AGENT SUPPORT MODEL FOR BEHAVIOUR CHANGE INTERVENTION

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Abstract: Agent applications have been widely used in decision making process and behaviour change interventions nowadays which might be due to the four unique features of agent proactiveness, reactivity, social ability and autonomy. However, psychological reactance has been identified as a limiting cause of agent interventions. Although, many studies have investigated into both psychological reactance and behaviour change nevertheless the mechanism behind factors interaction that generate reactance during behaviour change interventions (BCI) have not be well studied. Also, how reactive intervention can be supported to obtain an improved behaviour change intervention is still lacking in most previous studies. Therefore, this paper explored dynamic system in differential equation analysis to obtained an agent support model for behaviour change intervention which explicitly describes factors interaction leading to reactance and behaviour change. The model depicts how reactive intervention can be supported to obtain an improved behaviour change intervention. Specifically, this model is tailored to computer or software mediated intervention like agent, avatar, and animation. This paper will aid and guide agent intervention designers to fully comprehend the mechanism behind factors that enhance successful and efficient intervention for their designs.

Keywords: Behaviour change, psychological reactance, agent intervention, support model

Introduction

This paper presents an agent support model for behaviour change intervention which will explicitly depict how behavioural factors interact to obtain reactance and behaviour change. The study will also depict how audience reactance can be supported to give an improved behaviour change.

Behaviour change intervention and reactance

Agent behaviour change intervention embroils re-modification or prevention of undesirable behaviour using systematic planned operation in a process or system (Abraham & Michie, 2008; Hardeman *et al*., 2002). It is an intended, strategic and targeted implemented procedures based on communicable and social medium to achieve behaviour modification of an individual, a group or a population (Fogg, 2009). This involves scheme and procedure based on behavioural principles in order to achieve the targeted behavioural outcome. The target behaviour can be in health, politics, mental and physical contexts. The sustainability of this behaviour change intervention is of significant and value to agent community (Klein *et al.*, 2011; Andre *et al*., 2011). However, many behaviour change interventions were not able to achieve the target objective and reactance has been identified as the reason for these unsuccessful behavioural change interventions (Murtagh *et al.*, 2014; Folger *et al.*, 2013; Rains, 2013).

Psychological reactance occurs when the free behaviour of an individual is infringed by persuasive intention to cause behavioural change and it usually manifests in forms of anger, irritation, frustration and refusal of target behaviour or action (Folger *et al.*, 2013; Edwards *et al.*, 2002). This is as a result that the individual freedom to behave freely has been infringed during behaviour change intervention process which made it impossible to act autonomously in order to decide between the multiple possibilities of behaviour 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 behaviour which threatens the freedom of the individual. Thus, 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.

Furthermore, reactance can be obtained during threatening influence which usually manifests in forms of unfavourable emotion and cognitive responses (Quick & Stephenson, 2007; 2008). This unfavourable emotion and cognition directly triggers certain behavioural determinants that attempt to restore the perceived threatened freedom (Dillard & Shen, 2005). Consequently, one can infer that there are two assumptions involved in reactance concept. First, audience have a desire for freedom. Second, the attempt of agent behaviour change intervention 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. This phenomenon explains how behaviour change is resisted and leads to failure of behavioural change interventions. Thus, in order to design an effective agent intervention support system, it is necessary to understand the underlying mechanisms of psychological reactance with behaviour change and how these mechanisms can be influenced to establish the desired behaviour.

Although, there are few studies in the vast literature that examined how psychological reactance is generated with its relation to behaviour change. For instance, Brehm (1966) introduced psychological reactance theory as a framework for understanding why behaviour change attempts are unsuccessful. The theory assumes that reactance state occurs when the free behaviour of an individual is threatened or eliminated. Such an individual manifests reactance in form of anger, irritation, frustration and dislike. Therefore, it makes the individual to perform behaviour different from the targeted behaviour. Brehm conceptualized state reactance as an aversive motivational state that subsequently leads individual to want to restore a threatened or eliminated freedom. There is a growing interest among researchers to gain deeper understanding of the underlying mechanisms of state reactance and behaviour change so that they can prevent unintentionally triggering state reactance in their interventions.

Dillard and Shen (2005) presented four conceptions of reactance as show in Figs. 1 - 4 below. The first model was termed Single Process Cognitive Model because it assumes that reactance is a purely cognitive phenomenon. For the same reason, the second was termed Single Process Affective Model. The third was referred to as Dual Process Model due to the assumption that cognition and affect can be discriminated. The last model was termed Intertwined Process Model because affect and cognition are assumed interwoven as show in Fig. 5.

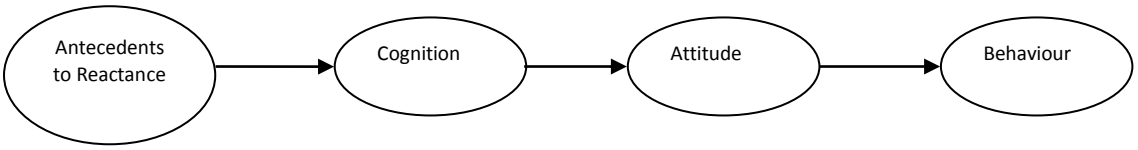

Fig. 1: A single process cognitive model

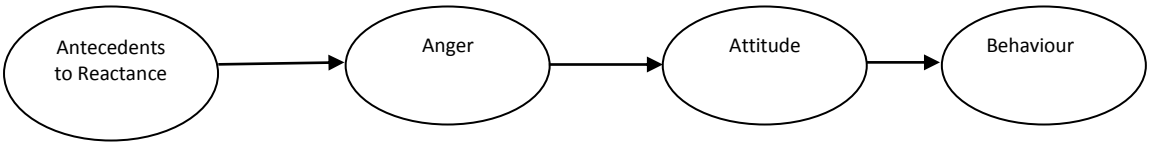

Fig. 2: A single process affective model

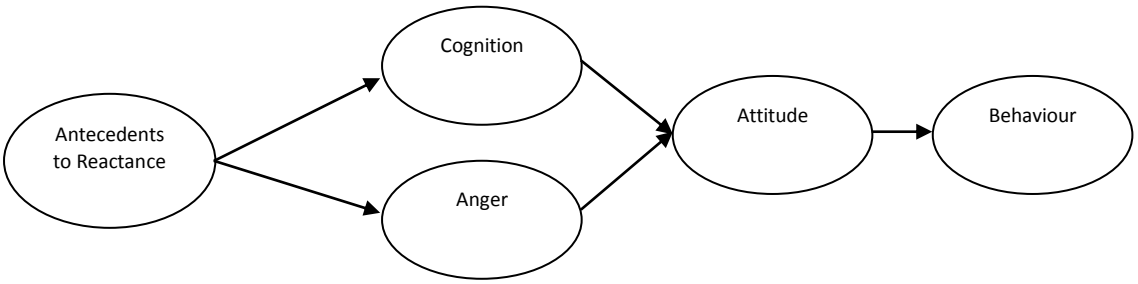

Fig. 3: A dual process cognitive-affective model

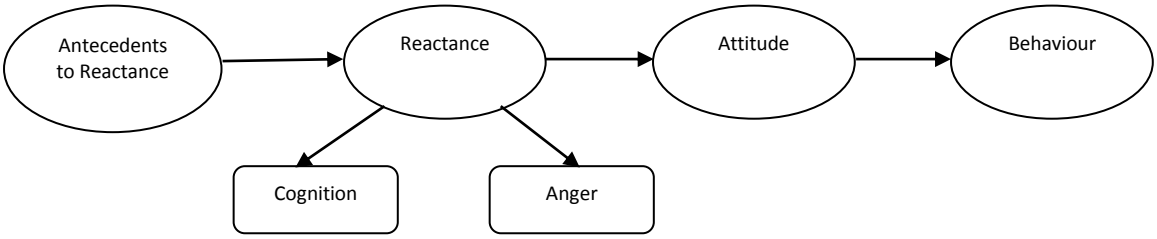

Fig. 4: An intertwined process cognitive-affective model (Dillard & Shen, 2005)

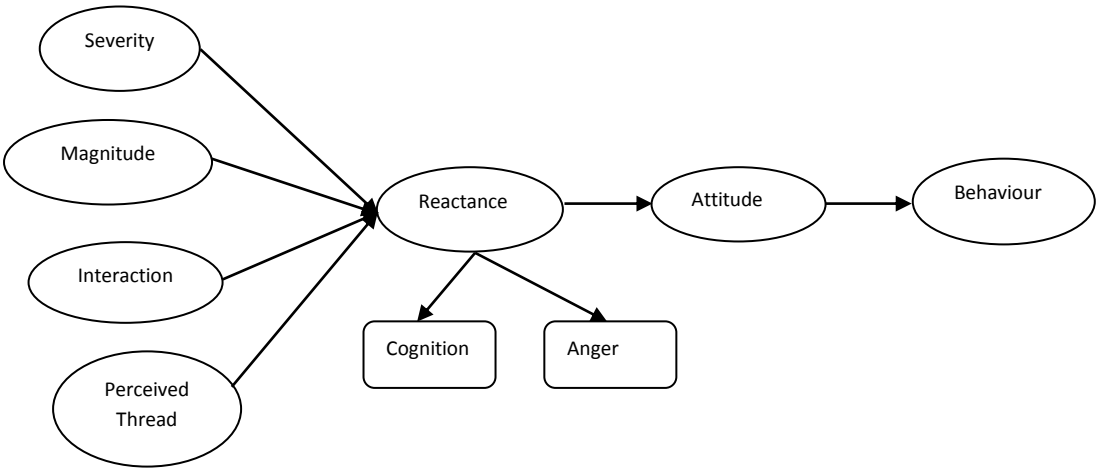

Fig. 5: An intertwined process cognitive-affective model (Rain & Turner, 2007)

These four models were tested by Dillard and Shen (2005) by manipulating high-low threat flossing and alcohol consumption instructions. Hong (1992) was used to analyse individual reactions from the threat manipulation and the trait reactance. It was concluded that the intertwined model of affect and cognition best fit the data in their studies.

In another major study, Rain and Turner (2007) conceptualized reactance as affective and cognitive. According to them an individual shows reactance as a result of threats to free behaviour. They termed cognition as negative-relevant cognitions (counterarguments) which are against freedom limiting behaviour whereas affective was termed as a response to the freedom limiting behaviour.

Their conclusion was similar to Dillard and Shen (2005) that the intertwined model best fit the data in their studies. However, it was mentioned that only magnitude of request had an impact on the intertwined model whereas the other factors were found to be less significant to reactance. It was further discussed that reactance was increased when the request was large but reduced when the request was small.

These studies show how reactance is generated and its linkage to behaviour change, however there have being arguments that social, motivation, personality and behaviour nature were not considered in the models (Knight *et al.*, 2014; Liu *et al.*, 2012; Roubroeks *et al.*, 2011). Likewise, these studies did not explicitly show the mechanism of interaction of each factor as they produce reactance and behavioural change. Thus, this paper will employ computational modelling of psychology theories and models to further study the interaction factors that produce reactance and behaviour change.

The reactance model of behaviour change (Rembec)

In order to explicitly understand how behavioural factors interact to produce reactance and behaviour change, this study explored on eight existing psychological and behaviour change theories namely self-efficacy theory, self-regulation theory, reasoned action theory, planned behaviour theory, health belief model, Fogg's behaviour theory, relapse prevention model and trans-theoretical model. For instance, self-efficacy depict appraisal of agent's self-ability and capability to perform designated behaviour. It was summarized by Bandura (1977) that behavioural changes occurs based on three events which include one's 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 to perform the target behaviour. Based on Bandura and Admas (1977) ability and motivation can be built as a result of social support or influence in order to achieve a targeted behaviour. Thus, this theory depicts the important of four main factors in behaviour change intervention namely self-efficacy, ability, motivation and social influence.

Another behavioural theory that is closely associated with self-efficacy theory is known as self-regulation theory. Theory maintains that for an intervention to result to behaviour change, the user should experience some level of decline in the effect of self-determination, self-discipline and self-control (Vohs & Baumeister, 2011). It reflects desire to change and effort to be 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 *et al.*, 2003). Likewise, the theories of reasoned action and planned behaviour depicts factors like attitude, intention to change, belief, challenge, perceived benefit and risk (Ajzen & Fishbein, 1977). These two theories pointed out that for intention to change depend on attitude and severity of the behaviour. This implies that severity of behaviour and attitude toward the behaviour determines achievement of the behaviour (Hale, 2002). Complimenting these two theories is the health belief model which consists of perceived susceptibility, perceived severity, perceived benefits, perceived barriers, perceived motivation and perceived cue (Henshaw & Freedman-Doan, 2009). In the same vein, Fogg's (2009) behavioural theory depict the important of motivation, ability and trigger as factors that interplays to determine the success or failure of target behaviour. The theory explains that when there is high motivation, sufficient ability and right trigger then the possibility of achieving target behaviour will be high.

A critical investigation into these six above mentioned theories revealed that their factors are positive outcome determinants whereas there are two behavioural theories that explain negative outcome determinants namely Relapse prevention and Trans-theoretical theories. Relapse prevention theory clarify that an initial setback, or lapse, may either translate into a return to the previous problematic behaviour (relapse) or into the individual turning again towards positive change (prolapsed) (Larimer & Palmer, 1999). The theory is a multi-determined, especially by self-efficacy, outcome expectancies, craving, motivation, coping, emotional states, and interpersonal factors (Hendershot *et al.*, 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. Also, the theory of Trans-theoretical involves transitions between the stages of behaviour change as affected by a set of factors known as the processes of change (Tierney and McCabe, 2001). 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). The theory has five stages of behaviour change namely pre- contemplation, contemplation, preparation, action, and maintenance (Tierney and McCabe, 2001). Progress on these stages depends on awareness, motivation and commitment of the audience. Pre-contemplation is the stage where the audience is unaware of the need to change the behaviour (not aware of the benefits of changing his behaviour).

Although, the eight theories mentioned above are widely used in behaviour change intervention however many of these theories omitted some major factors in behaviour change process (Sutton, 1998). Also there is an overlapping of factors between the different theories and most of the theories shared some common factors (Ojeniyi *et al.*, 2015a; 2016). Therefore, this study presents reactance model of behaviour change known as Rembec which is based on the integration of these eight theories in order to explicitly understand how behavioural factors interact to produce reactance and behaviour change. Likewise, the model depicts how reactance can be supported to obtain an improved behaviour which will enhance successful and efficient behaviour change intervention. Table 1 shows the model factors description and its relation to the eight theories.

Based on Table 1, Rembec factor interaction is show in Fig. 6 which can is divided into four main parts namely external, support, instantaneous and temporal. The external part of the model includes factors like behavioural task (*Ba*), planned action (*Pa*), ability (*Ab*), society influence (*Si*), behavioural knowledge (*Bk*), belief (*Bf*), facilitation conditions (*Fc*) and Openness to Behaviour (*Ob*) which are the determinant attribution functionalities of the model. The support part depict agent's support factors like reward, trigger, facilitating condition, openness to behaviour change and openness to FBM which were represented under support stage. The agent's mental stances are represented under initial, reasoning, action determinant, action and consistence stages. The initial stage is where information about the agent's plan is conceived. This stage can also be term information state where agent acquires knowledge and belief on its action. While agent's desire is represented under reasoning stage and defines agent's reasoning stage or motivational state. This stage is influenced by many other interplaying factors like severity of the action, perceived benefit of the action to the agent and the nature of challenge the action is posing to agent's plan and agent's desire which form the reasoning stage of the agent. The action determinant stage house the agent intention and it can be called the deliberative state of the agent. This is the stage that depicts the action that the agent has chosen to perform. Intentions are desires to which the agent has to some extent committed and this commitment is represented in the agent's self-efficacy. The action stage is where the agent's action is undertaken and the future action is represented under consistence stage.

Table 1: The concept of the model

No	Concept	Formalization	Description	Related Theory
1	Openness to FBM	**Of*	State of acceptance of the support	FBM
2	Reward	**Rd*	Gain on the behaviour	FBM
3	Trigger	**Tg*	Right timing to perform the behaviour	FBM
4	Openness to Behaviour Change	**Ob*	State of acceptance of the behaviour	FBM
5	Facilitating Condition	**Fc*	Other physical resources that will aid the behaviour	FBM
1	Ability	*Ab*	The capability to perform a behaviour	FBM, SET
2	Behaviour Knowledge	*Bk*	The knowledge about the behaviour	TM, FBM
3	Behaviour Task	*Ba*	Nature of the behaviour	TPB, TRA
4	Social Influence	*Si*	External factors that enable the behaviour	TPB, TRA
5	Attitude to Change	*Ac*	Mental state	TPB, TRA
6	Challenge	*Cg*	Perceived obstacle or impediment	HBM, TPB
7	Motivation	*Mv*	Desire to perform the behaviour	FBM, TM, HBM
8	Perceived Risk	*Pr*	Negative consequences of the behaviour	HBM, TPB
9	Perceived Benefit	*Pb*	Positive consequences of the behaviour	HBM, TPB
10	Threat	*Hr*	Perceived risk to perform behaviour	FBM, HBM
11	Intention to Change	*Ic*	The Willingness to perform the behaviour	FBM, HBM, RPM
12	Dissatisfaction	*Df*	Negative reaction toward the behaviour	HBM, TPB
13	Negative Thoughts	*Ng*	Negative perception and belief about the behaviour	HBM, TPB
14	Self-efficacy	*Se*	The belief in one's capabilities or ability to perform a target behaviour or action.	RPM, TPB, SET
15	Severity of Behaviour	*Sb*	The strictness of the consequences of a behaviour or action.	HBM
16	Performed Action	*Pc*	A state when the behaviour or action is obtainable	SET
17	Planned Action	*Pa*	The authorization of the behaviour or action	SET
18	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
19	Desire to Change	*Dc*	Emotional sense of longing or wishing to change	SRT
20	Consistency in Action	*Ca*	A state when the action or behaviour is obtainable continuously	RMP, TM
21	Action Reject	*Ar*	A state when the behaviour or action is deflected	SET
22	Consistency Refusal in Action	*Cr*	A state when the behaviour or action is deflected continuously	SET

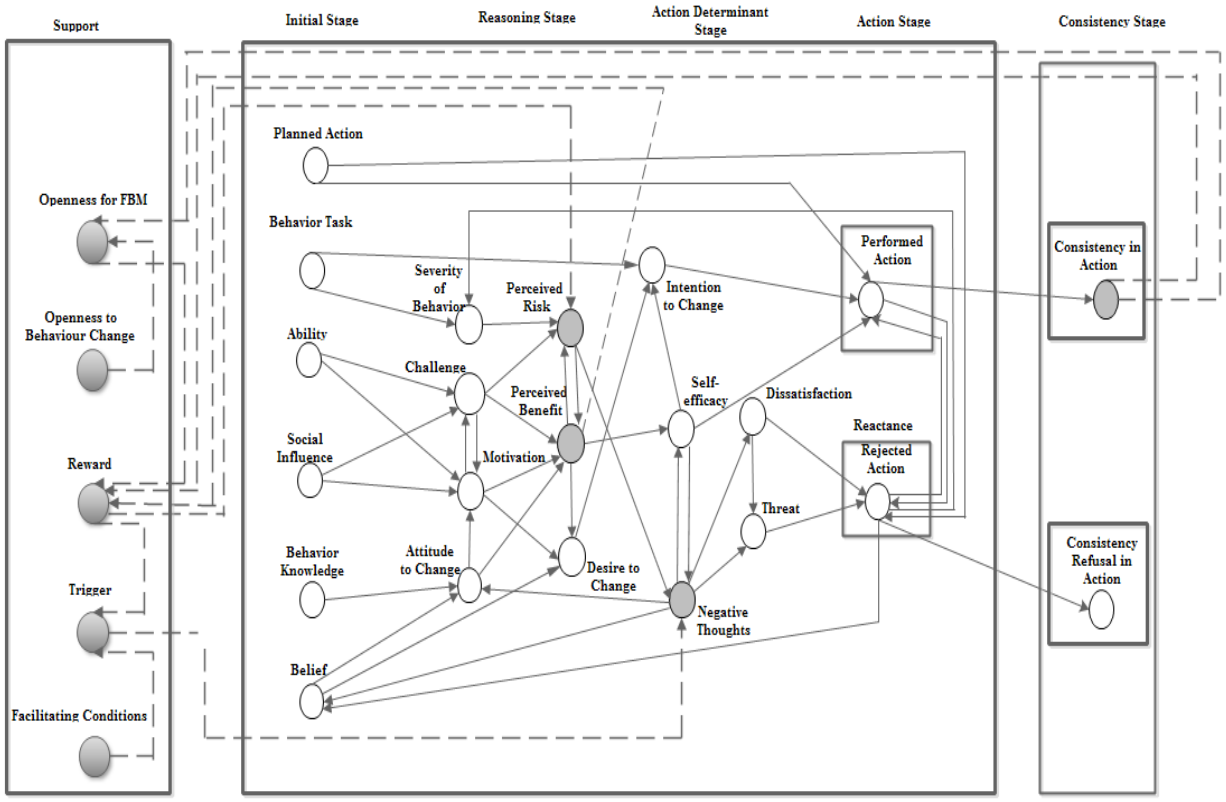

Fig. 6: Reactance model of behaviour change (Rembec)

The arrows in Fig. 6 denote causal dependencies of interplaying factors. The formalization of the model was done using dynamic system in differential equation and was in respect to time (t). For instance, the concept of openness to FBM is the state that a support is freely and unrestrictedly entertained or allowed. It depicts a condition that the support is free to occur without restriction or hindrance. The designed model depicts that Openness to FBM *(*Of)* is high when any of consistency in action (*Ca*) or openness to behaviour *(*Ob)* is high which was formalized as shows in equation (1) and a similar concept was used for equation (2) and (3).

$$*Of\,(t) = \beta.Ca(t) + [\,(1-\beta_f).Ob(t)] \quad (1)$$
$$Sb\,(t) = Ba(t)\,[1-(1-Ar(t))] \quad (2)$$
$$Se\,(t) = Pb(t).[1-Ng(t)] \quad (3)$$

Challenge (*Cg*) is perceived obstacle or impediment to target behaviour. From the designed model challenge (*Cg*) is high when any two of ability (*Ab*), social influence (*Si*) and motivation (*Mv*) are high which was formalized as shown in equation (4). This same procedure was used for the concept formalization of both perceived benefit (*Pb*), performed action (*Pc*) and action reject (*Ar*) as presented in equations (5), (6) and (7), respectively.

$$Cg(t)=w_{c1}.Ab(t) + w_{c2}.Si(t) + w_{c3}.Mv(t) \quad (4)$$
$$Pb(t)=[w_{pb1}.Ac(t)+w_{pb2}.Mv(t)+ w_{pb3}.Cg(t)].(1-Pr(t)) \quad (5)$$
$$Pc(t)=[w_{Pc1}.Pa(t)+w_{Pc2}.Ic(t)+w_{Pc3}.Se(t)].(1-Ar(t)) \quad (6)$$
$$Ar(t)=[w_{Ar1}.Df(t)+w_{Ar2}.Hr(t)+w_{Ar3}.\mathrm{Pa}(t)].(1-(Pc(t)) \quad (7)$$

Where: $\sum_{j=3}^{1} Wcj = 1$, $\sum_{j=3}^{1} Wpbj = 1$, $\sum_{j=3}^{1} \mathrm{Wpcj} = 1$and $\sum_{j=3}^{1} \mathrm{Warj} = 1$

Also, w_{c1}, w_{c2}, w_{c3}, w_{pb1}, w_{pb2}, w_{pb3}, w_{Pc1}, w_{Pc2}, w_{Pc3}, w_{Ar1}, w_{Ar2} and w_{Ar3} are the weight of the equations.

Similarly, motivation (*Mv*) is the simulative drive and intrinsic interest in performing behaviour. Based on the designed model motivation (*Mv*) is low if attitude to change (*Ac*) is low and one of ability (*Ab*), challenge (*Cg*) and social influence (*Si*) are low as presented in equation (8). Also, Attitude to Change (*Ac*) is the mental state which implies a formed view or perception about a behaviour. It is high when negative thoughts (*Ng*) is low and any of behaviour knowledge (*Bk*) or belief (*Bf*) is high as presented in equation (9). This same procedure was used for the concept formalization of equations (10), (11), (12), (13), (14), (15) and (16).

$$Mv\,(t) = \sigma\,(w_{m1}.Ab(t) + w_{m2}.Si(t) + w_{m1}.Cg(t))+ (1-\sigma)\,(Ac(t)) \quad (8)$$
$$Ac\,(t) = [\gamma * Bk(t) + (1-\gamma) * Bf(t)]\,[1-Ng(t)] \quad (9)$$
$$Pr\,(t) = Sb(t) * [1-\rho * Cg(t) + (1-\rho) * Pb(t))] \quad (10)$$
$$*Tg\,(t) = \mu.*Fc(t) + [\,(1-\mu).*Rd(t)] \quad (11)$$
$$*Rd\,(t) = Pb(t).[\bar{w}.Ca(t) + (1-\bar{w}).*Of(t)] \quad (12)$$
$$Dc\,(t) = Bf(t).[\,\eta.Mv(t) + (1-\eta).Pb(t)] \quad (13)$$
$$Ic\,(t) = Dc(t) * [\nu * Se(t) + (1-\nu) * Ba(t)] \quad (14)$$
$$Ng\,(t) = \psi.Pr(t) + [\,(1-\psi).Se(t)] \quad (15)$$
$$Hr\,(t) = \phi * Df(t) + [\,(1-\phi) * Ng(t)] \quad (16)$$

Likewise, dissatisfaction (*Df*) is the negative unpleasant feeling, negative expectation and negative reaction from behaviour. Dissatisfaction (*Df*) is high when negative thought (*Ng*) is high which was formalized in equation (17). The same procedure were used to formalize for consistency in action (*Ca*) and consistency refusal in action (*Cr*) as presented in equations (18) and (19). Also, these equations (17) to (19) are known as the temporal equation of the model because they show the resultant outcome of behaviour. While equations (1) to (16) are the instantaneous equations because they give resultant process that led to the temporal equations.

$$Df(t+\Delta t)=Df(t)+\lambda*[Ng(t)-Df(t)]*(1-Df(t))*(Df(t)*\Delta t) \quad (17)$$
$$Ca(t+\Delta t)=Ca(t)+\zeta*[Pc(t)-Ca(t)]*(1-Ca(t))*(Ca(t)*\Delta t) \quad (18)$$
$$Cr(t+\Delta t)=Cr(t)+\varphi*[Ar(t)-Cr(t)]*(1-Cr(t))*(Cr(t)*\Delta t) \quad (19)$$

The σ, γ, ρ, μ, ν, λ, *η*, ψ, ϕ, $\bar{w}$, ζ and φ are all regulating parameters while Δt is the change in time (*t*).

Simulation traces

Based on the formal model, the instantaneous formalization parameters represent the equalization of corresponded contribution towards the overall equations. In addition, parameters for temporal equations denote the contribution for change rate. The formal model was implemented in the numerical Matlab simulation environment using four case conditions as shown in Table 2. Each of the four case conditions defines different characteristics that can be possessed. For instance, uninspiring defines an agent attribution with high Behavioural task (*Ba*) and low Planned action (*Pa*), Ability (*Ab*), Society influence (*Si*), Behavioural knowledge (*Bk*) and Belief (*Bf*). While ability deficient defines an individual with high Behavioural task (*Ba*), Behavioural knowledge (*Bk*) and Belief (*Bf*) and low Planned action (*Pa*), Ability (*Ab*) and Society influence (*Si*). On the other hand, all the four case conditions were supported with high Planned Action (*Pa*), Facilitation Conditions (*Fc*) and Openness to Behaviour (*Ob*).

Table 2: Simulation case condition

Concept	Case Condition			
	Uninspiring	Belief deficient	Ability deficient	Influential
Pa	0.2	0.2	0.2	0.5
Ba	0.9	0.9	0.9	0.2
Ab	0.2	0.9	0.2	0.9
Si	0.2	0.9	0.2	0.9
Bk	0.2	0.2	0.9	0.9
Bf	0.2	0.2	0.9	0.9

Figures 7, 8, 9 and 10 illustrate the case condition simulation results while Figs. 7a, 8a, 9a and 10a show case conditions without support and Figs. 7b, 8b, 9b and 10b show case condition with support. The simulation results display the fundamental uniqueness of each case condition. The established simulations reflected that the model can account for behavioural phenomena found in psychology and sociology. For instance, Fig. 7a and 7b depict an uninspiring agent attribution with high behavioural task and low planned action, ability, society influence, behavioural knowledge and belief. Fig. 7a shows that when this attribution is without support, there will be an increased dissatisfaction which will be followed by consistency refusal in the target action with a reduced consistency in target action. This implies that agent with such attribution will be characterizes with high reactance because of the increased dissatisfaction and consistency refusal in action which will make consistency in target action or behaviour to be impossible. However, a different scenario was obtained when the support was introduced at time step 1000 as shown in Fig. 7b whereas there was a sharp increment in consistency in action which led 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 uninspiring agent

attribution is acquired with adequate support then the obtained action or behaviour will be characterized by reduced reactance which will make consistency in action or behaviour to be possible.

Similarly, Fig. 8a and 8b depict a belief deficient agent attribution with low belief, behavioural knowledge, planned action and high ability, society influence, behavioural task. When this attribution is without support, there will be an increased dissatisfaction with reduced consistency in action as show in Fig. 8a.

This implies that agent with such attribution will be characterizes with high reactance because of the increased dissatisfaction which will make consistency in target action or behaviour to be impossible.

The introduction of support at time step 1000 gave a totally different situation whereas there was a sharp increment in consistency in action which leads both dissatisfaction and consistency refusal in action as shown in Fig. 8b. Additionally, the leading of consistency in action was with a very wide range margin whereas dissatisfaction was found to be constant at 0.05 and consistency refusal in action was tending to 0. This implies that when belief deficient agent attribution is acquired with adequate support then the obtained behaviour will be characterized by reduced reactance which will make consistency in action or behaviour to be possible.

Likewise, Fig. 9a and 9b depict ability deficient agent attribution with low ability, social influence, planned action and high belief, behaviour knowledge, behavioural task. When this attribution is without support, there will be an increased dissatisfaction with an extremely reduced consistency refusal in action as show in Fig. 9a.

Conclusion

Based on the review of similar research work conducted, it was found that most of the research work could not meet up with the minimum CTHD and VTHD set out by IEEE519-1992 of below 3 and 5% in current and voltage, respectively. This research work presented a model of a PV array which considers some factors that constrained PV module output power based on Sun-power datasheet, it has also modelled a boost DC-DC converter, an inverter and presented a simulation model of the PV array, DC-DC converter as a standalone and finally the complete system (PV array, DC-DC converter and inverter) and the control unit. However, results obtained from the simulation which comprises a PV array, DC-DC converter, an Inverter, the Controller unit results were presented and discussed. Validation of the simulated result based on total harmonic distortion were carried out and the validation has shown that the proposed topology gives better result with an error of 1.06 and 1.99% for current and voltage, respectively which is far below the standard set out by IEEE519-1992. This research work has presented an effective approach for simulating a grid tie inverter for photovoltaic applications. It was evident from the results obtained that multi-level grid tie inverter improves power quality by reducing the total harmonic distortions below the specified minimum. Also, if grid tie inverter like this can be design and connected to the grid, it can improve power availability in Nigerian grid and can specifically promote increase in sustainability of hybrid energy systems which is a cost effective and environmentally friendly green source of energy.

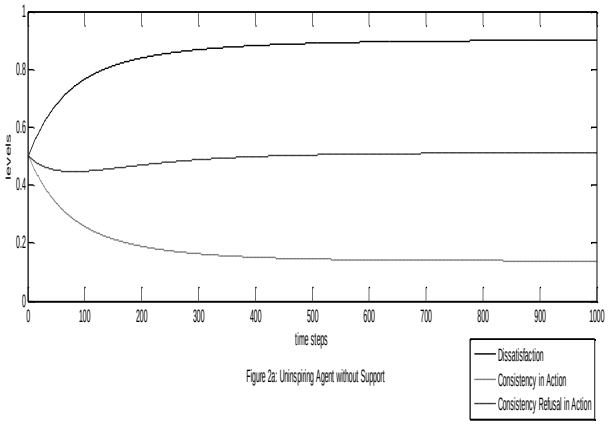

Fig. 7a: Uninspiring case condition without support

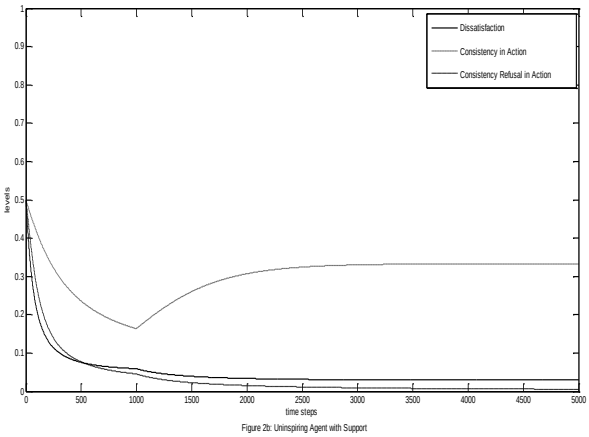

Fig. 7b: Uninspiring case condition with support

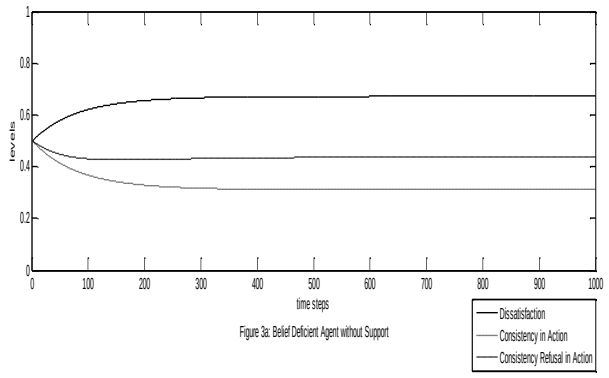

Fig. 8a: Belief deficient case condition without support

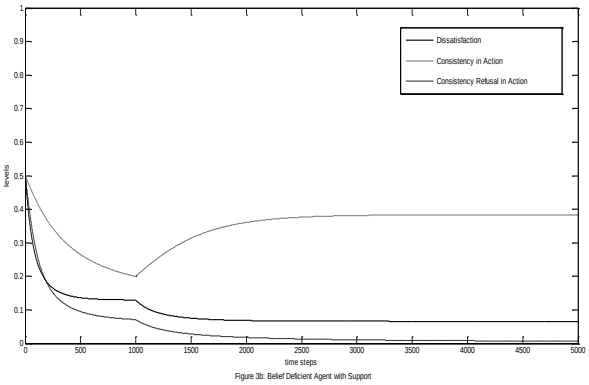

Fig. 8b: Belief deficient case condition with support

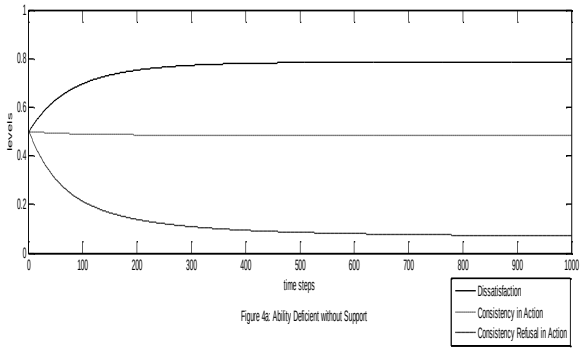

Fig. 9a: Ability deficient case condition without support

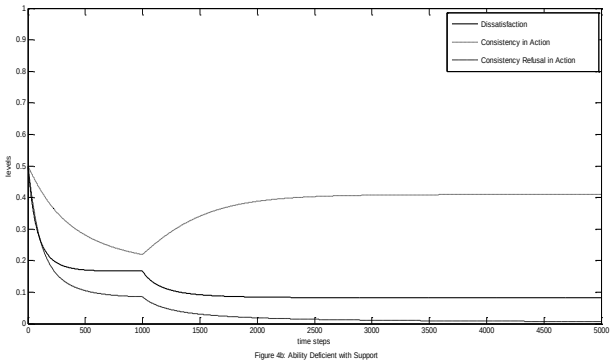

Fig. 9b: Ability deficient case condition without support

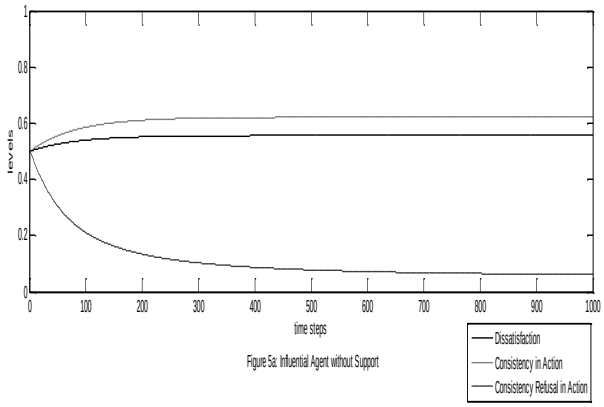

Fig. 10a: Influential case condition without support

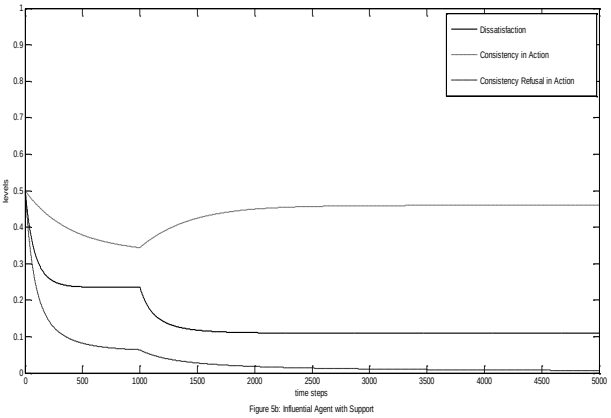

Fig. 10b: Influential case condition support

This implies that agent with such attribution will be characterizes with reduced reactance because of the reduced consistency refusal in action which will make consistency in target action or behaviour to be possible but with increased dissatisfaction. Whereas a different situation was obtained when the support was introduced at time step 1000 as shown in Fig. 9b. There was a sharp increment in consistency in action which led both dissatisfaction and consistency refusal in action. Also, the leading of consistency in action was with a very wide range margin whereas dissatisfaction was found to be constant at 0.1 while consistency refusal in action was found to be tending to 0. This implies that when ability deficient agent attribution is acquired with adequate support then the resultant behaviour will be characterized with an extremely 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 action or behaviour.

On the other hand, Fig. 10a and 10b depict influential agent attribution with high ability, social influence, planned action, belief, behaviour knowledge and low behavioural task. When this attribution is without support, there will be an increased consistency in action, reduced dissatisfaction and extremely reduced consistency refusal in action as show in Fig. 10a.

In the same vein, when the support is introduced there will an increment in consistency in action which leads both dissatisfaction and consistency refusal in action as shown in Fig. 10b. 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 influential agent attribution is acquired with adequate support then it will be characterized with an extremely high consistency in action, reduced dissatisfaction and vanishing consistency refusal in action which indicates that there will be ability to consistently perform the target behaviour.

In summary, it can be seen from the above cases that with an adequate support reactance attribution agent can be supported to generate an improved behaviour or action. Hence, this study gives a comprehensive understanding on how behavioural factors interact to generate psychological reactance and behaviour change. It further explicitly depict how reactance can be supported to generate an improved behaviour change outcome as seen from Figs. 7b, 8b, 9b and 10b. Many studies such as Gifford (2011), Quick and Stephenson (2007), Rains and Turner (2007) and Dillard and Shen (2005) suggested that psychological reactance defect 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 Klein *et al.* (2011); Ritterband *et al.* (2009) and Fogg (2009) explained the processes involved in an improved behaviour change however, these studies did not explicitly explained how psychological reactance can be supported to have an improved behaviour change outcome which will lead to successful behaviour change interventions. Therefore, this study had provided a computational model that can explicitly explain how psychological reactance can be supported to obtain an improved behaviour change intervention.

Conclusion

It is hoped that this study will assist intervention designers to further understand the mechanism behind behaviour change process and psychological reactance which can enable them to design more successful interventions that will be void of reactance on their target audience. Although, the study covered mechanism on human behaviour however it is

believed that not every aspect of human behaviour were covered. This is because human behaviour is as a result of complex interplaying factors that comprise of socio-demographic, cognitive, biological and environmental factors. Nevertheless, the study is specifically tailored to computer or software mediated intervention like agent, avatar, animation and others. Whereas, the ultimate goal of the study is to ensure that designers fully comprehend mechanism that will enhance successful and efficient intervention for their designs. There is still future work enveloped in this study. Firstly, due to the complexity in human behaviour there maybe need to explore other factors such biological and personality traits to extend this study. This will further depict the influence of such factors on behaviour change process. Also, psychological reactance can be further segmented into elements to explore the effect of each in behaviour change process.

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