (2013) proposed a design of persuasive teachable agent (PTA) that is based on the notion of learning-and-teaching by Biswas and Leeawong (2005) and Elaboration Likelihood Model (ELM) by Petty and Cacioppo (1986). The persuasive teachable agent was aimed at incorporating ELM persuasion theory into the teachable agent with the purpose of achieving influence during behaviour change process behaviour in learning. The agent architecture is presented in Figure 2.5 which is made up of five major components namely knowledge base, teachability reasoning, events tracker, persuasion reasoning and persuasive teachable agent action components.

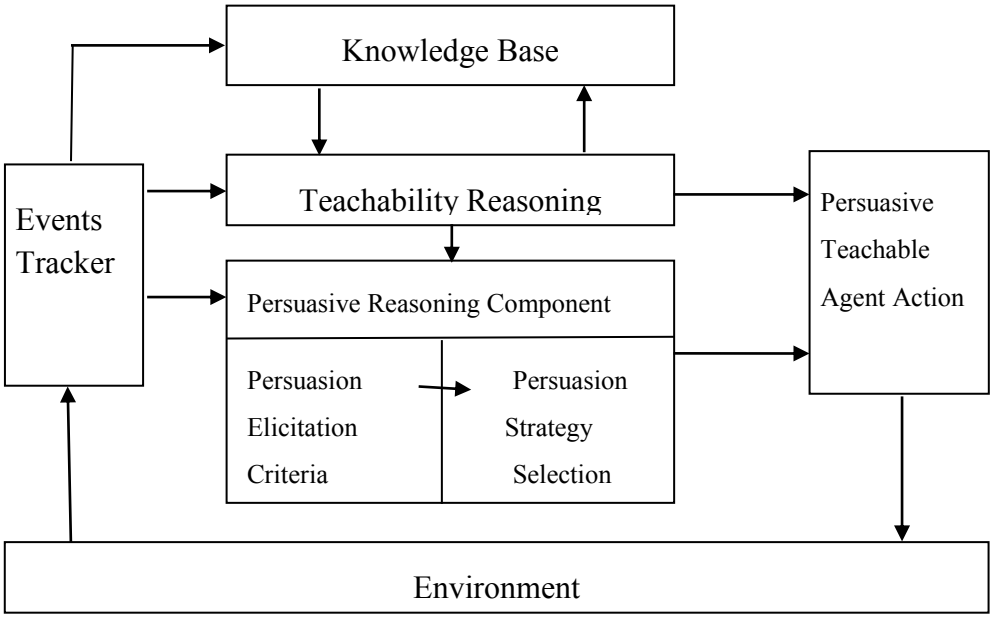

Figure 2.5. Persuasive Teachable Agent Architecture (Lim, Miao & Shen, 2013)

The events tracker receives information from the environment which is stored in the knowledge base as the PTA's perceived acquired knowledge. The teachability reasoning component handles the agent learning and reasoning processes which is interconnected with the persuasive reasoning component. The persuasive reasoning component encapsulates two sub-components namely persuasion elicitation criteria and the persuasive strategy selection. Both sub components are based on ELM theory of persuasion and define audiences' route of persuasion. Whereas processed feedback and responses are based on the persuasive teachable agent action which is then effected on the environment.

These studies (Huber, 1999; Liu, Helfenstein & Wahlstedt, 2008; Lim, Miao & Shen, 2013) have demonstrated that agent can persuade human being however, how agent processes persuasion to achieve motivational influence on its audience behaviour is not

well established. Also, it has been observed that users of these systems usually reject the instructions given by the system which was argued by Roubroeks, Ham and Midden (2009; 2010 & 2011) to be as a result of psychological reactance. Likewise, these designs lack explicit expression of persuasion model to achieve agent reasoning component. In addition, these agent designs focused more on the technical elements, such as highly sensitive and thorough algorithms however, less effort has gone into comprehending how designers can design a convincing or persuasive agent that can support change in behaviour. Therefore, this present study is concerned with how agents not only are computationally intelligent, but also socially intelligent to support behaviour change process. It focuses mainly on how persuasion can be used to build-up and sustain an interaction collaborative relationship between agent and its audience during behaviour change process. The focus of the study is on how agent can possess the ability to effectively persuade audience during behaviour change tasks in system interaction (Stock, Guerini, & Zancanaro, 2006; Fogg, 2003; Stiff & Mongeau, 2002; Parise, Kiesler, Sproull, & Waters, 1999).

2.3.3 Persuasion Expression in Persuasive Agent

Agent persuasive influence can be better comprehended from Elaboration Likelihood Model (ELM) by Petty and Cacioppo (1984 & 1986). The ELM is based on the initiative that attitudes are important because attitude guides behaviour process. While behaviour change can result from a number of processes, persuasion can be a primary source (Falk, Berkman, Mann, Harrison & Lieberman, 2010). The ELM features two routes of persuasive influence: central and peripheral routes.

The central route is mostly activated when the audience is motivated to think about the persuasive attempt and has the ability to think about the persuasion. Behaviour change usually occurs at this route if the audience thinks, or rehearses, favourable thoughts about

the persuasive attempts. A rebound effect (moving away from the advocated position) is likely to occur if the audience rehearses unfavourable thoughts about the persuasive attempt (Petty & Briñol, 2011). On the other hand, the Peripheral route occurs when the audience decides whether to agree with the persuasive attempt based on other cues besides the persuasive expression or ideas in the persuasion. This is when the audience lacks the ability or motivation to think about the persuasive attempt personally but might be persuaded due to other cues like source expertise (credibility) or facial attraction (Clark, Wegener, Habashi & Evans, 2012).

The ELM explains the differences in persuasive impact produced by a persuasive agent. It depicts the extent to which audience is willing and able to think about the position advocated by the persuasive agent. When people are persuaded and able to think about the content of the persuasion, elaboration is high. Elaboration involves cognitive processes such as recall, evaluation, inferential judgment, and critical judgment. When elaboration is high, the central persuasive route is likely to occur; conversely, the peripheral route is the likely result of low elaboration. Persuasion rarely occurs with low elaboration. This is because the audience is not guided by his or her assessment of the persuasion, as in the case of the central route. However, persuasion might occur if the audience decides to follow a principle or a decision-rule which is not directly derived from the persuasion (Petty & Briñol, 2011).

Therefore, persuasive agents with low persuasive influence possess low elaboration and follow the peripheral route which makes it difficult to achieve behaviour change. Hence, for successful behaviour change to be obtained then the persuasive agent must posseses persuasive influence that is moderately high elaboration and it should follow the central route (Li, 2012; Petty & Briñol, 2011; Douglas, Sutton & Stathi, 2010). This is because persuasive agent with enormous persuasive influence can also experience psychological

reactance which can be seen as force or coercion experience (Roubroeks, Ham & Midden, 2010). Thus, this current study proposed a formal model of persuasive agent that explicates agent persuasive influence in order to reduce psychological reactance and support audience behaviour change process.

2.4 Human Behavioural Models

Human behaviour is made up of both action and inaction which is determined by many factors like personality, temperament, genetics, environment and others (Le Grand, 1997). Observation of people's behaviour has aid the understanding and prediction of human behaviour (Schmidt, 2000). It has be proved that in order to better understand behaviour all the factors involves must be well understood and considered (Kosinski, Stillwell & Graepel, 2013). This is because behaviour does not just occur without a stimulus or cause (Kanai & Rees, 2011). The drive to understand and predict behaviour has given birth to theories and models of behaviour. These theories and models have aided breakthrough in many domain like criminology (Hollin, 2013), healthcare (Brannon, Feist, & Updegraff, 2013), disease control (Marteau, Hollands & Fletcher, 2012) and energy (Poortinga, Steg, & Vlek, 2004). One of such model in the vast literature that based on understanding and prediction of human behaviour is the human function model as discussed in the next sub-section.

2.4.1 Human Functioning Models

Human functioning refers to the behavioural style and pattern that an individual display at different conditions, states, events and roles within a situated environment (Levasseur, Tribble & Desrosiers, 2009). It is discovered that individuals react to their immediate environment differently which is based on their different objectives or motives within that environment. This usually leads to difference in expectation, achievement,

satisfaction and experience, in the case that these are not positively obtained then frustration, helplessness, and stress will be generated (McLeod, 2008). Thus, it is assumes that positive forces like high motivation, reward and benefit will lead to positive outcome. Nevertheless, how that outcome is obtained has been one of the greatest concerns of human functioning researchers (Stucki, 2005). It is believed that individual action and behaviour occurs at different time frame and there are other factors that interplay with it (Faul, 1995). Therefore, to assume that positive input gives positive output without considering other interplaying factors might not be totally correct (Borji & Itti 2013; Kielhofner, 2002). Hence, it necessitates research to explore and investigates on how factors interact to determine and produce specific outcomes which are known as human functioning models.

There have been many studies on human functioning especially in medicine, sociology, psychology and psychiatry. For instance the medical model by Pritchett, Kim and Feigh (2014), An (2012) and McLeod (2008). In the study by McLeod (2008) which was based on Laing (1971) study on family politics and others revealed that abnormal behaviour is generated due to problematic physical factors and can only be tamed by medical treatment. The human functioning model of disability depicts factors associated with disability behaviours (Ormseth et al 2015; Tate, 2014; Perenboom et al 2012; Stucki, Cieza & Melvin, 2007; Stucki, 2005; Üstün, Chatterji, Bickenbach, Kostanjsek & Schneider, 2003; Bickenbach, Chatterji, Bradley, Ustun, 1999). Likewise in sociology, human functioning model is develop to understand and predicts social behavioural pattern. For example the determinants model of parenting (Belsky, 1984). This model depicts that children behaviour is a result of parents' personality and environmental factors. Other human functioning model include a tripartite model of ego functioning (Haan, 1969), human territorial functioning (Taylor, 1988), social work practice

(Tolliver, 1997), task problem solving (Child, 2000) human occupation model (Kielhofner, 2002), bioecological model of human development (Bronfenbrenmer & Morris, 2006), positive counseling functioning (Lopez, 2006), older adult human functioning model (Levasseur, Tribble & Desrosiers, 2009).

Although, these studies presented human functioning model which depicts human behavioural factors, none of these studies specifically investigated behaviour change and reactance phenomenon. Also, many of these models are informal model whereas formal model serves the purpose of scientific reasoning which aid prediction of behaviour. When human functioning is depicted in computational or formal environment, then it will create virtual meaning to better predict future behavioural outcomes. Among these studies is one notable model which is closely related to this present study. The notable model is Bosse, Hoogendoorn, Klein and Treur (2008) which presented a formal human functioning model of wellbeing. The model can gain knowledge. This study presented a formal model but it focus on human support wellbeing model and not behaviour change nor psychological reactance. Therefore, this present study will explore behavioural model in the next sub-section to further understand human behavioural factors that are responsible for behaviour changes.

2.4.2 Behavioural Model

Behavioural models are systematically aimed at exploring and explaining the phenomena behind human actions and inactions. Many of these models identify personality, behavioural characteristics and environmental factors as major determinant factors in behavioural change process. Applications of these models have been implemented in domains like healthcare, criminology, energy conservation, learning, education and persuasive agent technology. These models are implemented in these domains to support and maintain behaviours. Therefore, the comprehension and proper understanding of

these models in persuasive agent design greatly improve the successful implementation of these agents in intervention.

Abraham and Michie, (2008) and Hardeman, et al., (2002) pointed out that behaviour change is the transformation or modification of an individual's behaviour over a period of time. Similarly, Fogg (2009) explained behaviour change in terms of compliance behavioural change which takes place within a time-frame and when a persuadee changes its behaviour for a time-frame to perform the action (one time action) as persuaded by the persuader. The sustainability of behaviour change is a significant and valuable target for agent community designers (Klein, Mogles & Wissen, 2011; Andre, et al. 2011). For this to be achieved there is a need to explore the underlying theories of behaviour change. For a persuasive agent to effectively cause behaviour change by employing the act of persuasion during its interaction with audiences; then the theories that leads to behaviour change should be well understood and incorporated by designers (Oinas-Kukkonen & Harjumaa, 2008). There are several models that describe different mechanisms of behaviour change in psychology. These theories can be divided into two main groups namely: Social Cognition Models and Stage Models (Sutton, 2001).

2.4.2.1 Social Cognition Models

Social Cognition Model (SCM) is set of similar theories which show the imperative of cognition and their inter-relationship in the regulation of behaviour (Erdley, Rivera, & Shepherd, 2010). These theories (Self-Efficacy Theory, Self-Regulation Theory, Theory of Reasoned Action and Planned Behaviour and Health Belief Model) that made up the Social Cognition Model only explicate major factors that affect behaviour change (Sutton, 2001). SCM are used to identify and explain how expectations, judgments, beliefs, and intentions lead to the performance of various behaviours (Conner & Norman, 1996). Despite the widespread use in behaviour changes interventions, the SCM has been

criticized for instance, Sutton (2001; 1998) criticized the models to have omitted some major factors in behaviour changes. Conner and Norman (2005) likewise pointed out that there is an overlap of factors between the different theories. It was observed that most of the theories shared some common factors.

Self-Efficacy Theory (SET) is the appraisal of one's self ability and capability to complete tasks and acheive predefined objectives and goals. Individual's knowledge acquisition might be directly related to observations of others within the context of social interactions and experiences. It was summarized by Bandura (1977) that behavioural changes occurs based on three events which lead to the self-efficacy trait as shown in Figure 2.6. These three events include when one have the ability to control the resultant behaviour, perceived control over external barrier and having confident in one's own ability to perform the actions that might lead to the change. This implies that for behavioural change to occur there is need for a strong inter-self-motivation (self-efficacy) to perform the action that might lead to the change. According to Bandura and Adam (1977) this motivation is built as a result of social interaction with others. However, Pinker (2010) argued that some behaviour is as a result of emotional responses determined largely by biological factors, which are controlled heavily by evolution, and has little to do with motivation or observation. For instance, jealousy can drive one to behave in a way that is not consistent with one's normal behaviour. Additionally, the human biological factors differences and hormonal responses were not considered in this theory.

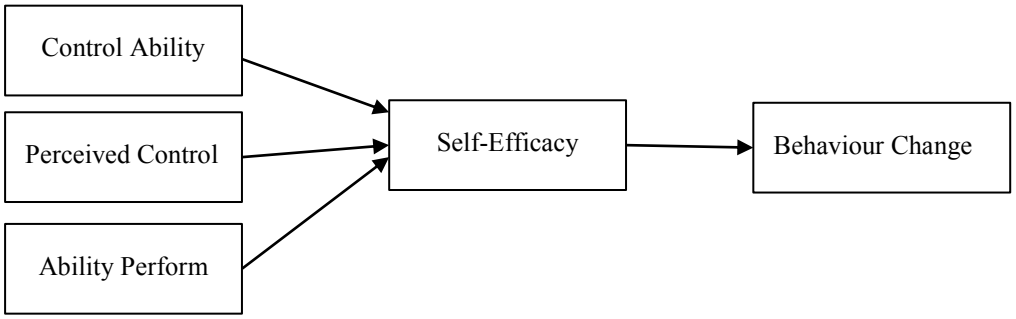

Figure 2.6. Self-Efficacy Theory (Bandura, 1977)

Vohs and Baumeister (2011) suggested that for a persuasive attempt to result to behaviour change, the persuadee should experience some level of reduction in self-determination, self-discipline and self-control as shown in Figure 2.7. This is known as Self-regulation theory (SRT) and it explains that we expend effort in control of what we think, say, do and trying to be the person we want to be, both in particular situations and in the longer-term (Fenton-O'Creevy, Nicholson, Soane & Willman, 2003).

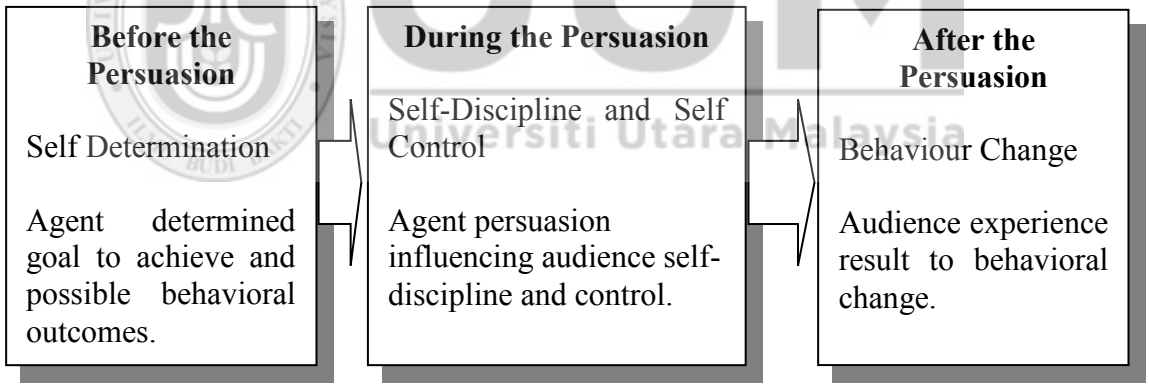

Figure 2.7. Self-Regulation Process (Vohs & Baumeister, 2011)

Therefore, self-regulation is a mechanism to prevent us from doing things we know we should not do. For instance caution on saying impolite words to other people. Self-regulation can be applied in creating positive behaviours, such as studying for exams. The theory is individualistic based and does not consider social norms and environmental factors. It explores more of inner motivation or strength that leads to behaviour change

than external motivation. While in the real world, it takes both inter factor and external factor to lead to behaviour change (Dubois, Rucker, & Petty, 2010)

Similarly, the Theory of Reasoned Action (TRA) was used to initialize conditions under which attitude would or would not predict behaviour (Ajzen & Fishbein, 1977). The components of TRA are three general factors: behavioural intention, attitude, and subjective norm. TRA suggests that a person's behavioural intention depends on the person's attitude about the behaviour and subjective norms. This means that a person's volitional (voluntary) behaviour is predicted by his attitude toward that behaviour and how he thinks other people would view them if he performed the behaviour (Hale, 2002). A person's attitude, combined with subjective norms, forms his behavioural intention. If a person intends to do the behaviour then it is likely that the person will do it (Ajzen, 2001). Behavioural intention measures a person's relative strength of intention to perform the behaviour. Attitude consists of beliefs about the consequences of performing the behaviour multiplied by his or her evaluation of these consequences. Subjective norm is seen as a combination of perceived expectations from relevant individuals or groups along with intentions to comply with these expectations (Fishbein & Ajzen, 2005). This theory assumes that environmental, demographical factors do not directly influence the likelihood of a person performing behaviour; these were regarded as peripheral factors yet it has been observed that these peripheral aspects are very significant factor as to whether behaviour change shall occur. However, this was later improved by the Theory of Planned Behaviour; which gives a better and refined understanding about attitude and behaviour.

Theory of Planned Behaviour was designed out of a counter-argument against the high relationship between behavioural intention and actual behaviour, as the results of some studies have shown that behavioural intention does not always lead to actual behaviour

because of circumstantial limitations (Wicker, 1969). Since behavioural intention cannot be the exclusive determinant of behaviour where an individual's control over the behaviour is incomplete (Warehime, 1972), Ajzen introduced the Theory of Planned Behaviour by adding a new factor known as perceived behavioural control as shown in Figure 2.8 (Montano & Kasprzyk, 2008). By this, he extended the Theory of Reasoned Action to cover non-volitional behaviours for predicting behavioural intention and actual behaviour. This concept has been widely used in persuasion and behavioural prediction in many domains like marketing, media, communication, computer science and other. The theory of planned behaviour overlooks emotional variables such as threat, fear, mood and negative or positive feeling and assessed them in a limited fashion.

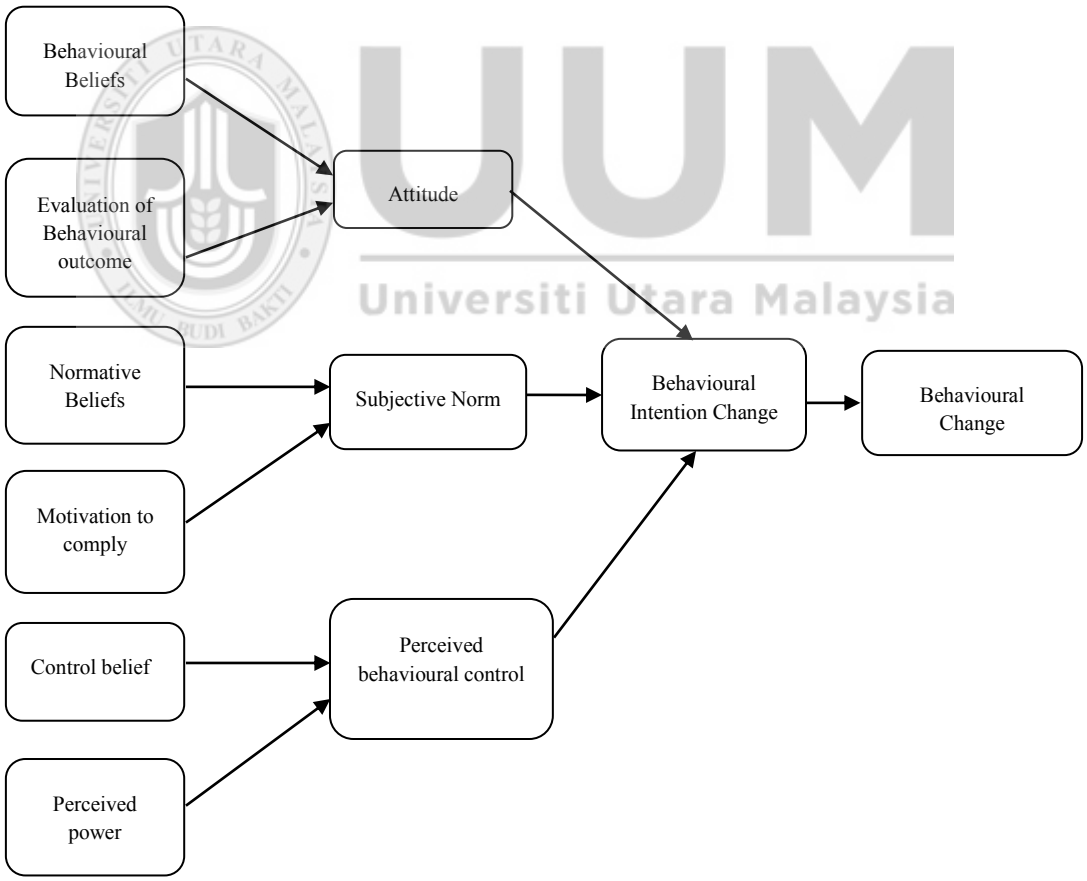

Figure 2.8. Theory of Reason Action and Planned Behaviour (Montano & Kasprzyk, 2008)

Another model of behaviour is the Health belief model and the model explored six factors that are essential for behaviour change to occur perceived susceptibility, perceived severity, perceived benefits, perceived barriers, perceived motivation and perceived cue as shown in Figure 2.9. According to Sutton (2001), Perceived Susceptibility means vulnerability of the audience's perceived risk of performing the behaviour. Perceived severity connotes the seriousness of the action and its consequences as perceived by the audience. Perceived benefits refer to the perceived advantages of the alternative course of action including the extent to which it reduces the risk of the behaviour or the severity of its consequences. Perceived barriers (or perceived costs) refer to the perceived disadvantages of adopting the recommended behaviour as well as perceived obstacles that may prevent or hinder its successful performance of the behaviour. Perceived motivation is the enabling ability to perform the behaviour while Perceived Cue is a trigger factor that enables the other five concepts to result the behaviour change. Although this model provides a framework to explain and predict behaviour change of individuals, it does not incorporate the influence of social norms and environment influences (Henshaw & Freedman-Doan, 2009).

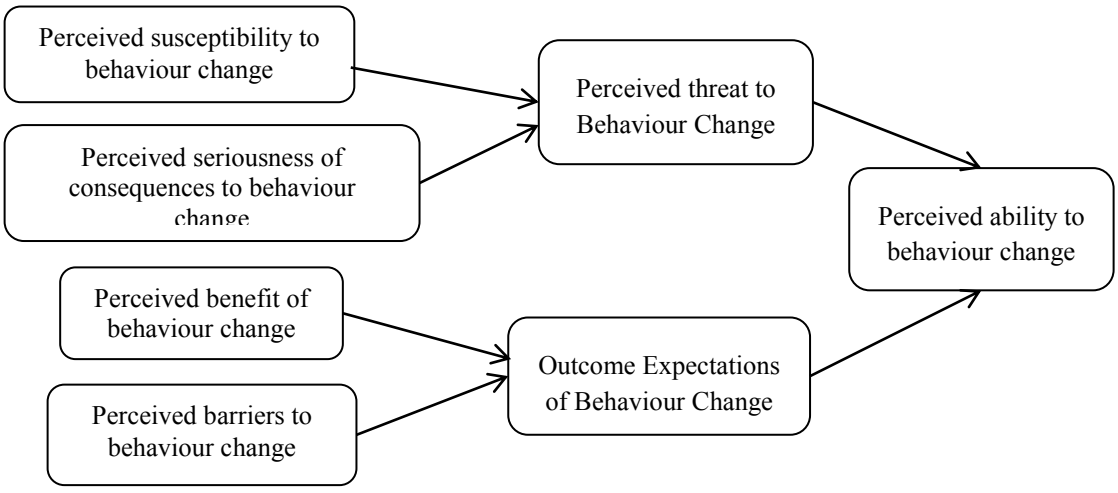

Figure 2.9. Health Beliefs Model (Henshaw & Freedman-Doan, 2009)

On the other hand, it has been proves that it is possible for a computer system to persuade a user or audience (Fogg, 2003) which will result to attitude or behavioural changes of the audience. This understanding has influenced designers in the breakthrough of new technological devices for human usage. Recently, scholars (Mukhtar, Belaid & Lee, 2012; Jawdat, Obeidat & Aljanaby, 2011) have identified the Fogg (2009a) Behaviour Model out of the many behaviour models in literature to be the most suitable and appropriate for persuasive behaviour system design.

The model was also suggested to be generic for any persuasive design. The model illustrates three factors that are essential for behaviour change to occur, these factors are: motivation, ability and triggers as shown in Figure 2.10. For the target behaviour to occur, a person must have sufficient motivation, enabling ability, and an effective trigger. All the three factors must be present at the same instant for the behaviour change to occur. This model was adopted for the purpose of this research; as the basic and underpinning model.

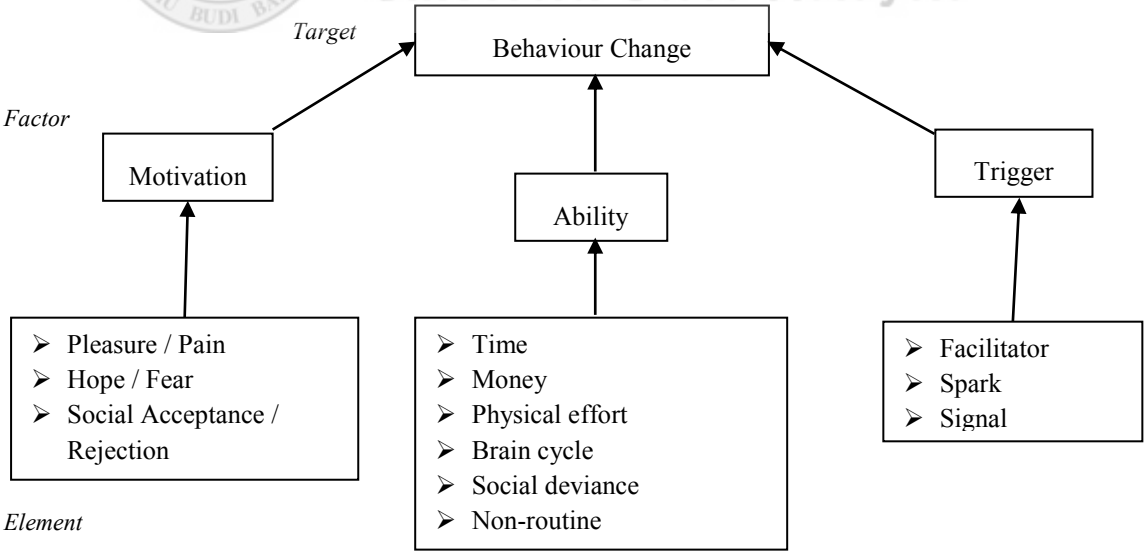

Figure 2.10. Behaviour Model (Fogg, 2009a)

The model had been used in many motivational and persuasive system designs. For instance, Young (2010) incorporated the Fogg behaviour model to design a micro-blogging site called Twitter me. The site was integrated with phone application to motivate teenage girls towards exercises. The phone application was integrated to support social network with their peers, it acts as a persuasive platform for behaviour change. Linehan, Doughty and Lawson (2010) used the Fogg behaviour model to design a social tagging system application known as Tagliatelle. The system was developed to motivate users' toward healthier eating habits. The system was designed for the purpose of reduction of obesity in both adult and children.

Similarly, Mukhtar, Ali, Belaid, and Lee (2012) used the Fogg behaviour model to design an intelligent environment that can monitor user activities and help them in making decisions. Expert's recommendations and social network entities were integrated to enhance feedback from users. Diabetes self-management environment was used as a case study and the main idea is to change the behaviour of the user for the improvement of diabetes treatment and management.

In another study, Thieme, Comber and Miebach (2012) incorporated the model in designing a system that support and manage recycling habits in young adults. The system is known as BinCam; it is designed to support social persuasion for the promotion of sustainable lifestyles, by replacing the existing traditional kitchen refuse-bin using automatic logs disposed of items via digital images analysis. These researches have shown that Fogg behaviour model is efficient within the domain of persuasive systems. Hence, the Fogg behaviour model is adopts as the basic and underpinning model for this current study.

Based on Fogg Behaviour Model in Figure 2.10; the model suggested that there are three important factors to cause behaviour change to occur namely motivation, ability and

trigger. The first factor is motivation; which is the process that initiates, guides and maintains goal-oriented behaviours. Motivation causes us to act; the element of inner forces that pulls human towards a particular goal (Alderman, 2013). A person who is low on motivation to perform the target behaviour would be less likely to perform that target action. One or more strategies pertinent to motivation can be used to increase the motivational level. From Fogg perspective, motivation can be increased with three motivators namely; pleasure/pain motivators; hope/fear motivators; social acceptance/rejection. These motivators increase the level of motivation to achieve behaviour changes whereas pleasure/pain is the most powerful motivator out of the three (Fogg, 2009b). Examples of motivation are doing something for pleasure, achieving of some status or expecting some reward. It involves the biological, emotional, social and cognitive forces that activate behaviour.

Vossen, Ham and Midden (2009) pointed out that feedback (vocal, factual or non-vocal) motivates audience to be persuaded by agent social influence in achieving audience behaviour change. Feedback can be used as a motivator in achieving behaviour change. Similarly, Salam, Yahaya and Ali (2010) used the persuasive design principles and multimedia design principles to create a motivational multimedia interactive environment in persuading children on dental anxiety. The persuasive design principles were incorporated in Fogg (2009a) Behaviour Model as motivational factor of sensation (pleasure and pain), anticipation (fear and hope) and social cohesion (social acceptance and rejection).

Kirman, et al., (2010) studied on Neg-Baztag, an internet connected agent that enhance environmental friendliness at home. This work illustrates how motivation can be used to achieve behavioural change. They argued that agent feedback responses to target audience are a good motivational factor for audience behavioural change to occur.

Likewise, in oral healthcare most research conducted on children tooth-brushing identified lack of motivation and unsupervised brushing as the major cause of dental diseases in children (Frazao, 2011). A research conducted by Sandstrom, Cressey and Stecksen-Blicks (2011) observed that younger children within the range of six years are of poorer quality in tooth-brushing skills, motivation and ability to perform the target behaviour of healthy tooth-brushing compared with older age group like 15 years above. Equally, Husni, Rahim and Salam (2012) used the principle of motivation as combination of core-affect theory, learning model and conversation agent to create motivational learning environment for young rural school children in Malaysia. The factor of motivation was incorporated to promote good learning environment for rural children.

These studies show that in everyday usage, the term motivation is frequently used to describe why a person does something. If the reason of performing a particular action is highly justified then the action will be carried out urgently. It can be argued that an increase in motivation as shown in the above researches can alter the effect of psychological reactance on audience. This is because when a person's behavioural freedom is threatened; the person becomes motivationally aroused to overcome the threat (Foster, Linehan, Kirman, Lawson & James, 2010). Hence, increase in motivation generates free choices and increase audience willpower to perform the target behaviour (Hettema, Steele, & Miller, 2005; Fogg, 2009a; Resnicow, et al., 2012).

According to Fogg (2009a) the second factor of behaviour changes is ability; which can be referred to as simplicity and easy task. Ability has six elements such as time, money, physical effort, brain cycle, social deviance and non-routine (Fogg, 2009a). A person who has low ability to perform the target behaviour would be less likely to perform the target action. One or more strategies pertinent to ability should be used to enable the

person. Ability can be seen as possessing enough time, requiring less effort or thinking to do some activity. Similarly, Carroll (1998) defined ability as the likely variation over individuals in the minimal levels of task difficulty (or in derived measurements based on such minimal levels) at which, on any given occurrence in which all conditions emerge favourable, individuals perform successfully on a defined class of task. In this definition, a scale is used to measure the amount of difficulty of a task in defining the ability of the individual undertaking the task. But it was argued that ability has to do with how a person understands and acts in performing a task. It is a set of skills or processes that enable an individual to achieve a task.

For example, Soler, Zacarías and Lucero (2009) designed a mobile persuasive game called Molarcropolis. The game employs the principle of persuasion to motivate audience during the game playing-time to achieve the target behaviour. It gives enabling ability to the target audience in identifying and overcoming dental disease related cases. The role of a bacteria or antagonist in the game environment is assigned to a player. The player is expected to destroy the environment while information on oral illnesses with causes, habits and activities are displayed on the game screen. During the game tips, how to improve oral health and advice are given. The game was specially designed for children within 7-12 years (Soler, Zacarías & Lucero 2009) to serve as awareness campaign on dental diseases.

Fogg (2009a) pointed out the third principal factor of behaviour changes as triggers. Without an appropriate trigger, behaviour will not occur even if both adequate motivation and enabling ability are high. A trigger is an event or its associated action that can be used to increase motivation or ability. In fact, without an appropriate trigger, behaviour will not occur even if both motivation and ability are high. Examples of trigger are reminders for exercise, alarms, and a growling stomach. Successful triggers

have the following uniqueness: First, it must be noticeable. Second, it must be relating to the target behaviour. Third, it must occur when both motivation and ability to perform the behaviour are present. The three types of triggers as proposed by Fogg (2009a) are: sparks, facilitators, and signals. Rudman and Zajicek (2006) defined trigger as the opportunistic moment or timing (right timing or moment for an action to be taken) for a persuasive interaction agent to cause behaviour change. It might be problematic and provocative to audience when agent intends to offer persuasive advice when the audience does not needs it at that particular period.

An example was found in the work of Rudman and Zajicek (2006) where a persuasive agent was trying to persuade a user. The agent waited until the document had been opened and the first line had been read before persuading the user that reading an important email now would be better than starting this long document. The user might be upset and annoyed by the advice of the agent to go for mail checking instead of reading his document; even when such email is important than the document. Similarly, in children oral healthcare, Hasbro (2007) designed a persuasive tool known as tooth tunes with Tiger electronics. This tool uses music to trigger its audience to perform the target behaviour of tooth brushing. It's made of sensor in the toothbrush section that triggers a song for two minutes to motivate children to brush for that amount of time. The song is an act of persuasion to allow the children to stick to toothbrush; it creates an environment of friendliness to reach the target behaviour. Thus, it is very important for developers to take the timing and trigger factors of agent persuasion very vital in achieving persuasion attempts that leads to behavioural change and reduces reactance. Thus, the reduction of psychological reactant on persuasive agent is very important for a more coherent and flexible agent influence to achieve behavioural change.

2.4.2.2 Stage Models

Unlike SCM, stage models are set of models that are based on segmentation of behavioural change factors. It defined these factors to move through a pattern of distinct stages over time and that these stages can be explained only based on their distinguishing characteristics (Layne & Lee, 2001). In particular, stage models in cognitive development have layer of succession, output stage (later stages) integrate the achievements of initial stage (earlier stages). And each has well defined mental processes which are meant for them which might be dependent on time frame

One of the stage models is the relapse prevention model (RPM) and the model is an outcome of behaviour that can be negative in the term of behaviour change processes. An initial setback, or lapse, may either translate into a return to the previous problematic behaviour, known as relapse, or into the individual turning again towards positive change, called prolapse depending on the situation (Larimer & Palmer, 1999). Hendershot, Witkiewitz, George and Marlatt (2011) argued that relapse is multi-determined, especially by self-efficacy, outcome expectancies, craving, motivation, coping, emotional states, and interpersonal factors as shown in Figure 2.11.

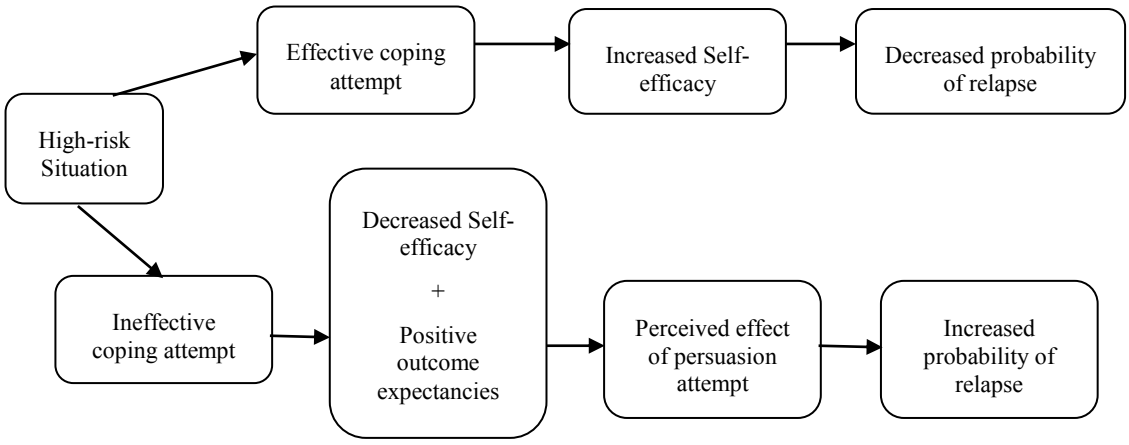

Figure 2.11. The Relapse Preventive Model (Hendershot, Witkiewitz, George & Marlatt, 2011).

In particular, high self-efficacy, negative outcome expectancies, potent availability of coping skills following persuasion, positive effect, and functional social support are expected to predict positive outcome. This theory is classified as stage model because of it stage-wise structural explanation of behaviour change factors. Although the model is widely used in drug related health behaviour change but the primary limiting factor is that in humans, relapse rarely follows the strict extinction of drug-seeking behaviour. It is mainly based on drug-related case and behaviour cannot be generalized. Additionally, human self-reports show that drug-associated stimuli play a lesser role in craving in humans than in the laboratory models (Katz & Higgins, 2003).

Similarly, the theory of Trans-Theoretical Model is one of the successful ones that have been applied to many behaviour changes interventions. It involves transitions between the stages of behaviour change as affected by a set of factors known as the processes of change. These include decisional balance (the pros and cons of change), self-efficacy (confidence in the ability to change across problem situations), and situational temptations to engage in the problem behaviour, and behaviours which are specific to the problem area (Prochaska, et al., 2009). Tierney and McCabe (2001) summarized the model as shown in Figure 2.12 into five stage of behaviour change namely; pre-contemplation, contemplation, preparation, action, and maintenance.

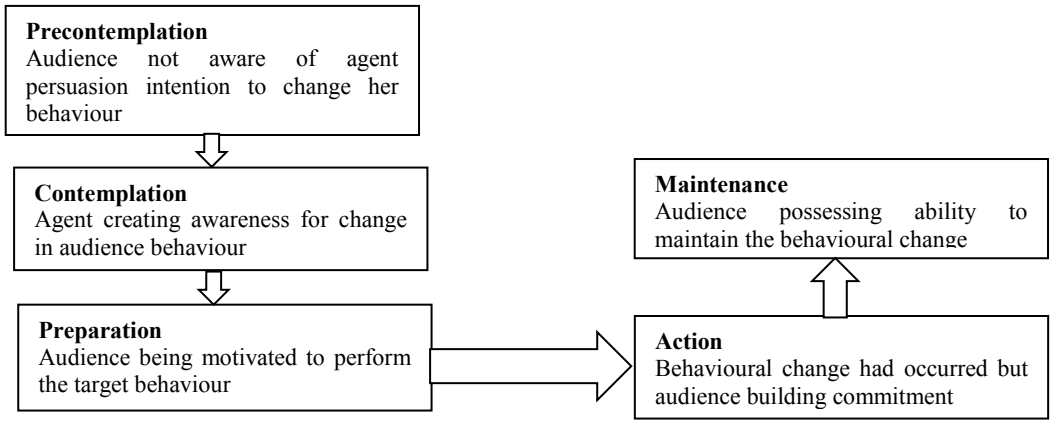

Figure 2.12. The Trans-theoretical Model (Tierney and McCabe, 2001)

In addition, Klein, Mogles, and Wissen (2011) suggested that progress on these stages depend on awareness, motivation and commitment of the audience. Pre-contemplation is the stage that the audience is unaware of the need to change its behaviour (not aware of the benefits of changing his behaviour). Contemplation is the stage that the audience has gained awareness about the benefits or gains due if the behaviour is changed. Preparation is the stage of building internal motivation and strength to perform the behaviour. Action stage is when behaviour change had occurred but the audience is building commitment to preserve the change. The maintenance stage is where there is awareness of a possible relapse or slip back to pervious stage or formal behaviour. This model is very imperative to understand how audience can develop long lasting behaviour change during persuasive interaction with agents. However, West (2009) criticized the model that the assumption on individuals typically making coherent and stable plans is not true. Human are known for incoherent and unstable decision and plans.

This present study adopts Fogg Behaviour Model (FBM) as a support model because the model has been rigorously implemented to achieve successful persuasive system in many domains (Oinas-Kukkonen & Harjumaa, 2009). However, the model is not computational which makes it open for formal analysis. Also only very few persuasive agents are based on formal models of behaviour changes models (Klein, Mogles & Wissen, 2011), which is the core underlying principle to understand how behaviour changes occurs (Michie, Johnston, Francis, Hardeman & Eccles, 2008). In addition, Table 2.4 shows the summary of behaviour change theories and model in persuasive agents such as Health Belief Model (HBM), Theory of Planned Behaviour (TPB), Relapse Prevention Model (RMP), Trans-Theoretical Model (TM), Self-Efficacy Theory (SET), Fogg Behaviour Model (FBM), Theory of Reasoned Action (TRA), Self Regulatory Theory (SRT).

Table 2.4
A Summary of Behaviour Change Theories and Model in Persuasive Agent

Theorem / **Application**	SET	SRT	TRA	TPB	HBM	FBM	RPM	TM
Klein, Mogles, and Wissen (2011)	X	X	X	X	X		X	X
Vries & Mudde, 1998	X	X	X	X	X			X
Hasbro (2007)	X		X	X	X			
Soler, Zacarías and Lucero (2009)		X	X	X	X			
Mukhtar, Ali, Belaid, and Lee (2012)						X		
Young (2010)						X		
Linehan, Doughty and Lawson (2010)						X		
Thieme, Comber and Miebach (2012)						X		
Kirman, et al., (2010)		X	X	X				
Vossen, Ham and Midden (2009)		X	X	X				

2.4.2.3 The Integrated Model of Behaviour Change (COMBI)

Computerized Behaviour Intervention (COMBI) model attempts to merge the theories aforementioned into a formal representation comprising of many mechanisms of behaviour change and also their interaction. Note that the combination of models requires handling with caution due to the effects of the interaction. Though, promising attempts have been made in this direction by scholars such as Armitage and Conner

(2000), Schwarzer (2008) and Glanz and Rimer (1995). However, model integration gives room for a better comprehensive and complete description of the quite complex human behaviour in the sense that there exists a simultaneous complement when referring to behaviour determinants which further leads to taking the core of the model as the overlapping elements. Case in point, if a particular theory gives an explanation of the formation of attitude and other theory gives the description of attitude impact on behaviour and motivation, then integrating both theories will not give a misrepresentation of the general picture. This is as a reason of these theories being complementary, that is, the concept of one theory is refined by the other.

A differentiation between the external and internal behaviour determinant is made by the model. External factors are susceptibility, high risk situation, severity, skills, pros/cons, barriers and social norms. Whereas, internal constructs are cues, mood, coping strategies, threat, self-efficacy and attitude. Five circles are used for the representation of the stages of change from the Transtheoretical Model (TM) which are Precontemplation (PC), Contemplation (C), Preparation (P), Action (A), and Maintenance (M). Preparation and contemplation ('P' and 'C', respectively) are elements in the 'intention' block and maintenance and action stages ('M' and 'A', respectively) are elements in the 'behaviour' block. Internal factors that aid the determination of change stage of a given personality consists of three different layers, and these layers, display the causal hierarchy existing between each layer. Also, the action stage possesses a feedback loop to self-efficacy and this follows from SRT.

These concepts define the three constructs of motivation, awareness and commitment whereas it is discovered that these constructs have a direct influence on behaviour change stage of a given individual. Likewise, an indirect influence on the behaviour change stage by the constructs in the intermediate result of the connectivity existing with

the other constructs is observed. There is just one external construct at the intermediate factors which is high risk situation while there are six internal constructs at the same intermediate stage. A causal hierarchy exists between the determinants in the model and the construction of the layers is based on the relationship existing with other constructs.

These above mentioned models have been the underpinning implementation of behavioural interventions however, many of these interventions have been unsuccessful and psychological reactance has been identified as the reason for these unsuccessful behavioural change interventions (Murtagh, Gatersleben & Uzzell, 2014; Folger, Ganegoda, Rice, Taylor & Wo, 2013; Rains, 2013). Therefore, the next sub-section examined existing psychological reactance models which will afford the opportunity to better understand how reactance affects behavioural interventions.

2.4.3 Psychological Reactant Model

There has been a great deal of research instituted to recognizes factors that lead to unsuccessful behavioural change interventions, whereas scholars have continuously argued that more attention should be focused on psychological reactance (Murtagh, Gatersleben, & Uzzell, 2012; Gifford, 2011; Quick & Stephenson, 2007; Rains & Turner, 2007; Dillard & Shen, 2005). Psychological reactance occurs when the free behaviour of an audience is infringes by persuasive intention to cause behavioural change and it manifests in the forms of anger, irritation, frustration and refusal of target behaviour or action (Folger, Ganegoda, Rice, Taylor & Wo, 2013; Edwards, Li & Lee, 2002). This phenomenon explains how behaviour change is resisted and leads to failure of behavioural change interventions.

Brehm and Brehm (1981) argued that psychological reactance is a state that is conjectured to occur when freedom is threatened or eliminated. The state is activated

when motivation is directed toward the re-establishment of the freedom (free behaviour) which is being threatened with elimination by persuasion attempt. There are four core elements composing psychological reactance namely; freedom, threat to freedom, reactance and restoration of freedom (Quick & Stephen, 2008). Figure 2.13 provides a conceptual design of the interconnected elements that made up the theory of psychological reactance.

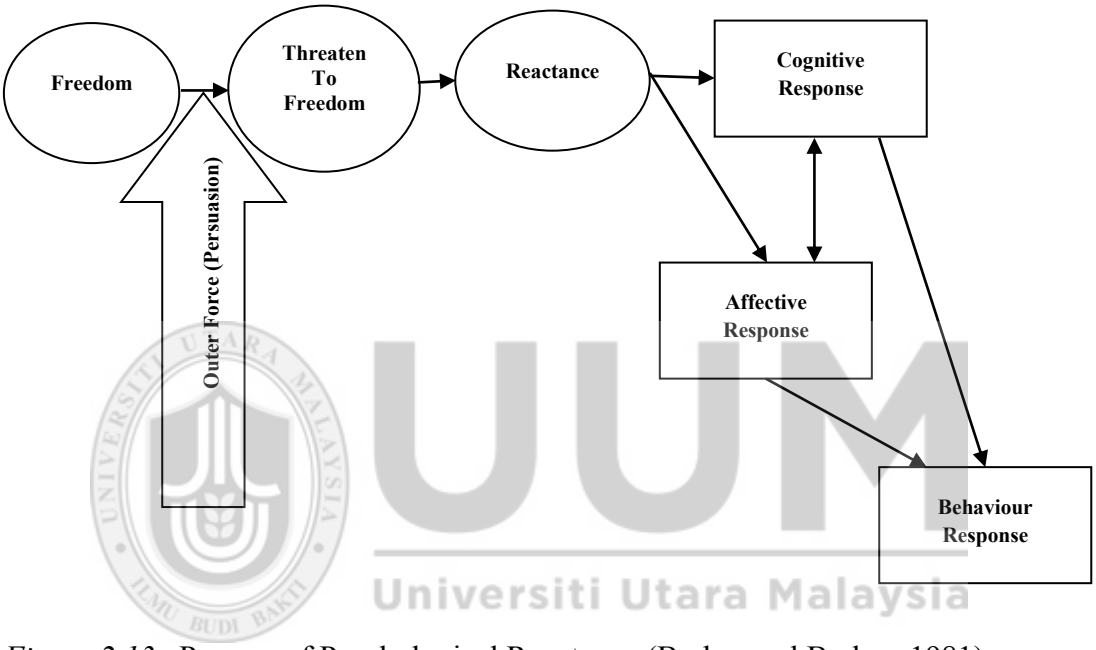

Figure 2.13. Process of Psychological Reactance (Brehm and Brehm, 1981)

Steindl and Jonas (2012) suggested that freedom is a belief that an individual involves in to achieve a particular behaviour. It was categorized as being subjective and specific rather than objective and general. The concept of freedom in reactant theory has a vital theoretical implication. This is because an individual is expected to have the freedom to act autonomously in order to decide between the multiple possibilities of action available to that person and can take the choice as intended. These multiple choices are what an agent is operating in narrowing it to a specific choice by the act of persuasion. When persuasion is applied as an outer force by an agent, it threatens the freedom of the individual. This is because individual generally expect freedom to maximize their needed

satisfaction. However, this need can only be satisfied with multiple possibilities and choices in action. Thus, if an individual behavioural freedom is threatened or reduced, the individual is motivated to act on this threat. The response to the freedom is known as reactance.

This implies that a perceived threat to freedom is the root cause of reactance. In another major study, Burgoon, Alvaro, Grandpre and Voulodakis (2002) found that reactance is an experience that occur whenever a free behaviour is restricted; an aversive affective reaction in response to regulations or impositions that impinge on freedom and autonomy. The notion of psychological reactance has been further explained through a process of emotional and cognitive responses after receiving threatening influence. That is, when freedom is threatened, state reactance is measured with unfavourable cognitions and anger, which directly triggers certain behaviour that attempt to restore the perceived threatened freedom (Quick & Stephenson, 2007; 2008; Dillard & Shen, 2005).

Moreover, during the psychological arousal state, audience have been found to exhibit different outcomes, some can totally reject or revolt against the persuasion attempt (Erceg-Hurn & Steed, 2011), some can derogate the persuasion source (Miller, et al., 2013), some increase their choice of likeness towards the persuasion attempt or show their preference for another method or style of persuasion (Liu, Smeesters & Vohs, 2012) and some can even deny the existence of the threat (Roubroeks, Midden & Ham, 2009) by enacting a different freedom to gain a contentment of choice and control. These show that different types of restoration of freedom exist among agent audience. This can be seen in Cameron, Jacks and O'Brien (2002) in which the study recognized five types of reactance response namely counter-argument (direct denial of persuasion), source derogation (dismissing the agent expertise or trustworthiness), negative affect (frustration, angry or upset) and assertions of the confidence (claiming that nothing or no

one could ever influence or change one's opinion) and attitude strengthening (support persuasion). In addition, Tormala and Petty (2004) concluded that counter-argument is an active strategy which includes careful consideration of the evidence compared with other types of resistance. It means that audience with low motivation and ability can made use of other strategies like source derogations or claim their own position.

Most importantly, it could be seen that behavioural restoration or restoration of freedom is of two categorizes namely direct and indirect restoration of freedom (Dillard & Shen, 2005). Direct restoration of freedom includes direct refusal, counter-argument and behavioural revolt while indirect restoration of freedom are alternated choice, assertions on one's position, source derogation and negative effect (Cameron et al., 2002; Tormala & Petty, 2004).

Threat can be seen as a judgmental perception of the audience based on the persuasive interaction between the audience and the agent (Dillard & Shen, 2005). It can be deduced that a perceived threat to an audience's freedom is a necessary condition or antecedent for occurrence of reactance but not reactance on its own (Rains & Turner, 2007). Consequently, one can infer that there are two assumptions involved in reactance theory. First, audience have a desire for freedom. Second, the attempt of agent persuasion usually threatens this intrinsic desire. When this intrinsic desire is threatened, it triggers an arousal state that operates to protect the further loss of freedom. This state is triggered to recover the loss of freedom or its reduction further. Similarly, Rains and Turner (2007) argued that reactance is a perceived threatening or limiting experience that occurs in response to an action or event. This experience leads to an arousal state which an individual engages in opposite behaviour to protect or restore the initial freedom or the further reduction of the freedom.

Therefore, perceived threat to freedom generates reactance that indirectly opposes persuasion in audience behaviour or attitude change. This can be seen from the example of Microsoft Clippy (Microsoft Agent, 2014; Baylor & Ryu, 2003), where most users dislike the agent because they perceive it as an intrusion to their work. The continuous reappearance of the agent caused anger for some users which they perceived as a distraction to their work. Swarz (2003) researched on Microsoft agent (paper clipper) by examining the agent internal cognitive labels (explicit system provided labels), the specific agent appearance and the agent interactive behaviour on users' perception. The author concluded that the agent fails to give enabling ability and adequate motivation to its users in achieving the target behaviour.

Another example was found in the work of Xiao, Stasko and Catrambone (2004) where the effects of an agent competence on user performance and perception were investigated. They found that the perceived utility of an agent is influenced by the types of errors made by user. Users' perceptions of an agent directly affect the overall performance of the user when the agent takes the role of a teacher or instructor. They observed that the level of motivation and ability given by the agent to its audience resulted in their corresponding performance. Similarly, Rudman and Zajicek (2006) revealed that reactance will be generated when persuasive agents try to assist users during examination period. This was the reason why most users during the examination did not follow the suggestions as offered by the agents. The persuasive attempt made users to experience frustration and dislike to the agent. Consequently, as system designers are giving more autonomy, reactivity, pro-activeness and social abilities to agent design, there is a need to evaluate such systems psychological reactant behaviours (Roubroeks, Ham & Midden, 2010). Roubroeks et al. (2010, 2011) and Rains (2013)

have confirmed that psychological reactant is an important factor against persuasion to yield behavioural change.

Similar conditions have been observed in several other works. Dilard and Shen (2005) found that when the participants received more reactant-inducing directive towards regular flossing and healthy drinking habits, they perceived these directives to be less persuasive (less motivational). These less persuasive directive perceptions of participants led to more negative attitudes and behavioural intensions toward the target behaviour. Similarly, Quick and Considine (2008) discovered that college students with higher levels of reactance experience negatively evaluated effectiveness of exercise ads than those with lower level of reactance. Erceg-Hurn and Steed (2011) investigated the effect of exposure of cigarette health warnings to elicit psychological reactant in smokers using text and graphic warnings. Interestingly, they discovered that smokers experience reactance which was the reason why the persuasive text and graphic warnings deflect the target behaviour of decline in smoking. It was because the warnings signs were found to be less persuasive (less motivating) or appealing to the smokers. Also, Quick (2012) identified attitude, motivation and source appraisal as factors that might enhance reduction of psychological reactance on audience. Thus, as discovered in these studies if a motivational factor and enabling ability can be enhanced, it will reduce the effect of reactance which later improves the achievement of the behaviour change.

Rummel, Howard, Swinton and Seymour (2000) researched on psychological reactance effect on children and discovered that children form reactance when parent used the phrase "*You can't have that*". The findings of their research shows that male children largely disapproved parental advice compare to female children in the same age. They argued that male children increase in reactance as they increase in age compare to female children. This argument is similar to Brehm and Weinraub (1977) findings that children

will experience reactance when there is a restriction before them. This work made used of a physical barrier placed with an identical object and allowing the children to make their choice in a free-play session. Interestingly, it was observed that boys preferred the object behind the barrier only when the barrier was large and the object were dissimilar. This result supported the prediction derived from reactance theory for response to physical barriers. Thus, this established the fact that children are affected by psychological reactance. This research explored persuasive agent model that shall deflect the effect of psychological reactance. It made use of children within the age of 7-12 years as the research respondents. This is because this group of children had been identified to have poor oral hygiene due to their inabilities to achieve proper teeth brushing (Edelstein, 2002; Saddki, Yusof, & Hwang, 2010; Gao et al., 2010; Sharma & Yeluri, 2012).

2.5 Behavioural Support Models

It has been established in previous sections that behavioural theories and models provides understanding to prevent and maintain targeted behaviours which is evident from various studies discussed. However, research on human behaviour is more that prevention and maintenance but also support and sustenance of these target behaviours. The issue of behavioural prevention, maintenance, support and sustenance are very crucial to behaviour change, persuasive technology and agent technology domains because these domains revolve around developing technologies that will better human lifestyle especially on human challenging behaviours. Challenging behaviour is when the physical safety of an individual or the society is in serious danger or harm due to the individual action or inaction (Emerson et al., 1988). This is an inappropriate behaviour which might be very difficult to change because it is a functional behaviour serving a specific purpose. These behaviours are supported with the aid of technology in order to

be more appropriate to the society and many of these technology or behavioural support management are based on behavioural support models which are summarized in Table 2.5.

Table 2.5
Summary of Behavioural Support Models

s/n	Author	Model	Target Respondent	Target Behaviour
1	LaVigna & Willis (2005)	support model for breaking the barriers to social and community inclusion	Disabilities	Social acceptability
2	Jensen, Romano, Turner, Good & Wald, (1999)	support for a cognitive-behavioural model of chronic pain	patients with chronic pain	Patient beliefs
3	McClean, Grey & McCracken, (2007)	positive behavioural support for people with very severe challenging behaviours in community-based settings	Disabilities	Psychotropic medications
4	Michie, Hyder, Walia & West, (2011)	behaviour change techniques used in individual behavioural support for smoking cessation	Smokers	Smoking cessation
5	Mohr, Cuijpers & Lehman,. (2011)	Supportive accountability support model for adherence to eHealth interventions	Healthcare patient	Accountability to health intervention coaches
6	Free et al (2011).	Smoking cessation support	Smokers	Smoking cessation
7	Nunkoo & Gursoy, (2012)	Residents' support model for tourism	Tourist	Social exchange
8	Ziauddeen, Farooqi & Fletcher,. (2012)	addiction model	Obesity	Food addiction
9	Wang, Zhang, Guo, Bubb & Ikeuchi, (2011).	safety-based approaching behavioural support model	Drivers	Driving speed
10	Mastellos, Gunn, Felix, Car & Majeed, (2014).	dietary and physical exercise support model	Obesity	Weight loss
11	Lin, Hsu, Cheng & Chiu, (2015	online social support model	Social media users	Willingness to offer help online
12	YILDIZ, Beskese & Bozbura,. (2015)	self-managed career support model	Career & working class	Career decisions
13	Rane,. (2015	clinical decision support	Clinician	Aid correct diagnosis
14	Katz,. (2014)	Peer support model	Alcohol drinkers	Safe drinking practices
15	Trivedi & Daly (2007).	clinical decision support	physicians	Medication, and dose optimization

For instance, LaVigna and Willis (2005) developed a support model of social acceptability for disability, Michie, Hyder, Walia and West (2011) also developed support for smoking cessation. More specifically, there are many studies that utilized agent support model on behavioural support such as Kierzkowski and Kisiel. (2015) and Kaluža et al (2014) while Table 2.6 gives summary of agent support behaviour model.

Table 2.6
Summary of agent support behaviour models

s/n	Author	Model	Target Respondent	Target Behaviour
1	Schelhorn, O'Sullivan, Haklay & Thurstain-Goodwin. (1999)	STREETS: An agent-based pedestrian model	Pedestrian	Safe road behaviour
2	Yu, Wang & Lai. (2009)	financial multicriteria decision support model	Financial managers	Risky finance decisions
3	Lee, Wang, Chen, & Hsu (2006)	decision support agent	Project Managers	Project monitoring and control
4	Fan, Sun, McNeese & Yen. (2005)	recognition-primed decision support model	Drivers	Primed decision making
5	Kop, Hoogendoorn & Klein (2014	Personalized agent Support model	Depressed Patients	Self-help therapies
6	Kierzkowski & Kisiel. (2015)	Logistic agent support model	Aircraft operators	Operations schedule
7	Di Stefano & Santoro. (2000)	NetChaser: Agent support for personal mobility	Internet service users	Mobility in accessing Internet service
8	Petrov & Stoyen (2000)	agent based decision support model	Human controllers	Critical decisions under strict timing constraints in a dynamically changing environment.
9	Gray, Cybenko, Kotz, Peterson & Rus (2002)	Agent support model	Military personal	Operational support for military field personnel's
10	Kaluža et al (2014)	Agent care support model	Elderly people	Independent living

2.6 Formal Model

The main aim of formal model is to create a representation of the system-in-context that approximates the underlying process of the phenomenon and behaviour of an agent. As suggested by Adner, Polos, Ryall and Sorenson (2009), formal models are more advantageous over verbal (non-formal) theories because they are more precise, transparent, and internally consistent approach for theorizing. Table 2.7 shows a summary of computational models and techniques. Two notable exceptions are the iChange model (Vries & Mudde, 1998) and COMBI (Klein, Mogles & Wissen, 2011).

Table 2.7
A Summary of computational model and technique

S/n	Author	Title	Technique
1	Soleimani and Kobti (2012)	A Mood Driven Computational Model for Gross Emotion Regulation Process Paradigm	Differential Equation
2	Bosse, Merk and Treur (2012)	Integrating Situation Awareness and Surprise: A Computational Agent Model	Differential Equation
3	Treur (2011)	A Computational Agent Model for Hebbian Learning of Social Interaction.	Differential Equation
4	Naze and Treur (2011)	A Computational Agent Model for Post-Traumatic Stress Disorders	Differential Equation And First Order Logic
5	Klein, Mogles, Treur and Wissen (2011).	A Computational Model of Habit Learning to Enable Ambient Support for Lifestyle Change	Differential Equation and First Order Logic
6	Treur (2011)	A Computational Agent Model using Internal Simulation to generate Emotional Dream Episodes	Differential Equation and First Order Logic
7	Aziz et al. (2010)	Design of an Intelligent Support Agent Model for people with a Cognitive Vulnerability	Differential Equation
8	Both, Hoogendoorn, Klein and Treur (2008)	Modelling the Dynamics of Mood and Depression	Differential Equation
9	Gebhard (2005)	Alma – A Layered Model of Affect	Rule-Based
10	Mui et al. (2002)	A Computational Model of Trust and Reputation	First Order Logic

In a major research, Vries and Muddle (1998) proposed iChange model, an integrated model that explains how behaviour change occurs. The model was derived from Theory of Planned Behaviour (Ajzen & Fishbein, 1977), Social Cognitive Theory (Bandura, 1977), Transtheoretical Model (Prochaska, 2009), Health Belief Model (Janz & Becker, 1984), and Goal Setting Theory (Locke & Latham, 1990). The model identified eight factors namely, knowledge, cue, risk perception, attitude, social influence, efficacy, ability and barrier. The model states that secret and open behaviour action occurs as a result of a person's motivation (intention), disposition (abilities) and awareness (Vries & Mudde, 1998). Motivation is determined by three elements; attitudes, social influences, and self-efficacy expectations while attitude consists of the perceived cognitive and emotional advantages and disadvantages of the behaviour. Awareness is the disposition at the right timing for behaviour to occur. The model describes the factors that influence behaviour change, nevertheless, fails to clearly explain how these factors interact (Klein, Mogles & Wissen, 2011). It is imperative to fully acknowledge the significance of each factors interaction to better understand the rationale behind behaviour change.

Similarly, Dong-Huynh, Jennings and Shadbolt (2004) proposed FIRE an integrated computational model that improves interaction behaviour in agent. It consist of four main factors namely interaction trust, role-based trust, witness reputation, and certified reputation. The model aims to help agent in reliable selection of partners for interaction. It facilitates agent to take into account diversity of sources of trust information in order to have a more accurate trust measure in achieving its target behaviour. Likewise it enables agent to be able to evaluate trust before executing an action in order to accomplish its predefined task with its situated environment. However, the model exclusively centred on trust and reputation which are not sufficient to achieve

behavioural change. Also, many factors of behavioural change were not incorporated in the model like attitude, self-efficacy, threat, cue and other persuasive factors.

In another major research, Klein, Mogles and Wissen (2011) proposed COMBI an integrated computational model for behaviour change which is based on six psychological theories (Social Cognitive Theory, Transtheoretical Model, Theory of Planned Behaviour, Self-Regulation Theory, Relapse Prevention Model and Health Belief Model). The model recognized thirteen factors which were classified into external and internal factors. It differentiates between the internal and external factors influencing behaviour change. The external factors are susceptibility, severity, pros/cons, social norms, barriers, skills and high risk situation. Whereas internal factors includes cues, threat, attitude, self-efficacy, coping strategies and mood. Severity and susceptibility shows how audience perceives the severity of the consequences of the performed behaviour and the likeliness of its outcomes, pros/cons represents the beliefs about the significance of the behaviour. Social norms mean the influence of the environment, and barriers stand for real obstacles that prevent the audience from achieving the target behaviour. Skills represent the experiences and capabilities that the audience possess to overcome these barriers. High risk situation depicts the likelihood of certain contexts to influence audience's behaviour. For instance, high risk situations are negative emotions as a result of an interaction with others. Table 2.8 gives more clarification on these factors with descriptions and related theories.

Table 2.8
COMBI Factors and Related Theories

No	Factor	Factor Classification	Description	Related Theory
1	Cues	Internal	Element of environmental or physical stimuli	HBM
2	Threat	Internal	Perceived risk of continuing to perform behaviour	HBM
3	Attitude	Internal	Mental state involving beliefs, emotions and dispositions.	TPB, AF
4	Self-Efficacy	Internal	Perceived behavioural control	SCT, TPB, RPM
5	Coping Strategies	Internal	The ability to deal with tempting situations and cues.	SRT, RPM
6	Mood	Internal	Temporary state of mind defined by feelings and dispositions.	SRT
7	Susceptibility	External	The likeliness of being affected by behaviour's consequences	HBM
8	Severity	External	The severity of the consequences of the behaviour	HBM
9	Pros/Cons	External	The beliefs about the importance of healthy lifestyle.	TPB, AF, HBM
10	Social Norms	External	The influence of culture and environment of a person.	TPB
11	Barriers	External	Practical obstacles that prevent behaviour change.	HBM
12	Skills	External	The experience and capabilities to overcome the barriers.	TPB, SCT
13	High Risk Situation	External	Contexts/environments that influence a person's behaviour.	RPM

However, the COMBI model does not capture persuasive factors like audience participation, suggestion for action, source credibility, motivation, ability, trigger and time (Klein et. al., 2013; 2011; Mattiske, 2012; Fogg, 2009). Petty and Brinol (2011) and Fogg (2009) have identified persuasive factors as a significant component of behaviour change. Mattiske (2012) pointed out that audience involvement or participation is a vital

factor in achieving behaviour change because it enhance attitude and believe. Similarly, Kim, Hong and Magerko (2010) mentioned the factor of suggestion for action as an important factor when designing a persuasive system. They explained that suggested action by a persuader usually create ideas in the mind of the persuadee. These ideas make the persuadee not to feel any coercion or force through the process of persuasion and its gives free wills to enhance behavioural change. As a result the model does not fully acknowledge evident expression of persuasive power. In addition, the model does present a computational representation of these factors nevertheless analytical testing and verification were not done on the model. Analytical testing and verification authenticate the internal correctness of computation model (Babuska & Oden, 2004). Therefore, the model is yet to show how persuasion can be employed to achieve behaviour change. Thus, COMBI will be used as the benchmark model for this research. The present research examined how persuasion can be employed to reduce the effect of reactance in order to achieve behaviour change. It explicitly expressed how persuasive power can be used to accomplish agents' audience behaviour change.

2.7 Evaluation Methods of Formal Model

Modelling as a field has kept up playing remarkable roles in the area of system development. This concept contributes to the ability to understand the approach with which things function and the importance to the efficient and effective design, operation and evaluation of new systems and products. The results obtained from modelling gives important information for actions and decisions in quite a number of behaviour of the developing system. Formal model evaluation on the other hand is a process that aids ensuring the correctness and reliability of the simulations and models. In a bid to find an evaluation for the computational model, otherwise referred to as the formal model, there exist two approaches to confirm the accuracy of the model and these approaches are

automated verification and mathematical verification (Ting, Zhou, & Hu, 2010; Both, Hoogendoorn, Klein, & Treur, 2008; Bosse, Pontier, & Treur, 2010).

2.7.1 Mathematical Verification

The major aim of mathematical verification is to investigate the structural and theoretical correctness of formal model which involve deductive arguments on the model logical statements (Salem da Silva & De Melo, 2013). These arguments are usually established in logical facts and theorems upon which the model is based and can be traced to the model axioms (Akhtar & Akhtar, 2014). Many mathematical techniques have been employed to investigate this structural and theoretical correctness such as stability analysis (Cai, Cao, Ma & Wang, 2014), consistency analysis (Liu, Wu & Qiao, 2014), convergence analysis (Qin, Gao, Hu & Ma, 2014), and boundedness analysis (Lee, Kou, Zhang, Liang & Liu, 2015).

Among these four aforementioned analyses, stability analysis also known as equilibra stability has been considered more vital because it is used to describe situations in models where the values (continuous) approach a limit under certain conditions and stabilize (Pan & Zheng, 2015; Gong, Korostelev, Bai, Biswas & Ferrese, 2015). One important note that an equillibria condition(s) is considered stable if the model always returns to it after small disturbances. These equillibria conditions are interesting to be explored, as it is possible to explain them using the knowledge from the theory or problem that is modelled (Ma, 2012). As such, the existence of reasonable equilibria is also an indication of the correctness of the model.

Another vital aspect is that in modelling, equilibra analysis focuses on the model stability solutions of trajectories dynamic systems under small disturbance. The analysis determines if a stable situation will hold or exist in the model when certain conditions are

imposed (Hu, 2012). This said equilibrium describes the situation where the stable situation has been attained and the corresponding equilibrium conditions happen to be an interesting discovery (Cepeda-Gomez & Olgac, 2011). There is a possibility of explaining these equilibrium conditions from prior knowledge of the problem or theory being modelled. The fact that a reasonable equilibrium exists, shows how correct the model under consideration is (Su & Huang, 2012). Although if a differential equation describes the dynamic of the system, then by setting all derivatives to be equal to zero, an estimation of the equilibrium can be derived (Dimarogonas & Johansson, 2010). Note that, an equilibrium condition will be considered as being stable if the system maintains its level of stability even after being acted upon by a small disturbance.

Generally, the equilibria analysis of any system modelled as a differential equation

$$\frac{dy}{dx} = f(x) \tag{2.1}$$

depends greatly on the form of the function f(x). This is because equilibria can be achieved for the system by obtaining an equilibrium solution of Equation 2.1 as a constant x, where f(x) = 0. This further implies that the constant function y(x) = 0 is a solution of the differential equation under consideration having initial condition y(0) = 0. Hence, as long as an equilibrium solution existed which is obtained as described above, the model is said to be stable, that is, retaining its properties irrespective of the introduction of a small change or disturbance.

2.7.2 Automated Verification

The approach of developing a model for the dynamics of systems with application to real life is actually very tasking. Presently, in a bid to handle this challenge, from the area of difference and differential equations, models' being referred to as continuous modelling

techniques have been developed for application in natural sciences but the success recorded is limited (Stålmarck & Säflund, 2014). For instance, to build a realistic continuous model for a given natural process, quite a number of equations together with lots of parameters are required and to analyse models of this kind is very difficult be it computationally or mathematically (Čermák, Lomuscio Mogavero & Murano, 2014).

In verification of model properties against its specifications, there are two widely used techniques for the analysis which includes checking of the model and logical proof procedures (Clarke, Emerson & Sistla, 1986). Using the approach of checking the model, a justification of the entailment relations is made through the verifying properties on the set of all theoretical traces possible gotten by executing the model of the system (Nakajima, 2002). However, for this verification or checking to be made feasible, the expressiveness of the language used for the expression of the properties and the language used for specifying the model has to be let down to a great extent (Mateescu & Thivolle, 2008). Hence, the language for the specification of the model provided by most model checkers gives room for the expression of just the simple temporal relations presented in the form of the transition rules with little expressiveness such as lack of the presence of quantifiers (Kant, Laarman, Meijer, van de Pol, Blom & van Dijk, 2015; Hutagalung & Lange, 2014). To specify complex temporal relations, quite a number (auxiliary included) of interrelated transition rules are required.

In addition, methods based on logic have been seen to be productive in application to formal qualitative modelling of systems having high levels of abstraction. Case in point, in the area of agent technology, variants of modal temporal logic have acquired a high level of popularity and also in the area of modelling social phenomenon. Though, methods based on logic most times do not possess expressions qualitatively which is

important for the modelling of accurate timing relations just like it is required in chemical or biological processes.

In addition, a lot of real life systems, for example, televisions, the human brain and a human organisation, are all seen to be hybrid in nature, meaning that they have both quantitative and qualitative aspects characteristics (Borji, Sihite & Itti, 2013). Representing and reasoning of structures and the corresponding system's dynamics requires the possibility of having an expression for the quantitative and qualitative (Chen, Han, Katoen & Mereacre, 2011). Also, to handle the challenge of scalability and complexity, there exists a demand for the possibility of presenting the system's model various levels of aggregation (Ball, Levin, & Rajamani, 2011). In a situation like this, meaningful relations between one part of the system and another should be expressed by the modelling languages.

Addressing the demand of the earlier discussed models brings about the proposition of the temporal logic which defines the symbolism and the rule of representation and reasoning in formal specification about propositions with respect to time. There are many forms of temporal logic in the vast literature such as interval temporal logic (ITL) (Allen & Ferguson, 1994), hennessy-milner logic (HML) (Larsen, 1990), computational tree logic (CTL) (Reynolds, 2001), linear temporal logic (LTL) (Vardi, 1996), metric interval temporal logic (MITL) (Koymans, 1990), signal temporal logic (STL) (Donzé & Maler, 2010) and temporal trace language (TTL) (Bosse, Jonker, van der Meij, Sharpanskykh & Treur, 2006). However, linear temporal logic and temporal trace language are specifically met for modal temporal logic because their modalities properties is time based and can be used for predictive function of future paths such as referring to the future trueness of a condition for another condition to be true (Gabbay, 2003). These two are also known as propositional temporal logic (PTL) because of their property of time

based however, only temporal trace language (TTL) has been found to express quantifier properties in terms of quantitative and qualitative (Bosse, Jonker, Van der Meij, Sharpanskykh & Treur, 2009; Tabakov, Kamhi, Vardi & Singerman, 2008). This quantifier expression aid modeling processes for an accurate formal specification with respect to time which is vital in biological, chemical and physical researches like agent-based modelling phenomenon.

Thus, most researches in agent specification tend to made use of temporal trace language (TTL) more recently due to its capability to quantifier specifications (Herd, Miles, McBurney & Luck, 2015; Jonker, Popova, Sharpanskykh, Treur & Yolum, 2012; Sharpanskykh & Treur, 2010). TTL subsumes languages on the basis of temporal logics and differential equations. At varying abstraction levels, TTL supports the system behaviour specification and generally, the expressiveness of the modelling languages has the limitation of the possibility to produce efficient and effective performance when analysing the models (Herd, Miles, McBurney & Luck, 2015). Some of the procedures for analysing complex systems are verifying the dynamic properties on the specifications of the model and traces which is generated as a result of simulation or probably empirically obtained, and simulation with focus on system models. TTL is a variant of an order-sorted predicate logic, where the standard multi-sorted predicate logic is used for the representation of static properties. It is an extended version of such language with facilities so explicit in the representation of the systems' dynamic properties. In the specification of state properties for the components of the system, there is use of ontology being specified by sorts of numbers, variables, sorted constants, predicates and functions. These state properties follow these specifications on the ground of this ontology with the application of a standard multi-sorted first-order predicate language. For instance, given every system component A (environment, agent or a group of

agents,) for the specification of different types of state properties, quite a number of ontologies can be distinguishably adopted.

In addition, in a bid to present verification for the developed model, that is, showing whether it truly produces results that correspond to psychological literatures, a group of properties will be adopted from related literatures. Next, there will be a specification of the properties using TTL, where this TTL is built on atoms to states of the world, traces and time points. The presentation of this relationship can be given as *holds(state (γ, t), p) or state(γ, t) |= p,* meaning that state property *p* holds in the state of trace *γ* at time point *t* (Bosse, Jonker, Van der Meij, Sharpanskykh, & Treur, 2009). A comparison can be made to the *Holds*-predicate in the Situation Calculus. Hence, on the basis of this concept, there can be a formulation of the dynamic properties with the use of a hybrid sorted predicate logic approach, with the application of quantifiers over time and traces and first-order logical connectives like ∧, ∨, ¬ and ∃.

2.8 Summary

This chapter explored in details major definitions and understanding within agent technology and grounding it with underlying concept of persuasion, behavioural change and psychological reactance. Also underlying theories and principles from developmental psychology were used to explain the concept of psychological reactance and its effect on persuasive agent to achieve audience behavioural change. Behaviour Change Models were explored and different researches done with these models as relating to behaviour change. This chapter has shows that there are limited studies done on persuasive agents and that most of these studies do not achieve successful behaviour change due to the effect of psychological reactance. It has also been seen that there are no model in the litereature that specifies how psychological reactance can be reduced in order for successful behaviour change to occur. Fourthermore, the chapter has shown the

important application of ABM, formal model and various agent-based verifications which will enrich this study quest. Thus, the chapter has provided theoretical understanding on which persuasive agent formal model can be formalized while Chapter Three explores the research methodology to answer all the research questions.

CHAPTER THREE

METHODOLOGY

Chapter Two presents the literature in the domain of agent technology, behaviour change, psychological reactance and computational model with underlying principle and theories. This chapter will describe the methodology that was used in answering the three research questions as stated in Chapter One. Section 3.1 presents the study framework as a reference for this study while Sections 3.2, 3.3, 3.4, and 3.5 present steps taken in answering all of the research questions. Finally, Section 3.6 concludes this chapter.

3.1 Research Framework

In this section, a framework is structured which includes the underlying principles, standards, procedures for study analysis, interpretation of results and conclusion. The framework implemented was based on Drogoul, Vanbergue, & Meurisse (2002) which is known as agent based simulation methodology as shown in Figure 3.1.

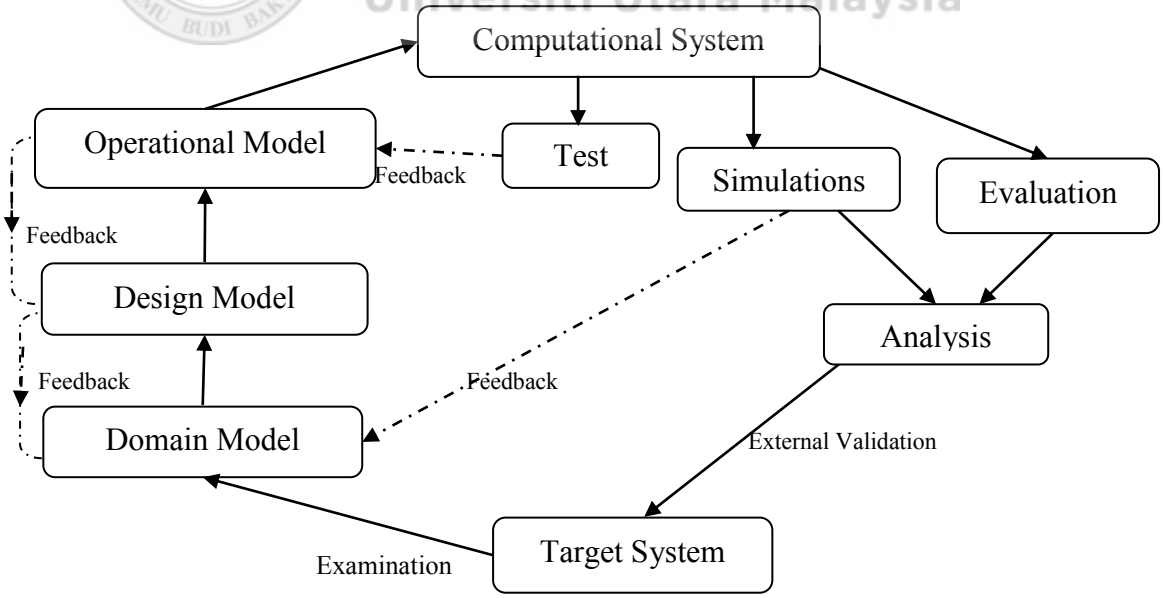

Figure 3.1. Research Methodology (Drogoul, Vanbergue, & Meurisse, 2002)

The framework was used as a guide to develop and validate the formal model which was grouped into five phases namely domain, design, operational, simulation and evaluation phases. For the formal model development, the first three phases (domain, design and operational) were used whereas for the model validation the remaining two phases (simulation and evaluation) were used. Figure 3.2 depicts the implementation and expected outcomes of these five models in this study starting from domain model to model evaluation.

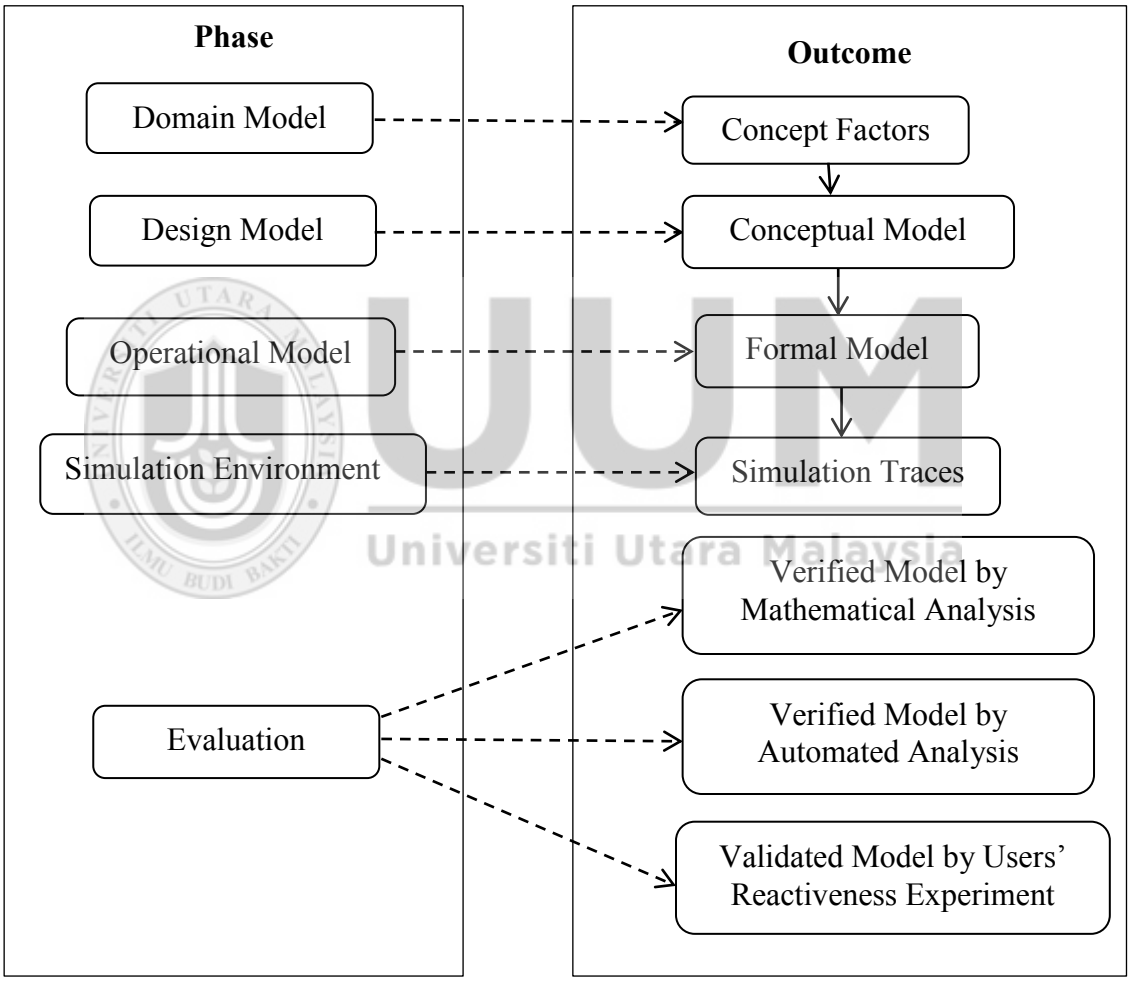

Figure 3.2. Methodology Model Flow with Outcomes

Agent based simulation methodology is employed in this current study because it focuses on model-oriented method compared to computer simulation methodology that is task-oriented. Task-oriented deals with simple entities or individuals as reactive to task

whereas model-oriented depicts the interactions among entities or group within a dynamic and unpredictable manner. The unpredictable manner makes these interactions to be complex in nature whereas decentralize methodology is considered applicable for their formal representations and analyses (Macal & North, 2010).

This methodology has been employed by many agent based modelling studies in different domains like in agriculture (Schreinemachers & Berger, 2011), economics (Luna & Stefansson, 2012), social behaviour (Conte & Paolucci (2014), environment (Serrano, Moncada, Garijo & Iglesias, 2014), medicine (Wang, Butner, Kerketta, Cristini & Deisboeck 2015) and energy consumption (Rai & Robinson, 2015). Each of these phases has different activities to achieve the study objectives as shown in Figures 3.3, 3.6, 3.9 and 3.11.

3.2. Domain Model Phase

This first phase is where the foundation of the study is created. It involves definition of the research objectives and identification of agent persuasion factors that lead to behaviour change. Examination of behaviour change and psychological reactance literature are conducted to identify important factors in persuasive agent. Figure 3.3 shows the activities undertaken for the examination.

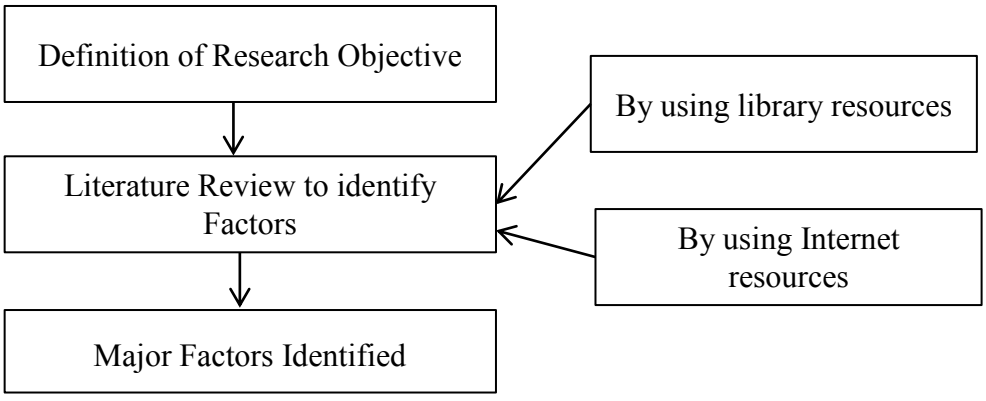

Figure 3.3. Domain Model Phase Activities

The investigations are done on persuasion, behavioural change and psychological reactance theories, models and empirical studies. This is based on Staples and Niazi (2007) suggestions to search for multiple bibliographic databases, reference list of previous eligible reviews, contacting scholars, conference proceedings, key journals and seminar articles on agent, behavioural change and psychological reactance studies. The outcome of this phase are fully presented and discussed in Chapter Four of this thesis which provides answer to the first research question.

3.3. Design Model Phase

This second phase is where the identified factors with their relationship were represented to design a conceptual model. Figure 3.4 shows the activities that were followed to achieve the representation. The representation followed the procedure used by Bosse, Hoogendoorn, Klein, Treur and van der Wal (2011).

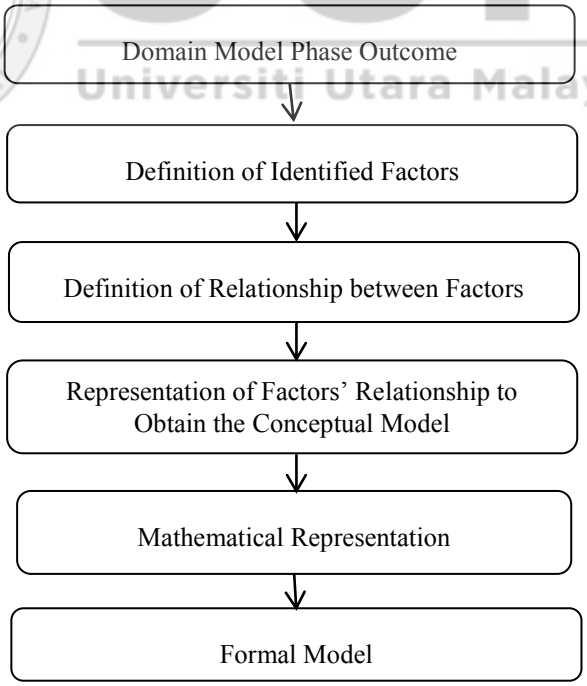

Figure 3.4. Design and Operational Model Phases Activities (Klein, Treur & van der Wal, 2011)

The obtained factors from the domain phase were given concept in the context of the study which is the definition of identified factors activity. Later, it followed by the definition of relationship activity where each factor interactions with other factors were obtained based on underpinning theories of each factors concept. This was achieved by defining the nature of these factors, as being instantaneous or temporal. Temporal factors are these that are time-bound and evolve with respects to changes in time whereas; instantaneous factors are not time-bound. The criterions for the relationship were based on the underpinning theories, models and empirical studies of the factors concepts. These two activities eliminate any overlapping of factors concepts. The outcome of this phase is presented in Chapter Four as the design model.

For instance, if *A, B*, *C* and *D* are identified agent factors obtained from domain model phase then the design model is given in Figure 3.5. It could be seen that the design model depict the relationship between the four factors (*A, B*, *C* and *D*). This relationship is based on theories where the factors were identified and the concept will be well explained under the domain model phase.

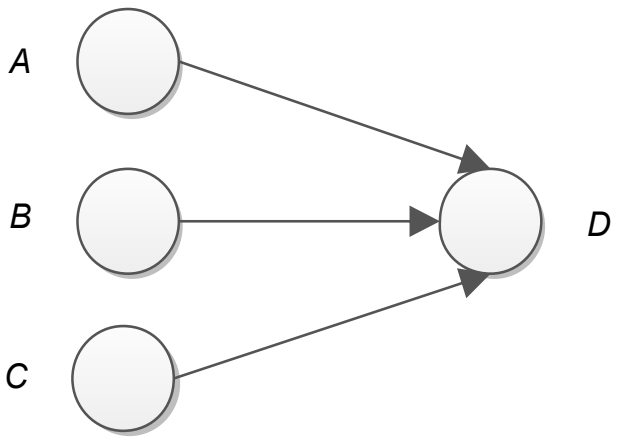

Figure 3.5. Example of Design Model

3.4. Operational Model Phase

This third phase is where the represented factors were formalized to obtain formal model which answer the second research question and objective. Figure 3.4 show the activities that were followed to achieve the formulation. The design model obtained under the second phase was formalized using dynamic system in differential equation which was also used by Conte and Paolucci (2014), Serrano, Moncada, Garijo and Iglesias (2014), Rai and Robinson (2015). This involved using formal specification and representation by symbolic representation of the design model. The major different between the design model and operational model is that the outcome of the domain model gives a conceptual model (design model) while the outcome of operational model gives the formal model which is presented and discussed in Chapter Four.

For instance, from Figure 3.5 under design model the relationship of the three identified factor under domain model phase was presented. It can be seen that *A, B* and C interacted to determines the phenomenon in *D*. This interaction is stated in the theory which creates the relationship as in Figure 3.5. Based on this theory, it can be assumed that from equation 3.1, 3.2 and 3.3 that if these are non-zero or not equal to 1 then it depicts the concepts conditions stated in Table 3.1 which can be further formalized to obtain equation 3.4. Assuming D is a combination of factors as depicted in Figure 3.5, therefore

$$D = f[A, B, C] \tag{3.1}$$

$$\text{Where } 0 \leq A \leq 1,\ 0 \leq B \leq 1,\ 0 \leq C \leq 1 \text{ and } 0 \leq D \leq 1 \tag{3.2}$$

Table 3.1
Example of Different Condition of D

Condition	Factor's values	D value	Description
Condition 1	*A*=low *B*=high *C*=high	*D*=high	D will be high when A, B or C are high
Condition 2	*A*=high *B*=high *C*=high	*D*=high	
Condition 3	*A*=high *B*=low *C*=low	*D* = low	

$$D(t) = W_{d_1} A(t) + W_{d_2} B(t) + W_{d_3} C(t) \tag{3.4}$$

where $\sum_{j=1}^{3} W_{d_j} = 1$

and W_{d_1} , W_{d_2} and W_{d_3} are the weight of the equation.

From Equation 3.4 it can be inferred that *D* will be high when any two of *A, B* and *C* are high. This gives the formal model for C and any of these three conditions state in Table 3.1 can be further investigated which can be implemented in a simulation environment. The procedure for the simulation environment will be explained in the next section.

3.5. Simulation Phase

The obtained formal model in the operational phase was implemented in numerical simulation environment. The outcome of the simulation phase provides scientific reasoning which gives the fundamental behaviour of the formal model in the simulation environment. Similarly, it provides insight into behavioural change phenomena by showing the complex interactions among factors. The simulation environment was implemented in a numerical simulation environment using Matlab. Figure 3.6 shows the activities that are performed in order to achieve the simulation result. The first activity in

the simulation phase is known as the executable model which is the coding of the formal model in the numeric simulation environment. This was done using Matlab codes to implement the formal model in the numerical environment. In this environment, the executable model was simulated by assigning scenario of cases or conditions. These cases generated simulation output which executed were presented and discussed in Chapter Five. The simulation output are the simulation traces that depict the behaviour of the formal model. The results obtained in this research phase provide answer on the third research question and objective. The designed formal model will be evaluated in the next phase.

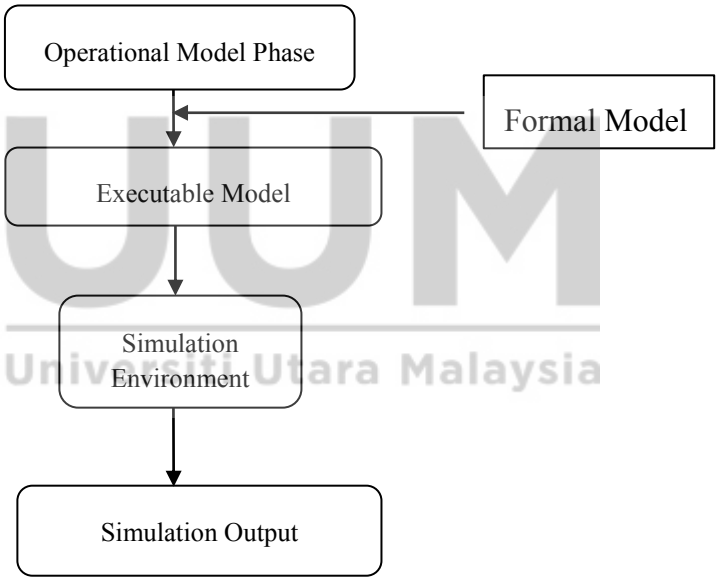

Figure 3.6. Simulation Phase Activities (Drogoul, Vanbergue & Meurisse, 2002)

For example, the simulation trace for Equation 3.4 using parameter combinations as stated in Table 3.2 is depicted in Figure 3.7. From Figure 3.7 it can be seen that the combinations of *A, B* and *C* provide a simulation trace that stabilized at time steps 100 which explains the simulation trace of *D* whereas level axis denotes the range value of D in terms of high (1) and low (0). On the other hand, time steps axis denotes the time range of D where 1time step represents 1hour.

Table 3.2
Example of Values of A, B and C

Concept	A	B	C
Values	0.3	0.7	0.5

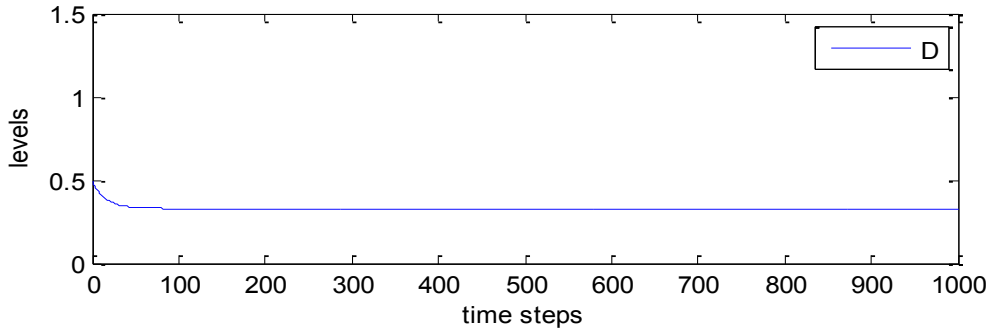

Figure 3.7. Simulation Trace of *D*

3.6. Evaluation Phase

Evaluation ensures that the formal model is the actual representation of the phenomenon under investigation. It also helps to gain insight into reflection and improvement of the formal model which can assist future modification and implementation (Gangemi, Catenacci, Ciaramita & Lehmann, 2005). The evaluation phase was done in two sub-phases namely, verification and validation as shown in Figure 3.8.

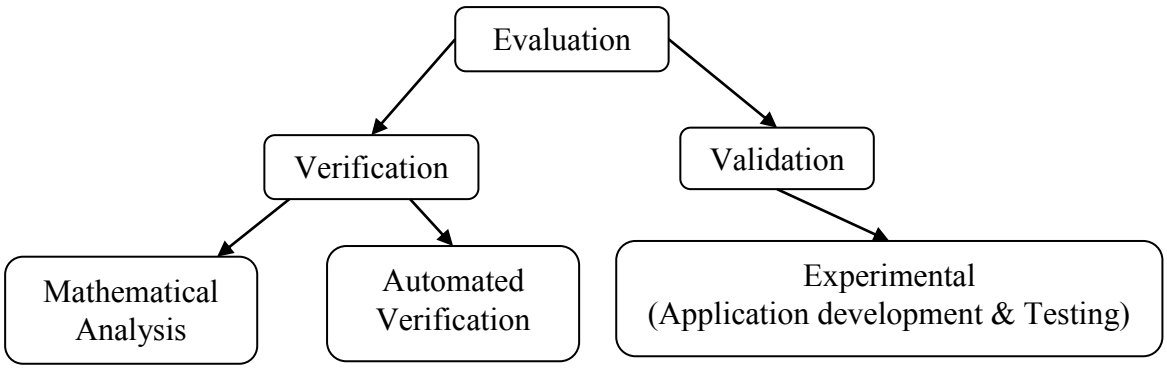

Figure 3.8. Evaluation Phase Activities

3.6.1 Verification Analysis

Verification analysis is the process of determining that the purpose of formalization is sufficiently achieved. It is aimed at the degree of correctness of the representation of the real target system as intended by the study (Thacker, Doebling & Hemez, 2004). The analysis is a form of model checking where all the representations, formalizations, and specifications of the formal model are checked for accuracies and consistencies. In order to ensure that checking process of these parameters in the proposed model are achieved, this study employed two different verification analyses namely mathematical and automated analyses. Figure 3.9 depicts the verification process that was involved on the proposed model.

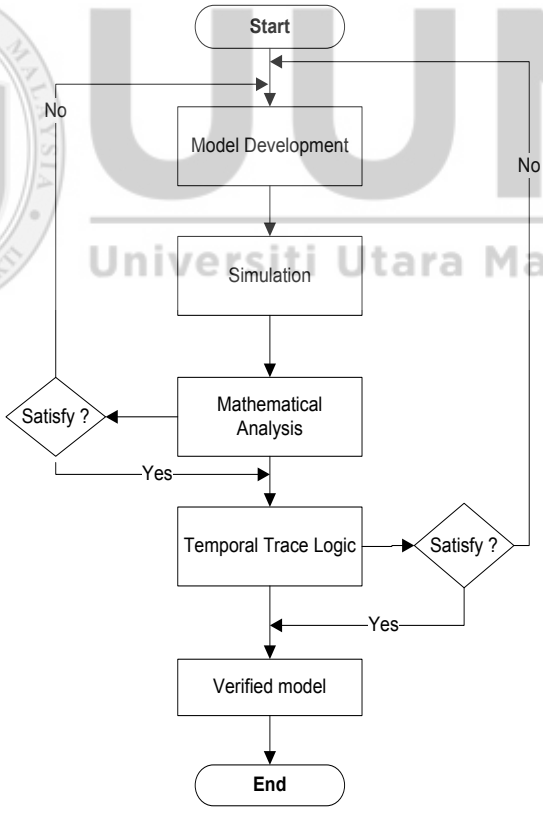

Figure 3.9. Model Verification Process (Aziz, Ahmad, Crepa & Mohd-Yusuf, 2013).

The proposed model is depicted as model development which when implemented in the numerical simulation environment will produce a number of simulation traces. Later, the model is verified using mathematical analysis which when satisfied will be further verified by temporal trace logic. Satisfied condition implies that the obtained result is consistent with previous related empirical studies in the literature and underpinning theories. However, if the verification of both were not satisfied then the procedure will be repeated from model development phase. The results of mathematical analysis and temporal trace logic analysis will provide a verified model which is the desired outcome of the verification analysis. The two following subsections (3.6.1.1 and 3.6.1.2) further explain the procedures that were used in verifying the model.

3.6.1.1 Mathematical Analysis

This analysis examined the correctness of the formal model representation and formalization which basically aimed to ensure that all syntax and semantic representations used in the formal model is consistent. There are many types of mathematical analyses such as real analysis, complex analysis, functional analysis, differential equation analysis, measureable analysis and numerical analysis (Balakrishnan, 2012). However, for this study numerical stability analysis which is also known as equilibria analysis was adopted because of the need to check the stability of finite specifications in the proposed model. In addition, to the fact that this analysis was based on Fourier decomposition of numerical error which addresses trajectories dynamic nature of the model under any small perturbations conditions and it is able to detect errors in any model even with a small disturbance (Das, Goswami, Chatterjee, & Mukherjee, 2014). Furthermore, the analysis was implemented in this study because of it wide usage in agent based simulation studies such as Cai, Cao, Ma and Wang (2014),

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It can be deduced from Figure 3.10 (a) to (c) that stability point is reached as the model simulation traces derivatives converges. This occurs when the model expands and the round-off error tends to zero or the truncation error vanished to zero. It gives a condition within the model whereby no increment (either large or small) can disturb (displace) the model at this stability point whereas Figure 3.10 (d) to (f) depict the opposite of these conditions simulation traces.

3.6.1.2 Automated Verification

This study's automated verification was utilized on Temporal Trace Language Logic (TTL) to confirm that the obtained results are consistent with the literature and previous empirical findings. The Temporal Trace Language (TTL) is used to perform an automated verification of specified properties and states against generated traces (Sharpanskykh & Treur, 2010; Bianculli, Ghezzi & Krstić, 2014). This was done by defining the proposed model ontology *Ont* which was assigned truth-values {true, false} based on the set of ground atoms *At(Ont)*. The set of all possible states for the ontology *Ont* was denoted by STATES(*Ont*). Therefore, STATES(*InteractionOnt*) is the set of *all interaction states*. The standard satisfaction relation |= between states and state properties was used as *S* |=*P* which means that property *P* holds in state *S*. Here, |= is a predicate symbol in the language which was used as infix notation (Lei, Qiu, & Shao, 2014; Ferrère, Maler & Ničković, 2015). The standard satisfaction relation was comparable to *Holds*-predicate in the modal logic formalization which represented the dynamic nature of the model. This is because a dynamic model is as a result of series of case conditions at different time interval within the model which are the cases representation of history of action. In addition to this, a fixed time *T* is assumed which is linearly ordered. Therefore, a trace γ over the model ontology *Ont* and time frame *T* as time-indexed set of states formalized as, $\gamma_t(t \in T)$ in STATES(*Ont*) mapped as;

$$\gamma: T \rightarrow STATES(Ont)$$

Thus, from the TTL a direct references based on the model case conditions were made to the time points and simulation traces while the relationship is presented as a *state(γ, t, output(R))|= p*, which means that state property *p* is true at the output of role *R* in the state of trace *γ* at time point *t*. In this verification, these kinds of atoms were referred as *Holds atoms*. Based on such *Holds atoms* the dynamic properties (from the differential equations) were built using the basic logical connectives and quantification. For example, the following dynamic properties was expressed based on the model factor of belief (*Bf*): In any trace, for any points in time *t1* and *t2* after *t1*, if the agent *A* has the belief *b* at t1 in the trace, then agent A has the belief b at *t2* in this trace. In formalized form, this statement was represented as:

$$\forall \gamma \in W \ \forall t1,t2$$
$$[state(\gamma,t1, internal) \models b \ \& \ t1 \leq t2$$
$$\Rightarrow state(\gamma,t2, internal) \models b]$$

Based on this concept, several dynamic properties were formulated using a sorted predicate logic approach on the formal model in order to verify it.

3.6.2 Validation

For the validation, this study made use of user-centred experiment approach which was adopted from Powers (2015) and Hong (1992). It was suggested by Hong (1992) that psychological reactance is best measured with users' experiences. Hence, it necessitated the development of the study application and the adoption of user-centred approach where the experiences of the users' were used to determine the workability of the model. Similarly, Powers (2015) pointed out recently that statistical approaches are one of the most suitable validations for computational model because the approaches explain the

phenomenon of the model both quantitatively and qualitatively which will be clearer and explicit in comprehension. Quantitative and qualitative approaches are widely used in behavioural computational science to give further clarification and explanation that mathematical relation might not provide. Thus, this study made use of both qualitative and observatory research approaches to validate the formal model. Whereas, the observatory research and qualitative mixed approached was based on Madigan et al., (2014) which suggested that observatory research can be used to triangulate qualitative research approach for a better validation.

3.6.2.1 Survey Validation

The study instrument was based on survey research approach which made use of closed ended questions to get information from respondents. The survey had six sections (A-F) where Section A focused on demographic of the respondent such as name of the respondent and parents details. Section B was on personality traits of the respondents which were based on suggestions from Senapati, Patnaik and Dash (2012), Restrepo, Vasquez, Alvarez and Valencia (2008), Growe and Levinson (1980), Willis and Seymour (1978) and Lessing and Barbera (1973). Ten personality traits were investigated but were grouped into five major categorises namely outgoing and reserved, more intelligent and less intelligent, affected emotionally and emotionally stable, excitable and phlegmatic, obedient and assertive.

These personalities' trait questions were taken from the children personality questionnaire (CPQ) which is specifically design for children within 7-12. It was used to measure their personal, social, and mental aspects of personality that mediate behaviour change process. Section C of the survey enquired on general knowledge of the target behaviour while Section D-F was used to examine respondents' reactance with the interacted application. Section D-F was formulated base on psychological reactance

measurement developed by Hong (1992) and suggestions from Salam, Yahaya and Ali (2010). Specifically, Section D questions were asked immediately after interaction with the application while Section E was asked after two weeks of interaction and Section F was asked after four weeks. The survey was formulated in the local dialect of the respondent as show in Appendix X while Appendix IX shows the survey in English language version.

3.6.2.2 Validation Protocol

The model validation followed user-centred design approach where a persuasive application was developed based on the proposed formal model based on suggestion from Yusoff, Zulkifli and Mohamed (2011) and Salam, Yahaya and Ali (2010) studies. The persuasive application was used to carry-out a study and the conclusion of the study conferred the validation and justification on the model. The validation study made used of Malaysian children within the age range of 7 to 9 years as study respondents. This group of children was selected because they have been identified to have poor oral hygiene due to their lack of motivation and inabilities to achieve proper and clean teeth brushing (Edelstein, 2002; Saddki, Yusoff, & Hwang, 2010; Gao, Hsu, Xu, Loh, Koh & Hwarng, 2010; Sharma & Yeluri, 2012). The survey research approach using survey with closed ended questions was used to get information from the respondents. The survey was formulated based psychological reactance measurement instrument developed by Hong (1999) and also, suggestions from Salam, Yahaya, and Ali (2010) study were followed. The survey was formulated in the local dialect of the respondent (see Appendix X for the study survey). The study engaged the service of an interpreter that is very fluent in both Malaysia Bahasa and English languages. This is important to eliminate the possible communication gap between the researcher and the respondents.

The study made use of 30 respondents using purposive sampling. The target behaviour of this study was the ability for respondents to perform teeth brushing daily. Purposive sampling technique is used because only respondents that lack the target behaviour were selected for the study respondent which was based on voluntarily only. The selection was done by conducting a pre-interaction survey with the respondent with the help of their class teacher. Based on Hansen (2006) and Patton (1990) a quiet and transparent room was used as research site where respondents were asked to interact with the persuasive application. Prior to the engagement of the respondents in the study, only those that are found to be lacking in the target behaviour of teeth brushing are selected for the study which was done based on respondents history as given by their class teachers. Each selected respondent were guided to complete Part A, B and C of the study survey which is made up of demographic and general knowledge about the respondents. Then, the selected respondents were made to interact with the application which lasted for about twelve (12) minutes.

During the interaction, observatory research approach was used to take note of respondents' action, feelings, reaction and body languages and picture capture of it were presented in Appendix VII. Observatory and survey research approaches were employed because they were the most suitable approach for the target respondent because many children might not be able to fully express their minds and opinions on subject matter (Einarsdottir, 2005). Similarly, Robson (1999) advocated that observatory research is used to validate findings from survey research approach. Immediately after the interaction, the respondents were guided to complete Part D of the study survey as the post-interaction phase. After two weeks and one month of the first interaction which denote the reinforcement, respondents were guided to complete Part E and F of the study survey respectively. Immediately after the completion of the survey, each respondent

was treated with goodies and gifts for taking part in the study. These activities were summarized in Figure 3.11.

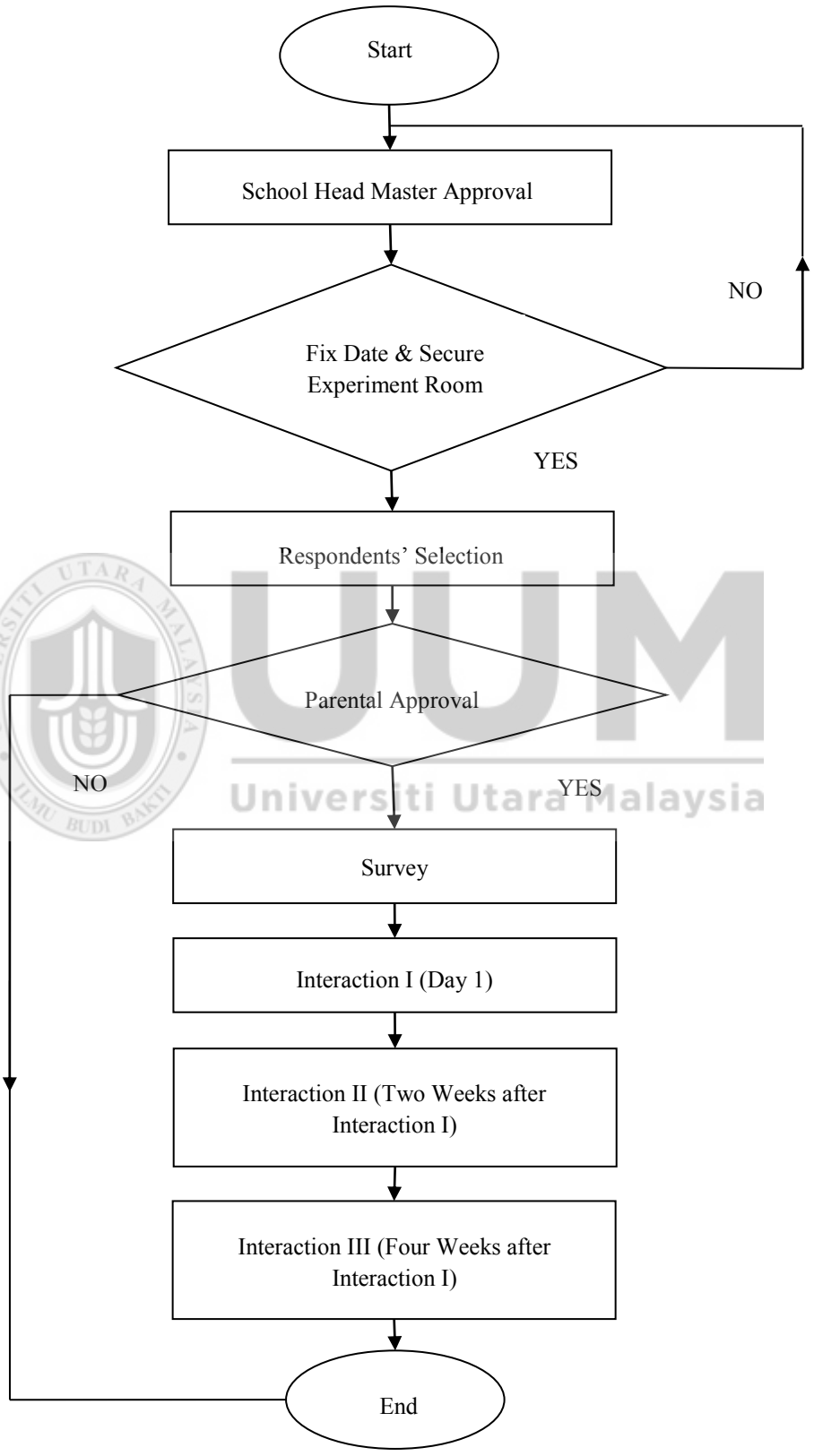

Figure 3.11. Validation Phase Flow Chart

For this study, both participation and non-participation observatory approaches were adapted which is based on Hansen (2006). Unstructured observatory research approach was adopted where the researcher took note of respondent behaviour, action, feelings, reaction and body language during the usage of the application. Each of these body responds during the usage of the application will help to understand how respondent perceived the application. There was a video recording with the use of camcorder for documentation of the sessions. Each session started with an ice breaking exercise for up to ten minutes which was used to ensure and improve familiarity, building of confidence and rapport among all the respondents.

The ice breaking exercise included questioning respondent if they have eaten and the type of food that ate. Other questions like their hobbies and colour likeness were asked in order to build familiarization and confidence. For the observatory research approach the instrument developed by de Lera and Garreta-Domingo (2007) was used to analyse data collected via camcorder while for the survey research approach SPSS Version 19 was used to analyse data collected via the study survey. The two results triangulate each other to form the validation for the proposed model. The results obtained in this phase provide answer to part of the third research question and objective. In summary, Table 3.3 shows the mapping of the research phases, methods, expected outcomes with corresponding research questions and objectives.

Table 3.3
Summary of the Research Phase

Phase	Method	Outcome	Research Question	Research Objective
Domain Model	Critical Literature Review	Agent Persuasion Factors	1	1
Design Model	Mathematical Specifications based on Literature Review	Formal Persuasive Agent Model	2	2
Operational Model	Coding / Simulator Development			
Simulation	Numerical Simulation Environment (Matlab)	Simulated Results	3	3
Evaluation	Observatory and Survey Research Approaches	Model Evaluation and Measurement of Persuasive Expression in Agent		

3.7 Summary

This chapter had looked into the methodology that was employed to answer the three research questions as stated in chapter one. The chapter took strength from previous studies such as Drogoul, Vanbergue, and Meurisse (2002), Pape and Tchoshanov (2001) and Hong (1999), whereas, Drogoul, Vanbergue and Meurisse (2002) was used as the main study methodology. The five main phases that made up the study methodology with their corresponding sub-phases will provide answers to the three research questions.

CHAPTER FOUR

MODEL DEVELOPMENT

This chapter discusses detail explanation on the development of an agent based model, a support model and an application development using the methodology presented in Chapter Three. The chapter clearly stated the phases and activities undertaken to develop these models such as domain, design and operational phases. Furthermore, this Chapter depicts how the models were utilized in the development of an application known as Dr Clean.

4.1 Agent Formal Model Development

The agent formal model was developed following three main phases namely domain, design and operational. These three phases are also known as construction phase because the rigorous step-wise development of the model were done based on many activities at each phase as stated in Chapter Three of this study under methodology. The following sub-sections present the results at each phase.

4.1.1 Domain Model Phase

The main aim of this phase was to identify persuasion factors in behaviour change. This was done based on literature review and empirical studies as stated in Chapter Three. The results from this phase presented twenty two (22) important factors. The identified factors were classified into three categories depending on the relations amongst the factors which form the model concepts. These factors classification include external, instantaneous and temporal. External factors are independent factors which contribute to other factors. Instantaneous factors are dependent factors that are non time bound

whereas temporal factors are time bound factors. Tables 4.1, 4.2 and 4.3 summarize the three classifications.

Table 4.1

External Factor Concept

No	Factor	Notation	Description	Related Theory	Reference
1	Ability	*Ab*	The capability to perform a behaviour	FBM, SET	Bandura (1977), Franklin & Graesser (1997), Fogg (2009), Bradshaw, Feltovich & Johnson (2012), Shaffer, Tendick and Davis (2014), De Massis, Kotlar, Chua & Chrisman (2014)
2	Behaviour Knowledge	*Bk*	The knowledge about the behaviour	TM, FBM	Kenkel (1991), Prochaska & Velicer (1997), Fogg (2009) Prochaska, Wright & Velicer (2008), Patterson & Nochajski (2010), Patterson & Buckingham (2010)
3	Behaviour Task	*Ba*	Nature of the behaviour	TPB, TRA	Alm & Nilsson (1995), De Dreu & Weingart (2003), Marks & Badovick (2015), Waugh, Brownell & Pollock (2015), Landers & Landers (2015)
4	Social Influence	*Si*	External factors that enable the behaviour	TPB, TRA	Marsella, Pynadath & Read (2004), García-Díaz & Moreno-Monroy (2012), van Maanen & van der Vecht (2014), Ruijten, Ham & Midden (2014), Zhang, Tong, Lamberson, Durazo-Arvizu, Luke & Shoham (2015)
5	Planned Action	*Pa*	The authorization of the behaviour or action	SET, TPB	Grosz and Kraus (1996), Intille and Bobick (2001) and Gasderell (2014)
6	Belief	*Bf*	A psychological state in which an individual holds a conjecture or premise on the validity and truthfulness of a behaviour or action	TPB, HBM, TRA	Hill, White, Marks & Borland (1993), Vitousek, Watson & Wilson, (1998), Baranowski, Cullen, Nicklas, Thompson & Baranowski (2003), Dawkins, Powell, Pickering, Powell & West (2009)

HBM – Health Belief Model, TPB – Theory of Planned Behaviour, RMP – Relapse Prevention Model, TM – Trans-Theoretical Model, SET – Self-Efficacy Theory, FBM – Fogg Behaviour Model, TRA – Theory of Reasoned Action, SRT – Self Regulatory Theory

External factor includes ability which Fogg behaviour model (2009) seen as the acquired condition that enables an agent to perform a particular task successfully. Self-Efficacy Theory by Bandura (1977) explained Ability (*Ab*) in term of agent capability or talent resolved or accomplished successful specific situations or in order to achieve a defined task. Based on these two theories used in previous studies like Franklin and Graesser

(1997), Bradshaw, Feltovich and Johnson (2012), Shaffer, Tendick and Davis (2014) and De Massis, Kotlar, Chua and Chrisman (2014), ability is connoted in this study as the capability for agent to successfully perform a defined behaviour or action. In addition, behaviour knowledge expresses agent understanding, familiarity and awareness on a target behaviour or action. It includes all the information, skills, facts and descriptions that an agent acquires in order to perform target behaviour or action. This is based on Trans-Theoretical (Prochaska & Velicer, 1997), Fogg's behaviour model (2009) and other empirical studies like Kenkel (1991), Prochaska, Wright and Velicer (2008), Patterson and Nochajski (2010) and Patterson and Buckingham (2010).

In the same vein, behaviour task defines the simplicity and complexity nature of the target behaviour or action which was taken from Theory of Reasoned Action (Fishbein,1979, Sheppard, Hartwick & Warshaw, 1988, Bang, Ellinger, Hadjimarcou & Traichal, 2000, Aleassa, Pearson & McClurg 2011, Bagozzi, Wong, Abe & Bergami, 2014, Kuo, Roldan-Bau & Lowinger, 2015), Theory of Planned Behaviour (Ajzen, 1991, Ajzen & Driver, 1992, Armitage & Conner, 2001, Ajzen, 2011, Kautonen, Van Gelderen & Tornikoski, 2013, Sniehotta, Presseau & Araújo-Soares, 2014, Lettow, Vries, Burdorf,, Conner & Empelen, 2015, Lapkin, Levett-Jones & Gilligan, 2015) and from other literature like Alm and Nilsson (1995), De Dreu and Weingart (2003), Marks and Badovick (2015), Waugh, Brownell and Pollock (2015) and Landers and Landers (2015). Another identified factor is social influence which depicts agents' external phenomenon that affects or change agent state in order to perform a behaviour or action. Social influence causes intentional or unintentional behaviour and it usually alters the mental instance of agent which can make the agent achieve its defined task or otherwise within its located environment. The factor has been previously explored in studies like Marsella, Pynadath and Read (2004), García-Díaz and Moreno-Monroy (2012), van Maanen and

van der Vecht (2014), Ruijten, Ham and Midden (2014), Zhang, Tong, Lamberson, Durazo-Arvizu, Luke and Shoham (2015) which has its root from Theory of Reasoned Action and Theory of Planned Behaviour.

Furthermore, the planned action depicts the authorization of an agent over its behaviour or action which is a function of the agent mental instance (Ferber, Gutknecht & Michel, 2004). It involves the willingness and intention of an agent to execute its desire, action and behaviour. This is because when an action or behaviour is perceived, intended or desire does not translate to the agent having premises to execute it (Kinny, Georgeff & Rao, 1996). This concept was inferred from previous studies like Grosz and Kraus (1996), Intille and Bobick (2001) and Gasderell (2014) which derived from Self-Efficacy Theory (Bandura, 1977) and Theory of Planned Behaviour (Armitage & Conner, 2001, Ajzen, 2011, Kautonen, Van Gelderen & Tornikoski, 2013, Sniehotta, Presseau & Araújo-Soares, 2014, Lettow, Vries, Burdorf,, Conner & Empelen, 2015). Table 4.2 and 4.3 shows the temporal and instantaneous concepts of the proposed agent-based model.

Table 4.*2*
Temporal Factor Concept

No	Factor	Formalization	Description	Related Theory	Reference
1	Dissatisfaction	*Df*	Negative reaction toward the behaviour	HBM, TPB	Dijkstra, Conijn, & De Vries, 2006; Sofronoff, Attwood, Hinton & Levin, 2007;
2	Consistency in Action	*Ca*	A state when the action or behaviour is obtainable continuously	RPM, TM	Cohn & Fredrickson, 2010; Fishbein & Ajzen, 2011; Teixeira, et al, 2012; Fishbein & Ajzen, 2011;
3	Consistency Refusal in Action	*Cr*	A state when the behaviour or action is deflected continuously	SET	Wicker, 1969; Chartrand, Dalton & Fitzsimons, 2007 McNulty & Russell, 2010; Dunn, et al, 2012;

HBM – Health Belief Model, TPB – Theory of Planned Behaviour, RMP – Relapse Prevention Model, TM – Trans-Theoretical Model, SET – Self-Efficacy Theory

Table 4.*3*

Instantaneous Factor Concept

No	Factor	Formalization	Description	Related Theory	Reference
1	Attitude to Change	*Ac*	Mental state	TPB, TRA	Prochaska, 2013; Petty & Krosnick, 2014
2	Challenge	*Cg*	Perceived obstacle or impediment	HBM, TPB	Kumar, et al, 2008; Montano & Kasprzyk, 2008; Prochaska, 2013
3	Motivation	*Mv*	Desire to perform the behaviour	FBM, TM, HBM	Kumar, et al, 2008; Rollnick, Miller & Butler, 2008
4	Perceived Risk	*Pr*	Negative consequences of the behaviour	HBM, TPB	Forsythe, Liu, Shannon & Gardner, 2006; Kim, Ferrin & Rao, 2008; Lee, 2009
5	Perceived Benefit	*Pb*	Positive consequences of the behaviour	HBM, TPB	O'Dea, 2003; Forsythe, Liu, Shannon & Gardner, 2006; Rothschild, Fang, Liu, Litvak, Yoon & Bates, 2006; Lee, 2009
6	Threat	*Hr*	Perceived risk to perform behaviour	FBM, HBM	Webb & Sheeran, 2006; Prochaska, 2013
7	Intention to Change	*Ic*	The Willingness to perform the behaviour	FBM, HBM, RPM	Webb & Sheeran, 2006; Schwarzer, 2008; Sniehotta, 2009
8	Negative Thoughts	*Ng*	Negative perception and belief about the behaviour	HBM, TPB	Brewin, 2006; Beck, 2011
9	Self-efficacy	*Se*	The belief in one's capabilities or ability to perform a target behaviour or action.	RPM, TPB, SET	Van't-Riet, Ruiter, Werrij & De Vries, 2010; Maloney, Lapinski & Witte, 2011; Maddux, 2011;
10	Severity of Behaviour	*Sb*	The strictness of the consequences of a behaviour or action.	HBM	Self & Rogers, 1990; Das, De Wit & Stroebe, 2003; Cameron, 2009; Feng & MacGeorge, 2010; Maloney, Lapinski & Witte, 2011
11	Desire to Change	*Dc*	Emotional sense of longing or wishing to change	TM	McConnaughy, Prochaska & Velicer, 1983; Miller & Mount, 2001; Prochaska, 2013; Barnett, Livengood, Sonnentag, Barlett & Witham, 2010; Moreno, 2014
12	Performed Action	*Pc*	A state when the behaviour or action is obtainable	SET	Prochaska, 2013; An, et al, 2013; Horwath, et al, 2013; Spring, et al, 2013
13	Action Reject	*Ar*	A state when the behaviour or action is deflected	SET	Dillard & Shen, 2005; Wright & Palmer, 2012; Murtagh, Gatersleben, & Uzzell, 2014

HBM – Health Belief Model, TPB – Theory of Planned Behaviour, RMP – Relapse Prevention Model, TM – Trans-Theoretical Model, SET – Self-Efficacy Theory, FBM – Fogg Behaviour Model, TRA – Theory of Reasoned Action

4.1.2 Design Model Phase

In this phase, the identified factors from the domain model are represented with corresponding relationships. The relationship representations are based on literature review, theories and empirical evidences which form the conceptual model. Figure 4.1 to 4.16 in the next subsection show these causal relationships that produce the conceptual model which is summarized in Figure 4.17.

4.1.3 Operational Phase

Basically, the main aim of this phase is to obtain an executable formal model to be executed in a simulation environment for further interpretation of the model. The design model obtained in the second phase with the identified factors and underlying concepts in phase one is formulated into formal representations. For the formalization, differential equation technique was used to represent the identified factors and its relationships. The formalization nodes are designed using a set of parameters ($0 \leq x \leq 1$) as low (0) and high (1) value. These set of parameters are used to regulate or control the formal model whereas details on the formalization of the model is given below:

Severity of Behaviour (*Sb*)

The Health Belief Model (Rosenstock, 1974; Carpenter, 2010; Rutter & Calnan, 2014) suggested that agents' action or behaviour is often depended on its perception of the c‹ *Figure 4.1* Design Model of Persuasive Agent . It further specifies perceived severity as one of the major factor that predicts agent behaviour or action. This refers to the consideration of agent consequences of performing an action or achieving a behaviour task based on the agent's defined objective within a situated environment. This depicts agent's mental instance on the seriousness and outcome of it action which involves risk and rejection (action reject, *Ar*) on its action or

behaviour. Thus, two major factors are found to contribute to behaviour severity. These are behaviour task (the complexity nature of the behaviour) and action reject (the risk and negative response of the target behaviour). The concept of severity of behaviour is depicted in Figure 4.1.

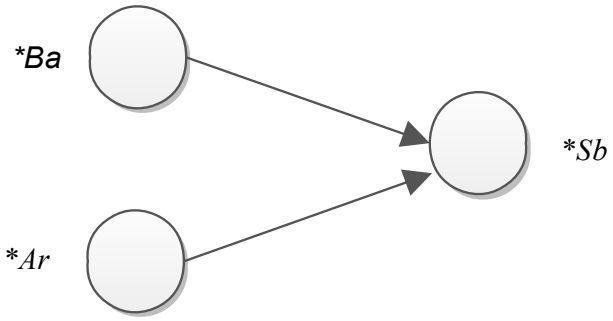

Figure 4.1. Causal Relationship of Severity of Behaviour

Therefore, severity of behaviour in this present study signifies the strictness of the consequences of behaviour or action. This is predicted by behaviour task and action reject which can be foreseen from two different conditions in the literature namely Obstinacy and Complexity conditions. Obstinacy is the condition where severity of behaviour is high which defines an extreme harsh behaviour (Vasconcelos, Santos, Pacheco & Levin, 2014). On the other hand, complexity condition describes a difficult or confusing state but not too extreme harsh in nature (French, et al., 2015). These two conditions are determined by the relationship between behavioural task and action reject. Table 4.4 shows these two conditions in the concept of severity of behaviour.

Table 4.4
Different Condition in Severity of Behaviour

Condition	Factor's values	Severity of Behaviour value	Description
Condition 1: Obstinacy	*Ba*=high *Ar*=high	*Sb*=high	Severity of behaviour is high when behavioural task and action reject are high
Condition 2: Complexity	*Ba*=low *Ar*=low	*Sb*=low	

It can be deduced from Table 4.4 that severity of behaviour is high when both behaviour task and action reject are high and verse vice. These causal relationships were used to formalize the equation 4.1.

$$Sb\ (t) = Ba(t)\ [1-(1-Ar(t))] \qquad (4.1)$$

Equation 4.1 reflects the causal linkage between behavioural task and action reject whereas both contributes simultaneously to severity of behaviour. It present a condition in which the concept of severity of behaviour is defined by the mutual contributions of both behaviour task and action reject. The contributory mutual causal relationships between these two concepts (behaviour task and action reject) determines the resultant nature of severity of behaviour as being obstinacy or complexity.

Challenge (*Cg*)

From Health Belief Model (Carpenter, 2010) and Theory of Planned Action (Ajzen & Sheikh, 2013) the challenge factor was identified as a predictive behaviour or action. Challenge is referred to an agents' mental instance which propels the drive to overcome perceived obstacle and impediment in order to achieve target behaviour or accomplished a defined task or action. Three factors were found to directly influence challenge namely ability, social influence and motivation (Crone & Dahl, 2012). These three factors define the concept of challenge in this study Figure 4.2 depicts the concept of challenge.

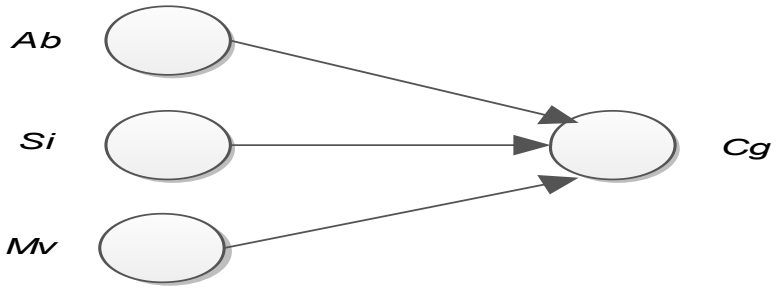

Figure 4.2. Causal Relationship of Challenge

Thus, the concept of challenge in this present study depicts an agent's drive to overcome perceived obstacle or impediment toward target behaviour or action in order to achieve its predefined objective within its situated environment. This concept can be viewed from three conditions namely disability, highly motivated and socially retarded (Chevallier et al 2012). Disability condition denotes agents without action capability but is mentally motivated and socially encouraged to preform target actions. Highly motivated condition illustrate agents with enabling ability, social influenced and mentally motivated to preform target actions whereas socially retarded condition describes agents that lack social support to perform target actions. Table 4.5 illustrates and describes the three conditions in the concept of challenge. From this concept it can be inferred that challenge will be high when any two of ability, social influence and motivation are high as presented in equation 4.2.

Table 4.5
Different Condition in Challenge

Condition	Factor's values	Challenge value	Description
Condition 1 Disability	*Ab*=low *Si*=high *Mv*=high	*Cg*=high	Challenge will be high when any two of ability, social influence and motivation are high
Condition 2 Highly motivated	*Ab*=high *Si*=high *Mv*=high	*Cg*=high	
Condition 3 Socially Retarded	*Ab*=high *Si*=low *Mv*=low	*Cg* = low	

From this concept it can be inferred that challenge will be high when any two of ability, social influence and motivation are high (Berson, Halevy, Shamir & Erez, 2015). These causal relationships were used to formalize equation 4.2.

$$Cg(t) = W_{c_1} Ab(t) + W_{c_2} Si(t) + W_{c_3} Mv(t) \quad (4.2)$$

where $\sum_{j=1}^{3} W_{c_j} = 1$

and W_{c_1}, W_{c_2} and W_{c_3} are weight factors.

The formalization reflects the exclusive contributory nature of the three factors of ability, social influence and motivation on challenge concept. It is seen from the formalization that challenge is only high when any two of the three contributory factors are high.

Motivation (*Mv*)

Another factor identified in this study is motivation and it was included because it has been proved to explain and predict the behaviour and action (Crilly & Le Grand 2004; Davis et al 2007; Teixeira, Patrick & Mata, 2011; Chan et al 2015). The factor represents the basic rationale for agents' desire, action, needs and behaviour which determines the reason why agent act in a certain way or the direction of its objective within situated environment. Motivation defines agent's direction, persistence and intensity of effort in order to accomplish the target objective. It gives the cause of agent intention to perform or repeat behaviour or act in a specific manner. The factor is rooted in Fogg Behaviour Model (2009), Trans-Theoretical Model (Kenanidou, 2014) and Health Belief Model (Noroozi, Jomand & Tahmasebi, 2011) which has been used in various empirical experience like Tierney and McCabe (2001), Fogg and Hreha (2010), Julinawati, Cawley, Domegan, Brenner and Rowan (2013), Lui, Blyth and Chirema (2014), Shaye, Bazzaz and Vakili (2015). Based on these premises four major factors are identified to contribute to motivation namely ability, social influence, attitude to change and challenge which is shown in Figure 4.3.

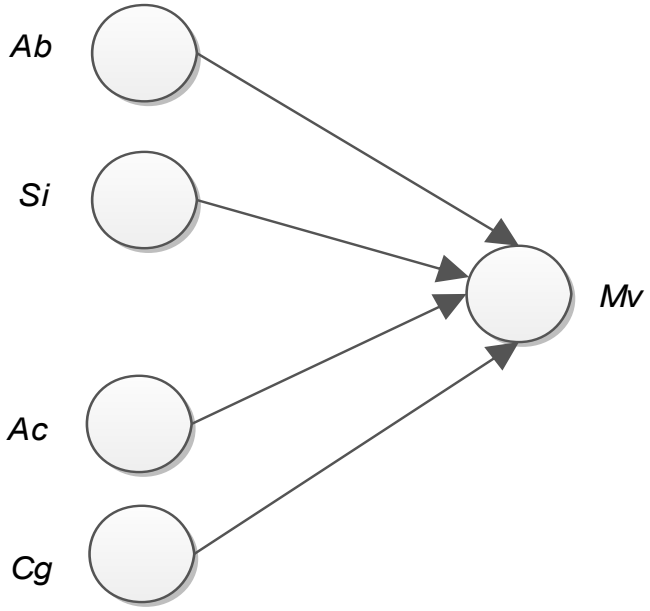

Figure 4.3. Causal Relationship of Motivation

Thus, motivation concept is the simulative drive and intrinsic interest in performing behaviour or action. The intrinsic interest is driven by agent's generated interest or enjoyment on the task which exists within the agent mental instance rather than relying on any external outcome or pressure. The concept of motivation can be assessed from three different concept conditions namely social-driven, self-driven and incentive (Sthapit, Lamers & Rao, 2013). Social-driven condition is when agents' social support generates motivation for the agent to perform target behaviour (Tello-Rozas, Pozzebon & Mailhot, 2015). This condition occurs when agent is high on both social influence and attitude to change. Incentive condition defines agents that possess adequate ability and challenges which generate motivation for the agent to perform target action. Although, in this condition agent might be deficient of social support however, its ability and pressing challenges can generates motivation to achieve target action (DeFreese & Smith, 2013). On the other hand, self-driven condition is obtained when the four contributory concepts (ability, social influence, attitude to change and challenge) are high. This condition describes an agent that is sufficient with all factors which generates motivation to

perform target action. Table 4.6 summarizes the concept in motivation with the three condition descriptions.

Table 4.6
Different Condition in Motivation

Condition	Factor's values	Motivation value	Description
Condition 1 Social-Driven	*Ab*=low *Si*=high *Ac*=high *Cg*=low	*Mv*=high	Motivation is low if attitude to change is low and one of ability, challenge and social influence are low
Condition 2 Self-Driven	*Ab*=high *Si*=high *Ac*=high *Cg*=high	*Mv*=high	
Condition 3 Incentive	*Ab*=high *Si*=low *Ac*=low *Cg*=high	*Mv* = low	

It can be deduced from the motivation causal as shown in Figure 4.4 and Table 4.6 that when motivation is low attitude to change will be low and one of ability, challenge and social influence will be low. These causal relationships of motivation are used to formalize equation 4.3.

$$Mv(t)=\left[\sigma W_{m_1} Ab(t)+W_{m_2} Si(t)+W_{m_3} Cg(t).(1-\sigma)\left(Ac(t)\right)\right] \quad (4.3)$$

where σ is the proportional factor and W_{m_1}, W_{m_2} and W_{m_3} are the weight factors

Equation 4.3 depicts the formalization of the concept of motivation with the exclusive contributory function of the three factors of ability, social influence, attitude to change and challenge. This denotes that each factor that contributes to motivation does not depend on each other.

Attitude to Change (*Ac*)

Theory of Reasoned Action (Ajzen, 2011) and Theory of Planned Behaviour (Head & Noar, 2014) have demonstrated attitude to change as a major factor which predicts

behaviour. This is the mental state which implies a formed view or perception about the target action. It is the position taken by an agent on its intended action which is usually based on past actions (knowledge of past action) and present mental state (agent's belief on the action). Three factors are pinpointed to contribute to this concept which is behaviour knowledge, belief and negative thought. These factors causal relationship is presented in Figure 4.4.

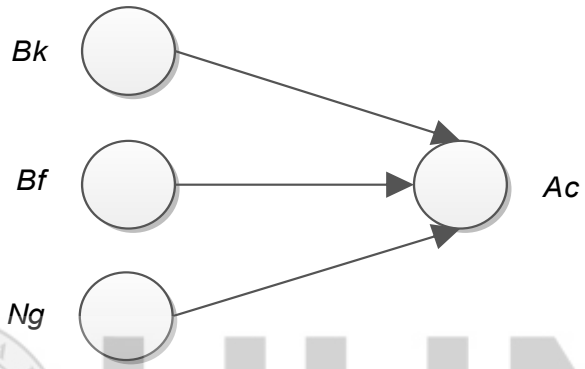

Figure 4.4. Causal Relationship of Attitude to Change

The causal relationship of attitude to change depicts that agents' attitude to change is formed based on negative thoughts, behaviour knowledge and belief. It can be viewed from three conditions namely indoctrinated, pessimism and optimism (Gellert, 2014; GoldmanEisler, 2013). Indoctrinated condition is when the agent holds its belief highly on the intended action which occurs as a result of the agent being low in behaviour knowledge and negative thought on the intended actions. Pessimism condition occurs when agent possess negative belief or knowledge on the intended action whereas optimism condition occurs when agent holds its past action or knowledge about its intended action highly and private on next planned actions. These three condition descriptions on the concept of attitude to change are summarized in Table 4.7

Table 4.7
Different Condition in Attitude to Change

Condition	Factor's values	Attitude to Change value	Description
Condition 1 Indoctrinated	*Bk*=low *Bf*=high *Ng*=low	*Ac*=high	Attitude to Change is high when negative thoughts is low and any of behaviour knowledge or belief is high
Condition 2 Pessimism	*Bk*=high *Bf*=high *Ng*=high	*Ac*=low	
Condition 3 Optimism	*Bk*=high *Bf*=low *Ng*=low	*Ac* = high	

From these different conditions (as summarized in Table 4.7 and shown in Figure 4.5), the concept of attitude of change is formalized as in equation 4.4.

$$Ac\,(t) = [\gamma * Bk(t) + (1-\gamma) * Bf(t)]\,[1-Ng(t)] \quad (4.4)$$

where γ is the proportional factor.

Equation 4.4 shows that there is exclusive contributory between behaviour knowledge and belief whereas negative thoughts have simultaneous contributory casual linkage with these two factors. This implies that for attitude to change to be high then negative thoughts must be reduced which can only occurs when one or both behaviour knowledge and belief are high.

Perceived Risk (*Pr*)

One of the factors that can limit any persuasive agent from achieving its objective within a situated environment is identified as perceived risk or negative consequences of such action or behaviour (Rodrigo & Hendry, 2015). Theory of Planned Behaviour (Lobb, Mazzocchi & Traill, 2007; Liao, Lin & Liu, 2010) and Health Belief Model (Rosenstock, Strecher & Becker, 1994; Clarke, Lovegrove, Williams & Machperson 2000; Huang, Kandiah, Yassin & Abedi, 2011; Che, Barrett, Velez, Conn, Heinert & Qiu, 2014)

specified perceived risk as a determinant of behaviour which explain it as the foreseen negative consequence involved in performing a behaviour or action. Based on these reviews, three factors were chosen to contribute to the concept of perceived risk. It consists of severity of behaviour, challenge and perceived benefits. These chosen factors were illustrated in Figure 4.5 which depicts the casual relationship of the concept.

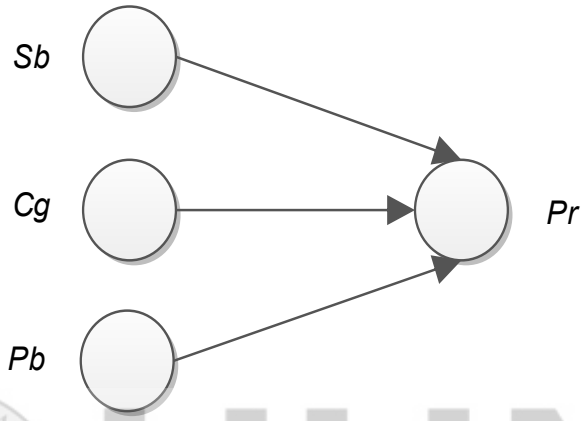

Figure 4.5. Casual Relationship of Perceived Risk

Thus, agents' perceived risk concept is based on its factor of perceived benefits of an intended action which defines the advantages of agents' action or inaction. It also depends on the kind of challenges that the intended action poses on agents' predefine objective within its environment. Likewise the severity of the action depicts the nature of the action itself either difficult or easy to be achieved by the agent. These factors can be explained under three conditions namely ease task, compliment and intense risk (Kim, Lee & Park, 2015). Ease task condition depict agent with low severity of behaviour and perceived benefit but high on challenge. This agent has a simple target action and little advantageous benefits from the target action whereas the agent is highly challenged to perform the action. This type of agent will experience a low perceived risk on the intended action. Compliment condition occurs when agents' benefits for performing an action is high which will make the agent not to perceive any risk associated to its

intended action (Gilsonet al, 2011). On the other hand, an intense risk condition characterizes agents with the difficult task whereas there are low benefits and challenges on the intended action. Table 4.8 summarized the three conditions in the concept.

Table 4.8
Different Condition in Perceived Risk

Condition	Factor's values	Perceived Risk value	Description
Condition 1 Ease task	*Sb*=low *Cg*=high *Pb*=low	*Pr*=low	Perceived risk is high when severity of the behaviour is high and either challenge or perceived benefit is low
Condition 2 Compliment	*Sb=low* *Cg*=high *Pb*=high	*Pr*=low	
Condition 3 Intense Risk	*Sb*=high *Cg*=low *Pb*=low	*Pr* = high	

Based on these concepts shown in the summarized table, it could be concluded that perceived risk is high when severity of the behaviour is high and either challenge or perceived benefit is low. These interpretations were used to formalize Equation 4.5.

$$Pr(t)=Sb(t).[\rho.Cg(t)+(1-\rho).Pb(t))] \quad (4.5)$$

where ρ is the proportional factor.

The formalization describes that severity of behaviour is in simultaneous contributory with both challenge and perceived benefits for agents' perceived risk to be obtained. It depicts that severity of behaviour is directly proportional to perceived risk which implies that if severity of behaviour is low, the perceive risk is most likely to be low provided that the mutual resultant of challenge and perceived benefit is low too. This can be inferred that there is an exclusive contributory function between challenge and perceived benefit.

Perceived Benefit (*Pb*)

Perceived benefit explain the logic of agent belief on the positive outcomes of action or behaviour despite of perceived threat or negative consequence to such action or behaviour (Taglienti et al 2015). It defines the agent perception of the positive outcome toward specific action or behaviour (Ford, Bryant & Kim, 2013). The factor is based on health belief model (Champion & Skinner, 2008) and theory of planned behaviour (Lee, 2009) which asserts that perceived benefit is agent major rationale for performing a defined behaviour or action within its situated environment in order to achieve its objective. Based on these findings, four factors were discovered to contribute to the concept of perceived benefit namely perceived risk, challenge, attitude to change and motivation which was visualized in Figure 4.6.

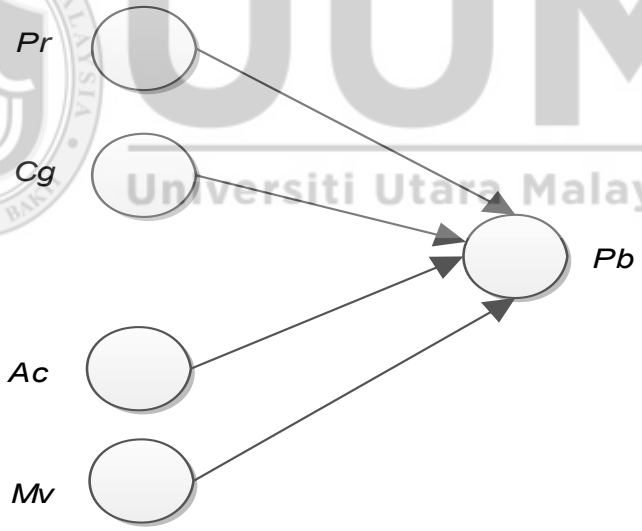

Figure 4.6. Casual Relationship of Perceived Benefit

Thus, perceived benefit is the foreseen positive advantage and consequence in performing a behaviour or action which is influenced by these four factors. The concept of perceived benefit can be viewed from three conditions namely boon, profitable and misfortune (Gabriel, Muhr & Linstead, 2014). Boon condition pictures an agent with

high perceived benefit due to low challenge and perceived risk while posing high attitude and motivation (Kervyn, Fiske & Malone, 2012). Profitable condition characterizes agent with high perceived benefit due to its positive attitude, adequate motivation and challenged to achieve target action. On the contrary, misfortune condition depicts agents with negative attitudes, lack of motivation and challenging drive to achieve the target action (Inbar, Pizarro & Cushman, 2012). These conditions descriptions were summarized in Table 4.9.

Table 4.9
Different Condition in Perceived Benefit

Condition	Factor's values	Perceived Benefit value	Description
Condition 1 Boon	*Pr*=low *Cg*=low *Ac*=high *Mv*=high	*Pb*=high	Perceived benefit is low when perceived risk is high and two of challenge, attitude to change and motivation are low
Condition 2 Profitable	*Pr*=low *Cg*=high *Ac*=high *Mv*=high	*Pb*=high	
Condition 3 Misfortune	*Pr*=low *Cg*=low *Ac*=low *Mv*=low	*Pb*=low	

It could be inferred based on these conditions and concept that perceived benefit is low when perceived risk is high and two of challenge, attitude to change and motivation are low. The formalization as presented in equation 4.6 was done using these condition concept and the casual relationship.

$$Pb(t) = \left[W_{pb_1} Ac(t) + W_{pb_2} Mv(t) + W_{pb_3} Cg(t) \right] \left(1 - \Pr(t)\right) \quad (4.6)$$

where $\sum_{j=1}^{3} W_{pb_j} = 1$, and W_{pb_1}, W_{pb_2} and W_{pb_3} are the weight factors.

Equation 4.6 depicts that agent's perceived benefit is formed by the three exclusive contributory functions between attitude to change, motivation and challenge while

perceived risk formed a simultaneous function with the combination of these three factors.

Desire to Change (*Dc*)

Desire to change reflect the sense of hoping or longing on favourable performance of action or behaviour that will match the defined objective (Baldino & Cabral, 2006). This occurs when agent's intended to achieve its objective within a situated environment. The agent foresees the need to modify its mental state in order to accomplish its intended objective. The sense of modification is defined as "agent desire to change", which is usually based on agent perceived benefits related to the target objective (Klonek, Lehmann-Willenbrock & Kauffeld, 2014). Trans-theoretical model (Prochaska & DiClemente, 1986; Harrell, Trenz, Scherer, Martins & Latimer, 2013; Grunschel & Schopenhauer, 2015) asserts that agent's desire is the fundamental motivation of all agent actions and behaviours. These reviews revealed that three major factors produce agents' desire to change namely belief, motivation and perceived benefit which is depicted in Figure 4.7

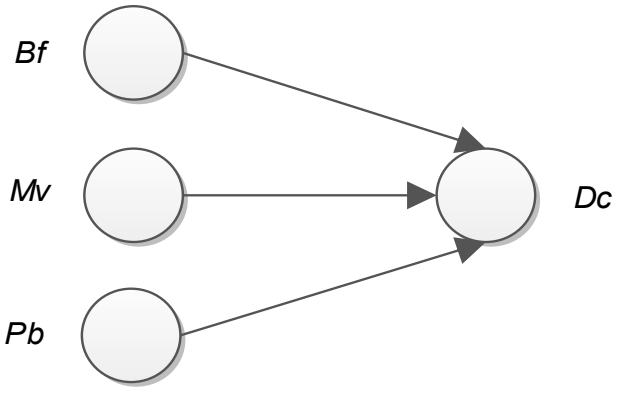

Figure 4.7. Casual Relationship of Desire to Change

Therefore, desire to change is the sense or interest to change a behaviour or action which can be explains using three concept conditions namely disaffection, discontent and passionate (Moreno, 2014). Disaffection condition characterizes agent with low belief, perceived benefit and motivation. This agent does not possess high desire to achieve target action because of its lack of motivation and belief on its ability to perform target action. Discontent condition is when agents possess sufficient motivation but low belief on its ability to perform the target action and do not perceived any advantageous on the outcome of its action. Passionate condition depicts agent with sufficient motivation, confident belief and high perceived benefit on the outcome of its action. All these three condition descriptions were summarized in Table 4.10

Table 4.10
Different Condition in Desire to Change

Condition	Factor's values	Desire to Change value	Description
Condition 1 Disaffection	*Bf*=low Pb=low *Mv*=low	*Dc*=low	Desire to change is low when belief is low and any of motivation and perceived benefit is low
Condition 2 Discontent	*Bf*=low Pb=low *Mv*=high	*Dc*=low	
Condition 3 Passionate	*Bf*=high Pb=high *Mv*=high	*Dc*=high	

Based on this, it can be pointed out that desire to change is low when belief is low. Using the concept of the desire to change and casual relationship stated above, equation 4.7 was formalized.

$$Dc\,(t) = Bf\,(t).[\,\eta.Mv(t) + (1-\eta).Pb(t)] \qquad (4.7)$$

where η is the proportional factor.

The combinations of these underpinning casual relationships formed the concept of desire to change. The formalization depicts that belief is directly proportional to desire to change whereas motivation and perceived benefit are mutually exclusive to each other.

On the other hand, belief was found to be simultaneously linked to the mutual exclusive of motivation and perceived benefit.

Intention to Change (*Ic*)

Agent intention to change represents its mental state which indicates its commitment to perform defined action or behaviour within the nearest purpose outcome. It involves agent mental activities which include agent planning ability and forethought capability. This factor took its root in Relapse Prevention Model (Prochaska, Redding, Harlow, Rossi & Velicer, 1994; Hildebran & Pithers, 2013; O'Brien, 2014; Bakker, Nijkamp, Sloot, Berndt & Bolman, 2015; Cheng, Sanders & Hampson, 2015), Fogg's Behaviour Model (Fogg, 1998; Oinas-Kukkonen, 2010; Oinas-Kukkonen, 2013; Sweeney & Moyer, 2015) and Health Belief Model (Webb & Sheeran, 2006; Gallagher & Updegraff, 2012; Hagger & Luszczynska 2014; Kim & Zane 2015) which classified intention to change as an agent function to accomplish the desired objective and is based on the belief that the course of action will satisfy an intended objective. This concept of intention to change is shown in Figure 4.8

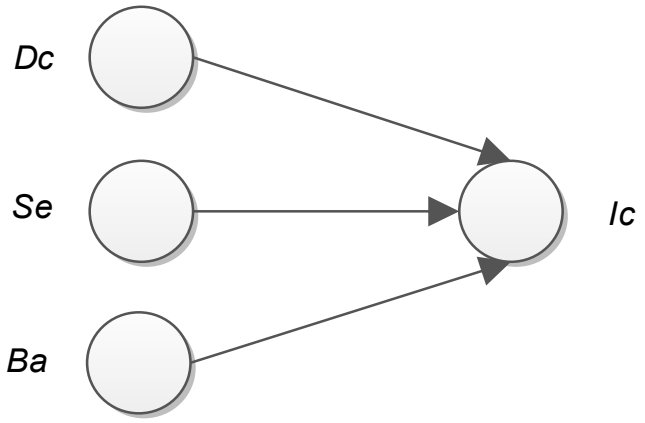

Figure 4.8. Causal Relationship of Intention to Change

Hence, intention to change in this current study depicts the willingness to change a behaviour or action. The concept can be viewed from three conditions namely reckless intent, passionate intent and negligent intent as shown in Table 4.11 (Crump, 2015; Roth, 2013). Reckless intent occurs when agent intention to change is low as a result of low desire to change and self-efficacy while the target action is perceived to be difficult by the agent (Brandt, & Renfroe, 2014). Negligent intent is when agent is characterizes with low desire to change, self-efficacy and simple action (Roth, 2013). On the other hand, passionate intent is when agent possesses sufficient desire to change, simple task action and low self-efficiency (Hosany & Prayag, 2013).

Table 4.11
Different Condition in Intention to Change

Condition	Factor's values	Intention to Change value	Description
Condition 1 Reckless Intent	*Dc*=low Se=low *Ba*=high	*Ic*=low	Intention to change is high when desire to change is high and any of behaviour task and self-efficacy is high
Condition 2 Passionate Intent	*Dc*=high Se=low *Ba*=low	*Ic*=high	
Condition 3 Negligent Intent	*Dc*=low Se=low *Ba*=low	*Ic*=low	

Based on the concept, intention to change is high when desire to change is high and any of behaviour task and self-efficacy is high. The formalization of the concept is presented in equation 4.8.

$$Ic\,(t) = Dc(t) * [v * Se(t) + (1- v\,) * Ba(t)] \qquad (4.8)$$

where v is the proportional factor.

Equation 4.8 depicts that intention to change is directly proportional to desire to change while desire to change is mutually simultaneous to both self-efficacy and behaviour task which are exclusive contributory in nature. This implies that only the combinational effect of both self-efficacy and behaviour task has direct impact on intention to change.

Self-Efficacy (*Se*)

The Theory of Planned Behaviour (Armitage & Conner, 1999; Hagger, Chatzisarantis & Biddle, 2002; Armitage, Wright, Parfitt, Pegington, Donnelly & Harvie, 2014; Chung & Fong, 2015), Relapse Prevention Model (Elfeddali, Bolman, Candel, Wiers & De Vries, 2012; Babbin, Yin, Rossi, Redding, Paiva & Velicer, 2015; Fledderus, Schreurs, Bohlmeijer & Vollenbroek-Hutten, 2015) and Health Belief Model (Gerend & Shepherd, 2012; Straub & Leahy, 2014; Walker & Jackson, 2015) pointed that self-efficacy is a key predictor of behaviour change. Self-efficacy can be deduced as an agent's belief and confident in its capability to execute a defined target action or behaviour in order to accomplish its predefined objective (Bandura, 1977, 1986, 1997). It denotes the agent's trust in its ability to exert control over its own motivation, action, and behaviour (as depicted in Figure 4.9

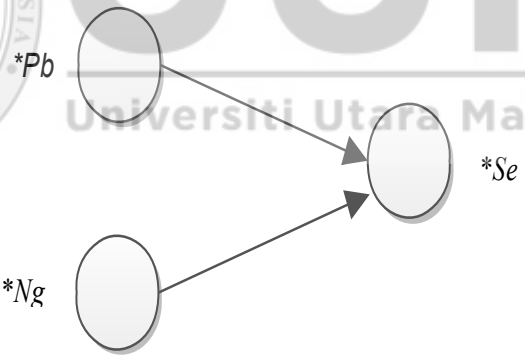

Figure 4.9. Causal Relationship of Self-Efficacy

This study implies self-efficacy as the confidence and assurance in agent capability to perform a behaviour or action. This is predicted by perceived benefit and negative thoughts which can be viewed under two different conditions namely insecurity and poise (Finley et al., 2015). Insecurity condition represents agent with high perceived benefit and low negative thoughts whereas low perceived benefit and high negative thoughts case condition is depicted by poise condition. Insecurity condition characterizes

agents that are open to threat and danger which mental stance is directed to negative consequences of performing an action or behaviour. On the other handle, poise condition relies on the positive advantages that will be achieved upon performing an action or behaviour. These two case conditions were summarized in Table 4.12 with their respective descriptions.

Table 4.12
Different Condition in Self-Efficacy

Condition	Factor's values	Self-Efficacy value	Description
Condition 1 Insecurity	*Pb*=low *Ng*=high	*Se*=low	Self-efficacy is high then perceived benefit is high and negative thought is low
Condition 2 Poise	*Pb*=high *Ng*=low	*Se*=high	

Agents with these two conditions possess different belief in order to execute actions to achieve their predefined objectives within situated environment. The concept depicts that when self-efficacy is high then perceived benefit is high and negative thought is low which was used to formalize equation 4.9.

$$Se\,(t) = Pb(t).[1 - Ng(t)] \quad (4.9)$$

The equation depicts that as negative thoughts increases self-efficacy decreases whereas perceived benefit is found to be directly proportional to self-efficacy. It shows that both perceived benefit and negative thoughts have mutual contributory nature in order to determine self-efficacy.

Negative Thoughts (*Ng*)

Health Belief Model (Sher, McGinn, Sirey & Meyers, 2014; Andrews, Netemeyer, Kees & Burton, 2014) and Theory of Planned Behaviour (Ajzen, Joyce, Sheikh & Cote, 2011) referred to agent plan or arrangements of plans which form the unexpected outcome of the execution of the agent mental state. It has been found to regulate many agent actions,

behaviour and interactions which enable the agent to process its objective within its situated environment (Kingston, Watkins & O'Mahen, 2013; Gkika & Wells, 2015). Therefore, this study refers to negative thoughts as undesirable perception and view about a behaviour or action as illustrated in Figure 4.10.

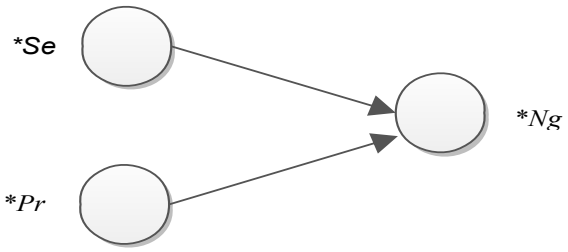

Figure 4.10. Causal Relationship of Negative Thought

The concept in negative thought reveals agents' mental stance of reduction of their belief in an action by considering the worst possible scenarios combinations in order to achieve their predefined objectives. Table 4.13 shows two major case conditions in the concept namely cynicism and fussy (Williams, 2014; Hattenhauer, 2012). Cynicism condition depicts agents' belief that other agents' actions and inactions are motivated purely on their own self goal in order for every agent to achieve their personal goals (Hattenhauer, 2012). This creates an environment of distrust and scepticism where every agent will tend to suspense other motives or actions. In another case condition, fussy state occurs when an agent's does not considered other agents actions or inaction before declaring them as being against its predefined objective within situated environment (Williams, 2014).

Table 4.13
Different Condition in Negative Thoughts

Condition	Factor's values	Negative Thoughts value	Description
Condition 1 Cynicism	*Se*=high *Pr*=low	*Ng*=low	Negative thought is high then perceived risk is high and self-efficacy is low
Condition 2 Fussy	*Se*=low *Pr*=high	*Ng*=high	

These two case conditions show the disposition that an agent have over other agents within the same situated environment. The concept depicts that when negative thought is high then perceived risk is high and self-efficacy is low as illustrated in Equation 4.10.

$$Ng\,(t) = \psi.Pr(t) + [(1- \psi).Se(t)] \quad (4.10)$$

where ψ is the proportional factor.

It can be seen that perceived risk and self-efficacy have a mutual simultaneous contributory to negative thoughts. As perceived risk increases negative thoughts also increases whereas self-efficacy decreases. These two mutual interactions define the characteristics as existed in both cynicism and fussy.

Threat (Hr)

The concept of threat stated by Health Belief Model (Rosenstock, 1974; James, Pobee, Brown & Joshi, 2012; Jones, Smith & Llewellyn, 2014) and Fogg Behaviour Model (2009) reflect a resultant behaviour outcome premises on compulsion, pressure and coercion. This occurs when agent's action or behaviour became necessary due to other agents action or inaction within the same environment (Vehanen & Hamari, 2004; Munshi, 2013). This necessity of this agent's action is usually based on its perceived negative consequence or dissatisfaction with other co-agent actions or in action (Kim, Ahn & No, 2012). In this present study, threat is defined as an indication of possible danger or other form of hostile consequence on the retribution for a behaviour or action which an agent perceived within its environment. Thus, it can limit its possibility of achieving its objective with that particular environment. Figure 4.11 show the causal relationship of the contributory factors of threat

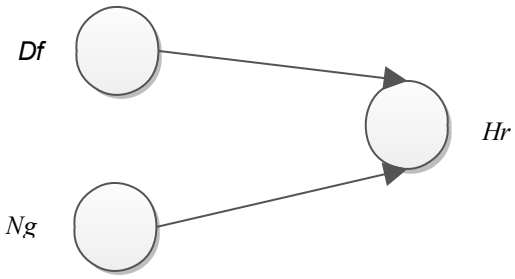

Figure 4.11: Causal Relationship of Threat

Two major factors were found to contribute to threat concept namely dissatisfaction and negative thoughts. The concept depicts agent belief on other agents' action or inaction as being a hindrance to achieve its predefined objective within situated environment. It can be viewed from two different case conditions namely fearing and intimidation (McDoom, 2012). Fearing condition is when an agent has the belief that anther agent's action or inaction can be a hindrance to achieve its predefined objective (Salazar et al 2011). In another twist, an intimidation condition is when the action performed by an agent hindered other agents to achieve their predefined goal within the same environment (Dvir et al 2012). These case condition concepts were summarizes in Table 4.14 with corresponding values and descriptions.

Table 4.14
Different Condition in Threat

Condition	Factor's values	Threat value	Description
Condition 1 Fearing	*Df*=high *Ng*=low	*Hr*=low	Threat is low when any of dissatisfaction and negative thought is low
Condition 2 Intimidation	*Df*=high *Ng*=high	*Hr*=high	

The contributory nature of both dissatisfaction and negative thoughts characterizes fearing and intimidation case conditions. Based on these it can be seen that threat is low when any of dissatisfaction and negative thought is low which were used to formalize equation 4.11.

$$Hr\,(t) = \phi.Df(t)+[(1- \phi)Ng(t)] \quad (4.11)$$

where ϕ is the proportional factor.

Performed Action (Pc)

Performed action as reflected by Self-Efficacy Theory (Bandura, 1977, 1986, 1997) describes that agents executed actions or behaviour patterns define their capability or ability. The performed action of an agent can be used to classifies or consider the agent if accomplishing it predefined objectives, to be achieved within situated environment. Figure 4.12 shows the concept of performed action in this study.

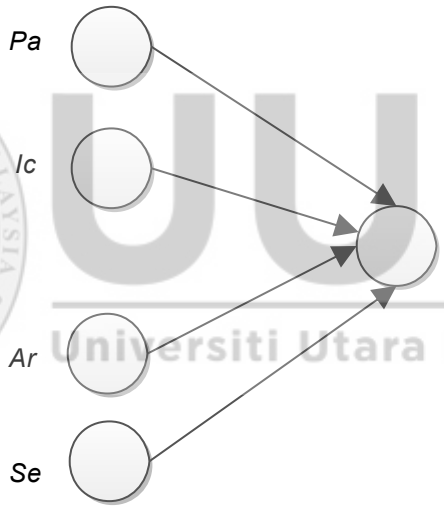

Figure 4.12. Causal Relationship of Performed Action

Thus, this study operationalized a performed action as the state where a target behaviour or action is positively obtainable. Table 4.15 shows the three conditions in the concept namely chaos, friction and non-consent actions (Gelot & Söderbaum, 2012). Chaos action condition occurs when agent is characterizes with low self-efficacy and the obtained performed action does not reflect agent belief and confidence (Washburn, 2014). The friction action condition represents agent with high self-efficacy and low

intention to change where the performed action does not reflect agent's true intention on the action (Poppe & ter Maat, 2014). Conversely, a non-consent action condition depicts agent with only high action reject which reflects agent perform action that will be unacceptable within its environment by other agents (Monrouxe, & Rees, 2012).

Table 4.15
Different Condition in Performed Action

Condition	Factor's values	Performed Action value	Description
Condition 1 Chaos Action	*Pa*=high *Ic*=high *Ar*=low *Se*=low	*Pc*=high	Performed action is high when action reject is low and any two of planned action, intention to change and self-efficacy is high.
Condition 2 Fiction Action	*Pa*=high *Ic*=low *Ar*=low *Se*=high	*Pc*=high	
Condition 3 Non-consent Action	*Pa*=low *Ic*=low *Ar*=high *Se*=low	*Pc*=low	

It could be inferred that the performed action is high when any two of other factors (planned action, intention to change and self-efficacy) are high as formalized in Equation 4.12.

$$Pc(t)=\left[W_{pc_1}Pa(t)+W_{pc_2}Ic(t)+W_{pc_3}Se(t)\right]\left(1-Ar(t)\right) \tag{4.12}$$

where $\sum_{j=1}^{3} W_{pc_j}=1$

and W_{pc_1}, W_{pc_2} and W_{pc_3} are the weight factors

The equation shows that performed action is directly proportional to the three combinational logic disjunction of planned action, intention to change and self-efficacy whereas these three are in mutual simultaneous contributory to action reject. It can be further seen that action reject is inversely related to performed action which explains the minus sign assigned to action reject.

Action Reject (Ar)

In this study, performed action is depicted as a positive outcome of agent action or behaviour whereas action reject is its opposite. The two factors were based on Self-Efficacy Theory (Bandura, 1977, 1986, 1997) which reflected that agent action pattern is a good indication of prediction of its behaviour. Therefore, this study operationalized action reject as the state where agent target behaviour or action is not achievable within its situated environment. Figure 4.13 shows the concept of action reject which includes the four contributory factors namely dissatisfaction, threat, planned action and performed action.

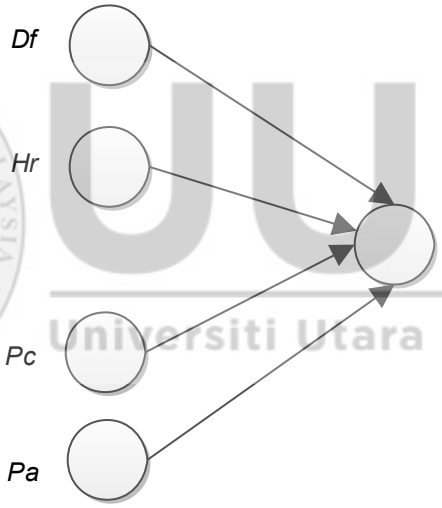

Figure 4.13. Causal Relationship of Action Reject

These four contributory concepts can be used to descript three case conditions namely acute reject, hyper-acute reject and chronic reject (Wood & Goto, 2012). Acute reject is as a result of low dissatisfaction, threat and planned action whereas with high performed action. It gives low action reject and descripts agents that are low in obtaining negative resultant actions (Trivedi & Neuberger, 2013). Hyperacute reject condition represents agent with only high dissatisfaction whereas low threat, planned action and performed action (Oh, Schwartz & Singh, 2012). Meanwhile, chronic reject occur when there are

high attributions of dissatisfaction, threat and planned action (Wood & Goto, 2012). Agent with this characteristic are discovered to possess high action reject due to their acquired attributions. Table 4.16 summarizes these case conditions in the concept.

Table 4.16
Different Condition of Action Reject

Condition	Factor's values	Action Reject Value	Description
Condition 1 Hyperacute Reject	*Df*=high *Hr*=low *Pa*=low *Pc*=low	*Ar*=low	Reject is high when any of dissatisfaction or threat is high and any of planned action or performed action is low
Condition 2 Chronic Reject	*Df*=high *Hr*=high *Pa*=high *Pc*=low	*Ar*=high	
Condition 3 Acute Reject	*Df*=low *Hr*=low *Pa*=low *Pc*=high	*Ar*=low	

These three case condition concepts reflects that action reject is high when any of dissatisfaction or threat is high and any of planned action or performed action is low which were used to formalize equation 4.13 which is found to be similar to the concept of equation 4.12.

$$Ar(t) = \left[W_{Ar_1} Df(t) + W_{Ar_2} Hr(t) + W_{Ar_3} Pa(t) \right] \left(1 - \left(Pc(t) \right) \right) \quad (4.13)$$

where $\sum_{j=1}^{3} W_{Ar_j} = 1$

and W_{Ar_1}, W_{Ar_2} and W_{Ar_3} are weight factors.

Dissatisfaction (Df)

Dissatisfaction occurs when agent is unable to execute its defined action or plan within its situated environment. Theory of Planned Action (Verplanken & Van Knippenberg, 1998; Fainstein, 2000) and Health Belief Model (Bandura, 2004; Brown, Ottney &

Nguyen, 2011) explained it as the condition of not being satisfied, content and being displeasure with executed actions or plans. Hence, the concept of dissatisfaction as presented in this study refers to the negative unpleasant feeling, negative expectation and negative reaction from behaviour which can visualized as passive or expressive dissatisfaction (Jankowski, Diedrichs & Halliwell, 2014). Passive dissatisfaction occurs when agent modifies its belief in order to reacts to undesirable reactions from other agent or its situated environment while, expressive dissatisfaction is when agent reacts to undesirable reactions from other agent or its situated environment without modifying its belief (Becker & Tausch, 2014). Figure 4.14 shows the concept in dissatisfaction while Table 4.17 shows some conditions in the concept. Based on the concept, it could be seen that when dissatisfaction is high then negative thought is high as illustrated in Table 4.17.

Figure 4.14. Causal Relationship of Dissatisfaction

Table 4.17
Different Condition in Dissatisfaction

Condition	Factor's values	Dissatisfaction value	Description
Condition 1 Passive Dissatisfaction	*Ng*=low	*Df*=low	Dissatisfaction is low when negative thought is low
Condition 2 Expressive Dissatisfaction	*Ng*=high	*Df*=high	

$$Df(t+\Delta t)=Df(t)+\lambda.[Ng(t)-Df(t)].(1-Df(t)).(Df(t).\Delta t) \quad (4.14)$$

where λ is the proportional factor and Δt is change interval in time.

This depicts the changes that occur with dissatisfaction as a temporal relation and the contribution by negative thoughts. This temporal relation was explored between time interval between t and t+Δt which were also used in equations 4.15 and 4.16.

Consistency in Action (Ca)

Consistency in action is the state when the action or behaviour is obtainable continuously and it can be viewed as strict and causal Consistency (Duval, Duval & Mayer, 2014). Causal consistency is the weak form of consistency which only reflect that a relationship exist among entities whereas strict consistency reflect total compliance, obedience or observance in the relationship among entities (Schmeltzer & Hilton, 2014). Figure 4.15 shows the concept in consistency in action while Table 4.18 shows two conditions in the concept. Based on the concept, as performed action is high then consistency in action is high as illustrated in equation (4.15).

Figure 4.15. Causal Relationship of Consistency in Action

Table 4.18
Different Condition in Consistency in Action

Condition	Factor's values	Consistency in Action value	Description
Condition 1 Strict Consistency	*Pc*=high	*Ca*=high	performed action is high then consistency in action is high
Condition 2 Causal Consistency	*Pc*=low	*Ca*=low	

$$Ca(t+\Delta t)=Ca(t)+\zeta\,[Pc(t)-Ca(t)](1-Ca(t))(Ca(t).\Delta t) \quad (4.15)$$

where ζ is the proportional factor and Δt is change interval in time.

Consistency in Refusal in Action (Cr)

Consistency in refusal in action is the state when the target behaviour or action cannot be achievable continuously which can either be denial consistency or turn-down consistency (Tyler, 2014). Turn-down consistency occurs when an action is continuously rejected at a particular time frame whereas denial consistency implies the action cannot be achieved within any time frame (Patrick & Hagtvedt, 2012). Figure 4.16 shows the concept in consistency in refusal in action while Table 4.19 shows some conditions in the concept. Based on the concept, as action reject is high then consistency in refusal in action will be high as illustrated in equation (4.16).

Figure 4.16: Casual Relationship of Refusal in Action

Table 4.19
Different Condition in Consistency in Refusal in Action

Condition	Factor's values	Consistency in Refusal in Action value	Description
Condition 1 Denial Consistency	*Ar*=high	*Cr*=high	Consistency in refusal in action is high then action reject is high.
Condition 2 Turndown Consistency	*Ar*=low	*Cr*=low	

$$Cr\,(t + \Delta t) = Cr(t) + \varphi * [Ar(t) - Cr(t)] * (1\text{-}Cr(t)) * (Cr(t)*\Delta t) \qquad (4.16)$$

where φ is the proportional factor and Δt is change interval in time.

In summary, these causal relationships presented in Figures 4.1 to 4.16 are summarized together to depicts Figure 4.17 which is the conceptual model showing the interactions of agent persuasion factors. This conceptual model explicitly shows the interplaying and

interactions between these factors with the processes involeved in psychological reactance and behaviour change.

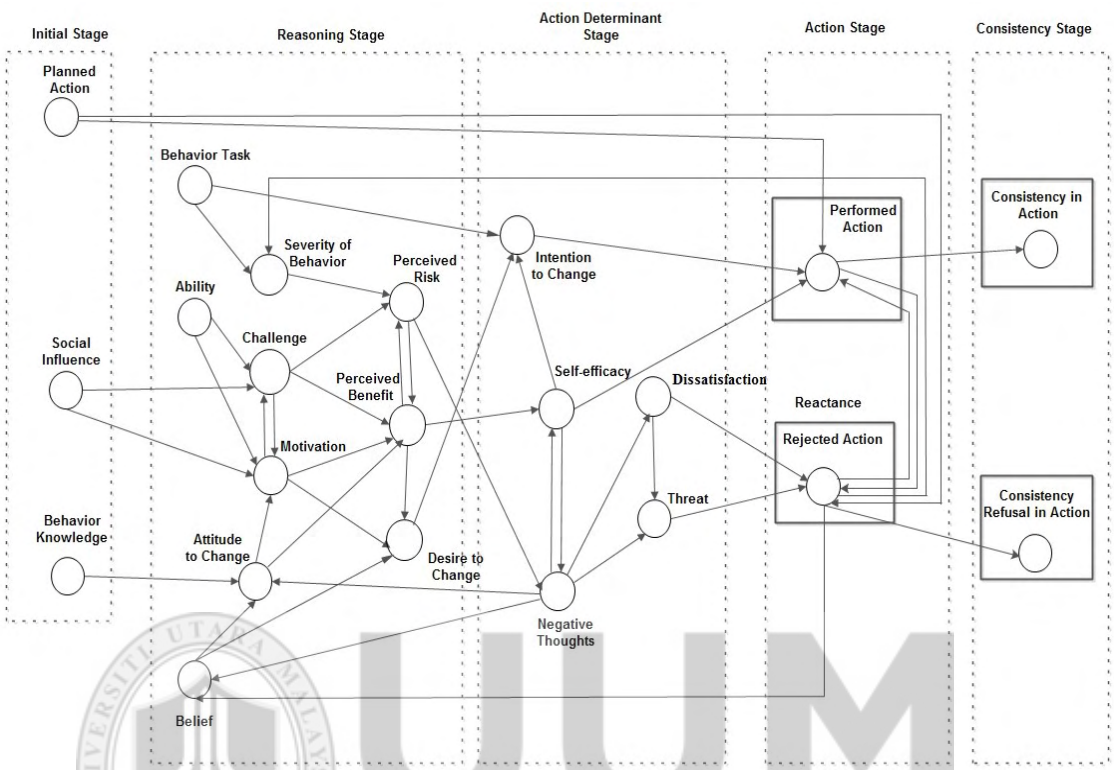

Figure 4.17: Conceptual Model

4.2 Support Model Development

This section discussed the development phases of the support model. Support is needed to reinforce factors that lead to reactance in order to achieve positive change in behaviour. The development phases were similar to the agent model developed above, using domain, design and operational phases.

4.2.1 Domain Model Phase

The concept of support in this work is to reduce reactance outcomes in order to obtain an improved behaviour or action. In this phase, the support factors of the model were

identified which was done based on literature review, empirical studies and expert opinions. The results from this phase produce a set of five important support factors. Table 4.20 shows a summary of the identified support factors.

Table 4.20
Summary of the Support Concept

No	Factors	Formalization	Description	Related Theory	Reference
1	Openness to FBM	*Of*	State of acceptance of the support	TM	Nass, Fogg & Moon, 1996; Rimal, Fogg & Flora, 2012; Ponnada, Ketan & Yammiyavar, 2012; Priyadarshy & Nguyen-Ngo, 2013
2	Openness to Behaviour Change	*Ob*	State of acceptance of the behaviour	TM, FBM	Vassileva, Greer & McCalla, 1999; Yu, 2001; Heinström, 2003; De Oliveira & Purvis, 2008; Seppälä, Lipponen, Bardi, & Pirttilä-Backman, 2012
3	Trigger	*Tg*	Right timing to perform the behaviour	FBM	Armstrong, Reyburn & Jones, 1996; Becker, Mayer, Nagenborg, El-Faddagh & Schmidt, 2004; Zeyl, & Laberge, 2011; Tegos, Demetriadis, & Tsiatsos, 2014; Burner, Menchine, Kubicek, Robles & Arora, 2014; Xi & Marsh 2014; Sankaran, Luyten, Dendale & Coninx, 2015
4	Facilitating Condition	*Fc*	Other physical resources that will aid the behaviour	FBM	Eichengreen, 2007; Fogg, 2099
5	Reward	*Rd*	Gain on the behaviour	FBM	Pessiglione, Seymour, Flandin, Dolan & Frith, 2006; Hayes & Greenshaw, 2011; Yu & Bhatti, 2014

TM – Trans-Theoretical Model, FBM – Fogg Behaviour Model

4.2.2 Design Model Phase

In this phase, the identified factors from the domain model were represented showing the causal relationships of the modelled concept. This causal relationship is based on Fogg (2009) Behaviour Model (FBM) which forms the support conceptual model. The different parts that made up the support conceptual model is presented in Figures 4.18 to 4.22 while Figure 4.23 shows the support conceptual model.

4.2.3 Operational Phase

The obtained support design model was formulated into a set of formal equations. The formalization, differential equation technique was used to represent the identified factors and its relationships as a formal model. These nodes were designed using a set of parameters high and low values ($0 \leq x \leq 1$) as a regulation or control on the formal model. The details on the formalization of the model are described as following:

Openness to FBM *(*Of)*

All agents have their private defined objective(s) within situated environment which they intend to achieve. They are surrounded by other agents who could provide help and support to further accomplish individual predefined objectives within the same environment. However, the provision of this support or help also depends to the openness and willingness of the agents towards each other within situated environment. Thus, openness is the perception and attitude towards support, which is based on free and unrestricted action to provide support. This phenomenon has been studied empirically by Nass, Fogg and Moon (1996), Rimal, Fogg and Flora (2012), Ponnada, Ketan and Yammiyavar (2012) and Priyadarshy and Nguyen-Ngo (2013) and it is found to depict a condition that the support is free to occur without restriction or hinders. Figure 4.18 shows the concept in openness to FBM.

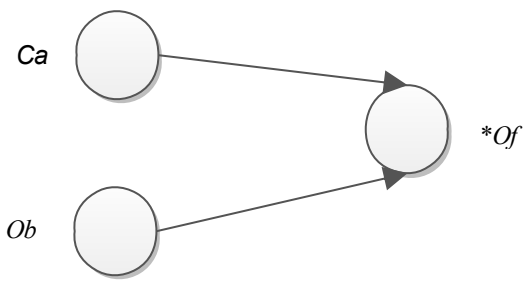

Figure 4.18. Causal Relationship of Openness to FBM

The casual relationship shows that two major factors contribute to the openness to support namely consistency in action, and openness to behaviour. The interactions of these two factors can be viewed under two case conditions dogmatic, and spontaneous (Dollinger, 2012). A dogmatic condition occurs when agent strictly executes its objective(s) within situated environment without considering collaboration or support from other co-agents within same environment (Fayn, MacCann, Tiliopoulos & Silvia, 2015). Agents with this attribution are classified as being close-minded, literal and enjoy having a routine intentions and desires. Moreover, spontaneous condition represents agent that are more open-minded, imaginative and curious of other possibilities within their situated environment. This type of agent usually freely engages the support of other situated co-agents within the same environment in order to achieve it predefined objective(s). Table 4.21 shows the two case conditions of dogmatic and spontaneous with the concept description and values.

Table 4.21
Different Condition of Openness to FBM

Condition	Factor's Values	Openness to FBM value	Description
Condition 1 Dogmatic Openness	*Ca*=low *Ob*=low	*Of*=low	Openness to FBM is high when any of consistency in action or openness to behaviour is high
Condition 2 Spontaneous Openness	*Ca*=high *Ob*=low	*Of*=high	

Openness reflects the reactiveness of agents to their immediate environment in order to gain support to achieve their predefined objective within that situated environment (Seppal, Lipponen, Bardi & Pirttila-Backman, 2012). It relies on the creativeness of agent to use, modify, and distribute opportunities within their reach (Ludeke, 2014). From the concept it is inferred that openness to FBM is high when any of consistency in action or openness to behaviour is high. These two condition concepts were used to formalize Equation 4.17.

$$*Of\,(t) = \beta.Ca(t) + [\,(1-\beta).Ob(t)] \qquad (4.17)$$

where β is the proportional factor.

The formalization reflects that openness to support relies on the mutual contributory factors of consistency in action and openness to behaviour, whereas both factors are not simultaneously contributory to each other.

Reward (Rd*)**

This is the gain or positive yielded satisfaction of performing a behaviour or action. Pessiglione, Seymour, Flandin, Dolan and Frith (2006), Hayes and Greenshaw (2011) and Yu and Bhatti (2014) have empirically suggested that reward is the consequence that happens to an agent as a result of worthy or unworthy action or inaction which usually influence the agent predefined objective within situated environment. Figure 4.19 shows the three contributory factors of reward

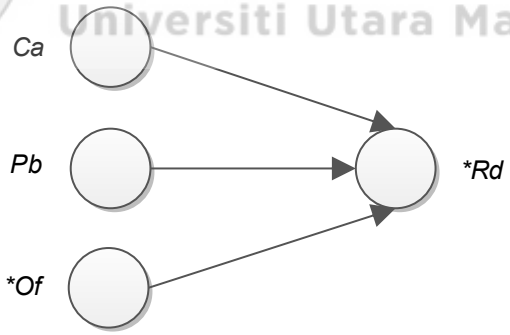

Figure 4.19. Casual Relationship of Reward

These three contributory factors namely consistency in action, perceived benefit and openness to support reflect the concept of reward. This concept can be interpreted from two case condition concepts namely random and earned rewards (Capa, Bustin, Cleeremans & Hansenne, 2015). Random reward condition is obtained when agents do not actively work out the process of the reward but anticipate and belief upon the reward

which usually creates uncertainty within the environment. Whereas, earned reward condition reflects agent's benefits on the reward for performing an action or inaction (Siegrist, 2012). These two concept conditions are summarized in Table 4.22 which also shows the concept conditions descriptions. Based on the two case condition concepts, reward is high when perceived benefit is high and any of consistency in action or openness to FBM is high as stated in Equation 4.18.

Table 4.22
Different Condition in Reward

Condition	Factor's values	Reward value	Description
Condition 1 Random Reward	*Ca*=low *Of*=high *Pb*= low	*Rd*=low	Reward is high when perceived benefit is high and any of consistency in action or openness to FBM is high
Condition 2 Earned Reward	*Ca*=low *Of*=high *Pb*=high	*Rd*=high	

$$*Rd\,(t) = Pb(t).[\tau.Ca(t) + (1-\tau).*Of(t)] \quad (4.18)$$

where τ is the proportional factor.

The equation shows that perceived benefit is directly proportional to reward whereas both consistency in action and openness to support possesses a mutual non-simultaneous contribution to reward (Fu, 2012). At the same time, perceived benefit is found to have a simultaneous combination to the mutual contribution of both consistency to action and openness (DeYoung, 2014). This implies that perceived benefit has the highest priority in the determination of reward.

Trigger (*Tg*)

The signal or sign that reflects the accurate and right timing for an agent to perform a behaviour or action is known as trigger as shown in Figure 4.20 (Fogg, 2009). It is the call to action reminder which can be internal (mental stance) or external as a sudden

signal to perform an action immediately. Timely and prompt facilitating action can make agents to achieve their predefined objective successfully within situated environment (Armstrong, Reyburn & Jones, 1996; Zeyl & Laberge, 2011; Tegos, Demetriadis & Tsiatsos, 2014; Sankaran, Luyten, Dendale & Coninx, 2015).

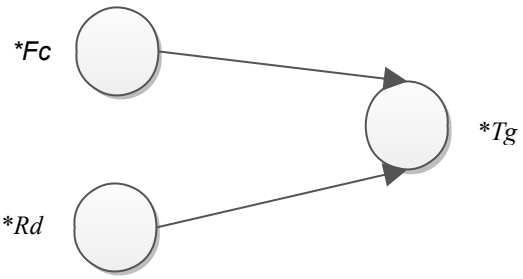

Figure 4.20. Casual Relationship of Trigger

The contributory factors include facilitating condition and reward which can either be signals or facilitator. A signal is a reminder, cue, sign or indication that prompts an agent to the timely performance of action (Zeyl & Laberge, 2011). Meanwhile, facilitator trigger is more intense because it not only prompts the agent but also guide the agent in order to perform the action both timely and adequately (Krieglmeyer, De Houwer & Deutsch, 2013). In other words, a facilitator trigger engaged the agent to efficiently achieve predefine objectives within its immediate environment because it will aid agent in planning and execution (Tegos, Demetriadis & Tsiatsos, 2014). Table 4.23 briefly displays the concept of trigger with its two case condition concepts.

Table 4.23
Different Condition in Trigger

Condition	Factor's values	Trigger value	Description
Condition 1 Signal	**Fc*=low **Rd=low*	**Tg*=low	Trigger is high when any of facilitating condition or reward is high
Condition 2 Facilitating	**Fc*=high **Rd*=low	**Tg*=high	

Trigger is the timely cause of action which permits or allows action to occur within set period in order to meet the purposeful indicated desire of an agent. It causes action mechanism to be performed in accordance with the agent plans, belief, desire and intention. Based on these two case conditions, it can be inferred that trigger is high when any of facilitating conditions or reward is high which are used to formalized equation 4.19. Thus, the equation implies that trigger occurs based on mutual non-simultaneous contribution between facilitating condition and reward.

$$*Tg\ (t) = \mu * Fc(t) + [\ (1- \mu).*Rd(t)] \qquad (4.19)$$

where μ is the proportional factor.

Support Negative Thoughts (Ng*)**

This implies the support to negative perception and belief about an action which has been proofed by many studies (Stroud, Thorn, Jensen & Boothby, 2000, Aydin & Oztutuncu, 2001, Masuda, Hayes, Sackett & Twohig, 2004, Gillath, Bunge, Shaver, Wendelken & Mikulincer, 2005, Gkika & Wells, 2015) that without the suppressed of negative consequences attached to an action then successful outcome of such action might be very difficult. Thus, this study considered Support Negative Thoughts (**Ng*) as a support concept which is visualized in Figure 4.21.

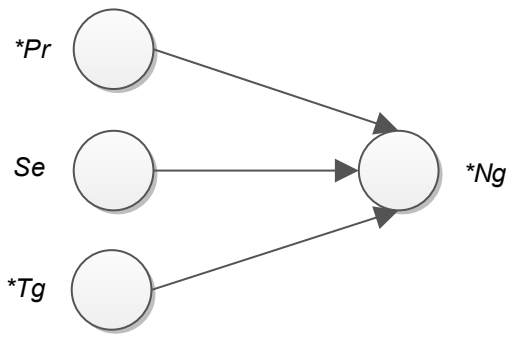

Figure 4.21. Casual Relationship of Support Negative Thoughts

From the literature, support perceived risk, self-efficacy and trigger are found to provide support to negative though (Ziner et al, 2012). These three factors provides support for the two previously discussed case condition under negative thoughts concepts which are cynicism and fussy. Support cynicism condition reinforces agents' belief in order to consider other agents' action scenarios beyond their personal goals but as social goals. This eliminates distrust and scepticism within the environment. In same case, support fussy condition makes agent to consider other agents' action scenario without declaring them as detriment for its predefined objective within situated environment. These case condition concepts are summarized in Table 4.24.

Table 4.24
Different Condition in Support Negative Thoughts

Condition	Factor's Values	Support Negative Thought value
Condition 1 Cynicism	**Pr*=low *Se*=high **Tg*=high	**Ng*=low
Condition 2 Fussy	**Pr*=high *Se*=high **Tg*=high	**Ng*=low

It could be seen in the concept that support negative thoughts is low if trigger and self-efficacy are high and support perceived risk is low. Based on the concept of the case condition concepts, the formalization of support negative thought was obtained as presented in equation 4.20.

$$*Ng\ (t) = [\psi.\mathrm{Pr}(t)+((1-\psi).\mathrm{Se}(t))].(1-\mathrm{Tg}(t)) \quad (4.20)$$

where ψ is the proportional factor.

The equation depicts that as support perceived risk increases then support negative thoughts will increases too while this relation form a non-simultaneous contribution with combined simultaneous relation between self-efficacy and trigger. This implies that the

introduction of the trigger will reduced negative thought because as trigger is high then negative thought will be reduced.

Support Perceived Risk (Pr)

Support perceived risk is the reinforcement of agent negative belief about an action in order to obtain successful and positive outcome. This is vital because many studies like Featherman and Pavlou (2003), Chen and Chang (2012), Carver, Timperio, Hesketh and Crawford (2012) and Sunitha, Justus, Frank, Ramesh and Felix (2014) have empirically pointed out that when perceived risk is reduced then it will increases more position outcome actions. Figure 4.22 shows the concept in the support perceived risk which indicates that four factors namely reward, severity of behaviour, challenges and perceived benefit contributes to support perceived risk

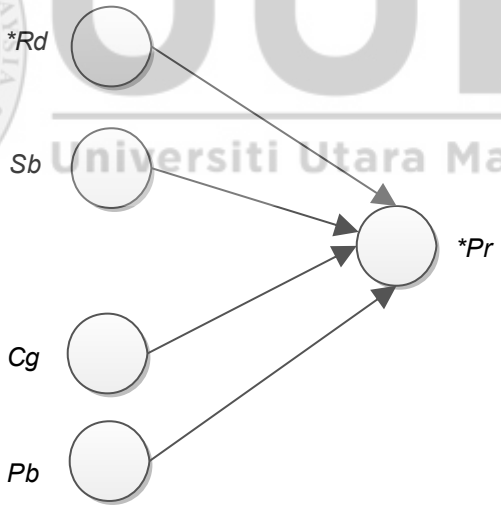

Figure 4.22. Casual Relationship of Support Perceived Risk

As mentioned under perceived risk concept, three case conditions namely ease task, compliment and intense risk will be mirrored by these case condition concepts. These three case conditions will reinforced in order to make the different attributed agents to

achieve their respective objective successfully. Table 4.25 summarizes the concept in support perceived risk and describes the three case conditions.

Table 4.25
Different Condition in Support Perceived Risk

Condition	Factor's values	Support Perceived Risk value	Description
Condition 1 Ease task	**Rd*=low *Pb*=low *Cg*=low *Sb*=low	*Pr*=low	Support perceived risk is low when reward and perceived benefit are high and any of challenge and sever of behaviour is high
Condition 2 Compliment	**Rd*=low *Pb*=high *Cg*=high *Sb*=low	*Pr*=low	
Condition 3 Intense risk	**Rd*=high *Pb*=high *Cg*=high *Sb*=high	*Pr*=low	

$$*Pr\,(t) = (1-Rd(t)).(Sb(t)).[1-(\rho.Cg(t)+(1-\rho).Pb(t))] \quad (4.21)$$

where ρ is the equation constant.

From Equation 4.21, it can be infer that the introduction of the reward will reduce perceived risk whereas the combination of reward and perceived benefit (both having high values) will further reduce perceived risk. Thus, the combination of reward and perceived benefit will provide the needed support for an improved behaviour outcome when perceived risk is reduced. Therefore summarize of these causal support relationships is summarized in Figure 4.23. It depicts the model support design concept and its relation with the agent reactance model while the greyish nodes represent the support factors and the dotted lines shows their interactions.

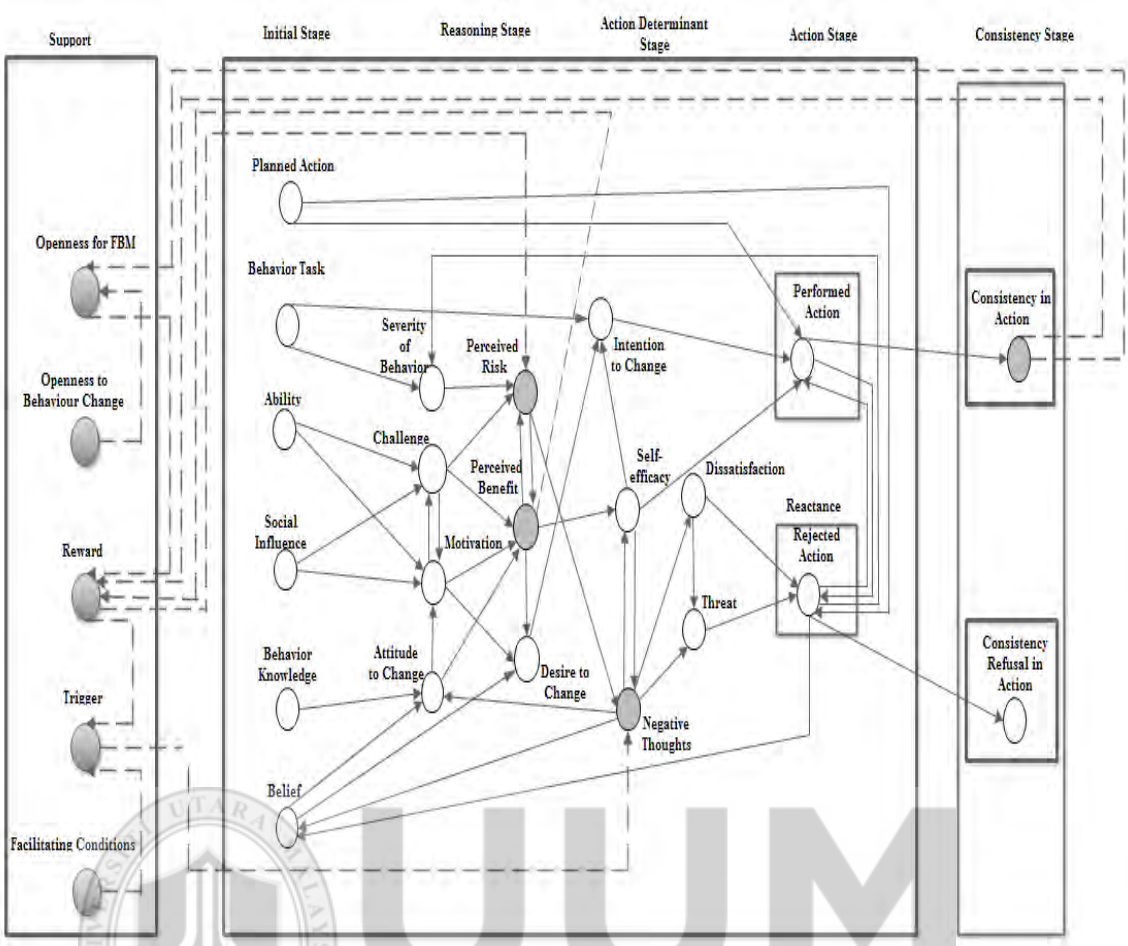

Figure 4.23. Support Conceptual Model of Persuasive Agent

4.3 Application Development

This section presents the development of the study application which was based on the proposed model. The application is further used to investigate issues around psychological reactance and behaviour change process. This is fully discussed in three different subsections namely the application design principles, prototyping development and the application features. The application design principles subsection depicts the implementation of the model factors in the development of the application while the application features subsection describes the various functionalities of the application.

4.3.1 Application Design Principles

In this study, user reactiveness is used to explain psychological reactance in the form of likeness, attention gaining and forming friendly bond with the application as mentioned by Hong (1992). User reactiveness is used to evaluate the proposed model based on the designed application. In order to achieve this main aim, the application is designed by implementing the six external factors of the proposed model. Table 4.26 shows summary of the proposed model factors implemented in the designed application. Each of these six factors is systematically implemented in the application. For instance, the concept of ability was implemented by making the application to provide simple and acceptable instructions to the audience like asking audience to observe their teeth brushing in the morning immediately after bed and last at night before going to bed. This instruction is simple and précise because those suggestions specifies when the action should be performed which depicts the concept of trigger. Similar concept and style are used for other factors implementations in the designed application as summarized in Table 4.26.

Table 4.26
The Integration of Model's External Factors in the Application Design

S/N	Factor	Description	Implementation	Reference
1	Ability	Having sufficient enablement to perform a behaviour or action	Gives simple and acceptable instructions to the audience.	Prochaska, 2013; Montano & Kasprzyk, 2008
2	Social Influence	Having the enablement to affect an opinion on others during interaction	Gives a smiling and cheerful appearance to the embodied agent in the application	Oinas-Kukkonen, 2013; Ryan, Patrick, Deci, & Williams, 2008; Sallis, Owen, & Fisher, 2008
3	Belief	A state of mind in which trust or confidence is placed in some person or thing	Makes a confident eye contact and attraction with audience	Kraemer & Mosler, 2010; Brinol & Petty, 2009; Jalnawala & Wilkin, 2007;
4	Behaviour Knowledge	Knowledge and understanding about the target behaviour	Gives simple, clear and understandable instructions on the target behaviour to the audience.	Abraham & Michie, 2008; Michie, Johnston, Francis, Hardeman, & Eccles, 2008
5	Planned action	A sequence of steps that must be taken, or activities that must be performed well, for a target behaviour to be achieved or successful	Gives stepwise and sequence steps to enable audience achieve the target behaviour.	Montano & Kasprzyk, 2008; Conner & Armitage, 1998
6	Behaviour Task	The nature of the behaviour	Gives likely complication and negativity associated with the target behaviour	Kolb, 2013; Michie, Johnston, Francis, Hardeman, & Eccles, 2008; Hyland, et al, 2006

In the same vein, the application is designed to reflect persuasive design elements as suggested by Oinas-Kukkonen and Harjumaa (2009). For example the element of tunnelling was depicted in the design application by employing storyboard which shows demonstrations to audience on the target behavior. These demonstrations are like tips or suggestions that make the target behaviour achievable for the audience. Furthermore, the designed application was made to interact with audience by employing an embodied female character agent that will be able to gaze to the eyes of audience in a friendly manner. This is known as personalization element in persuasive design which is aimed to offer a personalized content and services for the audience. A total of thirteen persuasive design elements were considered for the designed application which is summarized in Table 4.27.

Table 4.27
Persuasive Design Elements reflected by Application

Element	Description	Implementation	Reference
Reduction	A state of reducing effort and resources in achieving the target behaviour.	The application is designed to engage audience in simple and achievable target behaviour	Purpura, Schwanda, Williams, Stubler, & Sengers, 2011
Tunnelling	Guide audience in behaviour change process by providing tips or suggestions that makes the target behaviour achievable.	The application make use of storyboard and demonstration strategies to guide audience in performing the target behaviour.	Lehto & Oinas-Kukkonen, 2015; Chu, Deng & Chuang, 2014
Tailoring	Provision of tailored information for audience in achieving target behaviour.	The application is designed to provide audience with tailor information and tips which will enable them to perform the target behaviour.	Orji., Mandryk, Vassileva & Gerling, 2013
Personalization	Offering of personalized content and services for audience.	The application was designed to personalize its interaction with audience by the embodied agent gazing into the eye of audience and using friendly words.	Kulyk, Klaassen & Gemert-Pijnen, 2014
Self-monitoring	Provision of means for audience to track her performance or status.	The application was designed to demonstrate the target behaviour to the audience in order to be able to improve on the behaviour.	Chen, Hekler, Hu, J., Li, & Zhao, 2011
Rehearsal	Ability for audience to practice a target behaviour or action before carrying it out.	The application was designed to give room for the audience to practice the target behaviour which aid fast comprehension.	Marache-Francisco & Brangier, 2013
Praise	The use of praise via words, images, symbols, or sounds as a way to give positive feedback to audience.	The application was designed to start with an intro melodious music. Also praise words were used to motivate audience to perform the target behaviour	Langrial, Lehto, Oinas-Kukkonen, Harjumaa & Karppinen, 2012
Rewards	Provision of virtual rewards for audience in order to give	The application was designed to make use of motivational words and facial	Deterding, 2012

	credit for performing the target behaviour.	expression as rewards.	
Suggestion	Giving of suggestions to audience on certain behaviours during the system usage.	The application was designed to give useful suggestions to audience on the target behaviour	Lee & Gretzel, 2012;
Similarity	Imitates audience in some specific way to motivate the performance of the behaviour.	The application was designed to imitate target audience in order to rightly engage them	Lehto & Oinas-Kukkonen, 2015
Trust-worthiness	Provision of information that is truthful, fair and unbiased to the audience.	The application made used of medical conversational embodied agent that made used of medical terms (words) in its instructions.	Oduor, Alahäivälä & Oinas-Kukkonen, 2014
Expertise	Seen as professional and providing expert information.	The application was designed as a medical expert that prostrate it as a professional expert on the target behaviour.	Lehto & Oinas-Kukkonen, 2015
Surface Credibility	Competent feeling and look to the audience.	The designed application depicts professionalism and expertise as it was designed to be perceived as a professional medical doctor.	Lowry, Wilson & Haig, 2014

4.3.2 Prototype Development

These identified and implemented factors as discussed in previous subsection were capsulated to design the application. The designed application was implemented in order to evaluate the proposed model. In order to achieve this, a prototype was designed systematically by employing rapid prototyping activities. The study prototype was done based on Dey, Abowd and Salber (2001) and Lathia et al (2013) studies whereby it was advised that critical design specifications consideration should be done for any behavioural change intervention application development cycle. These were done by implementing the application design principles as previously discussed in Subsection 4.3.1. The prototyping activities used was based on evolutionary approach from Forward, Badreddin, Lethbridge and Solano (2012) and Leifer and Steinert (2014). This approach was used in order to keep or retain all design parts which will form the final or finished application.

The first part of the prototyping process is the requirement gathering where the system aims and concepts were defined. Specifically, the application is targeted toward children within the age of 7 to 12 years and it is aimed to encourage and motivate them on teeth brushing behaviour. Based on these concepts and the aforementioned application design principles and elements a quick design was implemented tobuild the prototype. The application was developed using Java programming language. Java was used because it is an integrated development environment (IDE) which permits customization and extension of other plug-in software. Other plug-in software used includes Crazytalk, Camtasia and Android Application Package (APK). The Carazytalk was used to configure the female character agent's facial and voice. It permits auto intensity motion engine enhancer to allow interaction in real time. The Camtasia software was used to integrate the application storyboard and sound. These integrations were done on the Eclipse software editor. The prototype is converted into the Android Application Package (APK) executable format. The APK is the main package file format and it is operating on android distribution platform software and middleware which makes the application to be android based. It was made android based application because the application was deployed on a mobile tablet which is considered more handle, easier and persuasive for the application target audiences. Figure 4.24 summarizes the various activities undertaken to obtain the designed and deployed prototype application.

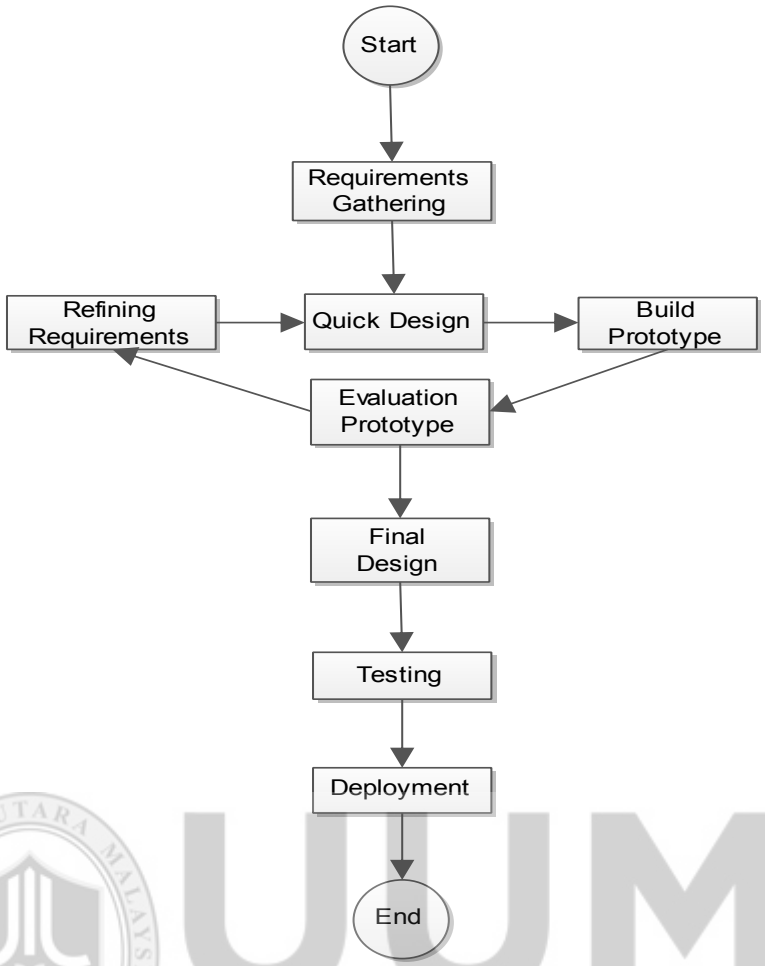

Figure 4.24. Prototype Activities

The prototype application development started with the application requirement gathering which was done based on the proposed model factors and previous empirical studies. The information was used to develop a quick design using Java programming language. The quick design undergoes several refining and evaluation which were based on the predefined objective that the application was met to achieve and possession application features. The outcomes of these refinement and evaluation produced the final prototype application. The final design was tested by performing a simple experiment with three respondents from the study group respondents. Feedbacks were received from these respondents which were used to further refine the application before it was finally

deployed for the study. The application activitiese were illustrated on Figure 4.25 to 4.27.

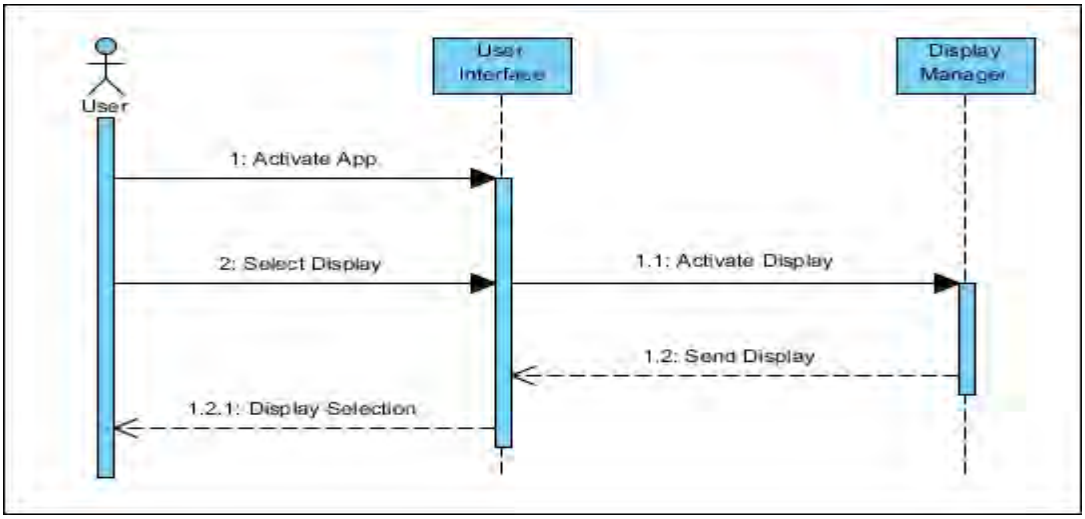

Figure 4.25. Sequence Diagram for Activities

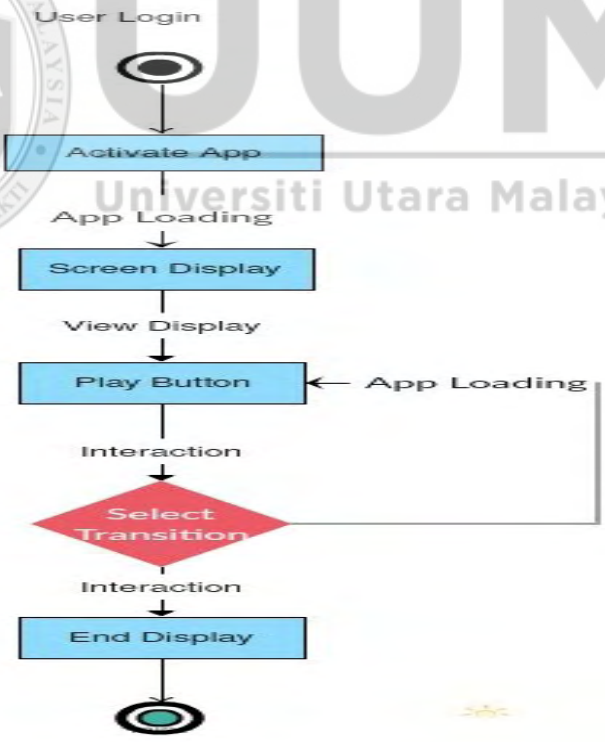

Figure 4.26. Application State Chart Diagram

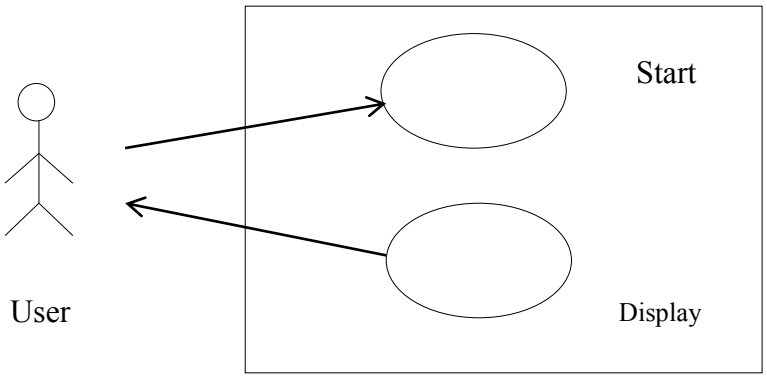

Figure 4.27. Application Use-Case Diagram

4.3.3 Application Architecture

The application architecture includes components such as the beliefs, plan library, intentions, goals, behaviour analysis, interface and the environment. Figure 4.28 shows the overview of the application architecture where the arrows depict the flows among each component.

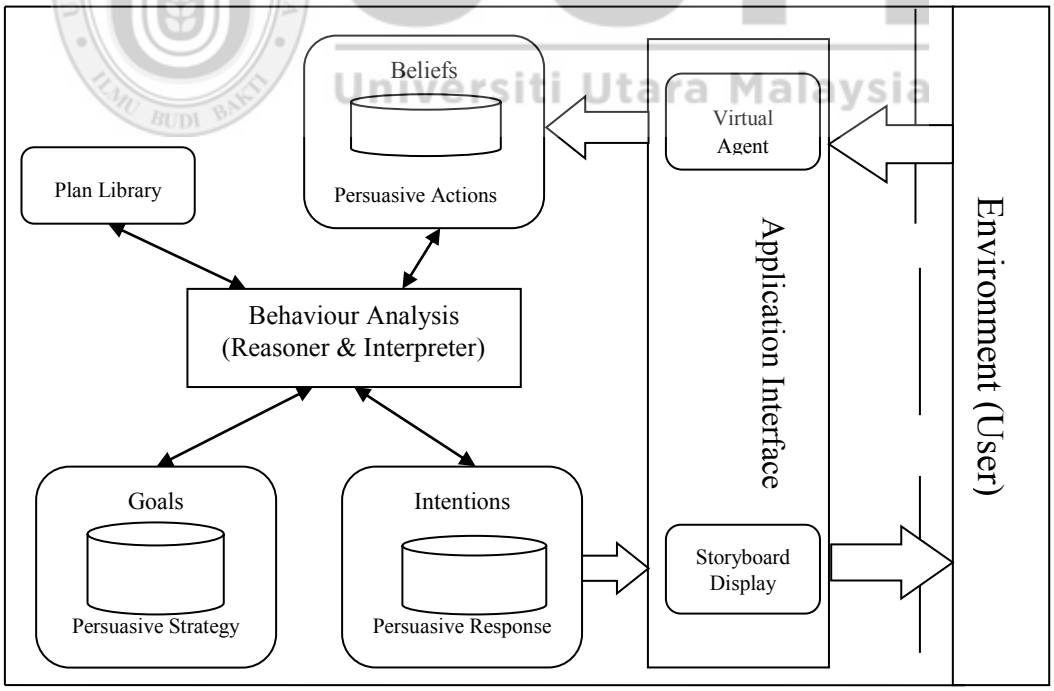

Figure 4.28. Application Architecture

The environment is made up of the users whose interacts with the application interface via the virtual agent and storyboard. In this study, the study respondents (Children within age 7 to 9 years old) are the users. The behaviour analysis component is responsible reasoning and interpretation of action plans which is the centre coordination of the application. Information such as personality traits, demographic and other behavioural traits about the user is stored in the plan library which is accessible by the behaviour analysis component. This behaviour analysis housed model that are used to interpret users' behaviours. An example of such models includes human functioning models where the proposed model in this current study is part of such models.

The belief component housed the agent's information state on the target behaviour and the user (environment). Such information includes the manner, time duration and processes involved in the target behaviour which is needed to be accessed by the application. The goal component housed the persuasive strategies that will be implemented by the agent which are different factors adjustment combinations (such as ability, social influence and others factors). The intention component is responsible for agent's persuasive interactive response which reflects the manner of feedback that the application interface implements with users. This interactive persuasive response is responsible for the choice of communication languages that are displaced on the storyboard and the verbal words used by the agent. Appendices IV and VII presents the scripts of the feedback that are given by the application. The interaction with the environment (user) take placed at the application interface which is coordinated by the virtual agent and the storyboard display. Furthermore, Figure 4.29 presents the application communication diagram which summarizes the interaction among the user and application.

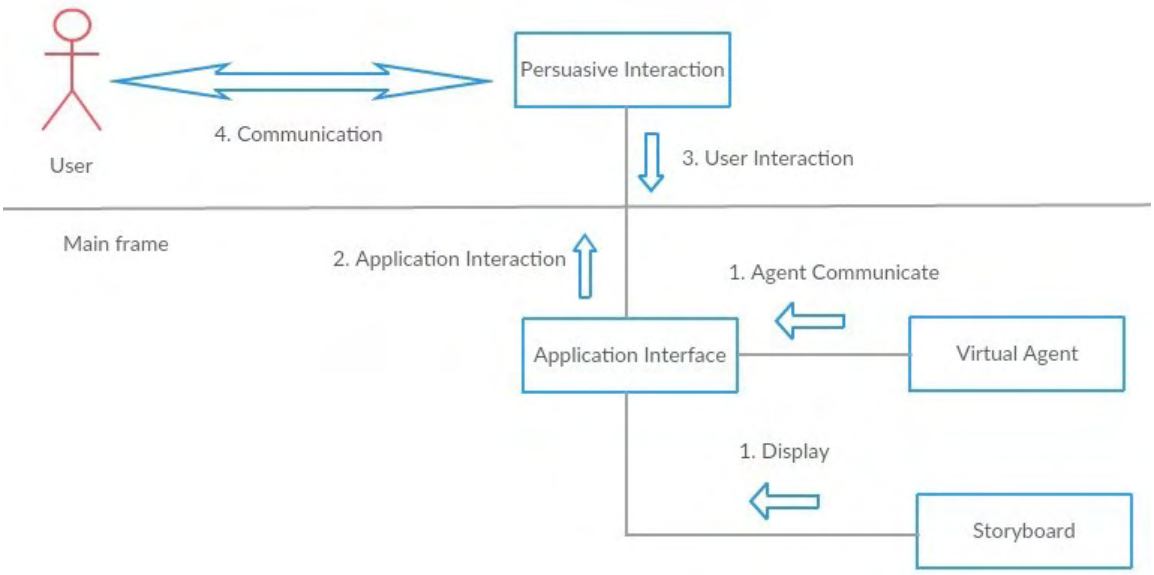

Figure 4.29. Application Communication Diagram

4.3.4 Application Features

In order to achieve attention from the users, the application was developed with a conversational embodied agent. The conversational embodied agent was designed as an image of a female expert giving professional instruction which is based on the principle of expertise, similarity, trustworthiness and attractiveness as show in Appendix I. A female character agent was used because of the soft affection, impression and attractiveness that female image possess especially on children (Gonçalves et al, 2015; Fouts & Burggraf, 1999). In addition, to a child, female image represents motherly care and affection as shown in Figure 4.30. Thus, the female conversational embodied agent reflects authority, attractiveness and human-likeness in order for the application to have user's attention, trust and confidence. The embodied agent further ensures that audience is motivated by provision of simple and achievable task for the attainment of the target behaviour.

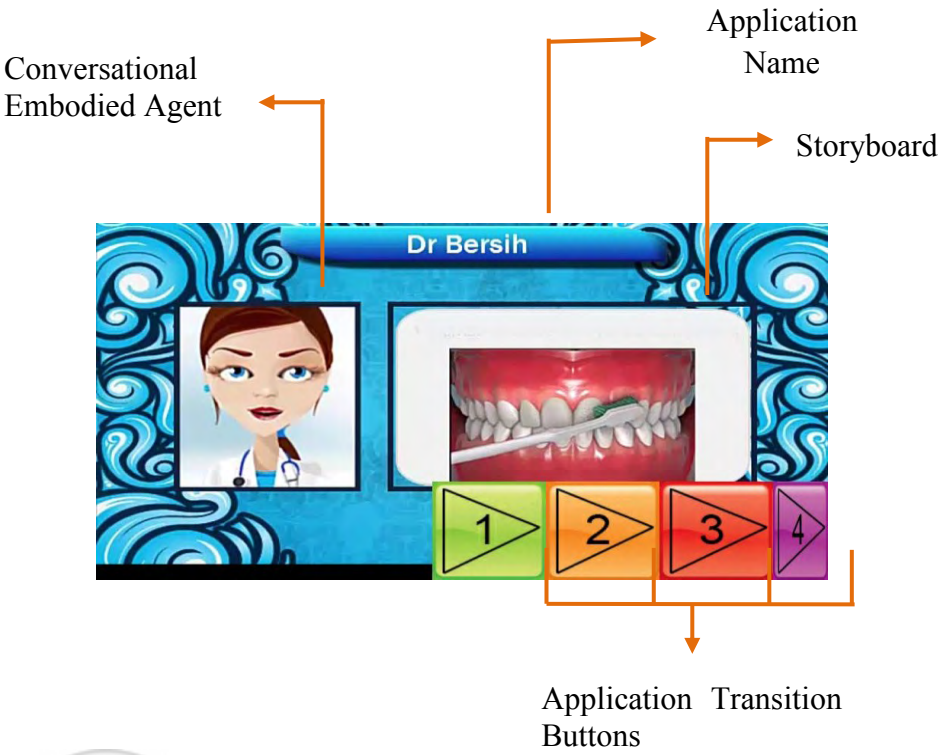

Figure 4.30. Application Interface

Furthermore, the application was designed to tailor the audience by demonstrating the target behaviour (teeth brushing) to them. This was achieved by the use of a storyboard as suggested by Bailey, Konstan and Carlis (2001) as show in Appendix II. Based on the principle of praise as suggested by Jot (1999), the application started with an introduction melody song titled "Brush Your Teeth" by Raffi (1995) as show in Appendix III and VI. The application was deployed on a mobile tablet to create a convenient environment for children application interaction (as seen in Appendix VII). Mobile tablet was chosen because is a natural part of children's life to communicate, create an identity, and social interaction. It is handy and easily movable for children to nearly everywhere (like school, friend's house and other places).

In addition, the application was systematically designed to attract and gain interest of children in order to make them learn teeth brushing without negative reactions to it. For

instance, the concept of ability was implemented by making the application to provide the audience with sufficient enablement like information, cue and motivational words in order to perform the target behaviour. Based on persuasive design elements of personalization, similarity and expertise, the embodied conversational agent implemented the concept of social influence by its smiling and cheerful appearance to influence the audience in accomplishing the target behaviour. The entire model's factor and the Persuasive Design Elements presented in Table 4.26 and Table 4.27 were implemented in the application. Three application versions were implemented based on the model's factors. Appendixes V & VI depict the scripts used for the three application versions.

4.4 Chapter Summary

This chapter presented twenty two (22) agent persuasion factors and five (5) support factors, making a total of twenty seven (27) factors that are involved in the behaviour change model. Based on these factors, the chapter further depicts the development of the model for behaviour change which is done in two phases namely the reactance model shown in Figure 4.17. This reactance model is the building block to the model of behaviour change presented in 4.23 which made used of the support concept. Equations 4.1 to 4.21 represent the formal model of the conceptual model presented in Figure 4.23. The final subsection of the chapter show the application application which is done based on the external factors of the models as summarized in Table 4.26 and 4.27.

CHAPTER FIVE
SIMULATION ENVIRONMENT

This chapter presents result obtained on the simulation traces using numerical simulation environment. The presented simulation traces were based on case conditions which defined the uniqueness of each trace. Furthermore, the model verification was presented in this chapter using mathematical and automated verification methods.

5.1 Simulation Environment

This study made use of simulation environment in order to critically experiment on the proposed model. This was done by using various combinations of parameter values and related factors of the proposed model concepts as implemented in previous studies like Bonabeau (2002), Taillandier, Vo, Amouroux and Drogoul (2012), Aziz, Treur and van der Wal (2012), Romero and Ruiz (2014) and Wang, Butner, Kerketta, Cristini and Deisboeck (2015). The resultant of these parameter variations of the proposed model concept is to obtain real-life situation conditions on the various parameters of selected case studies. This gives the simulated behaviours of the proposed model which allows better insight into the functionalities of the model at different selected cases.

In addition, the simulation environment was used to demonstrate the robustness of the proposed model by visualizing the model execution with respect to underpinning theories used in the study. This is done by interpreting the simulation traces of the proposed model with the grounding theories and selected literature. Based on suggestion from Grimm et al (2005) that model be robust if there are consistencies between the proposed model simulation traces (as generated by the proposed model) and the literature (with the underpinning theories). In other words, simulation environment provides insight into the

robustness nature of a model which depicts the eventual real effects of alternative conditions and concept variation in the proposed model.

These simulation traces are obtained through the implementation of different agent attribution for a number of selected cases out of the various instances. The simulation was conducted with respect to time (t) in order to provide insight into the sequential changes that occurs with the agent in specific case condition. Figure 5.1 shows the example of the designed and deployed simulation environment using Matlab programming language.

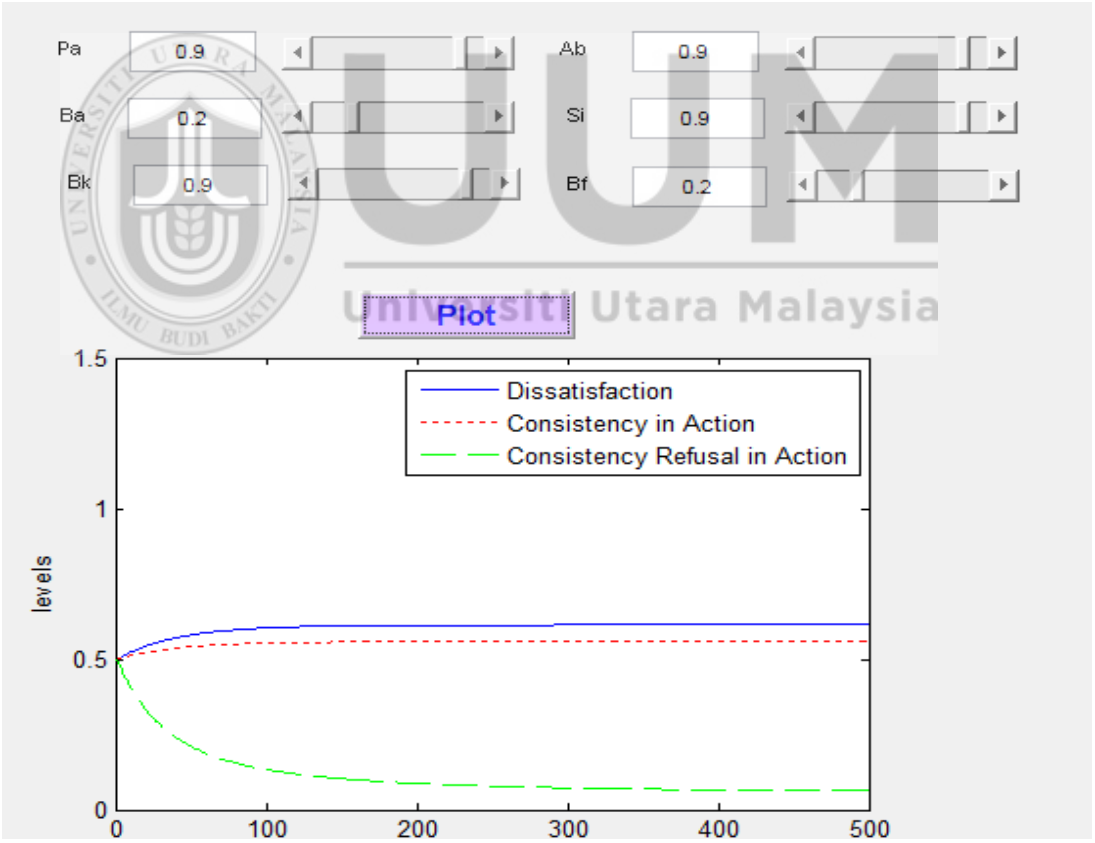

Figure 5.1. Model Simulation Environment

Eight selected case conditions were designed namely uninspiring agent, belief deficient agent, ability deficient agent, influential agent, social influence deficient agent, unknowledgeable agent, task challenging agent and planning deficient agent. The next subsection discussed the experimental parameter setting with values used for these eight selected case conditions.

5.2 Simulation Parameters

This study experimental parameter was done systematic by referring to several literatures to obtain the various estimations which were used based on Vidotto and Vicentini (2007), Vidotto, Massidda and Noventa (2010) and Vidotto (2013) studies guidelines. These studies explicitly highlighted the critical role which parameter values play on accurate description, prediction and investigation of the model behaviors. The proposed model parameter values were in two different forms namely the concept parameters and the regulating factor parameters. The model concept parameter estimation followed Ding (2014), Chen et al (2012), Aster, Borchers and Thurber (2011), Treur and Umair (2011) and Vidotto, Massidda and Noventa (2010) which suggested that 0.1 to 0.3 are low values, 0.4 to 0.6 as average values and 0.7 to 1.0 are high values. During the implementation of the model in the simulation environment, various literatures were used to obtain the values for the concept parameter. For instance, in a particular case condition 0.2 was implemented as low values, 0.5 averages while 0.9 was depicted as high values.

On the other hand, regulating parameters were in two different classes namely the weight factor parameter and the proportional parameter. The weight factor parameter is represented by w. For instance, Vidotto and Vicentini (2007) suggested the value of 0.33 in case of three concepts causal contributional factors. Also, proportional factor parameter is used for simultaneous concept causal relationship. An example of this

parameter values was suggested by Vidotto, Massidda and Noventa (2010) and Vidotto (2013) for 0.5 values for two concurrent concepts. Table 5.1 shows the regulating parameters and corresponding symbols.

Table 5.1
Simulation *Regulating Parameter Symbols with Values*

Symbol	Value	Type
Σ	0.5	Proportional
Γ	0.5	Proportional
P	0.5	Proportional
H	0.5	Proportional
Y	0.5	Proportional
Ψ	0.5	Proportional
Φ	0.5	Proportional
Λ	0.5	Proportional
Z	0.5	Proportional
Φ	0.5	Proportional
Δ	0.1	Rate
W	0.33	Weight

In general, this study made use of low values as ≤ 0.5 whereas high value as ≥ 0.5 for the simulation parameters. The differences in the simulation traces depict the unique differences in each agent attribution with respect to time. These unique differences in the simulation traces were interpreted to evaluate the model which provided answer to part of the research question three as stated in Chapter One. This objective was achieved by designing a simulator using Matlab programming language. Detailed description of the designed and developed simulators for both agent model and support are presented in sections 5.3 and 5.4 respectively.

5.3 Agent Model Simulation Environment

For the agent model, the simulator was developed using Matlab programming language. Figure 5.2 shows the pseudo-code for the proposed model execution while Appendix XI shows the full simulator script code which illustrates how the simulation was programmed by using Matlab programming.

```
Start
Initialize numSteps
Initialize array size
Initialize instantaneous parameter
Initialize temporal parameter
Select Scenario
        Case 1
        Case 2
        Case 3
State=Selected_Case
end
Initialize instantaneous equations at t=1
Do      t=2: numStep
Compute Instantaneous equations
        Compute temporal equations
Until   t=numSteps
End
```

Figure 5.2. Agent Model Simulation Pseudo-codes

The Matlab GUI programming language code shown in Figure 5.2 has four major sections namely the parameter initialization, declaration of concepts, concept operation and simulation implementation. The first section was where the simulation parameters used to control and regulate the simulation environment were initialized. Declaration and initialization of concepts used in the model in the simulation environment was carried out in the second section. Also at this section, initial values were assigned to both instantaneous and temporal concepts. The third section was where the model concepts were operationalized which was followed by the fourth section involving implementation of three case condition by plotting the values to generate simulation traces.

5.3.1 Case Condition One: Uninspiring Agent

In this case, agent was attributed with high Behaviour task (*Ba*) and low Planned action (*Pa*), Ability (*Ab*), Society influence (*Si*), Behavioural knowledge (*Bk*) and Belief (*Bf*) as show in Table 5.2. In this case condition, agent was characterized with low ability to perform the behaviour, lack support from others, inadequate understand and knowledge

about the target behaviour and low belief in the performance of the behaviour whereas the nature and complexity of the target behaviour was high (Kriticos, 2003). After running the simulation code the simulation traces obtained were presented in Figure 5.3.

Table 5.2
Values of Uninspiring Case Condition

Concept	Given Value	Level	Reference
Behaviour task (*Ba*)	0.9	High	Kolb, 2013; Michie, Johnston, Francis, Hardeman, & Eccles, 2008; Hyland, et al, 2006
Planned action (*Pa*)	0.2	Low	
Ability (*Ab*)	0.2	Low	
Society influence (*Si*)	0.2	Low	
Behavioural knowledge (*Bk*)	0.2	Low	
Belief (*Bf*)	0.2	Low	

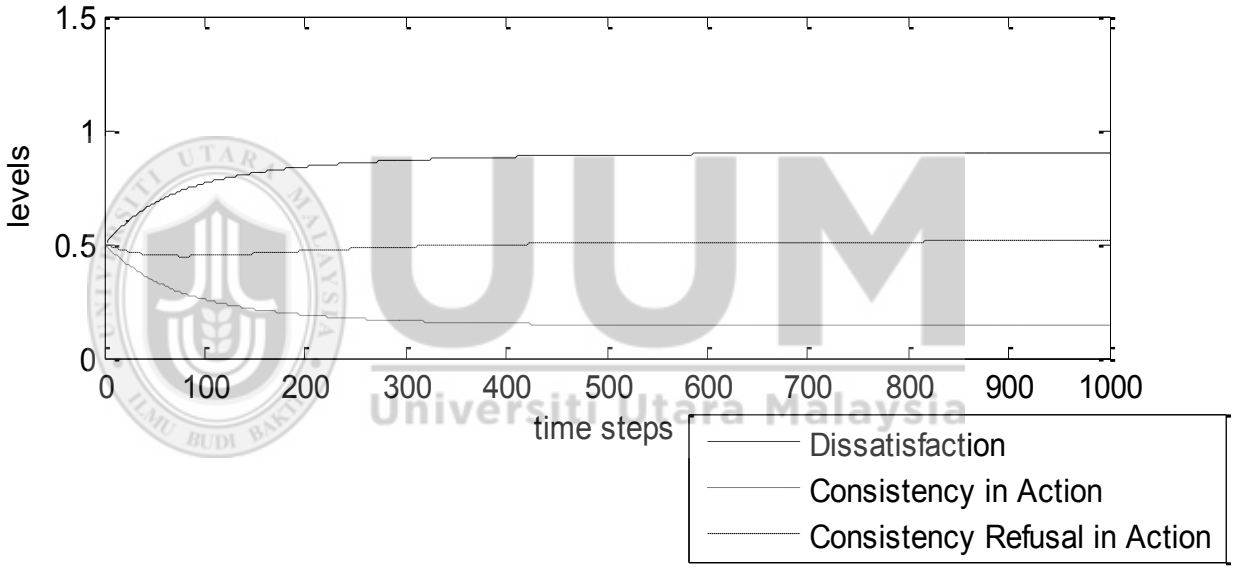

Figure 5.3. Simulation of Uninspiring Case Condition without Support

Based on Figure 5.3 it is observed that dissatisfaction leads both consistency refusal in action and consistency in action whereas there was a very wide range margin between the three. Dissatisfaction was found tending to 1 whereas consistency in actin was tending to 0. This implies that when an agent acquires this case condition attribution then its action will be characterized by high dissatisfaction and low consistency in action which indicates that the agent will not be able to consistently perform the target behaviour and it's extremely susceptible to high dissatisfaction (Atkin, & Rice, 2013).

5.3.2 Case Condition Two: Task Challenging Agent

Task challenging agent attribution is characterized with low Ability (*Ab*) and Planned action (*Pa*) while high Behaviour task (*Ba*), Social influence (*Si*), Belief (*Bf*) and Behaviour knowledge (*Bk*) as shown in Table 5.3. In this case condition, agent possesses low capability and initiative to perform difficult target behaviour. After running the simulation code by clicking on the Matlab GUI plot button, the simulation traces obtained were presented in Figure 5.4.

Table 5.3
Values of Task Challenging Case Condition

Concept	Given Value	Level	Reference
Behaviour task (*Ba*)	0.9	High	Abraham & Michie, 2008; Michie, Johnston, Francis, Hardeman & Eccles, 2008; Kolb, 2013
Planned action (*Pa*)	0.2	Low	
Ability (*Ab*)	0.2	Low	
Society influence (*Si*)	0.9	High	
Behavioural knowledge (*Bk*)	0.9	High	
Belief (*Bf*)	0.9	High	

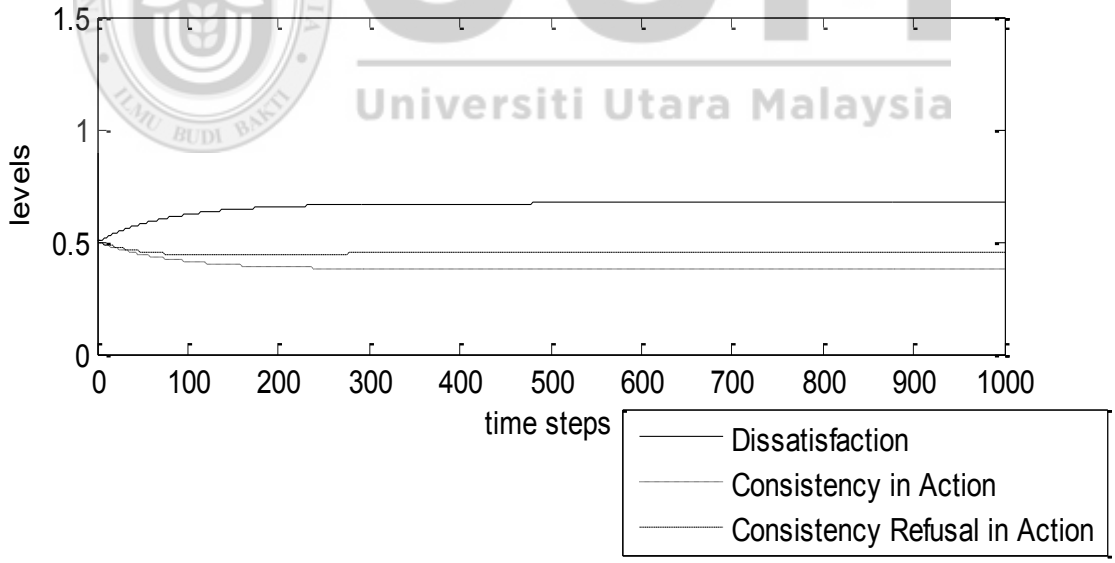

Figure 5.4. Simulation of Task Challenging Case Condition without Support

The simulation traces in Figure 5.9 shown that dissatisfaction leads both consistency refusal in action and consistency in action whereas consistency refusal in action leads consistency in action with a close margin. Therefore, this implies that agents with this

attribution will exhibits dissatisfaction without ability to perform target behaviour due to reactance (Prochaska, 2013; Kumar, et al, 2008).

5.3.3 Case Condition Three: Influential Agent

The case condition presented agent with attribution that was only low Behaviour task (*Ba*) while high Ability (*Ab*), Society influence (*Si*), Belief (*Bf*), Planned action (*Pa*) and Behavioural knowledge (*Bk*) as show in Table 5.4. This case condition characterized agent with high influence in order to achieve the target behaviour. After running the simulation code by clicking on the Matlab GUI plot button, the simulation traces obtained were presented in Figure 5.5.

Table 5.4
Values of Influential Case Condition

Concept	Given Value	Level	Reference
Behaviour task (*Ba*)	0.2	Low	Abraham & Michie, 2008; Michie, Johnston, Francis, Hardeman, & Eccles, 2008
Planned action (*Pa*)	0.9	High	
Ability (*Ab*)	0.9	High	
Society influence (*Si*)	0.9	High	
Behavioural knowledge (*Bk*)	0.9	High	
Belief (*Bf*)	0.9	High	

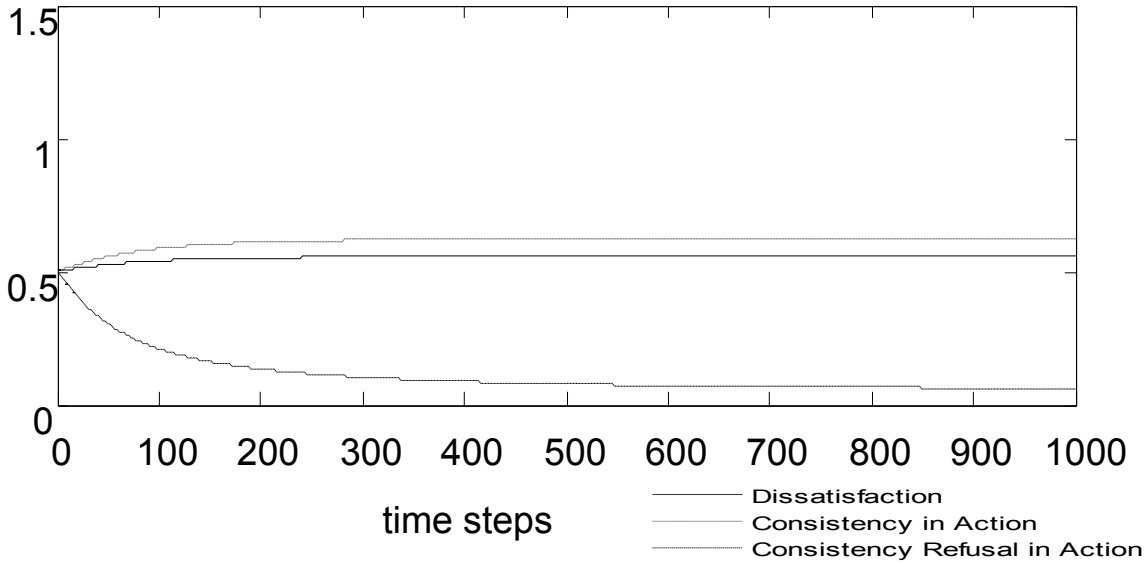

Figure 5.5. Simulation of Influential Case Condition without Support

Based on simulation traces as shown in Figure 5.6, it can be depict that consistency in action leads both dissatisfaction and consistency refusal. Whereas, a very wide lagging range margin was observed between dissatisfaction and consistency refusal in action while a close leading range margin was observed between consistency in action and dissatisfaction. This can be due to the low attribute of behaviour task because Fogg (2009) pointed out that when behaviour is not challenging then the probability of its being perform consistently will be low. In other words, this implies that when an agent acquires this case condition attribution then its action will be characterized by a high consistency in action, reduced level in dissatisfaction and extremely low consistency refusal in action. The agent will be able to consistently perform the target behaviour while there will be a little level of dissatisfaction due to low behaviour task. Table 5.5 summarized the three selected cased conditions whereas other five possible case conditions are presented in Appendix XIII.

Table 5.5

Summary of the three Selected Agent Model Case Conditions without Support

Case Condition	Dissatisfaction	Consistency Refusal in Action	Consistency in Action	Psychological Reactance	Behaviours	Reference
Uninspiring Agent	High	Average	Low	High	Unable to perform targeted action	Maloney, Lapinski & Witte, 2011; Beck, 2011
Influential Agent	Average	Very low	High	Low	Can conveniently perform target action	Montano & Kasprzyk, 2008; Conner & Armitage, 1998
Task Challenging Agent	High	Low	Very low	High	Unable to perform targeted action	Prochaska, 2013; Kumar, et al, 2008; Montano & Kasprzyk, 2008

Only influential agent acquired characteristic is found to experienced low psychological reactance which made it to conveniently able to perform target actions. On the other hand, uninspiring, and task challenging agents acquired characteristics are found to be

experiencing high psychological reactance These have provided explicit understanding of factor interplaying to generate psychological reactance. Furthermore, the next subsection will investigate the introduction of support for these acquired agents in order to enable them overcome low psychological reactance experiences which made it impossible for target actions to be achieved.

5.4 Support Model Simulation Environment

For the support model, a simulator was designed and developed using Matlab programming language. Figure 5.6 shows the pseudo-code for the model execution. The Appendix XII presents the full simulator script code which illustrates how the simulation was developed using Matlab programming language.


```
Start
Initialize numSteps
Initialize delta
Declare the concepts of the model //variable declarations
Initialize temporal parameter
Initialize instantaneous parameter
Initialize support parameter
Select ScenarioNum
        State=ScenarioNum
//Execute the support model for State
        Do t=1:numSteps
                {Instantaneous parameters, temporal parameters}
                IF t=t/2 or any selected value

                END
        Until
Simulate temporal equations
End
```

Figure 5.6. Pseudocode for Support Model

The Matlab programming language code shown above has four major sections namely the parameter initialization, declaration of concepts, concept operation and simulation implementation. The first section is where the simulation parameters used to control and regulate the simulation environment are initialized. Declaration and initialization of concepts used in the model in the simulation environment was carried out in the second section. Also at this section, initial values were assigned to both instantaneous and temporal concepts. The third section was where the model support concepts were operationalized which was followed by the fourth section involving implementation by plotting the values to generate simulation traces. The support simulation code was designed to simulate the agent model from time step 1 to 1000 whereas at time step 1000 the support parameters were introduced which cover-up to time step 5000. The eight selected case conditions support that were obtained from the agent model namely uninspiring agent support, belief deficient agent support, ability deficient agent support, influential agent support, social influence deficient agent support, unknowledgeable agent support, task challenging agent support and planning deficient agent support were implemented on this environment. Table 5.6 show the summary of the support case conditions that were implemented on the simulation environment.

Table 5.6
Values of Selected Support Case Conditions

	Case Condition		
Concept	**Uninspiring**	**Influential**	**Task Challenging**
Pa	0.2	0.5	0.2
Ba	0.9	0.2	0.9
Ab	0.2	0.9	0.2
Si	0.2	0.9	0.9
Bk	0.2	0.9	0.9
Bf	0.2	0.9	0.9
Support			
Pa	0.9	0.9	0.9
Fc	0.9	0.9	0.9
Ob	0.9	0.9	0.9

5.4.1 Case Condition One: Uninspiring Agent Support

From Table 5.6 uninspiring attribution depict an agent with high Behaviour task (*Ba*) and low Planned action (*Pa*), Ability (*Ab*), Society influence (*Si*), Behavioural knowledge (*Bk*) and Belief (*Bf*). In this case condition, agent was characterized with low ability to perform the behaviour, lack support from others, inadequate understand and knowledge about the target behaviour and low belief in the performance of the behaviour whereas the nature and complexity of the target behaviour was high (Beck, 2011; Prochaska, 2013; Webb & Sheeran, 2006). The support parameter depict agent with high openness to behaviour change, Planned action and facilitating conditions. After running the simulation code, the simulation traces obtained are presented in Figure 5.7.

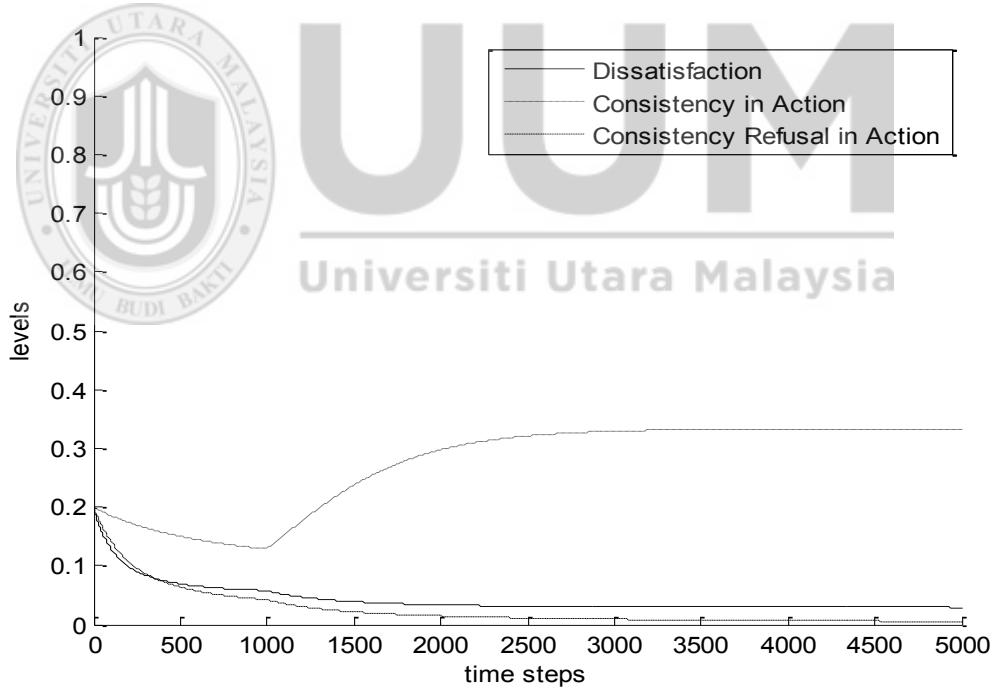

Figure 5.7. Simulation of Uninspiring Case Condition with Support

From Figure 5.7 the support was introduced at time step 1000 and it is can be observed that there was a sharp increment in consistency in action which leads both dissatisfaction and consistency refusal in action. Additionally, the leading of consistency in action was

with a very wide range margin whereas dissatisfaction and consistency refusal in action were very close to 0. This implies that when an uninspiring agent acquires support attribution then its action will be characterized by high consistency in action and low dissatisfaction and consistency refusal in action which indicates that the agent will be able to consistently perform the target behaviour without the effect of reactance.

5.4.2 Case Condition Two: Task Challenging Agent Support

Task challenging agent referred to the condition where agent is characterized with low Planned action (*Pa*) and Ability (*Ab*) while having high Behaviour knowledge (*Bk*), Behaviour task (*Ba*), Belief (*Bf*), and Social influence (*Si*) as shown in Table 5.6. This case condition characterized agents having difficulties performing target behaviour due to its low capability and initiative on the behaviour. The introduction of the support parameter with high openness to behaviour change, planned action and facilitating conditions obtained simulation traces shows in Figure 5.8.

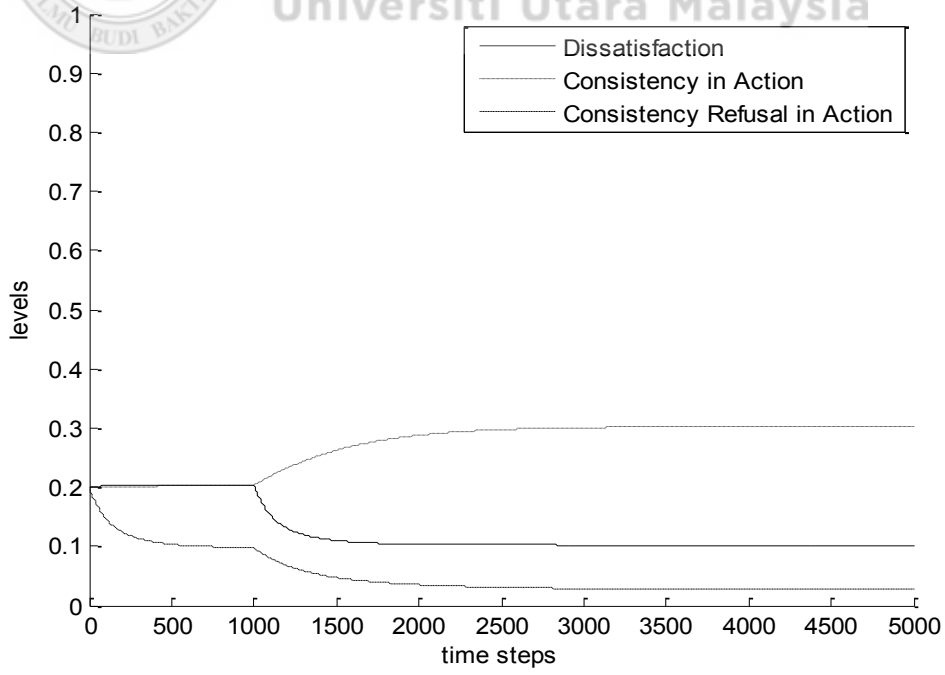

Figure 5.8. Simulation of Task Challenging Case Condition with Support

The obtained simulation traces as shown in Figure 5.8 show that the introduction of support at time step 1000 made consistency in action to increase which leads both dissatisfaction and consistency refusal in action. Additionally, the leading of consistency in action was with a very wide range margin whereas dissatisfaction was found to be constant at 0.1 and reduced consistency refusal in action. This implies that when task challenging agent acquire support attribution then its action will be characterized by high consistency in action, reduced dissatisfaction and consistency refusal in action which indicates that the agent will be able to consistently perform the target behaviour (Grant & Patil, 2012; Liu, Smeesters & Vohs, 2012).

5.4.3 Case Condition Three: Influential Agent Support

The case condition presented an agent with attribution that is only low Behaviour task (*Ba*) and have average Planned action (*Pa*) while high Ability (*Ab*), Society influence (*Si*), Belief (*Bf*), and Behavioural knowledge (*Bk*) as shown in Table 5.6. This case condition characterized the agent with high influence in order to achieve the target behaviour. The introduction of the support parameter depict agent with high openness to behaviour change, planned action and facilitating conditions. After running the simulation code, the simulation traces obtained are presented in Figure 5.9.

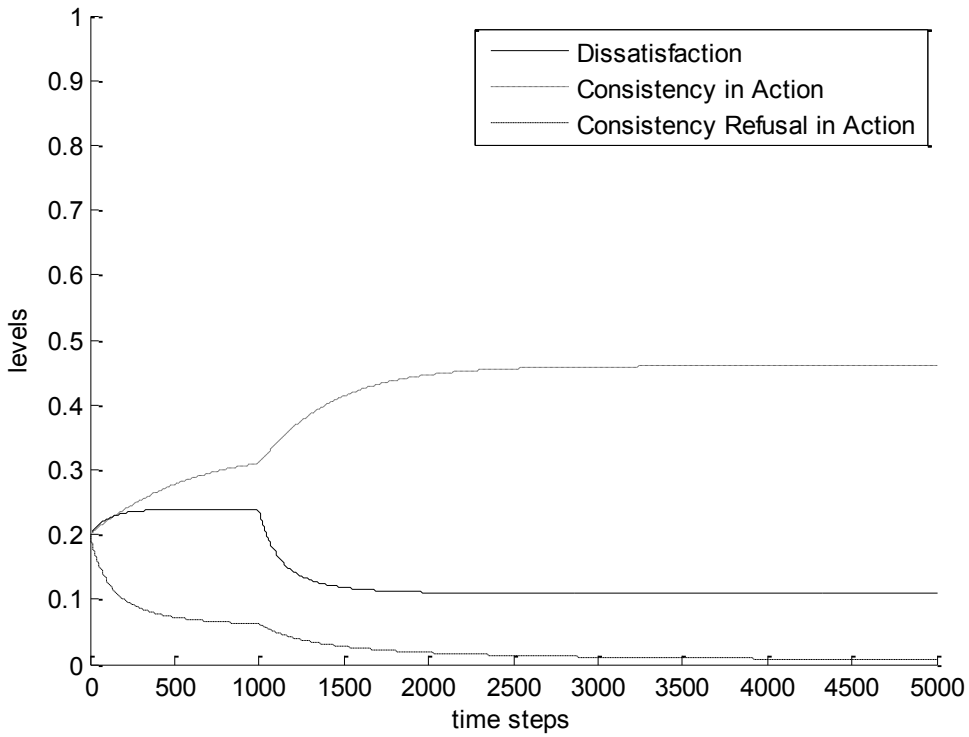

Figure 5.9. Simulation of Influential Case Condition with Support

Figure 5.9 support was introduced at time step 1000 and it is can be observed that there was a sharp increment in consistency in action which leads both dissatisfaction and consistency refusal in action. Additionally, the leading of consistency in action was with a very wide range margin whereas dissatisfaction was found to be constant at 0.1 and consistency refusal in action was tending to 0. This implies that when an agent acquires support attribution then its action will be characterized by high consistency in action, reduced dissatisfaction and vanishing consistency refusal in action which indicates that the agent will be able to consistently perform the target behaviour however, with a reduced dissatisfaction and no form of consistency refusal in action and psychological reactance will be experienced (Kumar et al., 2008; Rollnick, Miller & Butler, 2008). Other five case conditions are presented in Appendix XIV while in summary the support is able to increase the agent ability to perform target action as seen in Table 5.7. However, only task challenging agent experience reduced dissatisfaction. These results

have explicitly depicts how reactance can be supported to obtain improved behaviour outcome.

Table 5.7
Summary of Agent Model Support Case Conditions

Case Condition	Dissatisfaction	Consistency Refusal in Action	Consistency in Action	Psychological Reactance	Behaviour
Uninspiring Agent	Reduced	Close to zero	Increased	Reduced	Perform target action
Task Challenging Agent	Reduced	Reduced	Increased	Reduced	
Influential Agent	Reduced	Close to zero	Increased	Reduced	

5.5 Chapter Summary

This chapter has presented the simulation traces based on three case conditions namely Uninspiring, Task Challenging and Influential agents whereas other five possible case conditions are presented in Appendices VIII and XIV. The simulation traces in Figures 5.3 to 5.5 show that agents with these attributions will experience reactance whereas the interoduction of support will reduce their reactance experiences as shown in Figure 5.7 to 5.9.

CHAPTER SIX

EVALUATION

This chapter explores the systematic determination of the merit and validity of the model in this study. It is equally important in order to ensure that the model produces the actual representation of the phenomenon under investigation. It also helps to gain insight into reflection and improvement of the formal model which can assist future modification and implementation. The evaluation phase was done in two sub-phases namely, verification and validation as shown previously in Figure 3.8 and well discussed in Section 3.6 under Chapter Three.

6.1 Model Verification

Model verification is the process of ensuring that the conceptual description and the solution of the model are implemented correctly. Moreover, this process is performed to improve important understanding of system behaviour, improve computational models, estimate values of parameters, and evaluate system performance. It is done to ensure that the model reflects the real world. For instance, if the behaviours of the system of interest are linear, then those linear behaviours must be reflected in the formal specification underlying the model. To address this purpose, factors of the models are evaluated. These model factors were evaluated with important characteristics as reported in the literature.

Mathematical analysis was conducted to verify the structural and theoretical correctness of the model. For this study, equilibria analysis is performed. The equilibria describe situations in which a stable situation has been reached. It means, if the dynamics of a system is described by a differential equation, then equilibria can be estimated by setting a derivative (or all derivatives) to zero. One important note that an equilibria condition(s)

is considered stable if the system always returns to it after small disturbances. These equilibria conditions give the indication for the correctness of the proposed model which is pivoted on the model concept. For the logical verification, the ability of the Temporal Trace Language (TTL) and its software environment as a specification language and verification tool was used. TTL allows researchers to verify both qualitatively and quantitatively the model under analysis and has the ability to reason about time. This was done by identifying case conditions from the proposed model and implementing it using TTL. These two verification analysis were presented in subsection 6.1.1 and 6.1.2 respectively.

6.1.1 Mathematical Verification

Model stability can be defined in terms of its response to external inputs or in terms of bounded inputs. This is because a model is stable if its impulse response zero as time approaches infinity or if every bounded input produces a bounded output. One important note is the fact that an equillibria condition(s) is considered stable if the model always returns to its original position after small disturbances. These equillibria conditions are interesting to be explored, as it is possible to explain them using the knowledge from the theory or problem that is modelled. As such, the existence of reasonable equilibria is also an indication for the correctness of the model. To obtain possible equilibrium values for the other concepts, first the temporal equations previously presented in Equation 4.14, 4.15 and 4.16 in Section 4.1 under Chapter Four are described in differential equations 5.1, 5.2 and 5.3. These three differential equations 5.1, 5.2 and 5.3 present the differential values for Dissatisfaction, Consistency Action and Consistency in Refusal in Action.

$$\frac{dDf(t)}{dt} = \lambda.[Ng(t) - Df(t)].\big(1 - Df(t)\big).(Df(t)) \qquad (5.1)$$

$$\frac{dCa(t)}{dt} = \zeta.[Pc(t) - Ca(t)].\big(1 - Ca(t)\big).Ca(t)) \quad (5.2)$$

$$\frac{dCr(t)}{dt} = \varphi.[Ar(t) - Cr(t)].\big(1 - Cr(t)\big).Cr(t)) \quad (5.3)$$

Assuming the parameters φ, ζ, λ, are nonzero, from the equations 5.1, 5.2 and 5.3, the following cases can be distinguish.

$$[Ng(t) - Df(t)].\big(1 - Df(t)\big).(Df(t)) =$$
$$[Pc(t) - Ca(t)].\big(1 - Ca(t)\big).Ca(t)) = 0$$

$$[Ar(t) - Cr(t)].\big(1 - Cr(t)\big).Cr(t)) = 0$$

Later these cases can be distinguished into

$$(Ng = Df) \vee (Df = 1) \vee (Df = 0)$$

$$(Pc = Ca) \vee (Ca = 1) \vee (Ca = 0)$$

$$(Ar = Cr) \vee (Cr = 1) \vee (Cr = 0)$$

From here, a first of conclusions can be derived where the equilibrium can only occur when $Ng=D_f$, $Df=1$, or $Df=0$. By combining these three conditions, it can be re-written into a set of relationship in $(A \vee B) \wedge (D \vee E)$ expression:

$$\big((Ng = Df) \vee (Df = 1) \vee (Df = 0)\big) \wedge$$

$$\big((Pc = Ca) \vee (Ca = 1) \vee (Ca = 0)\big) \wedge$$

$$((Ar = Cr) \vee (Cr = 1) \vee (Cr = 0))$$

This expression can be elaborated using the *law of distributivity* as $(A \wedge D) \vee (A \wedge E) \vee,..,\vee (C \wedge F)$.

$$(Ng = Df \wedge Pc = Ca \wedge Ar = Cr) \vee$$
$$(Ng = Df \wedge Ca = 1 \wedge Cr = 1) \vee \ldots$$
$$(Df = 0 \wedge Ca = 0 \wedge Cr = 0)$$

Table 6.1 provides a summarization of these equilibria.

Table 6.1
Summary of Equilibrium Equation

Concept	Equilibrium Equations
Sb	$Sb = Ba.\ [1-(1-Ar)]$
Se	$Se = Pb.[1- Ng]$
Cg	$Cg = w_{c_1} Ab + w_{c_2} Si + w_{c_3} Mv$
Pb	$Pb = \left[w_{pb_1} Ac + w_{pb_2} Mv + w_{pb_3} Cg \right].(1-\Pr)$
Pc	$Pc = \left[w_{pc_1} Pa + w_{pc_2} Ic + w_{pc_3} Se \right].(1-Ar)$
Ar	$Ar = \left[w_{Ar_1} Df + w_{Ar_2} Hr + w_{Ar_3} Pa \right].(1-Pc)$
Mv	$Mv = \sigma\ (Ab+ Si+ Cg) + (1- \sigma)\ (Ac)$
Ac	$Ac = [\gamma.\ Bk + (1- \gamma).Bf]\ [1-Ng]$
Pr	$Pr = Sb.\ [1-\rho.\ Cg + (1- \rho)\ .Pb]$
Dc	$Dc = Bf.[\ \eta.Mv + (1- \eta\ ).Pb]$
Ic	$Ic = Dc.\ [\nu.Se + (1- \nu\ ).Ba]$
Ng	$Ng = \psi.Pr + [\ (1- \psi).Se]$
Hr	$Hr = \phi.Df + [\ (1- \phi).Ng]$

This later provides possible combinations equillibria points to be further analysed which is of huge amount of possible combinations, (in this case, 3^3= 27 possibilities) whereas some typical cases were further analysed as follows:

Case 1: (*Ng=Df*)

From Table 6.1, the expression for *Df* can be obtained from

$$Ar = \left[w_{Ar_1} Df + w_{Ar_2} Hr + w_{Ar_3} Pa \right].(1-Pc)$$

Where $Ar/(1-Pc) = w_{Ar1}Df + w_{Ar2}Hr + W_{Ar3}Pa$

Recall from the *law of distributivity* expression stated previously that *Ar* = *Cr* and *Pc* = *Ca*

Hence, *Ar*/(1-*Pc*) gives *Cr*/(1-*Cr*) = 0

Thus, $w_{Ar1}Df + w_{Ar2}Hr + W_{Ar3}Pa = 0$

And $Df = -\ (w_{Ar2}Hr + W_{Ar3}Pa)/\ w_{Ar1}$

Further from Table 6.1, it can be seen that only *Se*, *Ac* and *Hr* have the factor of *Ng* whereby introducing *Df* expression into these three factors then this expressions are possible:

For $Se = Pb[1 - Df]$

$$= Pb\left[1 + \left(w_{Ar_2} Hr + w_{Ar_3} Pa\right) / w_{Ar_1}\right]$$

This expression depicts that negative thoughts equals to dissatisfaction then self-efficcy is defined by the direct combination of perceived benefit, threat and planned action factors.

Likewise, $Ac = \left[\gamma.Bk + (1-\gamma).Bf\right].[1 - Df]$

$$= \left[\gamma.Bk + (1-\gamma).Bf\right].\left[1 - \left(w_{Ar_2} Hr + w_{Ar_3} Pa\right) / w_{Ar_1}\right]$$

It indicates that at this case condition, attitude to change is characterized by behaviour knowledge, belief, threat and planned action.

$Hr = \phi.Df(t) + \left[(1-\phi).Df\right]$, assuming $\phi = 0.5$

Then, *Hr* = *Df* which depicts that when negative thoughts equals to dissatisfaction then threat is generated. In summary, this first case example depicts the condition whereby negative thoughts leads to dissatisfaction. It shows that the interplay between negative thoughts and dissatisfaction lead to threat. In other words, it proves that there is a connection between the three factors namely negative thoughts, dissatisfaction and threat. This finding is supported by Coyle (1999), Godin, Kittel, Coppieters and Siegrist (2005) and Varga and Freyberg-Inan (2012) studies where it was admitted that there are connection between the three factors. Specifically, Varga and Freyberg-Inan (2012) pointed it out that dissatisfaction give rooms to negative thoughts which usually form

threat toward or on an action. Similarly Coyle (1999) argued that the interplay of these three factors usually cause a situation in which agent might feel it action might be perceived negatively (or rejected) by other agents. This phenomenon was referred to as personality identity threat by Schmader, Johns and Forbes (2008) which was admitted to be caused by dissatisfaction and negative thoughts.

Case 2: (*Df = 1)*

From Table 6.1

$$Ng = \psi \,\mathrm{Pr} + \left[\left(1-\psi\right) Se\right]$$

$$Hr = \phi + \left[\left(1-\phi\right) Ng\right], \text{ assuming } \phi = 0,$$

Then, $Hr = Ng$

Recall in Table 6.1

$$Ar = \left[w_{Ar_1} Df + w_{Ar_2} Hr + w_{Ar_3} Pa\right].\left(1-Pc\right)$$

When $Df = 1$, then $Ar = \left[w_{Ar_1} + w_{Ar_2} Hr + w_{Ar_3} Pa\right].\left(1-Pc\right)$

$$= \left[w_{Ar_1} + w_{Ar_2}.\left(\psi \,\mathrm{Pr} + \left[\left(1-\psi\right) Se\right]\right) + w_{Ar_3} Pa\right].\left(1-Pc\right)$$

Another case example is when dissatisfaction is high (Df=1) which depicts a condition whereby threat leads to negative thoughts and will be directly proportional to perceived risk while inverse to self-efficacy. This case was found to be consistency with Rader, May and Goodrum (2007) study which affirms that agent perception of risk form negative belief which might threat its intended actions. This affirmation was supported by May, Rader and Goodrum (2009) that perceived risk and threat usually reduce agent's confident or self-efficacy to execute a planned and desire action.

Case 3: (*Pc = Ca*)

From Table 6.1, $Hr = \phi.Df + [\,(1-\phi).Ng]$

Substituting $Df = -(w_{Ar2}Hr + W_{Ar3}Pa)/\, w_{Ar1}$ (from Case 1)

Then, $w_{Ar2}Hr = [(w_{Ar2}\phi\ w_{Ar2}Hr + w_{Ar2}\phi\ w_{Ar3}Pa)/\, w_{Ar1}] + w_{Ar2}(1-\phi)Ng$

It is know in Table 6.1 that $Ar = \left[w_{Ar_1} Df + w_{Ar_2} Hr + w_{Ar_3} Pa \right](1-Ca)$

By substituting *Df* and $w_{Ar2}Hr$ *t*hen *Ar* is given as

$$= \left[w_{Ar_1} \left(w_{Ar_2} Hr + w_{Ar_3} Pa \right) / w_{Ar_1} + w_{Ar_2} \phi w_{Ar_2} Hr + w_{Ar_3} Pa / w_{Ar_1} + \left((1-\phi) Ng \right) + w_{Ar_3} Pa \right](1-Ca)$$

This third case shows a condition where performed action is found to be equal to consistency in action. At this condition, threat will be supported by planned action whereas negative thoughts will decrease which will make action reject to be reduced. This implies that at a point that positive performed action becomes continuously obtainable action then there will be no room for action reject or negative responses (Harmer, Shelley, Cowen & Goodwin, 2014)

Case 4: (*Df = 0*)

$$Ar = \left[w_{Ar_2} Hr + w_{Ar_3} Pa \right](1-Pc)$$

$$= \left[w_{Ar_2} Hr + w_{Ar_3} Pa \right]\left(1-\left[w_{Pc_1} Pa + w_{Pc_2} Ic + w_{Pc_3} Se \right](1-Ar)\right)$$

$Hr = (1-\phi) Ng,$ assuming $\phi = 0,$

$$Ng = \psi \Pr + \left[(1-\psi) Se \right]$$

$$= \psi Sb\left[1-\rho Cg + (1-\rho) Pb \right] + \left[(1-\psi) Pb(1-Ng) \right]$$

This case instance relates the point when dissatisfaction tends to zero which depicts that both action reject and threat will be characterized with combination of increased severity of behaviour, challenge and perceived benefit with reduced negative thoughts. This was in line with Kim, Kim, Im and Shin (2003) and McHugh, Kutney-Lee, Cimiotti, Sloane and Aiken (2011) results which assert that when an agent is challenged to perform a difficult action (high severity of behavior) that has vital advantages (high perceived benefit) to its predefined objective then nothing can prevents it from execution. Even when the executed action is found unfavorable to the agent there will be no form of dissatisfaction because the agent achieved its planned execution (Coyle, 1999). This proves that when challenge, severity of behaviour and perceived benefit are high with reduced negative thoughts then agent will be satisfied with its action performed. In summary, these four case examples are part of the numerous different instances which depict the model equillibria conditions as obtained in the simulation traces discussed in Chapter Four previously.

6.1.2 Automated Verification

This section deals with the verification of relevant dynamic properties of the cases considered in the agent based model, which is consistent with literatures. The Temporal Trace Language (TTL) is used to perform an automated verification of specified properties and states against generated traces. Based on the concept discussed under Chapter Three, several dynamic properties were formulated using a sorted predicate logic approach. As for the local properties, several properties reflected the proposed model which was further verified using causal relationship as related to empirically founded literature. In addition, the global properties were generated from the simulation traces and related empirically literature which was based on achievement, equilibrium, representation and comparison properties. Achievement property was where certainty

conditions (initial and/or intermediate) on the model state was defined achievable while equilibrium property defined the stability state of function of the model. The representation property depicts the internal states related to external states in past and /or future states. This was done using both backward relations (relations to the pre-cursor conditions) and forward relations (relations to the future conditions). The comparison property was utilized to appraised states in the model by exploring different time points (monotonically increasing or decreasing) and different generated traces (case conditions). This will be explored for both the Agent Model and Support Model in the next subsections 6.1.2.1 and 6.1.2.2 respectively.

6.1.2.1 Agent Model Automated Verification

The Agent Model discussed in Section 4.1 and presented in Figure 4.17 automated verification is described in this subsection. Based on the model, four case conditions were given in the verified properties (VP1 to VP4) which were introduced in semi-formal and informal representations showing the application of these properties:

VP1: High Ability Will Reduce Dissatisfaction

Individuals with high ability to perform certain actions develop lesser chance of having dissatisfaction.

VP1≡ ∀γ:TRACE, t1, t2, t3 :TIME, v1,v2,w1,w1:REAL

[state(γ, t1)|= personal_ability(v1) &

state(γ, t1)|=level_dissatisfaction(w1) &

state(γ, t2)|=personal_ability(v2) &

v2 > v1] ⇒ ∃t3:TIME > t2:TIME &

t2: TIME > t1:TIME [state(γ, t3)|= level_dissatisfaction (w2) & w1 > w2]

This property instance is implemented and it is discovered that agent with sufficient ability usually possess the capability to overcome dissatisfaction over its cause action. This property is reflected in influential attribution in Figure 5.5 and planning deficient agents' attribution presented in Appendix VIII. In these simulation traces, it can be inferred that when agent possesses high ability then dissatisfaction will be reduced. This property finding is found to be consistent with Phillips and Green (2002) and Fogg (2009) results that sufficient ability within the right time frame has the potential to reduce the impact of dissatisfaction over action performed.

VP2: Belief and Knowledge Will Improve Willingness to Change

Individuals with high self-belief and knowledgeable tend to develop high chance to change their behaviour.

VP2 ≡ ∀γ: TRACE, ∀t1, t2:TIME, ∀F1,H1, M1, d:REAL

[state(γ,t1)|= self_belief(F1) &

state(γ,t1)|= consistency_refusal_action(H1) &

state(γ,t1)|= social_influence (F1) &

state(γ,t2)|= consistency_ action (M1) &

t2 ≥t1 +d & F1 ≥ 0.8 & H1 ≥ 0.8] ⇒ M1 ≥ 0.5

This second property instance shows that strong self-belief and insightful knowledge about attribution agents possess high prevalence to change intentions. The property instance is reflected in social influence deficient as presented in Appendix VIII and influential agent attributions as shown in simulation trace Figures 5.5. These agent attribution traces depict that self-belief and sufficient knowledge will increase intention to change and desire to change. This is also found evident in some studies like Sniehotta, Scholz and Schwarzer (2005), Webb and Sheeran (2006) and Schwarzer (2008) where it

is maintained that for willingness to change to be reinforcement then there is need for a strong based belief and profundity knowledge of the target behavior.

VP3: Monotonic Increase of Variable, v for Planned Action Amplifies Future Positive Response over Willingness to Change

For all time points t1 and t2 between tb and te in trace γ if at t1 the value of v is x1 and at t2 the value of v is x2 and $t1 < t2$, then $x2 \geq x1$

VP3 ≡ ∀γ: TRACE, ∀t1, t2:TIME, ∀X1,X2:REAL

[state(γ,t1)|= has_value(v, X1) &

state(γ,t2)|= has_value(v, X2) &

$tb \leq t1 \leq te$ &

$tb \leq t2 \leq te$ &

$\Rightarrow x2 \geq x1$

In this third property instance, it is pictured that adequate and continuous planning over time will increase and improved performed action outcome positively. The property is mirrored in both social influential deficient and unknowledgeable agent attributions as illustrated in simulation traces under Appendix VIII. The two attribution gives that increase in planned action will increase both intention to change and desire to change. This property instance is in line with Fogg (2009), Thomaschke, Hopkins and Miall (2012) and Zhou, Sun, Knoll, Hamilton and Schwarzer (2015) findings that for successful intervention or action to achieved then there must be conscious and systematic planning toward it. This phenomenon was referred by Fogg (2009) as behavioural facilitator (Planned Action) and it was concluded that for successful behaviour outcome to be achievable then this facilitator must occurs in a precise manner.

VP4: Monotonic Decrease of Variable, v for Belief Amplifies Future Negative Response over Willingness to Change

For all time points t1 and t2 between tb and te in trace γ if at t1 the value of v is y1 and at t2 the value of v is y2 and t1 < t2, then y1 ≥ y2

VP4 ≡ ∀γ: TRACE, ∀t1, t2:TIME, ∀Y1,Y2:REAL

[state(γ,t1)|= has_value(v, Y1) &

state(γ,t2)|= has_value(v, Y2) &

tb ≤ t1 ≤ te &

tb ≤ t2 ≤ te &

⇒ Y1 ≥ Y2

It was discovered at this property illustration that continuous decline of self-belief will increase negative reaction and intention to change as obtained in belief deficient agent attribution simulation trace illustrated in Appendix VIII. It depicts a condition where agent does not have strong self believe in the outcome of its action which will give rooms for the agent to consider other agents beliefs and intentions (Baranowski, Cullen, Nicklas, Thompson & Baranowski, 2003). It will lead to a state that agent will not have confident on its action and it will also affect its desire and intention negatively (Dawkins, Powell, Pickering, Powell & West, 2009).

6.1.2.2 Support Model Automated Verification

This subsection presents the automated verification of the support model which was discussed in Section 4.2 and illustrated in Figure 4.23. Similar to the agent model automated verification, this support model automated verification made use of four case conditions as verified properties (VP1 to VP4) which were introduced in semi-formal and informal representations showing the application of these properties:

VP1: Low in Social Influence Will Increase Refusal Behaviour

Individuals with low social influence tend to develop high chance in refusing to perform actions.

VP1 ≡ ∀γ: TRACE, ∀t1, t2:TIME, ∀F1,F2,H1,H2, d:REAL

[state(γ,t1)|= social_influence(F1) &

state(γ,t1)|= consistency_refusal_action(H1) &

state(γ,t2)|= social_influence (F2) &

state(γ,t2)|= consistency_refusal_action (H2) &

t2 ≥t1 +d & F1 < 0.3 & F1 > F2] ⇒ H2 > H1

This property reflects that when there is lack of social support or collaboration then the possibility for the agent to achieve target behaviour will be low. This property is similar with the simulation trace of social influence deficient agent attribution as shown under Appendices VIII and XIV. The attribution depicts that with adequate support agent probability of achieving target predefined objective is high. This property is consistent with previous studies like Garg, Srinivasan and Jaglan (2011), Zheng (2013) and Ramchurn et al (2015) where it was discovered that the collaboration and teamwork among agents will aid and increase individual target accomplishment within the same environment.

VP2: Low in Planned Action Will Increase Refusal Behaviour

Individuals with low planned action tend to develop high chance in refusing to perform actions.

VP2 ≡ ∀γ: TRACE, ∀t1, t2:TIME, ∀F1,F2,H1,H2, d:REAL

[state(γ,t1)|= planned _action (F1) &

state(γ,t1)|= consistency_refusal_action(H1) &

state(γ,t2)|= planned_action (F2) &

state(γ,t2)|= consistency_refusal_action (H2) &

t2 ≥t1 +d & F1 < 0.3 & F1 > F2] ⇒ H2 > H1

In this property it is seen that low in planned action will result to increase in behaviour refusal. The property is reflected in planning deficient agent as illustrated in Appendeices VIII and XIV which depicts that when there is lack of planning by an agent then the possibility of achieving target behaviour by agent will be low. This property finding is evidence in some previous studies like Oinas-Kukkonen (2013), Kolb (2013), Michie, Johnston, Francis, Hardeman and Eccles (2008) and Hyland et al (2006) where it was discovered agents' planning has direct implication on its successful and unsuccessful action.

VP3: Trigger Will Reduce Negative Thoughts

Individuals with high trigger tend to develop lesser chance of having negative thoughts.

VP3 ≡ ∀γ: TRACE, ∀t1, t2:TIME, ∀F1,H1, M1, d:REAL

[state(γ, t1)|= trigger(v1) &

state(γ, t1)|=level_negative_thoughts(w1) &

state(γ, t2)|=personal_ trigger (v2) &

v2 > v1] ⇒ ∃t3:TIME > t2:TIME &

t2:TIME > t1:TIME [state(γ, t3)|= level_negative_thoughts (w2) & w1 > w2]

It was discovered at this property instance that precise and timely trigger will reduce negative thought and reduce threat as obtained in uninspiring agent attribution trace illustrated in Figure 5.7. The finding of this property instance is found to be similar with Palumbo (2015), Aronson, Burgess, Phelan and Juarez (2013) and Schmader and Beilock

(2012) results which pointed out that trigger is a vital element in reduction of negative thoughts in order to obtain an achievable actions.

VP4: High Social Influence Will Reduce Dissatisfaction

Individuals with high social Influence to perform certain actions develop lesser chance of having dissatisfaction.

VP4≡ ∀γ:TRACE, t1, t2, t3 :TIME, v1,v2,w1,w1:REAL

[state(γ, t1)|= personal_social_influence(v1) &

state(γ, t1)|=level_dissatisfaction(w1) &

state(γ, t2)|=personal_ social_influence (v2) &

v2 > v1] ⇒ ∃t3:TIME > t2:TIME &

t2:TIME > t1:TIME [state(γ, t3)|= level_dissatisfaction (w2) & w1 > w2]

This property instance depicts the reduction of dissatisfaction with social influence which is reflected in social influence deficient agent attribution as illustrated in Appendices VIII and XIV where agent with sufficient support will be able to achieve target action. This property finding is evidence in some previous studies like Ferguson, Muñoz, Garza and Galindo (2014), Vartanian and Dey (2013) and Sridhar and Srinivasan (2012) which mentioned that agent that enjoys support from other agents will be able to achieve its target action.

6.2 VALIDATION

This subsection presents the validation results of the proposed model. The developed application as presented in Section 4.3 under Chapter Four was used to conduct user centred experiment on Malaysian children. Based on previous studies children are known to posses' poor oral hygiene due to their inabilities to achieve proper and clean teeth

brushing behaviour (Saddki, Yusoff & Hwang, 2010). Oral hygiene behavioural action was investigated in this study because many children usually lack the motivation to perform it regularly (Krishnan, Kumari, Sivakumar, Iyer & Ganesh, 2014; Grey, Harcourt, O'Sullivan, Buchanan & Kilpatrick, 2013). This might be because of the boring nature of the behaviour which is mostly defect by children (Sundell, Ullbro, Marcusson & Twetman, 2015; Olak, 2013). A tooth brushing behaviour of brushing twice a day both morning (after bed) and night (before bed) was the target behaviour. The study made use of both qualitative and observatory research approaches to validate the formal model based on Madigan et al (2014) suggestion that observatory research can be used to triangulate qualitative research approach for a better validation. The thirty respondents were selected using purposive sampling method. This method was employed because only voluntary respondents that were found to be unable to perform the target behaviour for the study were selected.

The validation stages were implemented in three interaction stages. An initial interaction was performed (Interaction I), two weeks later another interaction was conducted (Interaction II) and the final interaction stage (Interaction III) was conducted four weeks after the initial interaction stage. The implementation is splited into these three stages of interactions to observe the reaction of the respondents with the application. Whereas, reinforcements are make on the designed model factors of the application (Ability, Social Influence, Behaviour Knowledge, Behaviour Task, Planned Action and Belief), with the aim of improving the persuasiveness of the designed application. Figure 6.1 below gives an overview of the implementation process. After first interaction (interaction I), based on the results obtained, certain improvements were made on the designed application based on the model factors. These improvements were implemented to have positive impact on the respondents' which is specifically tailored to reduce psychological

reactance. Table 6.2 shows the application implementation improvement during the three interactions.

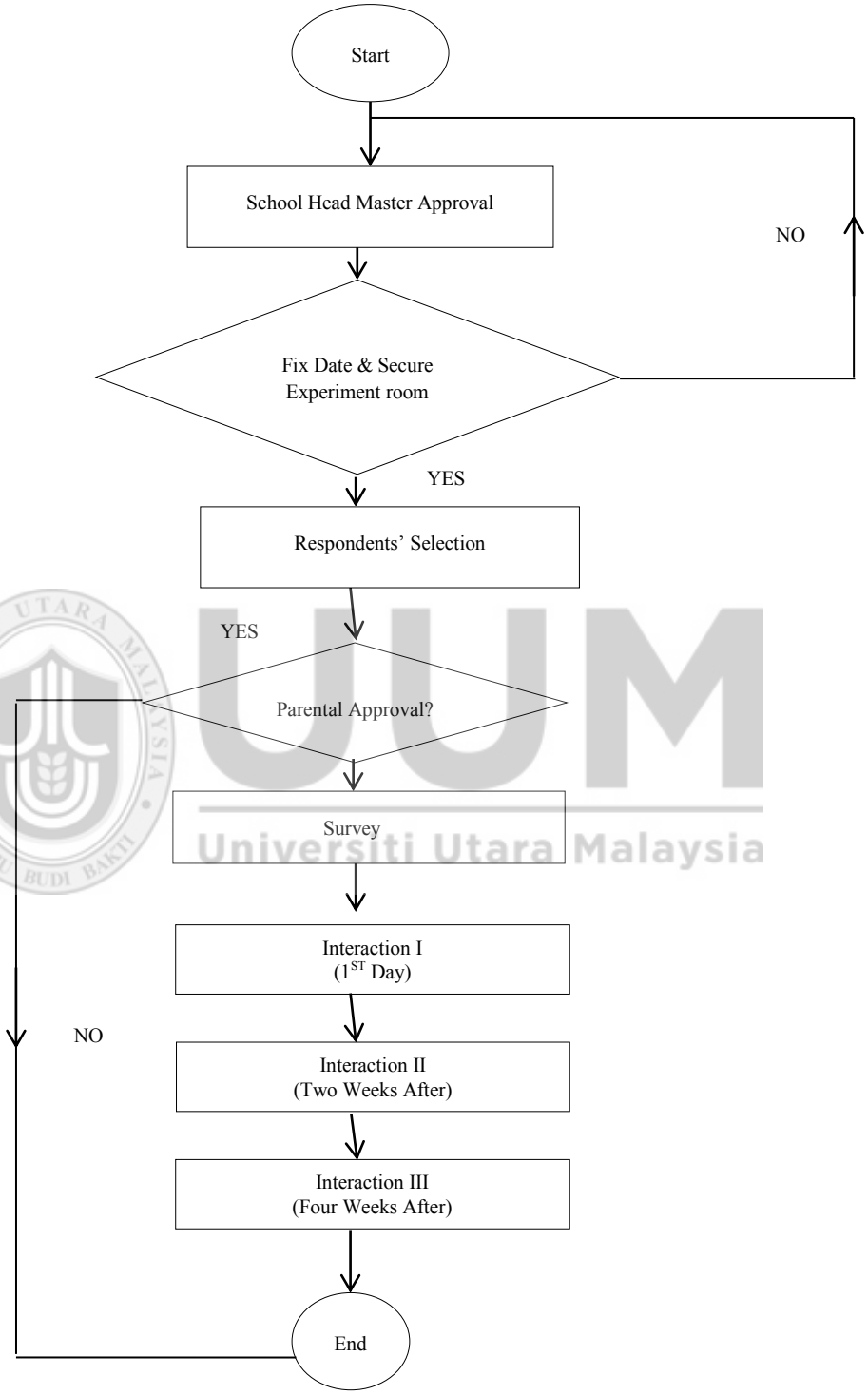

Figure 6.1. Validation Phase Flowchart

Table 6.2

Application Improvement during Three Interactions

S/N	Factor	Description	Implementation			References
			Interaction I (Uninspiring Agent)	**Interaction II (Task Challenging Agent)**	**Interaction III (Influential Agent)**	
1	Ability	Giving simple and acceptable instructions to audience	*I am speaking to you today on the need to maintain a better oral hygiene,* *This can only be achieved when you know and constantly practice these instructions,* *A good oral hygiene includes constant teeth brushing which must be done in a proper systematic method,* *Teeth brushing should be observed twice a day,* *This should be observed in the morning after bedtime and late at night before going to bed,* *Lastly, proper teeth brushing should take at least 2 minutes making 120 seconds.*	*I am speaking to you today on the need to maintain a better oral hygiene,* *For a good oral hygiene constant teeth brushing must be done in a proper systematic method,* *This should be observed in the morning after bedtime and late at night before going to bed,* *Proper teeth brushing should take at least 2 minutes.*	*Oral hygiene is important,* *It will give you fresher breath and confident during playtime with friends,* *You can do this by constant teeth brushing twice a day,* *Morning after bedtime and night before going to bed,* *Make sure it last at least 2 minutes.*	Boyland, Harrold, Kirkham, & Halford, (2012)
2	Social Influence	Giving a smiling and cheerful appearance to the embodied agent in the application	Embodied agent was seen to give a straight line tight lipped smile	Embodied agent was seen to give a sly smile with one side of the mouth lifted up	Embodied agent was seen to give a concave sideways looking up smile	Salgado-Montejo, Tapia Leon, Elliot, Salgado & Spence, (2015) Van Kleef, Van den Berg & Heerdink, (2015)
3	Belief	Making confident eye contact and attraction with audience	*Hi!*	*Hi kids!*	*Hi Friend!*	Thrush (2013) Hayes, & Keogh, (2012) Chen, Minson, Schöne, & Heinrichs, (2013)
			Now is time to put into practice these instructions, *You must follow all my instructions obediently,* *I believe you will remember and practice them well.*	*Try to put into practice these instructions,* *Hope you can remember and practice them well,* *If you do then we will be very good friends!*	*I promise you a reward if you follow my instructions,* *Will you win my reward?* *Bye Bye Friend*	
			Embodied agent held a direct gaze with the user initially and then looked away in the concluding part of giving instructions on the target behaviour.	Embodied agent held a gaze for a couple of seconds and looked away for a few seconds and returned to hold a direct gaze with the user.	Embodied agent was seen to hold a direct gaze with the user all through the period of instructing the user on the target behaviour.	

Table 6.2 Cont'

Application Improvement during Three Interactions

S/N	Factor	Description	Implementation			References
			Interaction I	**Interaction II**	**Interaction III**	
4	Behaviour Knowledge	Giving simple, clear and understandable instructions on the target behaviour to audience	*Kids, for a thorough teeth brushing experience the following must be properly and obediently followed in the manner I will be directing you now:*	*Kids, for a thorough teeth brushing experience the following must be properly observed:*	*Just follow these 5 easy steps:*	Slaughter, Peterson, & Moore, (2013)
5	Planned Action	Giving stepwise and sequence steps to enable audience achieve the target behaviour	*The first thing to do is the cleaning of the outer surface of your upper teeth,* *Next, you start cleaning the lower surface of your outer teeth,* *Secondly, the cleaning of the inner surface of your upper teeth is also important,* *Before going on to clean the lower surface of your inner teeth,* *Thirdly, use sweeping strokes to clean the chewing surface of the teeth,* *Fourth, for a fresher breath ensure you brush the tongue from back to front,* *Last, take a sip of clean water and swish it around your mouth,* *Then spit the swished water out of your mouth.*	*First, clean the outer surface of your upper teeth,* *Then go to the lower surface of the outer teeth,* *Second, clean the inner surface of your upper teeth,* *Then go to the lower surface of the inner teeth,* *Third, use sweeping strokes to clean the chewing surface of the teeth,* *Forth, for a fresher breath ensure you brush the tongue from back to front,* *Last, take a sip of clean water and swish it around your mouth,* *Then spit the swished water out of your mouth.*	*1. Clean the outer surface of your upper teeth,* *Then the lower surface of the outer teeth* *2. Clean the inner surface of your upper teeth,* *Then the lower surface of the inner teeth* *3. Using your brush in a up-down way, clean the chewing surface of the teeth* *4. Brush your tongue from back to front* *5. Sip clean water, swish it around your mouth and spit out.*	
6	Behaviour Task	Giving likely complication and negativity associated with the target behaviour	*Likewise, you must ensure that fluoride toothpaste is used,* *This will not only help removal plaques but will also strengthen your tooth enamel*	*Likewise, you must ensure that fluoride toothpaste is used,* *This will strengthen your tooth enamel*	*For a happier playtime with other friends at school* *Oral hygiene is important* *For a shining teeth to show your friends use fluoride toothpaste*	Kadomura, Li, Tsukada, Chu, & Siio (2014) Fink, Lemaignan, Dillenbourg, Rétornaz, Vaussard, Berthoud, Franinović (2014)

For instance, ability factor which aims at making the instructions simple and acceptable for the user was very worded, technical and not easy enough for a child to comprehend at the initial interaction stage. This was improved upon in the second and third interaction stages, although the third interaction stage gave the instructions in a manner that was friendly, less formal and more comprehensible to a child. The appearance of the embodied agent also had an effect on the response of the user. This is seen in the social influence and belief factors as the agent with the concave sideways up happy smile had a greater persuasive effect on the user, likewise the holding and locking a straight gaze also improves the persuasive ability of the agent because at the moment the agent looks away or unlocks gaze with the user, the user is seen to be distracted and hence losing concentration on listening to the instructions on the target action.

The instructions given on the target behaviour in simple, clear and easy to understand manner also helps the user to be more receptive to the instructions. Avoiding complicated vocabulary and too much preamble but rather going straight to giving the instructions is an easier way to get the job done. Encouraging the respondents that the target action is easy and can be remembered by counting in a step-by-step manner will increase the receptiveness of the user. This is because respondents of this group are more inclined to counting and numerals. Finally, giving positive comments such as the target behaviour helping in making of friends and having shinier teeth, rather than being scared of plagues and tooth decay is more persuasive to the user.

These model factors were implemented in the designed application at three different levels (which is known as the three interactions; interaction I, II & III). The second and third (interaction II & III) are the reinforcements which are met to improve the acceptance of the application by the users. Based on Table 6.2 the persuasiveness of the

application is a function of the model factors implemented in the designed application as discussed in Section 4.3.1 and summarized in Table 4.26 under Chapter Four.

In addition, the model factors summarized in Table 6.2 depicts examples of the case condition discussed in Section 5.3 and 5.4 namely uninspiring agent, belief deficient agent, ability deficient agent, influential agent, social influence deficient agent, unknowledgeable agent, task challenging agent and planning deficient agent. Whereas, only three case conditions were considered in the human experiment namely uninspiring agent, task challenging agent and influential agent in order to validate the model. For the first interaction (interaction I), the designed application was with low persuasiveness (low ability, social influence, behaviour task, planned action, belief and behaviour knowledge) which reflects uninspiring agent. Interactions II used application based on task challenging while interaction III depicts influential agent attribution.

The familiarization and provisions of needed resources with favourable (conducive) environment for the experiment interactions depict both support model factors of openness to Behaviour Change and facilitating conditions as discussed in Section 4.2 and summarized in Table 4.20. The human experiment was analysed base on qualitative approach in order to discover deeper understanding and comprehension. Detailed explanation of the qualitative analysis of the experiment is given in Subsection 6.2.1 while Subsection 6.2.2 presents the observation analysis where the body language reaction of the users was observed.

6.2.1 Qualitative Analysis

A qualitative analysis of the implementation of the application on the thirty respondents is discussed in this section. The reaction of the respondents at three stages was recorded and analysed. Furthermore, a background check was also conducted on the respondents

to check if there is a connection between the level of psychological reactance displayed by any of the respondents and his or her background. Details of each interaction scenario are given in the following sections and a summary of the respondents' background which was obtained from the survey distributed to the respondents is presented.

6.2.1.1 Respondent's Background

The study wass carried out in a timber plantation village primary school in Kedah State Malaysia using Standard One to Three students. This study made use of this location because it is a rural setting and most rural children seen to lack motivation for teeth brushing behaviour particularly children between 5 to 12 years as pointed out by Mittal, Chaudhary, Chopra and Khattar (2014) and Damle, Patil, Jain, Damle and Chopal (2014). The students were within the age range of seven to nine years which was done by using purposive sampling. Purposive sampling was used because only children that were identified with poor oral hygiene and brushing experiences were selected for the study which is based on Christian et al (2015) and Hsieh, Huang, Tsai and Hsiao (2014) studies. Figure 6.2 summarized the study respondents' recruitment flow chart.

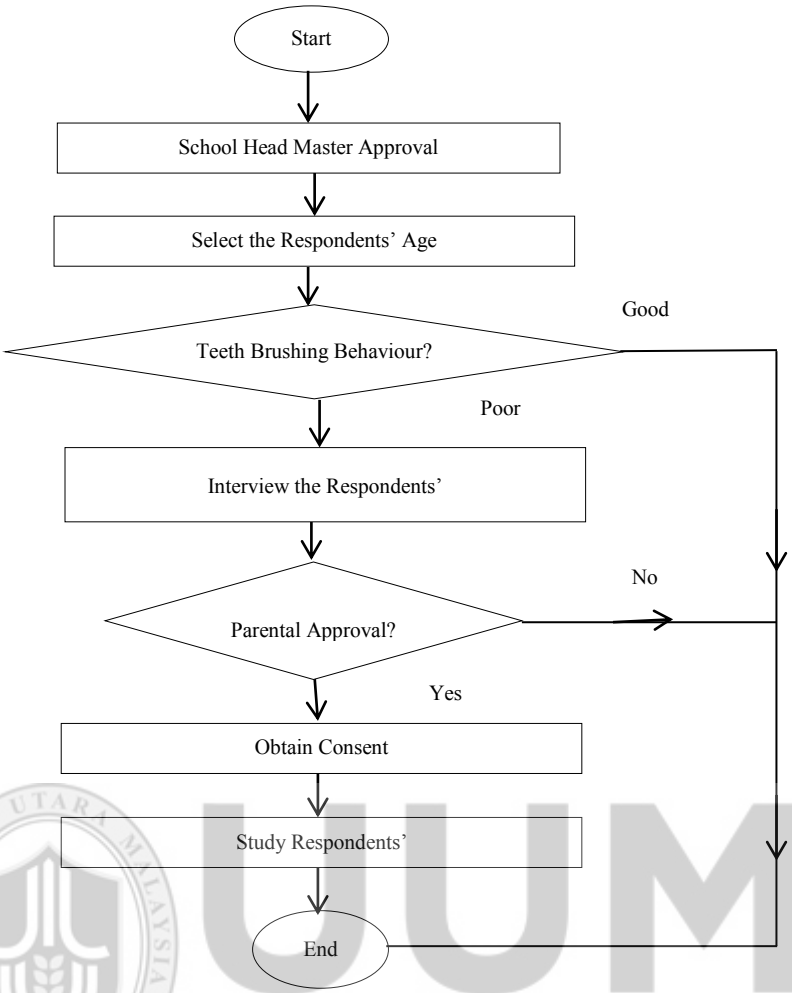

Figure 6.2. Respondents' Recruitment Flowchart

Based on Figure 6.2, students were assessed by their Headmaster and Class teacher to determine those students with poor teeth brushing behavior and out of the respondent class suitable for the purpose of the survey, thirty students were selected. The approach adopted for the streamlining of the respondent group by the Headmaster and Class teacher was a review of their teeth brushing behavior history. After the respondents suitable for the survey were grouped out, their voluntary consent was sought and the parents of the students who agreed to participate were contacted. The return of the parent's consent document served as the final criteria for the respondent to be listed amongst the thirty needed for the survey which is presented in Appendix VIII. The details of the respondent group showed that the higher percentage of the children were 7

years of age with 36.7% while children aged 8 and 9 years were 33.3% and 30.0% respectively. The respondents consisted of 11 children from Standard One, 10 children in Standard Two and 9 in Standard Three where the total population was dominated by boys at 60% and the rest were girls. Taking a further investigation into the family background of the children, it was observed that a higher percentage of the parents of the respondents had their secondary school education as their highest education with 76.7% for the mothers and 86.7% for the fathers as is presented in Figure 6.3.

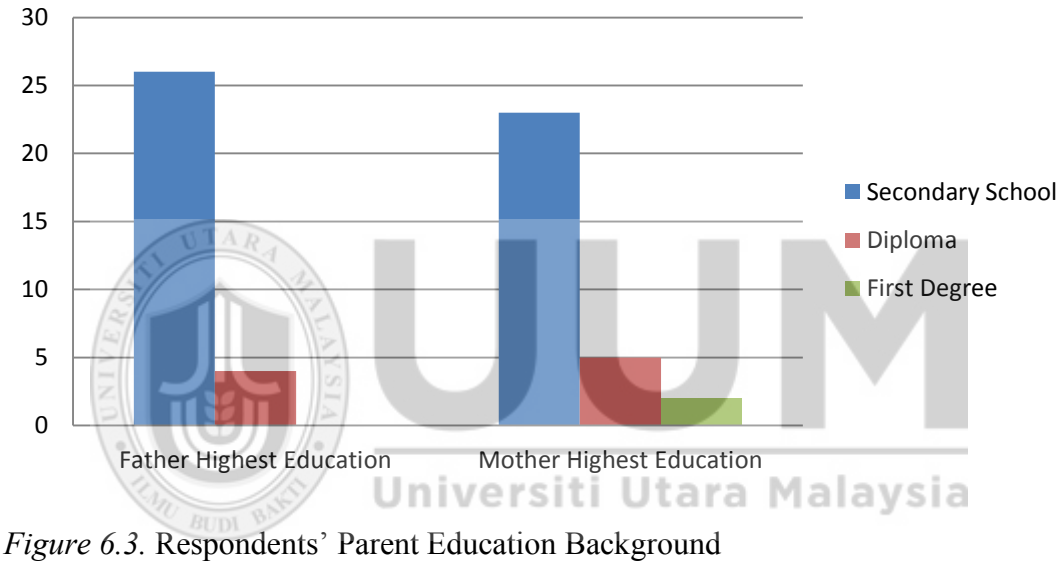

Figure 6.3. Respondents' Parent Education Background

Based on the model factors as summarized in both Table 4.1 and 4.20, this study depicts outgoing and reserved traits as social influence (Brandts, Giritligil & Weber, 2015), gentle and smart as ability (Gonzalez-Mulé, Mount & Oh, 2014), affected emotion and emotion stable as planned action (Lehtonen, Howie, Trump & Huson, 2013), excitable and moody as openness to behaviour (Gaddis & Foster, 2015) and obedient and assertive as belief (Hagadone, 2012). The respondents were observed to be outgoing, gentle, affected emotionally and assertive in nature whereas some were observed to be mixed in excitable and Strung in traits as summarized in Table 6.3

Table 6.3
Summary of Respondent Background

Factor	Personality Traits	Percentage	Remark
Social Influence	Outgoing	76.7	Respondents are more outgoing than reserved
	Reserved	23.3	
Ability	Smart	33.3	Respondent perceived themselves to be less intelligent
	Gentle	66.7	
Planned Action	Affected Emotion	90.0	Most of the respondent were discovered to be more affected emotionally than being stable
	Emotion Stable	10.0	
Openness to Behaviour	Excitable	50.0	There is a mixed finding on these two traits because half of the respondents agreed to be both
	Moody	50.0	
Belief	Obedient	46.7	Most of the respondents shown more assertive traits than obedient
	Assertive	53.3	
Behaviour Knowledge	2 minutes	40	Most of the respondents were not knowledgeable about the behaviour
	5 minutes	60	
Behaviour Task	Sad	53	Respondents were found to dislike performing the behaviour
	Happy	47	

After the study respondents were determined, the respondents were allowed to have a pre-interaction session with the application. This stage started with an ice-breaking exercise for up to five minutes which was used to ensure and improve familiarity, building of confidence and rapport amongst all the respondents. During this exercise, a level of familiarization was established by inquiring from the respondents about their best color, best food, if they had eaten, what were their hobbies amongst other questions to lighten the mood. To further build a level of familiarity from the respondents, the application which was installed on an android tablet was handed over to the children to browse and peruse through, hence getting familiar with the features of the application.

After the session of familiarization with the application, the respondents were assisted in giving response to a pre-interaction survey. The response from the questions administered showed all the children admitting to brushing their teeth with toothbrush and paste. Although, a higher percentage of the children (60%) admitted to brushing for two minutes while the remaining 40% claimed to brush for five minutes. It was also discovered that most of the respondents (46.7%) claim to brush twice daily, followed by

30.0% of the respondents claiming to brush thrice and the last group of 10% brushing just once a day. 90% of the children brush their teeth at morning and at night, though a further investigation into the feeling observed when performing the action showed 53.3% of the children claiming to be sad when performing the brushing behaviour. These findings were represented in Figure 6.5 to 6.8 respectfully.

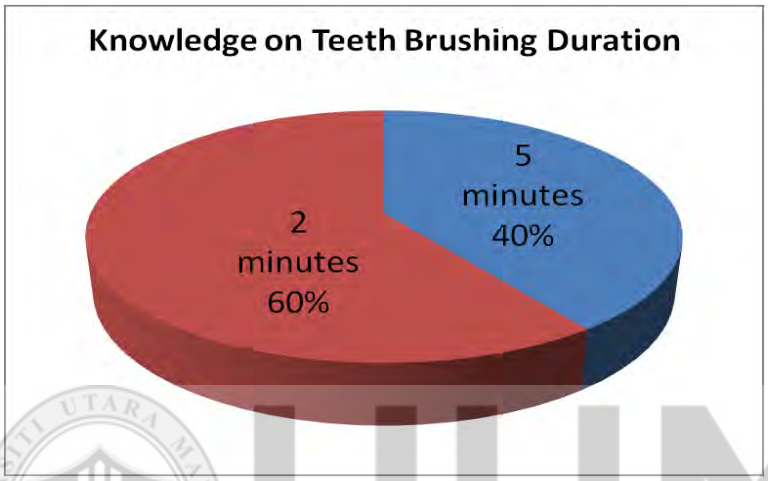

Figure 6.4. Respondents' Behaviour Knowledge

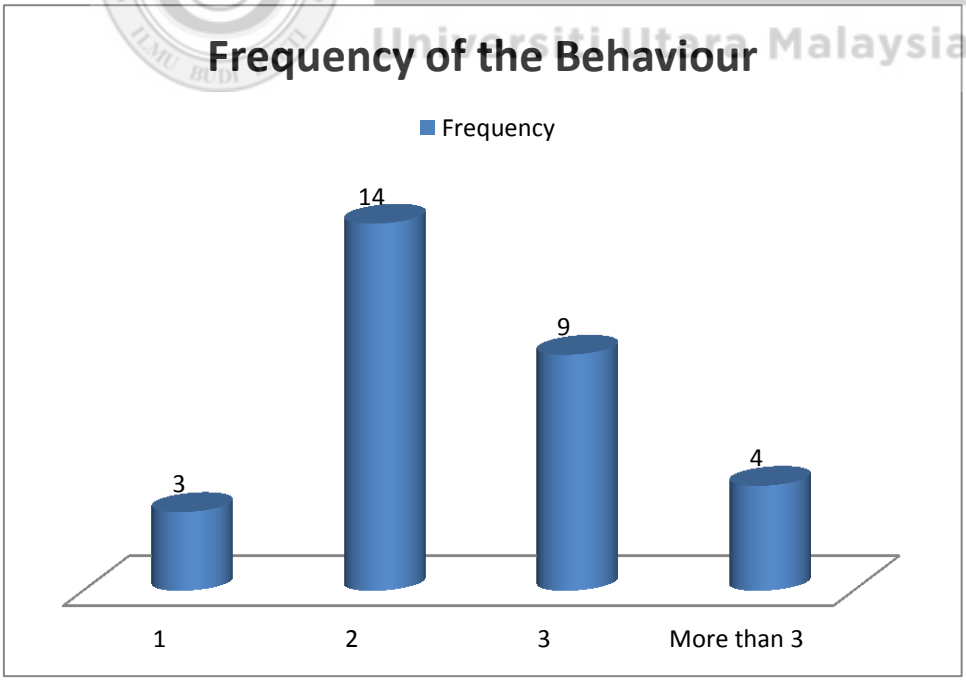

Figure 6.5. Respondents' Behaviour Frequencies

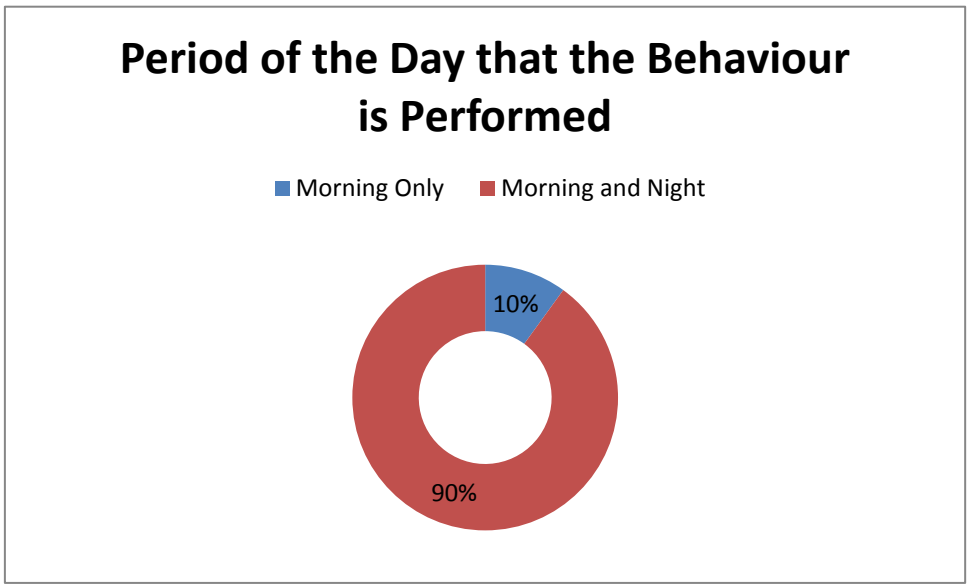

Figure 6.6. Respondents' Period of Performing the Behaviour

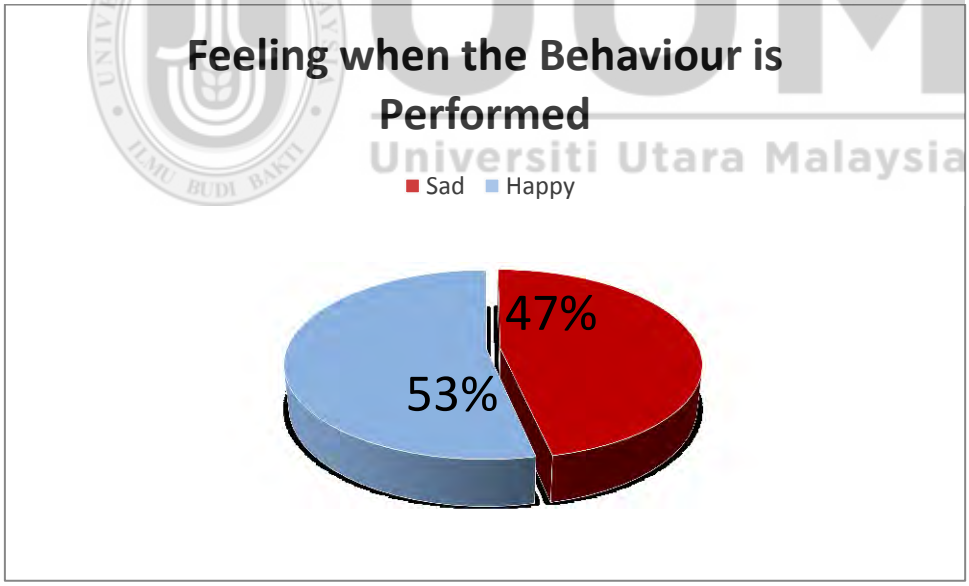

Figure 6.7. Respondents' Feeling about the Behaviour

After the pre-interaction session, the initial interaction stage (Interaction I) was implemented and the other interaction stages; Interaction II and Interaction III were conducted two and four weeks respectively from the initial interaction. Details of the activities of each stage are explained in Subsections 6.2.1.2 to 6.2.1.4.

6.2.1.2 Interaction I

After the survey was administered to obtain respondents background information, the children were made to interact with the application in a quiet and transparent room which was used as the study research site. The results obtained as shown in Table 6.4 depict that 100% of the children admired that they have adequate resources at their disposal to perform the behaviour while only 88% can remember the instructions if asked to perform the behaviour. Furthermore, 90% planned to always perform the behaviour according to the instruction and 97% perceived Dr Clean as a good and happy personal brushing companion. Table 6.4 summarized the results obtained during this first interaction (interaction I).

Table 6.4
Interaction I

Factor	Item	Positive (%)	Negative (%)
Behaviour Knowledge	Do you understand the explanation of Dr Clean?	97	3
Openness to behaviour	Are you happy to meet Dr Clean?	97	3
Ability	Can you do what Dr Clean asked?	97	3
Behaviour Task	Do you think Dr Clean instruction is easy?	97	0
Facilitating Condition	Were all resources needed to perform the behaviour available?	100	0
Social Influence	Can you take Dr Clean as your personal brushing companion?	97	3
Belief	Can you remember Dr Clean instruction when brushing your teeth?	88	12
Planned Action	Do you plan to always perform Dr Clean instruction?	90	10

6.2.1.3 Interaction II

The second interaction (interaction II) stage was conducted two weeks after the initial interaction (interaction I) took place with all the 30 respondents. The second interaction was conducted using the improved application as shown in Table 6.2. This improvement followed the support model concept of increment in the respondent openness to Behaviour Change (*Ob*) and Facilitating Condition (*Fc*) as discussed in Section 4.2. These were implemented by the application giving simpler, easy to understand, child-friendly approach to the instructions on performing the target behaviour. In addition, more attractive and fancy tooth brush, toothpastes and cups were given to the respondents. The result presented in Table 6.4 was compared against Table 6.5. It shows respondents significant improvement on the behaviour.

Table 6.5
Interaction II

Factor	Item	Positive (%)	Negative (%)
Behaviour Knowledge	Do you understand the explanation of Dr Clean?	97	3
Openness to behaviour	Are you happy to meet Dr Clean?	100	0
Ability	Can you do what Dr Clean asked?	97	3
Behaviour Task	Do you think Dr Clean instruction is easy?	100	0
Facilitating Condition	Were all resources needed to perform the behaviour available?	100	0
Social Influence	Can you take Dr Clean as your personal brushing companion?	100	0
Belief	Can you remember Dr Clean instruction when brushing your teeth?	90	10
Planned Action	Do you plan to always perform Dr Clean instruction?	90	10

From Table 6.5 it could be seen that 100% of the respondents totally agree that they remember Dr Clean instructions and the instructions were of help to them. However, a percentage still felt reluctant in sharing the application with friends which depicts psychlological reactant. Thus, the third interaction (interaction III) was aimed at improving the persuasiveness of Dr Clean in order to deflect psychological reactant on respondents which was discussed in the next subsection.

6.2.1.4 Interaction III

The final interaction stage was conducted four weeks after the first interaction. The same procedure was used and the result obtained is presented in Table 6.6. While comparing this result with Table 6.5, a significant improvement was observed on the behaviour of the respondents.

Table 6.6
Interaction III

Factor	Item	Positive (%)	Negative (%)
Behaviour Knowledge	Do you understand the explanation of Dr Clean?	97	3
Openness to behaviour	Are you happy to meet Dr Clean?	100	0
Ability	Can you do what Dr Clean asked?	97	3
Behaviour Task	Do you think Dr Clean instruction is easy?	100	0
Facilitating Condition	Were all resources needed to perform the behaviour available?	100	0
Social Influence	Do you think Dr Clean is as your personal brushing companion?	100	0
Belief	Can you remember Dr Clean instruction when brushing your teeth?	100	0
Planned Action	Do you plan to always perform Dr Clean instruction?	97	3

From Table 6.6 it could be seen that 100% of the respondents totally agree that they remember Dr Clean instructions and think the instructions were easy to be achieved. Nevertheless, 3% affirmed not to understand and have difficulty performing the behaviour. This percentage account for one individual because 3% out of 30 respondents represent one respondent. Thus, only one respondent experienced psychological reactance while twenty nine respondents did not experience psychological reactance with Dr Clean instructions.

6.2.2 Observation Analysis

The three interaction stages were recored with a camcorder with was further analysed using observation research approach. Generally, respondents were seen to be full of smiles and some were eager to call their friends to join them in interacting with the application as shown in Appendix VII. Some of the children also had locked gaze (engaged attention) with the system with high level of concentration and were also seen to be very excited with the application and some were not willing to let it go even after the survey had been completed. This observed high concentration was referred by De-Lera and Garreta-Domingo (2007) in their study on the ten emotion heuristics as frowning. They pointed out that when a user frown or show high gazing concentration on an application, it is a sign that the users are experiencing deep and perplexed reflection on the application. This implies that they were interested to use and interact with the application. Hence, the application was found to gain and attract the attention of the respondents. Detailed discussion on the result of the observation approach is presented in the next section.

In addition, user reactions were also measured using the respondents' body languages which are their nonverbal communication. This was used because it depicts the respondents' subconscious mind, thoughts, feeling and intention on the application

which can be used to draw conclusion on their psychological reactance on the application and it can validate the model under evaluation. Respondents' body language proves their perception and reactance to complement with what was said verbally about the application. This was based on Quick, Kam, Morgan, Montero Liberona and Smith (2015), Lee, K. C., Lee and Hwang (2014) and Zhu and Huberman (2014) studies which pointed out that user reactions with an application can be used to measure their psychological reactance. This was analyzed using their facial expression, body posture, gesture and eye movements which is presented in the following subsections. These were used to gain deeper understanding into the mind and feeling of the respondents on the application.

6.2.2.1 Facial Expression

Respondents' facial expression is a vital part of their body emotion expression which is the combinations of their eyebrow, cheek movement, eyes and lips. This was employed because faces and bodies are normally integrated which are coordinated by the brain and are naturally simultaneously interacting to give emotion on an issue (Gu, Mai & Luo, 2013). Thus, their facial expressions were used to gain deeper understanding and interpretation on their reactiveness on the application whether they accept, reject, happy, sad, depressed or angered with the persuasive instruction of the application. The analysis of respondents' facial expression was based on Gu, Mai and Luo (2013), Kret, Pichon, Grèzes and de Gelder (2011), Rane (2010) and Kurien, (2010) which were summarized in Table 6.7.

Table 6.7
Summary of Facial Expression Description

No	Expression	Description	Indication	Implication	Psychological Reactance
1	Smiling	This is when there is an elevation of the cheeks and a pleasant facial expression by respondent.	Concentration, Joy, Happiness and Acceptance	Acceptance	Reduced
2	Slightly Gazing away	This is when respondents are seen slightly gazing away or slightly looking away from the application. Such as looking or playing with other things.	Shame, hiding feeling, submissiveness and guilt	Acceptance	Reduced
3	Movement of the mouth	This is when the respondents are seen mouth gesturing or speaking to themselves.	Concentration, Uncertainty, Deep reflection and Trying to establish understanding	Acceptance	Reduced
4	Frowning	This is when the eyes are mopped together and an intense focal is given by the respondents.	Concentration, Seeking clarity and Deep reflection	Acceptance	Reduced
5	Compressing of the lip	This is when respondents mopped their lips or lip and jaw together.	Frustration, Confusion, Anxious, Nervousness, and Emotional concerns	Rejection	Increased
6	Using hand to touch the face	This is when respondents elevate one of their hands that were used to hold the application and used it to touch any part on their face.	Confusion, Uncertainty, Tiredness and Lost of interest	Rejection	Increased
7	Brow raising	This is when the arch of the short hairs is lifted above the eye.	Uncertainty, Disbelief, Surprise and Exasperation	Rejection	Increased
8	Vocal expression	This take place in form of sighing, moaning, gasping, groaning, coughing and exhaling.	Frustration or Deception	Rejection	Increased

During the first interaction session, it was noted that 86.7% of the respondents were smiling, 66.7% of them were slightly gazing away from the application during interaction and 20% were brow raising their eyes. Whereas, there were increments in the number of respondents smiling, frowning, movement of the mouth and slightly gazing away from the application during the second and third interactions compared to the decrease in the number of those found to be brow raising eyes, compressing the lip, using hand to touch their faces and vocal expression. A well detailed account of respondents' facial expression for the three interactions was presented in Table 6.8.

Table 6.8
Summary of Respondents' Facial Expression

	Interaction							
	Interaction I (Uninspiring Agent)		Interaction II (Task Challenging Agent)		Interaction III (Influential Agent)			
Expression	**Frequency**	**Percent**	**Frequency**	**Percent**	**Frequency**	**Percent**	**Implication**	**Psychological Reactance**
Smiling	26	86.7	27	90.0	29	96.7	Acceptance	Reduced
Slightly Gazing away	20	66.7	26	86.7	27	90.0	Acceptance	Reduced
Movement of the mouth	15	49.9	20	66.7	26	86.7	Acceptance	Reduced
Frowning	26	86.7	27	90.0	29	96.7	Acceptance	Reduced
Compressing of the lip	14	46.6	10	33.3	3	9.9	Rejection	Increased
Using hand to touch the face	4	13.3	3	10.0	1	3.3	Rejection	Increased
Brow raising	20	66.7	9	29.9	1	3.3	Rejection	Increased
Vocal expression	4	13.3	3	10.0	2	6.6	Rejection	Increased

Based on Table 6.8 it could be seen that there were increments in the number of respondents' indicators acceptance and reduction of other indicators confirming that respondents' reactance on the application reduced in the post-interactions especially during the third interaction on the four week after the first interaction. Hence, the application was found to attract respondents' attention and reduced their reactance levels.

6.2.2.2 Body Posture

Apart from respondents' facial expression, their body posture was another useful means used to examine their reactiveness on the application which depicts the justification for the proposed model. As suggested by various studies such as Mondloch, Nelson and Horner (2013), Carney, Cuddy and Yap (2010) and Kurien (2010), body posture is a vital means of detecting respondents' emotion and reactiveness of users' applications because it gives more accurate aspect of emotion when compared with different or neutral emotions. Based on these studies, respondents' body postures were mirrored under the two main postures namely leaning forward and tilting back on the chair. Table 6.9 summarized these two postures description with their respective indications and implications.

Table 6.9
Summary of Body posture Description with Implication

No	Postures	Description	Indication	Implication	Psychological Reactance
1	Leans forward	This is when respondents leaned forward on their chair toward the application or show a sunken chest during the interaction.	Attention, Concentration and intense interest	Acceptance	Reduced
2	Tilting back on the chair	This is when respondents' draw back on a chair while interacting with the application. This occurs when respondents' wish to withdraw from present situation.	Withdrawal and Refusal	Rejection	Increased

Closer observation of respondents' body posture revealed that during the first interaction 86.7% were seen leaning forward on their chairs and only 13.3% tilted back on the chair while interacting with the application. Whereas, there were increment in the number of respondents leaning forward 90.0% and 96.7% while interacting with the application during the second and third interactions respectively compared to the decrease in the number of those found to be tilling back on their chair 10.0% and 3.3% for the second and third interactions respectively. A detailed account of respondents' body postures for the three interactions was presented in Table 6.10.

Table 6.10
Summary of Respondents' Body Posture under Interactions

	Interaction							
	Interaction I (Uninspiring Agent)		Interaction II (Task Challenging Agent)		Interaction III (Influential Agent)			
Postures	**Frequency**	**Percent**	**Frequency**	**Percent**	**Frequency**	**Percent**	**Implication**	**Psychological Reactance**
Leans forward	26	86.7	27	90.0	29	96.7	Acceptance	Reduced
Tilling back on the chair	4	13.3	3	10.0	1	3.3	Rejection	Increased

As shown in Table 6.10, the increments in the number of respondents' indicator acceptance and reduction in rejection of other indicator confirms that respondents' reactance were reduced in the post-interaction stage especially during the third interaction on the fourth week after the first interaction. Hence, the application was found to attract respondents' attention and reduced their reactance levels.

6.2.2.3 Gesture

Furthermore, respondents' gesture is another body language that compliments their facial expressions and body postures which were used to reference their reactiveness on the application. Gestures can be voluntary or involuntary movements of parts of the body such as the hands, legs, arms and fingers. Based on Black (2011) and Kurien (2010) suggestions, six gestures were utilized namely head nodding, crossed legs, crossed arms, feet kicking, shoulder movement and wide open legs which are well described in Table 6.11.

Table 6.11
Summary of Gesture Description with Implication

No	Gestures	Description	Indication	Implication	Psychological Reactance
1	Head nodding	This is when the respondents are seen nodding their head in the course of interacting with the application	Concentration, Deep reflection, Trying to establish understanding and intense interest	Acceptance	Reduced
2	Crossed legs	This is when one leg of the respondents' crossed the other while interacting with the application.	Defensive, Deep reflection, argumentative, Concentration and Seeking clarity	Acceptance	Reduced
3	Crossed arms	This is when one arm of the respondents' crossed the other while interacting with the application.	Defensive, Deep reflection, argumentative, Concentration and Seeking clarity	Acceptance	Reduced
4	Feet kicking	This is when respondents continuously move their feet in a random manner.	Impatient, argumentative, defensive, Confusion, and Emotional concerns	Rejection	Increased
5	Shoulder movement	This is when respondents' feel tense and try to loosen up by shaking the shoulders a bit with a slight movement to the back while interacting with the application.	Confusion, Defensive, Uncertainty, Tiredness, Anxious and Nervousness	Rejection	Increased
6	Open wide legs	This is when the space in between the two legs of respondents is widely open or the space is wider than normal.	Over-confident, Defensive, Anxious and Self-judgmental	Rejection	Increased

An intense observation on respondents' parts of body gestures revealed that 66.7% were nodding their heads, 16.6% crossed their arms, 26.6% crossed legs, and 14.6% opened widely their legs while 13.3% were seen feet kicking and shoulder shaking during the first interaction with the application. For the post-interaction stage especially the third interaction, there were increase in the number of respondents nodding heads, crossed

arms and crossed legs which were 90.0%, 46.6% and 39.9% respectively. On the other hand, there were decrease in the number of respondents' feet kicking, shoulder movement and wider opening of legs which were 3.3%, 6.6% and 3.3% respectively. More detailed account of respondents' body gestures for the three interactions is presented in Table 6.12. From Table 6.12, it was concluded that respondents' reactance with the interacted application reduced as evident in the second and third post-interaction whereby there were reduction in the rejection indicators and increment in the acceptance indications.

Table 6.12
Summary of Respondents' Gesture under Interactions

	Interaction							
	Interaction I (Uninspiring Agent)		**Interaction II (Task Challenging Agent)**		**Interaction III (Influential Agent)**			
Gesture	**Frequency**	**Percent**	**Frequency**	**Percent**	**Frequency**	**Percent**	**Implication**	**Psychological Reactance**
Head nodding	20	66.7	26	86.7	27	90.0	Acceptance	Reduced
Crossed arms	5	16.6	10	33.3	12	39.9	Acceptance	Reduced
Crossed legs	8	26.6	12	39.9	14	46.6	Acceptance	Reduced
Feet kicking	4	13.3	3	10.0	1	3.3	Rejection	Increased
Shoulder movement	4	13.3	3	10.0	2	6.6	Rejection	Increased
Open wide legs	14	46.6	9	29.9	1	3.3	Rejection	Increased

6.2.2.4 Eye Movement

Another body language medium used to examine the respondents' reactiveness on the application is eye movement or eye contact. This was done by employing their eyes blinking and winking based on Mann, Vrij and Bull (2002), Hall, Coats and LeBeau (2005) and Lapidot-Lefler and Barak (2012) studies. Based on these studies eye blinking is an emotional medium which can reflect acceptance or rejection of behaviour especially during interactions. This was measured by eye blinking rate which has been

associated with respondents' emotional feeling and thinking responses and categorized into three namely normal blinking (6-10 blinks per minutes), staring blinking (2-5 blinks per minutes) and fast blinking (11 and above blinks per minutes). On the other hand, eye winking was when respondents' closed one of their eyes or the upward & downward movement of eyebrows which signified acceptance of behaviour. Full descriptions with implications of both respondents' eye blinking and winking were presented in Table 6.13

Table 6.13
Summary of Gesture Description with Implication

No	Eye Contact	Description	Indication	Implication	Psychological Reactance
1	Eye winking	This is when the respondents were seen moving their eyebrows or closing one of their eyes in the course of interacting with the application	Concentration, Deep reflection, Trying to establish understanding and intense interest	Acceptance	Reduced
2	Normal Blinking	This is when respondents' eye blinking rate was between 6-10 counts per minutes in the course of interacting with the application.	Interested, Deep reflection and likeness	Acceptance	Reduced
3	Staring Blinking	This is when respondents' eye blinking rate was between 2-5 counts per minutes in the course of interacting with the application	Defensive, Deep reflection, argumentative, Concentration and Unbelief	Rejection	Increased
4	Fast Blinking	This is when respondents' eye blinking rate was 11 and above counts per minutes in the course of interacting with the application	Impatient, argumentative, defensive, Confusion, and Emotional concerns	Rejection	Increased

It was inferred from respondents' eye contact that 46.6% winked eye, 59.9% normal blinking of eye, 13.3% stared eye and 26.6% fast eye during the first interaction with the application. On the other hand, there were increments in the acceptance behavior while reduction in the rejection behavior as detailed in Table 6.14. Thus, it was concluded that respondents' reactance with the interacted application reduced as evident in the second and third post-interaction showing the reduction in the rejection indicators and increment in the acceptance indications.

Table 6.14
Summary of Respondents' Eye Contact under Interactions

	Interaction							
	Interaction I (Uninspiring Agent)		Interaction II (Task Challenge Agent)		Interaction III (Influential Agent)			
Gesture	**Frequency**	**Percent**	**Frequency**	**Percent**	**Frequency**	**Percent**	**Implication**	**Psychological Reactance**
Eye Winking	14	46.6	18	59.9	22	73.3	Acceptance	Reduced
Normal Blinking	18	59.9	23	76.7	27	89.9	Acceptance	Reduced
Staring Blinking	4	13.3	3	10.0	1	3.3	Rejection	Increased
Fast Blinking	8	26.6	4	13.3	2	6.6	Rejection	Increased

6.2.3 Validation Result Implication

A closer examination and comparison of Table 6.8, 6.10, 6.12 and 6.14 depicts that the respondents' reactance were reduced in the reinforced interactions particularly during interaction III. This implies that the application design principle which was based on the proposed model indeed served as a pivot for behaviour change intervention and show an impervious nature to limit and deflect respondents' psychological reactance. In addition, results obtained from the three interactions which reflected the three selected case conditions used in this human experiment namely uninspiring, task challenging and influential agents are similar to their corresponding simulations as presented in Sections 5.4.1, 5.4.2 and 5.4.3 respectively. For example influential case condition simulation as shown in Figure 5.9 indicator that when adequate support is provided then psychological reactance will be reduced whereas the target behaviour will be accepted. This finding is summarized in Table 5.5 and Appendix XIV where results of agent model support case condition simulations were presented. These summarized results are found to be similar with results obtained in this human experiment as presented in Tables 6.8, 6.10, 6.12 and 6.14. However, it was observed that out of the 30 respondents for this study only one

respondent was found to experience reactance. Table 6.15 show summary of Information on the respondent that experienced psychological reactance

Table 6.15
Information on Respondent's that experienced Psychological Reactance

Information	**Class-type**
Respondent's Class	Standard two
Respondent's Parental education background	Secondary School
Respondent's Parental Marital Status	Divorced (Single Mother)
Teeth brushing duration	2 minutes
Teeth brushing frequency	Once
Period of the day teeth brushing is performed	Morning only
Feeling when performing teeth brushing	Sad
Respondent's Personality Traits	Outgoing, Gentle, Affected Emotional, Excitable and Assertive
Facial expression	Vocal expression, Compressing of lip and brow raising
Body posture	Tilting back on the chair
Gesture	Open wide legs and Feet kicking
Eye movement	Fast blinking
Psychological Reactance	Increased

Based on information obtained from Table 6.15, this respondent is from a humble background because the parents are separated whereas only the uneducated mother is the only person taking care of the respondent. Thus, the divorced, single and uneducated nature of the mother might explain the respondent's personality traits. This combination of traits was referred by Goldberg (1993) as difficult character because people with such personality traits are mostly strong headed, unsettled, unorganized and unwilling to take instructions from others. Hence, the combinations of this respondent personal trait might be the major reason why the respondent experienced reactance during the three interactions with the application. These facts are supported by Israel et al (2014), Hirsh, Kang and Bodenhausen (2012), Hampson, Goldberg, Vogt and Dubanoski (2006) and Friedman et al (1993) where it can be concluded that personality traits predicts respondents' reactiveness during behaviour change intervention interactions. Nevertheless, the results obtained from the other twenty nine respondents' showed that the application provided the needed support which allowed the respondents' to have

improved behaviour and deflect or reduce psychological reactance during interactions with the application.

6.3 Chapter Summary

Detailed explanations on the model evaluation is carried out in this chapter which was explored in two different stages namely verification and validation. The verification was done using mathematical verification based on stability analysis and automated verification based on temporal traces language. The results obtained from these two analyses shows that the model is consistent with the literature. Furthermore, the validation is carried out using user-centerd design whereby based on the model external factors an application is designed. Thirty primary school children bewtten ages 7 to 9 years are the study respondents whereas oral hygiene of tooth brushing is the target behaviour. It is observed that respondents responded positively with the application which depict that they did not experienced reactance with the application after three interactions.

CHAPTER SEVEN

CONCLUSION

This chapter gives a general idea of the study areas and objectives that are addressed on the development of the formal model for behaviour change as seen in the preceding chapters of this thesis. The results derived from stated objectives in Chapter One are discussed in details in Chapters Two to Six. Thus, the contribution of this thesis is presented in this chaper whereas the study trend will provide guidelines for future studies exploration. This chapter is organized as follows: Section 7.1 summarizes the conclusions from other preceding chapters' discussions while the study implication is presented in Section 7.2 which focuses on how the study contributes to other previous empirical studies and practice of support systems for behaviour change process. Section 7.3 discusses the limitations of this study whereas Section 7.4 shows how future works can be proposed based from this study.

7.1 Revisiting the Study Objective

This study presents a behaviour change model which clearly depicts how psychological reactance can be deflected to obtain an improved behaviour change outcome. As presented in Chapter One, there are core objectives as this research, namely; identifying the important factors in agent persuasion that reduce psychological reactance during behaviour change process, developing a formal model for behaviour change process and finally evaluating the developed model. These three objectives were achieved and the details have been illustrated in Chapter Four, Five and Six.

7.1.1 Research Objective #1:

To determine agent persuasion factors that reduce psychological reactance during behaviour change process

The study first research objective is to determine agent persuasion factors that reduce psychological reactance during behaviour change process. The study presented twenty-seven agent persuasion factors (Tables 4.1, 4.2 and 4.3 summarized the important factors in Chapter Four) based on related theories (Relapse Prevention Model (RPM), Trans-Theoretical Model (TM), Self-Efficacy Theory (SET), Self-Regulation Theory (SRT), Theory of Reasoned Action (TRA), Theory of Planned Behavior (TPB) and Health Belief Model (HBM), Fogg Behavior Model (FBM)), and literatures in psychological reactance and behaviour change. Previous related empirical studies were equally reviewed to capture these obtained factors which became imperative because of the complex and difficult nature of behaviour change process.

7.1.2 Research Objective #2:

To develop a formal model for behaviour change process

The next study objective is to develop a formal model for behaviour change process. Answering this second objective, the obtained factors related to their corresponding theories (which were in informal representation) were expressed in formal specifications in order to make them available for a computational modelling process. The formal specification followed the concepts of factors interactions as depicted in related corresponding theories and previous empirical studies while the formal specification expression is based on differential equations while agent-based modelling was adopted in the simulation of the formal model. This particular study objective is largely addressed

by the design of the computational model as presented in Figure 4.23 and equation 4.1 to 4.21 under Chapter Four.

7.1.3 Research Objective #3:

To evaluate the develop model for behaviour change process

The last study objective is to evaluate the developed model which is done in three different stages. The first stage was where the formal model is made executable in a numerical simulation environment like Matlab. Next, three case conditions namely uninspiring agent, task challenging agent and influential agent whereas other five case conditions are also explored as presented in Appendices VIII and XIV such as belief deficient agent, ability deficient agent, social influence deficient agent, unknowledgeable agent and planning deficient agent were selected for the simulation environment. The obtained simulation traces provided insight on the interactions among all identified factors to explicitly comprehend behaviour change process as shown in Chapter Five.

The second evaluation stage was achieved by verification analysis which was carried out using mathematical and automated verification methods. For mathematical verification, four cases from equilibria points were used to show the stability of the developed formal model as stated in Sub-section 5.2.1. The advantage of implementing the stability or equilibria analysis is to show how the model stabilizes under certain conditions despite the presence of a small disturbance in the model. On the other hand, five different empirical cases in behaviour change were selected from the literature and each case was formalized and analysed using Temporal Trace Language (TTL) in order to achieve automated verification which confirmed the logical verification of the developed formal model which was discussed in Sub-section 5.2.2.

The third evaluation stage was done by external validation using human experiment based on qualitative approach. This was to assert the logic correctness of the proposed model by employing thirty respondents as presented in Chapter Six. The study respondents were selected based on purposive sampling technique while qualitative and observatory research methods were mixed for the study. For, the qualitative research method, the instrument used was a survey which was developed based on Salam, Yahaya and Ali (2010), Senapati, Patnaik and Dash (2012), Restrepo, Vasquez, Alvarez and Valencia (2008), and Hong (1992) instrument. In addition, statistical analysis and observatory research method based on De-Lera and Garreta-Domingo (2007) suggestions were used to analyse the obtained data and the result showed that the proposed model is valid with real data. Table 7.1 summarizes the study findings whereas it can be conclude that the model provides understanding and comprehension on psychological reactance and behaviour change process. The study identified twenty-seven agent persuasion factors as summarized in Table 4.1, Table 4.2, Table 4.3 and Table 4.20 which provide accurately understanding and comprehension on psychological reactance and behaviour change process phenomena.

Table 7.1
Summary of the Study Findings

Objective	Method	Outcome	Chapter
To determine agent persuasion factors that reduce psychological reactance during behaviour change process	Critical literature review of theories, models and related previous empirical studies within psychological reactance and behaviour change domains.	Twenty-seven agent persuasion factors were identified	Chapter Four
To develop a formal model for behaviour change process	Computational modelling process	Computational Model	Chapter Four
To evaluate the developed model	Simulation, verification (using mathematical and automated analysis) and validation (using human experiment based on user-centred approach)	Verified and validated model.	Chapter Five and Chapter Six

Furthermore, this study maintains that out of these eight identified factors, three factors are the most supportive namely planned action, facilitating condition and openness to behaviour change. This is because as discussed in Subsection 5.1.2, it was observed that reduction in these three factors caused consistency in action to reduce too while dissatisfaction and consistency refusal in action increased. Additionally, this study explicitly depicts how psychological reactance can be supported in order to lead to behaviour change which was not well explained in previous studies like COMBI (Klein et al, 2009) and iChange Model (Vries & Muddle, 1998). Thus, this study suggests that for any development of agent behaviour change intervention, these three factors should be well considered in order to limit or deflect psychological reactance effect.

7.2 Implication of Study

The implication of this study can be viewed in three different ways. Firstly, this study has explicitly shown the process involved in psychological reactance as related to behaviour change. Although the effect of psychological reactance on behaviour change has been widely researched by Borland et al (2009), Ford, Ford and D'Amelio (2008), Matthews (1982), Clee, and Wicklund (1980) and Miller (1976), however how these behavioural factors interact to generate psychological reactance has not been clearly understood in these studies. Hence, this study has been able to explore computational analysis in comprehension of how behavioural factors interact to generate psychological reactance as presented in Figure 4.17 which is the study major contribution.

Secondly, the study similarly showed explicitly how behaviour change process can be obtained as presented in Figure 4.23 and Section 4.2. Although there have been many theories and models that explain behaviour change process like Self-Efficacy Theory (Bandura, 1977), Self-Regulation Theory (Vohs & Baumeister, 2011), Theory of Reasoned Action and Planned Behaviour (Montano & Kasprzyk, 2008), Health Belief

Model (Henshaw & Freedman-Doan, 2009), Relapse Prevention Model (Hendershot, Witkiewitz, George & Marlatt, 2011) and Trans-Theoretical Model (Tierney & McCabe, 2001), however, there are overlapping descriptions of these factors. It could be seen that many of these theories and models use similar factor names whereas different concepts were being defined. Hence, this study has been able to explore computational analysis in explicit comprehension of how behaviour change process can be obtained at different case conditions which shows the incoherent and unstable nature of human behaviour as suggested by West (2009).

Thirdly, the study explicitly showes the process that psychological reactance can be reduced to generate an improved behaviour change outcome. Many studies such as Murtagh, Gatersleben and Uzzell (2012), Gifford (2011), Quick and Stephenson (2007), Rains and Turner (2007) and Dillard and Shen (2005) had suggested that psychological reactance prevent behaviour change which was identified as a major cause of unsuccessful behaviour change intervention. However, most of these studies did not explicitly explain how psychological reactance defect behaviour. Although, studies like Fogg (2009), Ritterband, Thorndike, Cox, Kovatchev and Gonder-Frederick (2009) and Klein, Mogles and Wissen (2011) explained the processes involved in an improved behaviour change, however, most of these studies did not explicitly explain how psychological reactance can be reduced to have an improved behaviour change outcome which will lead to successful behaviour change interventions.

These three mentioned implications significantly contribute to the knowledge of designing and developing successful behaviour change interventions. The high point of this study is to enable designers of behaviour change intervention applications to know how to design successful behaviour change applications which can deflect psychological

reactance as discussed in Section 4.2. This study affords them the opportunity to comprehend application designs that will lead to acceptability from their users.

7.3 Limitation of Study

The study is specifically tailored to computer or software mediated intervention like agent, avatar, animation and others. Thus, the study did not coveres every aspect of human behaviour mechanism whereas only persuasive and reactance phenomena were focused. This is because human behaviour is as a result of complex interplaying factors that comprise of socio-demographic, cognitive, biological and environmental factors. It is believed also that the parameter estimation used in this study is not quite robust. This is because the parameter estimations used were only based on literature. Thus, there is need to further use sensitive analysis for a refined and precise result. Although, the study made use of user centred approach for validation whereas there maybe need to double-check the model validation by employing other approaches such as personalization, integration with other models and interactive agent simulation environment.

7.4 Future Work

There is still further work enveloped in this study which can be applicable to other various domains. This section will discuss these potential further works in four different subsections as apply to other areas.

7.4.1 Parameter Estimations and Sensitivity Analysis

Although in this study the experimental parameter discussion was made in Section 5.2 under Chapter Five however, further analysis can still be done using both parameter and sensitivity estimations which will aid accurate relationships between results from the human experiments and parameters involved. In order to achieve this, approaches such

as Simulated-annealing estimation, Gradient-based estimation, and Genetic algorithm can be implemented and compared to further proof the accuracy of the parameter estimation and sensitivity analysis. This will further established the empirical validation which will deflect noisy, over fitting and redundant features for a more prediction analysis results.

7.4.2 Human-like Agent for Simulated Training Environment

This study simulation results depicts various agents' case conditions as discussed in Chapter Five which were used to evaluate the developed computational model. In addition, these agents' case conditions can be integrated with human-like embedded interactive agents to simulate further social environment conditions in order to rigorously evaluate the developed computational model. This will be useful in the predictions of various behavioural personalities of human within a defined social environment in order to further understand the mechanism of psychological reactance and behaviour change process. It will likewise strengthen the position of predictions such as the boundary conditions which is based on complex interactions with the social environment. One of the implications of this is that it can be applied in the creation of robot (virtual human) within virtual environment which can be implemented in other domain experiments.

7.4.3 Personalization

This study validation using human experiment based on user-centred approach as discussed in Chapter Six have been successfully performed to guarantee internal validity. However, other approaches can be explored in order to further guarantee that this computational model is directly applicable to real persons. This can be done by exploring personality parameter values based on specific human needs and specifications. Thus,

further empirical validation of the model can be done with respect to target human behaviour or interventions using other human experimental approaches.

7.4.4 Integration of the Different Models

One of the unique contributions of this study is the application of computational model to comprehend and understand psychological reactance and behaviour change process. The study had clearly shown that models are vital building mechanism of theories whereas they provide explicitly comprehension of existing realities based on adoptable theories. Thus, various behaviour change process models can be built together in order to provide support for complicated behaviour or/and the management of healthcare interventions for both individual and societal levels. This integration of various models can be achieved either by endogenous or exogenous components. Likewise, it can be modelled by same functionalities at various abstraction levels or different functionalities integration processes which will aid complex behaviour analysis or provide desire support for the target behaviour intervention. Nevertheless, these models integration must follow existing theories and models which should be able to guide the theoretical structural support for the target complex behaviour and interventions.

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