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A persuasive agent architecture for behavior change intervention

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ABSTRACT

A persuasive agent makes use of persuasion attributions to ensure that its predefined objective(s) is achieved within its immediate environment. This is made possible based on the five unique features namely sociable, persuasive, autonomy, reactive, and proactive natures. However, there are limited successes recorded within the behavioural intervention and psychological reactance is responsible for these failures. Psychological reactance is the stage where rejection, negative response and frustration are felt by the users of the persuasive system. Thus, this study proposes a persuasive agent (PAT) architecture that limits the experience of psychological reactance to achieve an improved behavioural intervention. PAT architecture adopted the combination of the reactance model for behavior change and the persuasive design principle. The architecture is evaluated by conducting an experimental study using a user-centred approach. The evaluation reflected that there is a reduction in the number of users who experienced psychological reactance from 70 per cent to 3 per cent. The result is a better improvement compared with previous outcomes. The contribution made in this study would provide a design model and a steplike approach to software designers on how to limit the effect of psychological reactance on persuasive system applications and interventions.

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1. INTRODUCTION

The development of artificial intelligence (AI) has introduced human-like machines such as humanoids, cyborgs robots, and androids where our world fantasy of the co-living of machines and humans in a perfect ecological space. Although, this trend is perfectly documented in movies whereby people are made to believe the idea of the machine perfectly co-living with humans. However, some of these movies have showcased robots as destructive agents which can be harmful to the human race. This has provided a gap for AI and robotics designers on how to create a more persuasive non-human agent which is the major idea behind the introduction of a persuasive agent system. This idea is formed on the backdrop that the computer system can persuade and collaborate with human beings to take out joint assignments and tasks [1]. The manifestation of such collaboration is evident in many agent system applications such as computer graphics and games [2], mobile technology [3], health interventions [4], learning environment [5], advertisement campaigns [6], and others; where agents are persuading human in accomplishing a defined objective. These agents engaging in persuasion objectives are termed persuasive agents and are widely used in behavioural interventions [7].

As stated, there is increased usage of persuasive agent system as a support system in intervention domains however, many of the users of the interventions were found to experience psychological reactance which result in rejection and failure of the interventions [8]–[10]. Psychological reactance occurs when the users' freedom is infringed by the persuasive signals of the persuasive system during the intervention. This will generate anger, frustration, rejection, irritation, and refusal in the mind of the users which will make the target behavior or action unachievable [9]–[11]. The chain of the event showcase the process include including the unsuccessful intervention with the resultant rejection of the persuasive signals from the persuasive system. Thus, to design an effective persuasive agent system intervention, it is important to consider all the underlying architecture and mechanisms of the non-reactance persuasive agent working. Therefore, this paper presents persuasive agent architecture for behavioural intervention that limits the experience of psychological reactance on users to achieve successful behavioural interventions.

Agent designs such as studies [12]–[16] presented agent system architectures based on the beliefs, desires and intentions (BDI). The BDI architecture is an agent within a dynamic environment and the input received predefined the actions that will be taken in line with its set objective in the environment. The BDI is implemented in the architecture's internal mental state. The system's mental state is depicted based on the input information generation which reflects the three main attitudes of the system namely beliefs, desires, and intentions. The mental attitude further depicts the functionalities of other components such as the informational, decisional and motivational of the agent system. Similarly to the mental attitudes, other implementations like the agent system commitment, updates and capabilities are deployed to achieve the target object of the agent system. Many other concepts such as the multi-modal, temporal, action-oriented, and dynamic logic are implemented to create suitable agent systems [17], [18]. Although, there are many studies in the literature on the BDI agent system, however, there is little attention to the persuasive agent in the literature. Likewise, very few studies focus on the explicit description of a persuasive agent system design. In the literature, there are only three closely related studies that depict how persuasion characteristics are implemented in the agent system. The three closely related studies are the JAM by [19], the persuasive teachable agent (PTA) by [20] and the persuasive agent design (PAD) by [7].

The first closely related study is by Huber [19] and he presented a unique agent system architecture referenced as JAM. This is a hybrid architecture which is based on pragmatic BDI-based agent architecture. It implemented Ingrand *et al*. [21] theory of procedural reasoning system (PRS), Lee *et al*. [22] structured circuit semantics (SCS), and Levin *et al*. [23] act plan interlingua concept. These three theories and concepts formed its internal working which is subdivided into five major parts such as the plan library, the world model, the intention structure, the interpreter, and the observer as shown in Figure 1.

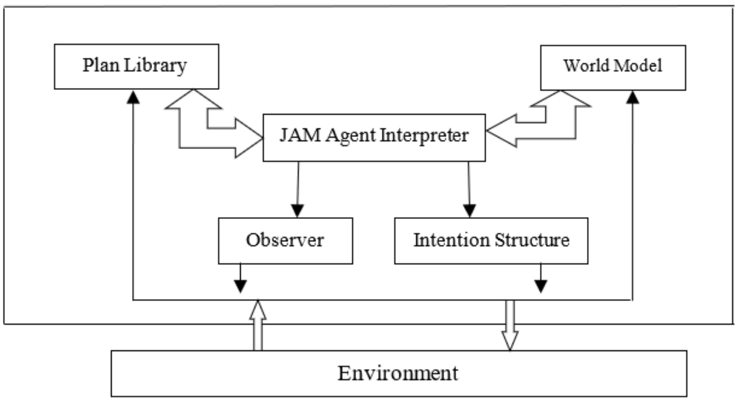

Figure 1. JAM agent system architecture [19]

The database of the agent system is implemented in the world model component that housed the agent's beliefs. The implementation of the agent strategies and dynamic initiatives is housed in the plan component. The interpreter component depicts the agent's brain where the autonomy and the reasoning logic residents. This component enables the agent to reason and decide about the input received from the environment based on its predefined aim and objectives. On the other hand, the observer component is the declarative procedure component where the agent receives and interprets inputs from its immediate environment. This component is known as the interconnection component that relates inputs to other components. Whereas the Intention structure is the component responsible for carrying-out actions decided by the agent based on the agent Interpreter component to achieve the predefined aim and objectives of the agent system.

In another study, the BDI architecture of Rao and Georgeff [24] was implemented by Liu *et al*. [7] to obtain a persuasive agent system. The persuasive agent system design is based on a mental notion of six sub-parts namely the multimodal interface, belief, plan library, reasoner, goals (desire), and intention (makeup of argumentation and decision models). This design is later improved by Ingrand *et al*. [21] and proposed as the PRS. Many studies such as [25]–[29] have implemented PRS and its applications which are based on cognitive BDI. Out of the many studies, one stand-out is by Liu *et al*. [7] where BDI and PRS were implemented as shown in Figure 2.

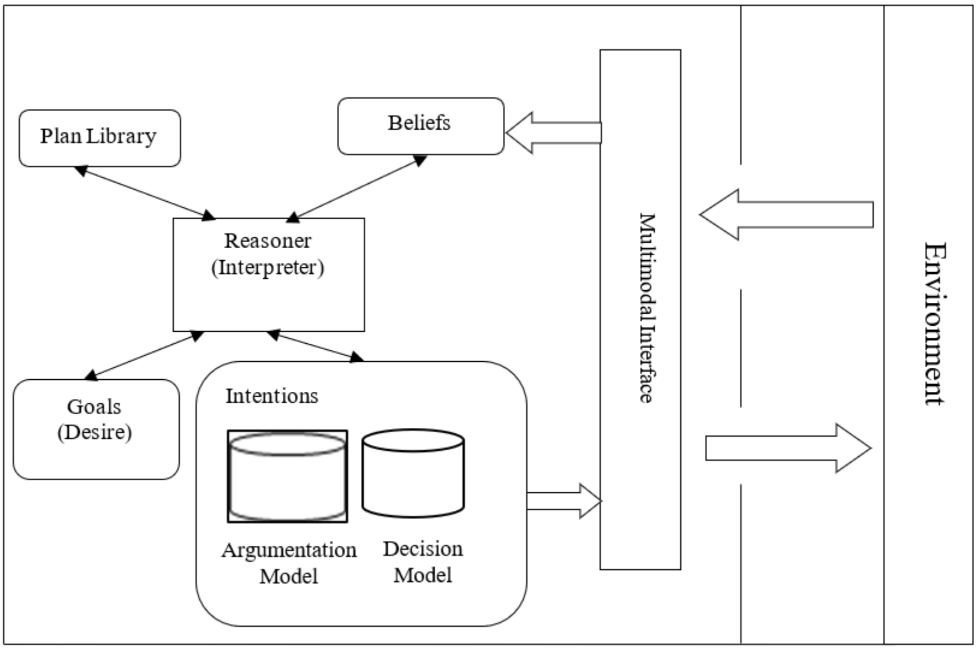

Figure 2. Procedure reasoning system [7]

The design depicts the PRS with the six major components. The plan library component is responsible for the decision-making of the system. The component house the system rule and algorithm on predefined activities of the system. It takes input from the belief and goal components which are centrally coordinated by the reasoner (the interpreter) component. Although the reasoner component coordinates the activities of the system, however, the intention component is another important part because it is made up of the argumentation and decision models. These two models are responsible for the decision making and formulation of an agent’s reactions to its immediate environment. Furthermore, the argumentation model is solely responsible for the agent’s interaction with its environment via the multimodal interface. The interconnection of these components with the multimodal interface is to ensure targeted and precise coordination with the environment.

The procedure reasoning system's target aim is to effectively engage its immediate environment in an argumentative nature to ensure persuasive signals transmission to the environment. This is made possible by implementing the heuristic model of persuasion in the argumentation model [30]–[32]. Also, the system employed the five communication strategies namely anthropomorphism, agreeableness, informativity, adaptivity, and persuasiveness [7] to achieve its predefined aim and objective within its immediate environment.

In the same way, Lim *et al*. [20] presented a study tilted design of PTA which employed the elaboration likelihood model (ELM) [32] with the teaching and learning concepts [14]. The PTA implemented the ELM to develop a persuasive teachable agent that can influence users during interaction in an atmosphere of teaching and learning. The PTA system architecture has five main parts namely teachability reasoning, knowledge base, events tracker, persuasive teachable agent action, and persuasion reasoning components as shown in Figure 3.

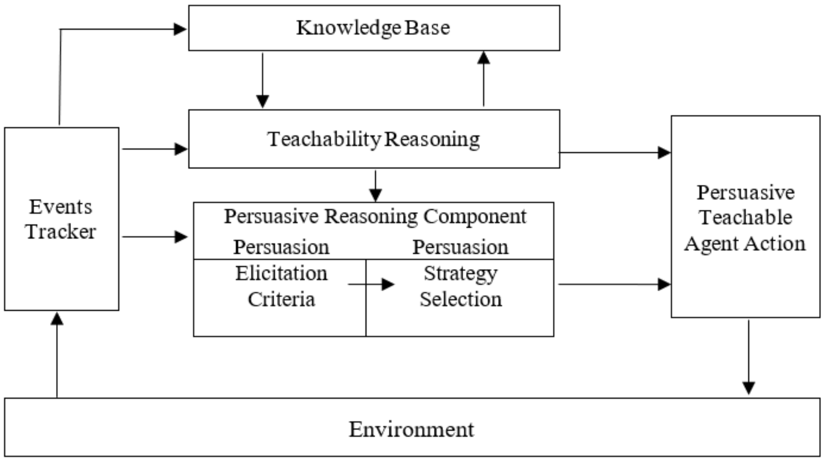

Figure 3. Persuasive teachable agent architecture [20]

Based on the figure, the events tracker component directly interacts with the system's immediate environment and harvests input from the environment. The input harvested is stored in the system component known as the knowledge base which acts as the system knowledge-based component. The knowledgebase interacts with the teachability reasoning part which is responsible for the agent reasoning and learning activities. This is linked with the persuasive reasoning part which is sub-divided into two parts namely the persuasive strategy selection and the persuasion elicitation criteria. These two parts employed the ELM theory of persuasion and they are responsible for the persuasive audiences' interaction with the system. Also, they implemented a feedback mechanism which processes the system's reaction to its immediate environment in a dynamic nature.

In summary, the studies [7], [19], [20] have depicted that the agent system does not have a neutral influence on its users. These studies have shown that the agent system can positively influence and persuade human beings, however, it is not explicitly seen how the agent processes the persuasive signals to achieve behavioural intervention. This is a major gap in the persuasive agent literature where there is a need to precisely understand how the persuasion processes from the system lead to a behavioural change in the users. Likewise, Roubroeks *et al*. [33]–[35] studies have disagreed that users of these systems usually experienced psychological reactance which leads to rejection of the system instructions. Thus, there is a need for an improved architecture that will prevent users from experiencing psychological reactance to achieve targeted behavioural interventions.

Hence, this study focuses on how persuasive elements can be enhanced to prevent psychological reactance in the persuasive agent system. The architecture will implement social, persuasive and interactive elements which can reduce the effect of psychological reactance in the persuasive agent system. This study is mainly concerned with persuasion attributions that can be used to sustain collaborative interaction between an agent and its user during interventions. The main target is how a persuasive agent can achieve successful intervention without the users experiencing psychological reactance as seen in previous studies like [36]–[39]. The next section will discuss the study design structure of the persuasive agent architecture known as persuasive agent (PAT).

2. THE PROPOSED ARCHITECTURE

This study presents a PAT architecture that is based on Adegoke *et al*. [40] reactance model for behavior change. This model is adopted because it provides a solution to user reactance which is one of the major limitations of successful behavioural intervention. The model employed persuasion, and social theories to implement the reduction of users experiencing psychological reactance during the system's interventions to achieve an improved behavior change outcome which is the main rationale for the adoption of the model in this study. The PAT architecture includes components such as behavior analysis, beliefs, intentions, application interface (virtual agent and storyboard), plan library, goals, and the environment. The architecture is pictured in Figure 4 which reflects the functionality and the arrows depict the components' flow.

The overall system environment contains the users who interact with the system application interface. This interaction is via the virtual agent and storyboard which are contained within the application interface. The environment depicts the domain that the intervention is taking up. It can be healthcare, education and driving situations. This is the location setting where the persuasive agent will be deployed to impact the users within that environmental domain. The interaction with the domain environment (user) takes place at the application interface. This interaction with both the virtual agent and the storyboard display employed persuasive strategies to achieve the predefined aim and objective.

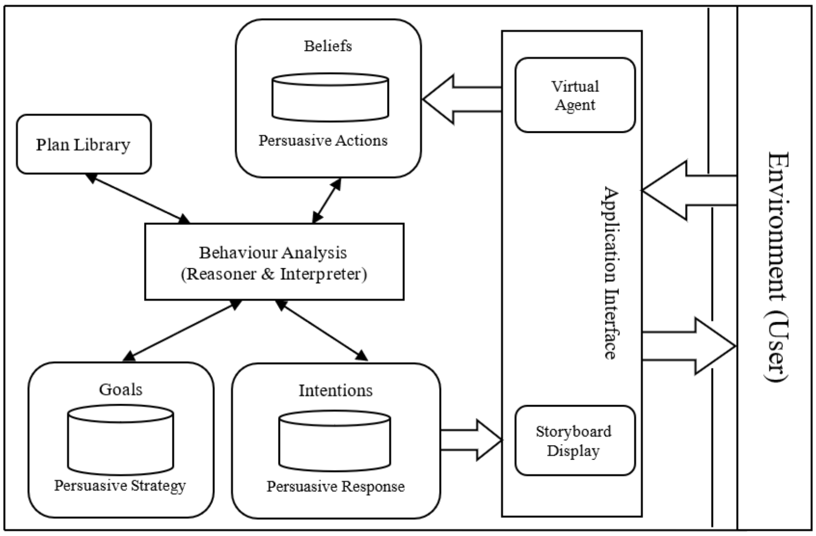

Figure 4. The PAT architecture

On one hand, the virtual agent is meant to impress the domain environment with persuasive attributes like expertise, connection, credibility, and attraction. On the other hand, the storyboard is meant to give visualising experience to the domain environment for clarity and comprehension. Whereas, the behavior analysis part is meant for interpretation and reasoning of the system’s activities and predefined action plans. The plan library part of the system housed information such as demographic, personality traits, and other behavioural traits which interlinked with the behavior analysis part.

The behavior analysis stored models that are responsible for users' interpretation of input received from the environment. For example, the human functioning models are part of the models in the behavior analysis part. Furthermore, the belief part stores information mental state of the agent based on the environment, users and target objective. The information mental state includes time activation, manner, state, and agent’s mental states based on the environment.

Additionally, the goal part stores the persuasive strategies that activate the persuasion attributions predefined by the agent’s objective. This made use of adjustment combinations where factors like social influence, ability, persuasiveness and other factors. Likewise, the intention part ensures that the agent’s persuasive interactive responses are reflected based on the manner of feedback that the application interface implements with users. The interactive persuasive response part is interlinked with the behavior analysis and the application interface to depict effective persuasive communication languages that are verbalized via the virtual agent and displaced on the storyboard for further persuasive communication.

3. METHOD

The architecture is implemented in an agent-based application called Dr Clean. Specifically, the application is targeted toward children between the age of 7 to 12 years and it is aimed to encourage and motivate them on teeth brushing behaviour. The application was developed using the Java programming language. Java was used because it is an integrated development environment (IDE) that permits customization and extension of other plug-in software such as Crazytalk, Camtasia, and android application package (APK). The Crazytalk was used to configure the female character agent’s facial and voice. It permits auto intensity motion engine enhancers to allow interaction in real-time. The Camtasia software is used to integrate the application storyboard and sound. It is made of android based applications because the application is deployed on a mobile tablet which is considered more handle, easier, and persuasive for the application's target audiences. Figure 5 summarises the various activities undertaken to obtain the designed and deployed prototype application.

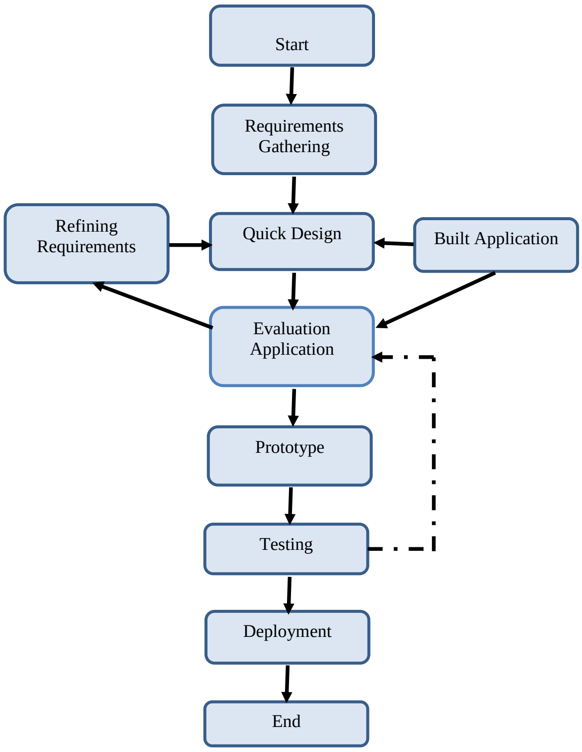

Figure 5. Implementation activities

The implementation of agent-based applications started with the application requirement gathering which was done based on the proposed architecture and persuasive design elements [41]. Furthermore, the agent-based application Dr Clean implemented a virtual agent as indicated in PAT. The virtual agent is designed as an image of a female expert giving professional instruction which is based on the principle of expertise, similarity, trustworthiness, and attractiveness. A female character agent was used because of the soft affection, impression and attractiveness that the female image possesses especially on children [42], [43]. Figure 6 shows the interface of Dr Clean.

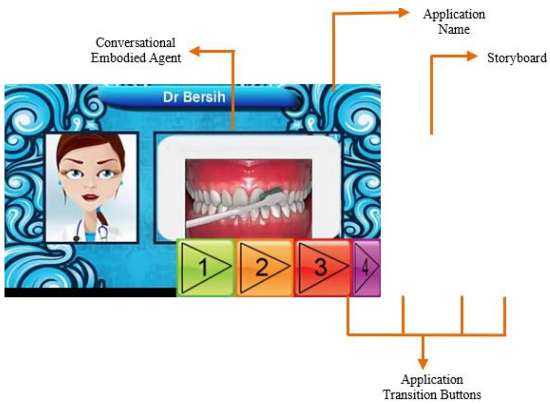

Figure 6. The interface of Dr Clean

As discussed under the architecture design, the Dr Clean belief component housed information about the respondents (users). This information is passed to the behavior analysis component which is responsible for reasoning and interpretation of Dr Clean action plans. All the action plans of Dr Clean are stored in the plan library which is coordinated by the behavior analysis component. The outcome of the behavior analysis component is related to the goal component which forms Dr Clean's goal and it is the composition of persuasive strategies to achieve the desired intervention. The determined goal is linked with the intention component which is responsible for Dr Clean persuasive interactive response to the user. This response is communicated via the Dr Clean interface which is made up of the storyboard and the female conversational embodied agent.

The study evaluation followed a user-centred design approach (UCD). This approach was used because it allows exploration of the needs, wishes, wants, expectations, and limitations of users of an application [44]. The user is the centre of this approach where the application design is mainly validated based on users' perspectives only [45]. The study made use of Malaysian children within the age range of 7 to 12 years as study respondents. This group of children has been identified to have poor oral hygiene due to their inability to achieve proper and clean teeth brushing [46]–[49]. Teeth brushing behavior of brushing twice a day both morning (after bed) and night (before bed) were the target behaviour. The study made use of 30 respondents from primary school standards 1 to 3 using purposive sampling. The purposive sampling technique was used because only voluntary respondents that are unable to perform the target behavior properly were selected for the study. This was based on a suggestion by Fogg [50] that behavior change intervention is specifically met for an audience that lacks the target behaviour. Only new behaviours can be tailored without the expectation of psychological reactance. Specifically, the study evaluation followed a systematic approach which started from approval seeking date fixing, arrangement for the study room, respondents' selection, pre-interaction, interaction and post-interaction as shown in Figure 7.

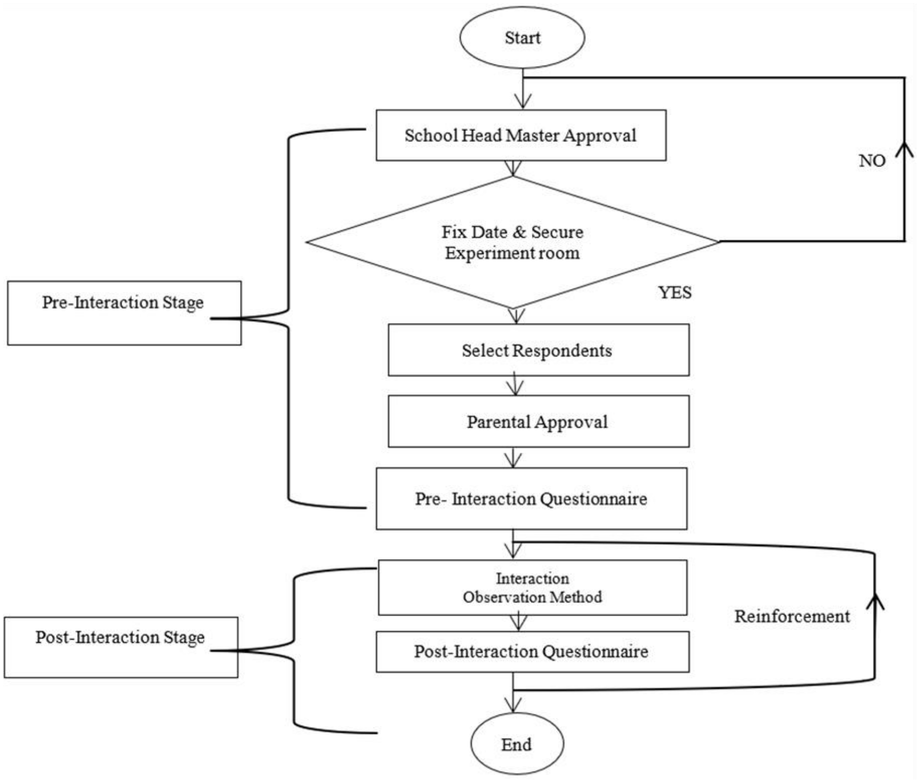

Figure 7. Evaluation activities

Studies [51], [52] suggest, that a quiet and transparent room was used as a research site where respondents interacted with the persuasive application. Before the interaction, respondents were interviewed to know their personal and family background details. Also, their general knowledge and understanding of teeth brushing behavior were enquired which made up the pre-interaction stage. During the interaction, an observatory research approach was used to take note of respondents' actions, feelings, reactions and body language. The interaction lasted for about 10 minutes. Immediately after the interaction respondents were assisted in completing the study questionnaire. Also, based on the principle of positive reinforcement as suggested by [53] the respondents were made to interact with the application two and four weeks after the first interaction.

The unstructured observatory research approach was similarly adopted for the study where the researcher took note of respondents' behaviour, action, feelings, reaction, and body language. There was video recording with the use of a camcorder for a document of the sessions. Each session started with an ice-breaking exercise for up to five minutes which was used to ensure and improve the familiarity, the building of confidence and rapport among all the respondents. The study survey made use of closed-ended questions to get information from the respondents. The survey questions are formulated based on previous studies [54]–[56].

4. RESULTS AND DISCUSSION

A total of 30 questionnaires were administered to male and female children in standard 1-3. The children ranged between ages 7-9 and Table 1 depicted that 36.7% is the highest percentage of the respondents who are 7 years of age whereas 33.3% and 30.0% respectively are for respondents aged between 8 and 9 years. Based on the result, standard 1 is 36.7%, standard 2 is 33.3%, and standard 3 is 30.0% where the whole respondent is found to be 60% male population and the rest respondents are females as shown in Table 1.

Table 1. Respondents' demographic

	Frequency	Percentage
Respondent's age		
7	11	36.7
8	10	33.3
9	9	30.0
Respondent's class		
1	11	36.7
2	10	33.3
3	9	30.0
Respondent's gender		
Boy	12	40.0
Girl	18	60.0
Respondent's mother education		
Secondary school	23	76.7
Diploma	5	16.7
First degree	2	6.7
Respondent's Father education		
Secondary School	26	86.7
Diploma	4	13.3
First degree	0	0
Knowledge of the behaviour		
Teeth brush and paste	30	100
Paper and water	0	0
Knowledge of the behavior duration		
5mins	12	40.0
2mins	18	60.0
Knowledge of frequency of the behavior per day		
One time daily	3	10.0
Two times daily	14	46.7
Three times daily	9	30.0
More three times daily	4	13.3
Period of the day that the behavior is performed		
Morning only	3	10.0
Morning and night	27	90.0
Feeling when the behavior is performed		
Sad	14	46.7
Happy	16	53.3

The Table 1 revealed the family background of the respondents which indicates their parents' education levels. It can be inferred that the majority of the parents of the study's respondents are secondary school leavers (as their highest qualification) with 86.7% for the fathers and 76.7% for the mothers. The further analysis reflects that all the respondents in the study admitted to observing their teeth brushing with toothbrushes and paste. This indicates that all the respondents are knowledgeable about the target behaviour. However, it is discovered that they are not knowledgeable about the duration that it should take them to perform the target behaviour. This is reflected in the table that 60% of the respondents admitted to just two minutes of brushing whereas the remaining 40% claimed to brush for five minutes. The number of times brushing a day was also investigated with a higher percentage of the 46.7% of the study respondents claiming to brush twice daily, followed by 30.0% of the study's respondents claiming to brush thrice in a day. The last group of 10% of the study's respondents affirms brushing just once a day.

Similarly, it can be seen that 90% of the study respondents brush their teeth both morning and night. Though a further evaluation showed that 53.3% of the study's respondents claimed to be sad when performing the brushing behaviour. Thus, taking into consideration the study location which is a timber plantation environment this report reviewed that a high percentage of the children are from a humble background with a low level of family income. Hence the children are seen to be poorly motivated with little information on proper brushing behaviour.

After the children interacted with Dr Clean showed a 100% per cent of the children saw Dr Clean as a good teacher and good medical doctor. Also, 96.7% of the children claimed to understand the explanation of Dr Clean, were happy to meet him and admitted to being able to perform the roles Dr Clean asked. 90% of the children also want Dr Clean to be their friend who is with them always and 86.7% claimed to remember Dr Clean instructions for proper brushing of their teeth as presented in Table 2. These results as presented in Table 2 showed that despite a higher percentage of children reported to be sad when performing the teeth-brushing behaviour, their interaction with Dr Clean was a happy one. Similarly, two weeks after the first interaction, 90% agreed to share Dr Clean with their friends, and 100% of the children agreed that they remember and like Dr Clean instructions as shown in Table 3.

Four weeks after the first interaction, the children were asked to interact with Dr Clean again and the report is presented in Table 3. 100% of the children remember and agreed that Dr Clean improved their brushing experience, however, only 96.7 wanted to share it with their friends. Thus they did not experience psychological reactance to the application or react negatively to the persuasive instruction of the application. Also, from observation, as shown in Table 4, the children were seen to be full of smiles and some were eager to call their friends to join them to interact with the app.

Table 2. Post interaction (immediately after the first Interaction)

No	Item	Yes/Happy (%)	No/Sad (%)
1	Do you understand the explanation of Dr Clean?	96.7	3.3
2	Are you happy to meet Dr Clean?	96.7	3.3
3	Can you do what Dr Clean asked?	96.7	3.3
4	Do you think Dr Clean is a good teacher?	100	0
5	Do you want Dr Clean to be your friend?	90	10
6	Do you think Dr Clean is a good medical doctor?	100	0
7	Can you remember Dr Clean's instructions when brushing your teeth?	86.7	13.3
8	Do you want Dr Clean to always be with you?	90	10

Table 3. Post interaction (2 and 4 weeks after the first interaction)

No	Item	Yes/Happy (%)		No/Sad (%)	
		2 weeks after the interaction	4 weeks after the interaction	2 weeks after the interaction	4 weeks after the interaction
1	Can you still remember Dr Clean instructions?	100	100	0	0
2	How do you feel now when you are brushing your teeth?	100	100	0	0
3	Have Dr Clean instructions helped you while brushing your teeth now?	100	100	0	0
4	Will you like to share Dr Clean with your friends?	90	96.7	10	3.3

Table 4. Respondents' eye contact under interactions

	Interaction							
	The uninspiring agent (Interaction 1)		The task challenge agent (Interaction 2)		The influential agent (Interaction 3)			
Gesture	Freq	Percentage	Freq	Percentage	Freq	Percent age	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

The study's respondents locked their gaze on the system app which depicts a high level of attention and concentration. They were observed to be excited during their interaction with the system app and many of them were unwilling to disengage from the app after the session. This attitude is known as frowning according to the ten emotion heuristics [57] which means that the respondents experienced perplexed and deep reflection on the application. This is positive feedback reflecting that the respondents do not experience any psychological reactance during their interaction with the app. Hence, the app attracts and full gains the attention of the study's respondents with reduced experience of psychological reactance.

5. CONCLUSION

Based on discussion, it can be concluded that the respondents experienced reduced psychological reactance. This is explicitly seen within the three interaction sessions (interaction 1-3) where interaction 3 recorded increased and higher acceptance values compared with interaction 1. This depicts that the app design principle which is based on the study's proposed architecture can effectively reduce the experience of psychological reactance on persuasive agent's respondents. Thus, this study argues that adequate persuasive support within the right environment and conditions can deflect users from experiencing psychological reactance during system interaction. Although the study result is consistent with related literature as stated in the paper, however, there is a need to further re-examine the architecture evaluation by implementing other methodologies. Also, the study can be improved by integrating it with other theories and models where personalization and interactive agent simulation environment can be deployed. This will further confirm and revalidate PAT architecture to deflect psychological reactance that limits successful behavioural interventions.

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