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A Personality Model Based on NEO PI-R for Emotion Simulation

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SUMMARY The last decade has witnessed an explosion of interest in research on human emotion modeling for generating intelligent virtual agents. This paper proposes a novel personality model based on the Revised NEO Personality Inventory (NEO PI-R). Compared to the popular Big-Five-Personality Factors (Big5) model, our proposed model is more capable than Big5 on describing a variety of personalities. Combining with emotion models it helps to produce more reasonable emotional reactions to external stimuli. A novel Resistant formulation is also proposed to effectively simulate the complicated negative emotions. Emotional reactions towards multiple stimuli are also effectively simulated with the proposed personality model.

key words: *affective computing, emotion, personality, NEO PI-R*

1. Introduction

An enduring challenge in affective computing is to model the complex personality of an intelligent agent in a proper way, so that it responds reasonably in emotions and/or behaviors towards different internal and external stimuli. For example, when watching the same movie, some people may smile for a happy ending, while others may cry because they are deeply touched by the story, but some others may be disappointed since the kitsch ending does not meet their expectations. The same external stimulus causes different emotional responses. Many factors contribute to such differences, but personality play one of the most important parts among them. Personality sometimes acts as a magnifier, amplifying certain aspects of the environment while ignoring others when people respond to the environment. This paper focuses on the study of personality and its effect on emotional responses for the purpose of creating intelligent virtual agent. We believe different personalities define different individuals in the affective computing field.

Many emotional models have been developed in affective computing, including the OCC (Ortony, Clore, & Collins) model [1], The European space model [7], EMA (Emotion and Adaptation) [5], the Ekman's model [2] and its extension WE-3RV model [4]. PAD model [6] uses three axes to represent Pleasure, Arousal and Dominance. Compared to other emotional models, PAD is simple to understand and easy to implement. For example, the emotion "anger" is represented using negative Pleasure, high Arousal and high Dominance (−P+A+D), while the emotion "fear" is represented as −P+A−D. Both anger and fear are negative emotions, but a person with anger emotion trends to seek control, while someone with fear emotion trends to be controlled. Such differences are represented simply and neatly in the PAD model.

The study on personality has also attracted some attention within the affective computing community. Most of the existing models are based on The Big Five Factor (Big5) [1] model. In this model, personality is modeled in five domains: Openness, Extraversion, conscientiousness, Agreeableness and Neuroticism. Mehrabian [6] described how the Big5 can be mapped into the PAD model. Reasonable emotion simulations have been reported [9]. However using only five factors to represent the extremely complicated human personalities is often too rough and lacks the ability to represent subtle personality differences. For example, in the Big5 Factor model, neuroticism manifests negative emotions, such as anger, anxiety or depression. It is very difficult (almost impossible) to distinguish these negative emotions from each other in this model. NEO PI-R [9] is a personality model well recognized internationally as a standard for personality assessment in the field of psychology. It is a measure of five major domains of personality: Neuroticism, Extraversion, Openness to Experience, Agreeableness and Conscientiousness. Each domain consists of six facets that make a total of thirty facet scales, facilitating a comprehensive and detailed description of personality. NEO PI-R as a psychology model has great success in personality tests such as those used as human resources tools. However, in the affective computing field, there is hardly any emotion model which has made use of the NEO model for personality representation.

In this paper, a novel model based on NEO PI-R is proposed to simulate different personalities for intelligent agents. Further, we provide a resistant formulation for the simulation of the complicated and often confusing negative emotional statuses Anger, Sadness, Fear and Disgust. The model is incorporated with the PAD model to simulate unique emotional responses of the agents to certain stimulus based on their own personalities and resistant values. A simple RPG game is created with the sole purpose of demonstrating the performance of the proposed personality models. Experiments show that the proposed personality model is able to provide better descriptions on different personalities and subsequently produce reasonable emotional responses based on them.

The rest of the paper is organized as follows: Section 2

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describes the modeling of emotions. Section 3 describes the personality models, esp. NEO PI-R and how it can be incorporated into the PAD model. Section 4 describes the experiments conducted to demonstrate the different emotional responses from different personality settings that our model is able to produce under various external stimuli, including multiple stimuli Sect. 5 concludes the paper and suggests some future work.

2. Emotion Modeling

Figure 1 provides an overview of our system for the simulation of emotion response towards internal and external stimuli.

Emotion is a complex psycho-physiological experience of an individual's state of mind as interacting with biochemical (internal) and environmental (external) influences. For humans, emotion fundamentally involves physiological arousal, expressive behaviours, and conscious experience [3]. Emotion is associated with mood, temperament, personality and disposition, and motivation. Emotion change is caused by stimuli, which is anything that could potentially affect the agent it applied to, such as events, facial expressions, gestures, voices etc. Emotions reflect short-term affect. After its occurrence it will usually decay and disappear. Many emotion models exist in the field of affective computing. In this project the PAD model is employed as the base emotion model [11].

$$E = [P \;\; A \;\; D], \quad -1 \le P,\, A,\, D \le 1 \tag{1}$$

$E = [0 \;\; 0 \;\; 0]$ is assumed as the neutral emotional state.

Mood reflects a relatively long-term emotional effect, which is generally not directly related to a stimulus. It has the feature of diffusivity. In other words, it is not a specific experience about a specific stimulus, but a relatively stable emotional state. For instance, an employee is in a positive mood when promoted for good performance. This experience will infect all his activities with happy mood in a relatively long term. Currently, mood is simply modeled as three basic states: Positive, Negative and Neutral. There is still no uniform definition in the psychology field on how to measure mood. In the field of affective computing, changes of emotions and moods etc. are generally formulated by empirical observations and we have taken a similar approach. In this project, mood is considered as a simple weighted extension of emotion.

Decay of emotion measures how fast the strength of a certain emotion decreases. It starts when a certain stimulus stops affecting the emotion. In this research we assume that decays happen exponentially, i.e., the emotion strength drops slowly in the beginning but the rate of decrement increases exponentially with time. It is assumed that decay will always happen to all emotions caused by a stimulus and the original emotional state before the stimulus happens will eventually be returned to over a given duration.

As mentioned before, anything that could affect the emotional state of an agent is considered a stimulus. In this research, stimuli are specifically defined as external stimuli. A stimulus is quantitatively defined as:

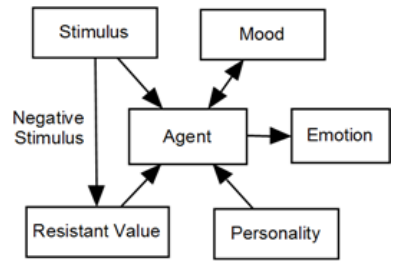

Fig. 1 Our emotion response model.

$$S = \mu \times S_{Intensity} \times S_{Effect} \times S_{Likelihood} \tag{2}$$

where

S denotes a stimulus;

μ denotes the weighting coefficient of S. It is ranged from 0 to 1;

$S_{Intensity}$ denotes the stimulus intensity;

S_{Effect} denotes whether the stimulus is considered positive or negative to the target;

and $S_{Likelihood}$ denotes the likelihood of the stimulus happening to the agent.

3. Personality in Emotion Modelling

Personality is the particular combination of emotional, attitudinal, and behavioral response patterns of an individual. Personality reflects the long term individual differences in mental characteristics.

3.1 The Big Five Model

To date the Big Five Factor (Big5) [1] model is the most popular personality model in the area of affective computing. It is a classic psychology personality model, which divide personality into five broad domains. They are openness, conscientiousness, extraversion, agreeableness and neuroticism respectively [10]. Openness is a general appreciation of all kinds of experience, such as art, imagination etc.; Conscientiousness is more related to self-discipline and dutifulness; Extraversion represents the tendency to be enthusiastic and the keenness to interact with people; Agreeableness shows whether how much the person can get alone with others; and neuroticism represent the likelihood to experience negative emotions, such as anger, anxiety, and depression. In the Big5 model, an agent's personality is represented as a 5-tuple, with each element representing its value in the 5 personality domains respectively, and the range of the values are 0 to 1.

The Big5 model has been incorporated with the PAD model to simulate the emotional response of agents with different personalities. The mapping to the PAD values is done based on the following principles [6]:

- Extraverts are primarily dominant and secondarily

pleasant.

- Agreeableness resembles dependency with pleasant, arousable, and submissive characteristics, but involved greater pleasantness;
- Conscientiousness includes equal degrees of pleasant and dominant qualities;
- Neuroticism involves almost equal degrees of pleasant and unarousable characteristics, lacking the important dominant feature;
- Openness is weighted primarily by dominant, and secondarily by arousal.

The commonly used mapping equations are hence as follows [6]:

$$P_{Big5} = .59 \times Agreeableness + .25 \times Neuroticism + 0.21 \times Extraversion \quad (3)$$

$$A_{Big5} = -0.57 \times Neuroticism + .30 \times Agreeableness + .15 \times Openness \quad (4)$$

$$D_{Big5} = .60 \times Extraversion - .32 \times Agreeableness + .25 \times Openness + .17 \times Conscientiousness \quad (5)$$

3.2 The NEO PI-R Model

The NEO PI-R personality model consists of five major domains of personality and each domain includes six facets [10]. It covers almost all usual personalities. The NEO PI-R is regarded as a standard for personality assessment in psychology, helping people to understand themselves, developing their strengths and avoiding the weaknesses. More and more employers use the NEO model as the benchmark for personality tests during recruitment. However in affective computing, there is hardly any emotion model which has made use of the NEO model for personality representation. In this paper we propose a novel model based on NEO PI-R to simulate different personalities for intelligent agents. 11 facets out of the 30 NEO PI-R personality facets are currently included in our proposed personality model. They are considered more significant than the others in affecting emotional responses. The 11 facets are described below.

Neuroticism domain is related to negative emotions. People with high value in this domain are more prone to psychological distress. Five facets in this domain are included in our model:

- Anxiety: people with this trait are easy to get anxious, distress or uneasiness by fear of danger or misfortune.
- Angry Hostility (AH): people with this trait tend to become unfriendly or angry easily.
- Depression: people with this trait usually feel sadness, despondency and loneliness. It is a condition of general emotional withdrawn and dejection.
- Self-consciousness (SC): also known as self-awareness; people with this trait tend to be excessively aware of being observed by others.
- Vulnerability: people with this facet are usually having less ability to handle a hostile environment. They can easily get wounded or hurt.

Extraversion domain measures people's willingness to be more active. People who have high extraversion tend to seek social stimulation to engage with others. Two facets here are included in our model:

- Warmth: people with this trait are friendly, enthusiastic and kind, interested in others.
- Positive emotion (PE): people with this trait often look at the bright side; have tendency to experience happiness, joy and gratitude.

Agreeableness is the domain that is more related to being kind, sympathetic and considerate, indicating individual differences in cooperation and social harmony. Three facets from this domain are included:

- Altruism: people with this trait are more likely to be unselfish; devote themselves into the welfare of others.
- Compliance: more related to interpersonal conflict; people with low compliance trend to be aggressive, quarrelsome and vindictive.
- Tender mindedness (TM): people with this trait have more sympathy or compassionate for the others.

Conscientiousness domain describes the degree of thoroughness, carefulness or vigilance. People with this trait are very motivated to complete a task well. One facet from this domain is included:

- Dutifulness: people with this trait are always filled with a sense of obligation.

The remaining 19 facets in the NEO PI-R model are more related to behavioural responses and are considered less important for emotional changes. They are not included in the proposed personality model currently. Their descriptions can be found in [8].

The 11 facets are defined as 11 personality traits in our model. They are assigned a value from 0 to 1, where 0.5 is assumed to be the neutral state. For example if the value for *Angry Hostility (AH)* is less than 0.5, the agent is assumed to be less likely to get angry. Among the 11 personality traits, *Anxiety*, *Depression*, and *Self-consciousness (SC)* are more related to the emotion "Sadness"; *Angry Hostility* and low *Compliance* are more related to "Anger"; and *Vulnerability* is more connected with "Fear"; *Positive Emotion* shows the agent's ability to look on the bright side and be "Happy". The following equations are derived to describe how the personality traits are connected to the respective emotion trends (ET), which represent the tendency for an agent to feel the respective emotions:

$$ET_{Fear} = (Vulnerability - 0.5) \times ABS(Vulnerability - 0.5) \quad (6)$$

$$ET_{Happiness} = (PE - 0.5) \times ABS(PE - 0.5) \quad (7)$$

$$ET_{Sadness} = \alpha(Anxiety - 0.5) \times ABS(Anxiety - 0.5)$$

$$+\beta(Depression-0.5) \times ABS(Depression-0.5) + \gamma(SC-0.5)\times ABS(SC-0.5) \quad (8)$$

$$ET_{Anger} = (AH-0.5)\times ABS(AH-0.5) - \delta(Compliance-0.5) \times ABS(Compliance-0.5) \quad (9)$$

where α, β, γ and δ are the weighting coefficients of *Anxiety*, *Depression*, *Self-Consciousness and Compliance* respectively. They are ranged from 0 to 1.

Altruism, *Tender-mindedness*, *Warmth*, and *Dutifulness* basically describe whether a person likes to interact with others and the manners he interacts with them. In the NEO PI-R model [13], *Altruism*, *Tender-mindedness*, and *Warmth* contribute less on emotional changes directly. However they are important when deciding whether a person is likely to get involved in certain situations when he is not directly affected. High values of these traits encourage an agent to accept stimulus from others, sometime even actively seek to be influenced by a stimulus, instead of just passively waiting and accepting stimuli. Agents with high values of these traits tend to interact actively with the environment through stimuli that are sometimes not directly applied to them, which make them more like vivid persons. One example can be found in [8].

The NEO PI-R personality model provides a much more detailed and subtle descriptions of the complicated human personality. Even with only 11 out of the 30 facets, our model is able to provide a better description for certain personalities. For example, an agent Alice can be described as having a personality trait of 0.7 AH and 0.8 Depression. When a negative stimulus applies to her, her emotional state could change into either anger or sadness, depending on some other factors in the emotion modeling. With the Big5 model, there is only one value for Neuroticism, which makes it very limited in representing and distinguishing between various personalities and emotions, especially the subtle ones.

3.3 PAD Trend Based on NEO PI-R Facets

According to the popularly used Ekman's model [2], there are six basic classes of people's emotions: Anger, Disgust, Fear, Happiness, Sadness and Surprise [9]. The first five emotions are implemented in this research at the moment, except Surprise. A set of PAD (Pleasure, Arousal and Dominance) values and its mood subspaces corresponding to the five emotion classes are shown in Table 1 [9].

Combining with the emotion trends derived above, the PAD trends of an agent, which describes the most possible PAD values an agent tends to have based on his personality traits, can be obtained as follows:

$$PAD_{Trend} = ET_1 \times PAD_1 + ET_2 \times PAD_2 \quad (10)$$

where ET_1 is the most dominate emotion trend;
ET_2 is the 2nd most dominate emotion trend;
PAD_1 and PAD_2 denote the standard PAD values in Table 1 corresponding to ET_1 and ET_2.

Table 1 Correspondence between PAD and emotion.

Emotion	P	A	D	Mood subspace
Anger	-0.51	0.59	0.25	-P+A+D
Disgust	-0.4	0.2	0.1	-P+A+D
Fear	-0.64	0.60	-0.43	-P+A-D
Happiness	0.4	0.2	0.15	+P+A+D
Sadness	-0.4	-0.2	-0.5	-P-A-D

Personalities and emotions are very complicated. A person could have many different sides of personality and at any time he/she could experience many different, sometimes conflicting, emotions. We consider an agent's emotions and behaviours are often only affected by a few dominant trends. In this research, only the first two dominant emotion trends are chosen at any time, as shown in Eq. (10).

3.4 Mapping NEO PI-R Facets to PAD Space

The emotional trends calculated based on the personality traits are constantly mapped into the PAD model to dynamically simulate the emotional change of an agent. Eq. (11), Eq. (12) and Eq. (13) below describe how the PAD values are dynamically updated at every time step.

$$\boldsymbol{E}_t = \boldsymbol{E}_{t-1} + M_t + (\rho \times PAD_{Trend}) \times S \times e^{\gamma(Requirement-0.5)} \frac{t}{T_{Duration}} - T_M$$
$$0 < t \le T_{Duration},\ 0 \le Requirement \le 0.5 \quad (11)$$

$$\boldsymbol{E}_t = \boldsymbol{E}_{t-1} + M_t + (\rho \times PAD_{Trend}) \times S \times e^{\gamma(Requirement-0.5)} \frac{T_{Duration}-t}{T_{Duration}} - T_M$$
$$0 < t \le T_{Duration},\ 0.5 < Requirement \le 1 \quad (12)$$

$$\boldsymbol{E}_t = \boldsymbol{E}_{t-1} + M_t - \mathrm{PAD}_{Decay} - T_M$$
$$T_{Duration} < t \le T_{Decay} \quad (13)$$

where $\boldsymbol{E}_t$ and $\boldsymbol{E}_{t-1}$ denotes the PAD value at time t and t-1;
M_t denotes the agent's mood at time t;
γ is the weighting coefficient of *Requirement*;
T_M is the threshold of PAD value. It is ranged from −1 to 1;
and ρ is the weighting coefficient for PAD_{Trend}.

Requirement denotes how much an agent desires a certain stimulus. The range for *Requirement* is 0 to 1 with the neutral state at 0.5. A negative stimulus usually comes with a *Requirement* value less than 0.5. As formulated in Eq. (11) and Eq. (12), the PAD values change depending on the stimuli, current mood, Requirement and the personality of the agent. After the PAD values are updated at every time step, they are compared against the values given in Table 1 and the closest emotion is regarded as the current emotion status.

3.5 Resistant Value

The PAD values are not always simply increased with

positive stimulus and decreased with negative stimulus. Their changes can be very complicated, especially with negative emotions, due to the sometimes very subtle distinctions between Sad, Fear, Disgust and Anger. In this research we propose a simple yet effective way to simulate the changes between negative emotions. A simple but effective method is proposed by using a *Resistant* value R_t to represent the real time stress index of an agent. $Resistant_A$ and $Resistant_B$ are the two thresholds used to change the PAD trends, with $0 < Resistant_A < Resistant_B < 1$. Table 2 demonstrates the PAD signs based on the R_t value. In short, an agent reaches a point where the negative stimulus becomes difficult to bear when R_t reaches $Resistant_A$. When R_t reaches $Resistant_B$, the agent's Dominance value will increase as well. He/she starts to get disgusted or angry, trying to fight against the stimulus. Eq. (14) describes how the *Resistant* values are updated.

$$R_t = R_{t-1} + \frac{ABS(\Delta P) + ABS(\Delta A) + ABS(\Delta D)}{3}$$
$$S_{Effect} \times S_{Likelihood} < 0 \tag{14}$$

where

R_t denotes the *Resistant* value at time t;

ΔP, ΔA *and* ΔD denote the difference of PAD values from time t-1 to time t.

The *Resistant* values and the two thresholds are used to change the sign of the PAD trends as shown in Table 2.

3.6 Multi-Stimuli

Stimuli do not always come one at a time. It is very possible that more than one stimuli happen to an agent at the same time, or within a short period of time. Emotional model subjected to more than one, sometimes conflicting, stimuli enables simulation of relatively complicated scenarios. Combining with the *Resistant* value discussed in the previous subsection, we are able to simulate emotional response to multi-stimuli in a more realistic fashion in our emotion simulation system. For example, NPC Nick is subjected to a positive stimulus, which makes him happy. At the same time or within the decaying time frame, a negative stimulus is applied to him. Some of the negative effort could be neutralized by the first stimulus, based on the PAD trends generated by both stimuli. On the other hand, two or more negative stimuli could make an agent's Arousal and Dominance values reach their Resistant thresholds faster. The agent could reach the emotions *anger, disgust or sadness* faster and in a more complicated manner than a simple linear accumulation.

Table 2 PAD signs based on Resistant value.

PAD Trend	Conditions
−P − A − D	$0 < R_t \le Resistant_A$
−P + A − D	$Resistant_A < R_t \le Resistant_B$
−P + A + D	$Resistant_B < R_t$

4. Experimental Results and Analysis

Conscript [12], an open source game engine, is used to develop a simple RPG game as our test environment, as shown in Fig. 2. The sole purpose of this game is to simulate the different emotional responses based on different personalities and different stimuli, hence the game interface is rather preliminary. The player chooses to impose certain stimulus/stimuli on different agents, hereby represented by NPCs, and their corresponding emotional changes are shown by the changing PAD graphs and simple animations of facial expressions, as shown in Fig. 3

Figure 2 shows that NPC Oven is chatting with the player through the dialogue boxes in the upper right of the figure and his emotion status details are displayed by both the bar chart and the PAD values shown in the bottom right. From different messages given by the player, Oven is imposed with different stimuli.

Figure 3 demonstrates snapshots of different facial expression animations and the corresponding graphs for the PAD value changes, where the red, white and cyan curves denote Pleasure, Arousal and Dominance respectively. The animations and the PAD graphs are changing constantly reflecting the emotional changes of the agents.

Four experiments have been conducted to evaluate the effect of different personality represented by our model on emotional changes. In all experiments the agents are given the same Resistant thresholds against negative stimulus ($Resistant_A = 0.6$ $Resistant_B = 0.8$).

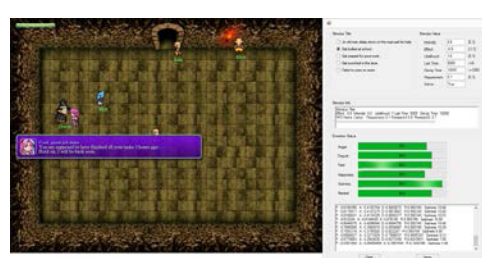

Fig. 2 Test environment.

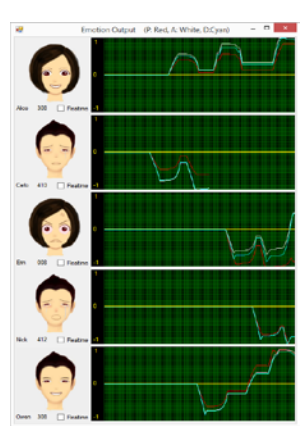

Fig. 3 Emotion status shown in facial animation and graph.

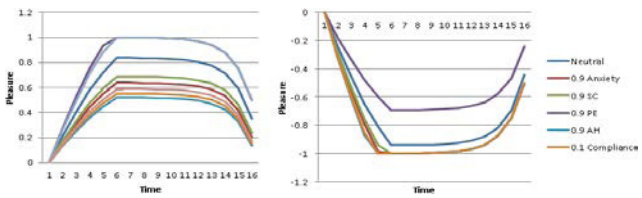

Fig. 4 Pleasure value on simple stimulus.

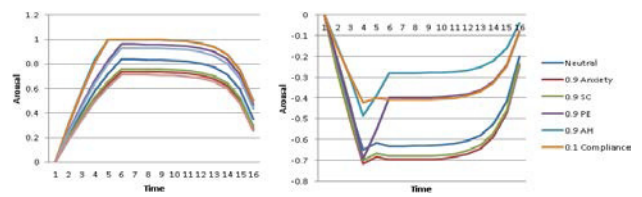

Fig. 5 Arousal value on simple stimulus.

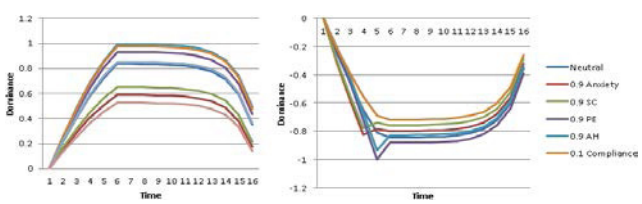

Fig. 6 Dominance on simple stimulus.

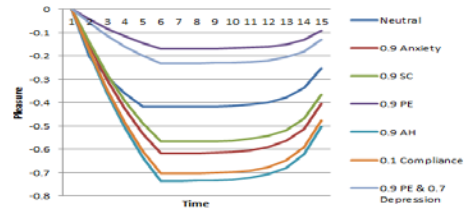

Fig. 7 Pleasure value on multi-stimulus A.

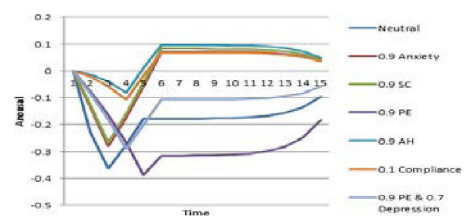

Fig. 8 Arousal value on multi-stimulus A.

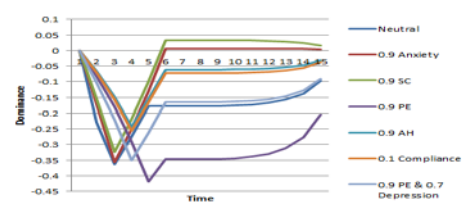

Fig. 9 Dominance value on multi-stimulus A.

4.1 Experiment 1 — Single Stimulus

This experiment tests the emotional response of an agent when subjected to a single stimulus. A positive stimulus and a negative stimulus are applied to NPC Alice individually: She is praised for good performance / She gets seriously bullied at school. A few different personality traits are assigned to Alice and her emotional reactions are recorded as shown in Fig. 4, Fig. 5 and Fig. 6. The left charts are the results from the positive stimulus, while the right charts are from the negative stimulus. The Happiness emotion is observed as the dominant emotion for Alice when the stimulus is the simple positive one. Meanwhile, the Sad emotion is observed as the dominant emotion for her when subjected to the negative stimulus. Figure 4 shows that PE has great contribution to Alice's Pleasure value, especially when she is imposed a negative stimulus. Both Fig. 5 and Fig. 6 show a rise after a dramatically drop for a negative stimulus. When the fast decreasing of Arousal value and Dominance value hit their *Resistant* thresholds, the drop stopped. Different personalities of Alice determine the different strengths of her urge to fight against this negative stimulus. Among these personalities, PE and AH both cause a relative high Arousal increase.

Although all personalities assigned to Alice lead to the same emotions: Happiness after the positive stimulus and Sadness after the strong negative stimulus, their PAD curves are different from each other and will have long term effect on the emotional changes and responses.

4.2 Experiment 2 — Multi-Stimuli A

In the second experiment, a light positive stimulus is applied with a strong negative stimulus: NPC Nick was given a candy when he got seriously bullied. The situation is referred to as Multi-Stimuli A. In this experiment, a candy represents an insignificant positive stimulus, which is far from sufficient in balancing the negative stimulus out. As a result, the Sad emotion is still observed while the personality is assigned as Neutral, 0.9 PE, or 0.9 PE & 0.7 Depression. Disgust and Sad emotions are triggered for the other personalities. The PAD values are recorded and shown in Figs. 7, 8 and 9 respectively.

Comparing the peak states of the PAD values in Experiment 2 with those for the single negative stimulus in Experiment 1, they rise only a little. As anticipated, a light positive stimulus is not enough to neutralize the negative stimulus, i.e., to cheer Nick up. According to Fig. 7, if Nick is assigned a value of 0.9 PE, his Pleasure value will rise up and slowly decay to around −0.1. PE makes Nick to think more on the good side of the situation: a candy is better than nothing; but the fact that he is bullied is still too frustrating for him to be happy. The other curves represent the changes of PAD based on other personality traits. The light positive stimulus causes even less PAD rise when Nick's dominant personality is not PE. According to Eq. (11) and Eq. (12), when a negative mood is in dominance, a slight PAD value increment resulted from a light positive stimulus will not

stop the PAD values from decreasing.

Figure 8 demonstrates Nick's Arousal response on Multi-stimuli A. 0.9 AH results in the highest Arousal value. As discussed before, the Anger emotion comes with a very high Arousal value. On the other end of the spectrum, 0.9 PE has extremely low Arousal value. The rise of Arousal value is caused by the *Resistant* value in this experiment. When Nick cannot stand the negative stimulus any more, his Arousal value begins to rise. However, his 0.9 PE personality and the light positive stimulus worked together to comfort him. Hence the lowest Arousal value is resulted from the 0.9 PE personality. Figure 9 shows the change of Nick's Dominance value from Multi-stimuli A. Understandably, 0.1 Compliance results in the highest Dominance value among the given personalities, and the next highest is from the 0.9 Anxiety personality. As shown in the figure, all the personalities see a rise of Dominance value after a dramatic decrease. It is caused by the *Resistant* value as well. The Dominance value rises when the negative stimulus lasts beyond the *Resistant* thresholds.

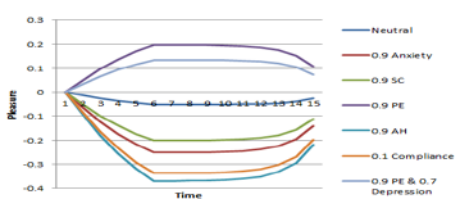

Fig. 10 Pleasure value on multi-stimuli B.

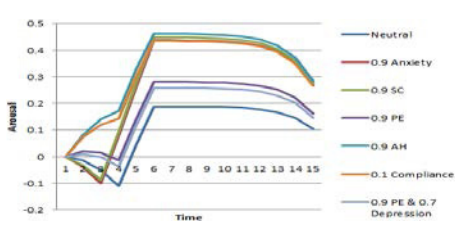

Fig. 11 Arousal value on multi-stimuli B.

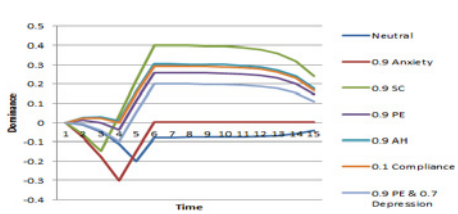

Fig. 12 Dominance value on multi-stimuli B.

4.3 Experiment 3 — Multi-Stimuli B

In the third experiment, a strong negative stimulus (Being bullied in school) is applied to Nick at the same time a relatively strong positive stimulus (still less strong than the negative stimulus) occurs: He is told that he is chosen to be in a prestigious school tour he has eagerly wanted for a long time. This situation is referred to as Multi-stimuli B. As a result, the Happy emotion is observed for Nick in this experiment for both 0.9 PE and 0.9 PE & 0.7 Depression personalities. The PAD values from different personalities are recorded and shown in Figs. 10, 11 and 12 respectively.

Figure 10 shows the Pleasure value on Multi-stimuli B. When Nick is assigned with personality traits of 0.9 PE, 0.9 PE & 0.7 Depression, his Pleasure value becomes positive after the stimuli. Among them, the personality of 0.9 PE results in the highest Pleasure value. The Pleasure value stays negative for other personality traits due to the existence of the strong negative stimulus. However, the Pleasure values are generally higher comparing to those in Experiment 1 (negative) and Experiment 2, towards the neutral value at the end of the duration. Figure 11 demonstrates the change of the Arousal value from Multi-stimuli B. When Nick is assigned with 0.9 AH or 0.1 Compliance, his Arousal value reaches its peak very quickly. The personality of 0.9 Self-conscious or 0.9 Anxiety results in a very high Arousal value as well. The dramatic increase starts when the *Resistant* value reaches $Resistant_A$ and $Resistant_B$. If Nick is assigned with the Neutral personality, the Arousal value becomes the lowest, resulting in less Arousal contribution. Figure 12 demonstrates the change of the Dominance value from Multi-stimuli B. When Nick is assigned a personality of 0.9 SC, his Dominance value reaches its peak very quickly. The personality of 0.9 Anxiety results in the lowest Dominance value in this Experiment. People with this personality have less Dominance to affect the surroundings and other people. Instead, they are easy to be influenced by others hence the low Dominance value.

4.4 Experiment 4 — Continuous Negative Stimuli

In the fourth experiment, the same negative stimulus is applied 4 times on Nick, i.e., he is bullied 4 times consecutively in school. The intention of this experiment is to evaluate the different emotional responses with reference to the

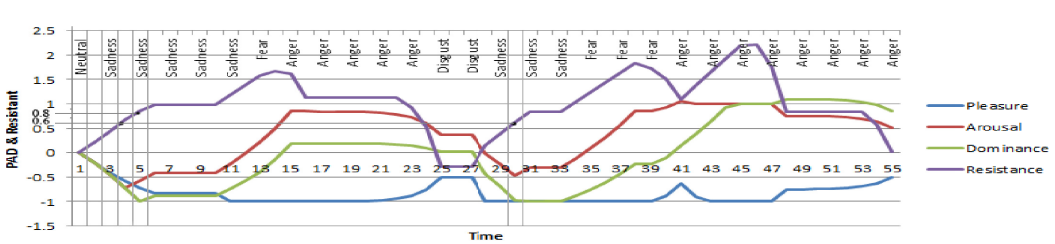

Fig. 13 Continuous negative stimuli.

proposed *Resistant* values as described in Sect. 3.5. The focus is on the changes of the *Resistant* value and its influence on the transition of negative emotions, hence Nick's personality is assigned as Neutral. Figure 13 demonstrates the changes of the Pleasure, Arousal and Dominance values as well as the *Resistant* value. The first stimulus happened at time step 1: Nick gradually became Sad during the duration of the stimulus. The second stimulus happened at time step 11: Nick became Fear at the beginning, then turned to Anger during the duration. When he gradually calmed down, a bully happened again on him at time step 27; his emotion changed into Disgust, Sadness and Fear subsequently. When the fourth stimulus happened at time 41, the Dominance value reaches its peak and Arousal is very high too, while Pleasure is in negative. This is the emotion of great Anger. As shown in Fig. 13, the Arousal (red curve) first starts to increase when the *Resistant* value (purple curve) is over 0.6 (at time step 4), and the Dominance (green curve) starts to increase after the *Resistant* value is over 0.8 (at time step 5). The next rises of the Arousal Dominance values are at time 30 and time 33 respectively, when the *Resistant* value is over 0.6 and 0.8 again respectively after the 3rd bully at time step 27. Similar to the PAD values, the *Resistant* value is also decayed after a stimulus stops applying. A new negative stimulus will interrupt the decay phase for the PAD and the *Resistant* values. Additionally, the *Resistant* value does not affect the PAD value during its decaying period. Emotion responses vary when the *Resistant* threshold and values changes.

5. Conclusion

In this paper we have proposed a new emotion model based on PAD and NEO PI-R. A novel *Resistant* value is also introduced, which enables our emotion model to simulate Sadness, Fear, Disgust and Anger vividly. Four experiments have been conducted to simulate different emotional responses under different stimuli with different personality traits. The first three experiments demonstrate that our personality model is able to simulate how personalities greatly influence the emotional responses towards the same stimulus or same set of stimuli. The last experiment shows the emotional changes under repeated negative stimuli and the effect of the *Resistant* value. Currently only 11 facets have been included in our personality model. We will consider adding more facets into the model in the future and make the whole emotion system more robust. Field test with ordinary user and professionals in similar fields will also be conducted to verify the correctness of the proposed models.

References

[1] P. Becker, "Structural and relational analyses of emotion and personality traits," Zeitschrift für Differentielle und Diagnostische Psychologie, vol.22, no.3, pp.155–172, 2001.
[2] M. Cohen and D.W. Massara, "Modelling co-articulation in synthetic visual speech," Computer Animation 1993, pp.139–156.
[3] P. Ekman, "An argument for basic emotions cognition and emotion," pp.169–200, 1992.
[4] J. Gratch and S. Marsella, "Evaluating a computational model of emotion," Autonomous Agents and Multi-Agent Systems, vol.11, pp.23–43, 2005.
[5] P. Gebhard, "ALMA-A layered model of affect," 4th International Joint Conference on Autonomous Agents and Multi-Agent Systems, pp.29–36, 2005.
[6] A. Mehrabian, "Analysis of the big-five personality in terms of the PAD temperament model," Australian Journal of Psychology, vol.48, pp.86–92, 1996.
[7] R.W. Picard, Affective Computing, MIT Press, London, England, 1997.
[8] Y. Zhang and L. Li, "A new model with NEO PI-R for emotion simulations," 2013 International Conference on Cyberworlds (CW), pp.310–317, 2013.
[9] Z. Shi, J. Wei, Z. Wang, J. Tu, and Q. Zhang, Q. "Affective transfer computing model based on attenuation emotion mechanism," J. Multimodal User Interfaces, vol.5, no.1-2, pp.3–18, 2012.
[10] T.J. Trull, J.D. Useda, P.T. Costa Jr., and R.R. McCrae, "Comparison of the MMPI-2 personality psychopathology five (PSY-5), the NEO-PI, and the NEO-PI—R," Psychological Assessment, vol.7, no.4, p.508, 1995.
[11] http://en.wikipedia.org/
[12] http://www.codeproject.com/
[13] http://www.unifr.ch/

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