Modeling Personality in the Affective Agent Architecture *GenIA*^{3}

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Abstract: In the last few years there has been a growing interest in affective computing. This type of computation tries to include and use emotions in different software processes. One of the most relevant areas is the simulation of human behavior where various affective models are used to represent different affective characteristics such as emotions, mood, or personality. Personality is defined as a set of individual characteristics that influence motivations and behaviors when a human being faces a particular circumstance. Personality plays a very important role in modeling affective processes. Through the simulation of emotions we can improve, among others, the experience of users dealing with machines, and human simulations in decision-making processes using multi-agent systems. In this work we propose a model for the use of personality in the general purpose architecture for affective agents *GenIA*^{3}, as well as the development of the model in the current *GenIA*^{3} platform.

1 INTRODUCTION

When we analyze human behavior from a rational point of view, we observe inconsistencies when human beings face a particular situations like a decision-making problem. These inconsistencies are due to the influence of emotions and affective characteristics. These characteristics influence the decision making and reasoning processes to a greater or lesser extent (Broome, 2002). Researchers in this area analyze the influence of emotions, mood and personality (Zelenski, 2007; Frijda, 1986). It is generally accepted that emotions are reactions to a certain stimuli (Ortony et al., 1990). Emotions are divided into two types: primary emotions, that have a direct relationship with expressive abilities such as facial expressions, body postures or voice inflections; and secondary emotions, that arise as the result of reasoning about current events taking into account expectations and past experiences. On the other hand mood is different from emotions or feelings: it is less specific, less intense, and less likely to be triggered by a particular stimulus or event. In addition, mood is less volatile than emotions (i.e. mood vary less over time and have a longer duration) (Becker, 2001). Finally personality is defined as a set of individual characteristics that influence motivations, behaviors, and emotions when facing a particular circumstance (Damasio and Sutherland, 1994).

Personality also refers to the characteristic way in which a person thinks, feels, behaves, and relates to others. Personality is the only affective trait that is maintained in the long term and reflects individual differences in mental characteristics (Ortony et al., 1990).

In recent years, the interest in analyzing and using these affective characteristics is increasing in the computing area. Affective computing is the area that deals with the treatment of emotions in computing science (Picard and Picard, 1997). It draws on different theories of the psychological and cognitive sciences. In the last years, different studies to incorporate emotions and affective characteristics in the software processes have been conducted to improve the simulation of human behavior (Becker-Asano, 2008; Gebhard, 2005; Alfonso et al., 2014). These proposals employ computational models to define emotions, mood, and personality. Generally the emotions are represented with the *OCC* (Ortony et al., 1990) model which classifies emotions into twenty-two categories based on reactions to different situations. The mood is usually represented using the PAD model. PAD is a three dimensional model proposed in (Mehrabian, 1996) that defines the mood as an average of individual emotional states across a representative variety of life situations. The three dimensions are: Pleasure, Arousal, and Dominance[1]. Plea-

[1] In some references this model is named *VAD* replacing the Pleasure by the Valance.

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sure denotes how pleasant or unpleasant a stimulus is, excitement is the activation that stimulus produces, and domination is the level of dominance or submission to that situation. Finally, one of the most popular models to represent the personality in affective computing is the Five Factor Model (FFM) (McCrae and John, 1992). The FFM divides personality into five dimensions: Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness to Experience. Each trait summarizes a large number of distinct and more specific personality characteristics. The five factors together determine how a person will respond to different stimuli during his or her life.

One of the technologies that is becoming more relevant in simulation environments are the multi-agent systems (Wooldridge and Jennings, 1994). These systems provide adaptability, scalability, versatility, autonomy, and have high fault tolerance. Currently there are representations and formalizations of agents that take into account the affective processes to make decisions simulating human behavior (Gebhard, 2005; Becker-Asano, 2008). These formalizations model the evaluation process, the dynamics of the emotions, or the effect that emotions have on the cognitive and behavioral processes of the agents. However, there are not many architectures for affective agents that make a general formalization of the interrelation between rational processes and affective processes. One of the formalizations that takes into account this interrelation is the *GenIA*^{3} architecture (Alfonso et al., 2017) that is the base of our a proposal to manage the personality in a multi-agent system. Our proposal allows the use of different personality theories and groups agents according to their personality by incorporating personality profiles.

2 BACKGROUND AND SUPPORTING THEORIES

Personality is a construct that is used in psychology to explain the individual differences that constitute a person and allows him/her to differentiate from others. Personality influences the way in which emotional responses to specific stimuli occur (Ortony et al., 1990), but there is no absolute consensus on what should be understood by personality. One of the most accepted definitions defines personality as the dynamic individual organization of the psychophysical systems responsible for their characteristic thinking and behavior (Allport, 1937). In a general way, it can be said that personality is a set of distinctive features of human beings that remain relatively stable over time and are invariant to different situations. Being a stable trait, personality allows to predict certain behaviors in people when they are in a concrete situation. In addition, personality theories also include other elements such as cognition, affection, or motivations that define the way people behave and allow to explain the inconsistencies that sometimes destabilize the personality.

There are two approaches to the classification of individuals based on their personality. The first one is the *type approach*, in which personality can be defined using a finite number of categories such as: optimistic, depressed, irascible, or melancholic. These types are used as categories of people with similar characteristics and each individual may or may not belong to a particular category (Clonninger, 1993). This model is criticized because it does not provide any information on the degree to which an individual belongs to a particular category. For this reason, in psychology the use of the traits approach is more popular. The *traits approach* allows to quantify the degree that a person has of a certain trait. Traits are characteristics that distinguish people from the rest and that affect the way they behave (Matthews et al., 2003). For example, a person can be very active and somewhat depressed. The traits allow to describe in a more precise way the personality and the behavior that the types.

2.1 Personality Affects on Cognition, Emotions, and Mood

Psychologists discuss of different cognitive processes that influence on humans own being. These processes include reasoning, memory, attention, decision making, problem-solving, and perception. There is a strong relationship between emotions and these cognitive processes, so that emotions are able to deform these processes and produce different results depending on the type of emotion. In fact, empirical evidence suggests a critical impact of emotions on cognition and a high variability of these effects among people with different personality traits. For example, people who have a high level of openness and a low level of neuroticism have a greater ability to perform different cognitive task. Extraverted people are better than intraverted people in reaction-based task, while introverted people are better than extraverted people in the processing and reasoning task (Allen et al., 2017).

Personality plays a very important role in emotions and mood. Personality can make the person more or less susceptible to experience certain types of emotions (Zelenski, 2007). For example, in the FFM, the extraversion trait is related with positive emotions

and moods like to joy, enthusiasm, emotion, energy, and also with daring and trust (Watson and Naragon-Gainey, 2014). On the other hand, neuroticism trait is related with negative emotions and moods like fear, anxiety, sadness, guilt, depression, dissatisfaction, or anger among others (John and Srivastava, 1999; Derryberry and Reed, 1994). Mood and emotions also influence cognitive processes. For example, negative mood affect people's judgments in a negative direction, increasing the perception of risk (Ditto et al., 2006). Therefore, the personality will be related to the appraisal process. The *appraisal* process comes from the psychological theory of appraisal (Lazarus, 1991) that argues that the emotions are the result of the interpretation and explanation that each person performs based on his/her circumstances and concerns (Scherer, 2001). So, emotions are not mere responses to stimuli but also the result of the individual's assessment of this stimuli (Roseman, 1996). Through this appraisal process, a person interprets his/her relationship with the environment (Smith et al., 1990; Scherer, 2001).

3 AGENT PERSONALITY IN *GenIA*^{3}

There are some previous works using the personality in multi-agent systems. (Santos et al., 2011) propose a multi-agent system model which employs personality to simulate a group of people in a negotiation task. Each agent was programmed according to the personality of the user, obtained by performing a personality test. The personality was modeled using the FFM grouping the agents in different personality profiles: negotiator, aggressive, submissive, and avoidant. Each profile was associated with a different behavior.

Another example is the OA3 architecture (Alfonso et al., 2015). They define different basic personality profiles: sociable, mediating, negotiating, and realistic, and compare several agents following these profiles through the use of classic games, such as the prisoner's dilemma and the trust game. One of the conclusions obtained is that personality is one of the factors that best explains the differences between the agents and the variability that occurs during the simulations. That conclusion is coherent and in accordance with the theories of personality previously explained.

3.1 *GenIA*^{3} Architecture

GenIA^3 (Alfonso et al., 2017) is a general-purpose architecture for intelligent agents based on the *BDI* (Believe, Desire, Intention) architecture using *Jason* (Bordini et al., 2007). *GenIA*^{3} facilitates the design of affective agents in a general way. Psychological and neurological theories have traditionally focused on the description of the characteristics and processes related to emotion and personality. Emotion-related processes are usually studied from a cognitive perspective and can be grouped into the generation of emotion, the experience of emotion, and the effects of emotion. The *GenIA*^{3} architecture includes the central processes of these three groups, as well as the processes of a traditional BDI agent architecture (see Figure 1). Currently *GenIA*^{3} offers a default design that includes an appraisal process based on (Marsella and Gratch, 2009) and uses *Jason* as a base platform for multi-agent systems, the FFM for representing the personality, and the PAD model for the mood. However, the *GenIA*^{3} architecture can be easily expanded and adapted to other psychological theories. For example, in (Taverner et al., 2016) the management of expectations is incorporated into *GenIA*^{3}.

The affective processes in *GenIA*^{3} include (see Figure 1): an *appraisal process* in which the appraisal variables (desirability, expectedness, likelihood, causal attribution, and controllability) are derived from the current situation and the emotions are generated; an *affect generator process* which determines the possible emotional behaviors and coping responses for a given situation; an *affective modulator of beliefs* which determines if and how the affective state biases the beliefs of the agent, contributing to the beliefs maintenance according to the affective state; and the *affect's temporal dynamic*, which determines the duration of the affective state's components as well as how their intensities decay over time.

The design of the *GenIA*^{3}architecture proposed in (Alfonso et al., 2017), allows the introduction of personality as a set of traits followed by the agent's rationality level and a list of coping strategies[2]. But initially, in the *GenIA*^{3} default design, personality is not used in the cognitive process of the agent. Our goal is to provide *GenIA*^{3} with different personality profiles so that users can implement different agent behaviors. In addition, we have identified and defined the necessary modifications for using the personality in both the cognitive and affective processes of the agents in the *GenIA*^{3} default design.

[2]Coping strategies are both physical and physiological responses produced by the individual to face a situation such as anxiety or stress. Coping strategies define how the individual reacts to an event involving emotional changes, and these reactions may be involuntary manifestations or more planned actions.

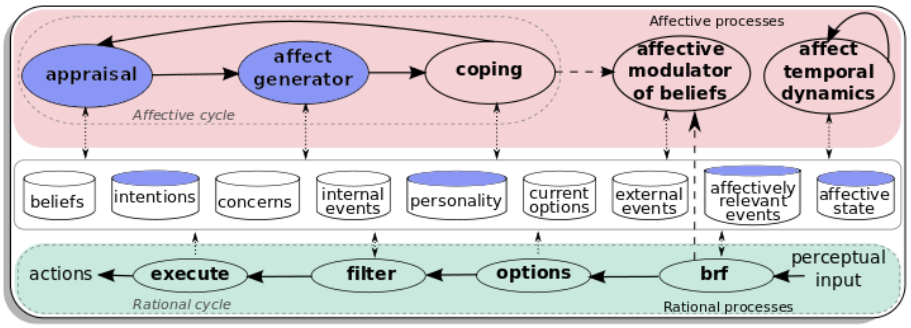

Figure 1: The *GenIA*^{3} architecture (Alfonso et al., 2017). The processes modified by our proposal are highlighted.

3.2 Defining the Personality Model

In this section we present an extension of *GenIA*^{3} to facilitate the use of agents with personality profiles and to incorporate any personality theory based on types. Personality profiles are very useful in modeling different behaviors since they allow to create groups of agents with similar personality traits. We propose a model to define these profiles following the structures of Figure 2.

```
personality_profiles→
            "personality_profiles:"
            personality_profile
            (","personality_profile)*";"

personality_profile→ <ATOM>
            ["("traits_range")"]

traits_range→ (<NUMBER>|range)
            (","<NUMBER>|range)*

range    → "<" (<NUMBER> | "-"<NUMBER>) :
            (<NUMBER> | "-"<NUMBER>)">"

personality_types→ "personality_types:"
            <ATOM> (","<ATOM>)*";"
```

Figure 2: Extension of *GenIA*^{3} multi-agent system syntax to define personality profiles. The complete EBNF of the *GenIA*^{3} architecture can be found in (Alfonso et al., 2017).

We also propose to modify the specification of the multi-agent system to incorporate the definition of the necessary personality profiles. In this model each personality profile is defined by the ranges of the different traits (in case of employing a trait based theory). For example, if using the FFM the traits are openness, conscientiousness, extraversion, agreeableness, and neuroticism. Two profiles using this model: *Profile_A* and *Profile_B* can be defined as follows:

```
personality_profiles:
Profile_A(< 0.6, 1.0 >, < 0.5, 0.7 >,
                    < 0.5, 0.7 >, < 0.7, 1.0 >, < 0.1, 0.6 >).
Profile_B(< 0.3, 0.5 >, < 0.0, 0.6 >,
                    < 0.2, 0.6 >, < 0.5, 1.0 >, < 0.0, 0.2 >).
```

were each pair of numbers correspond to the interval of values for the traits openness, conscientiousness, extraversion, agreeableness, and neuroticism respectively. An agent will be considered in *Profile_A* if it has a value between 0.6 and 1.0 of openness, from 0.5 to 0.7 of conscientiousness, from 0.5 to 0.7 of extraversion, from 0.7 to 1.0 of agreeableness, and between 0.1 and 0.6 of neuroticism. For example, an agent whose personality is defined as [0.7, 0.5, 0.6, 0.8, 0.1] will be part of the *Profile_A*. But, it will not be part of the *Profile_B* because it does not satisfy the value of openness ($< 0.3, 0.5 >$) in *Profile_B*.

But in the personality model incorporated to *GenIA*^{3} is also possible to use a type-based model of personality. For example, if we use the Myers-Briggs Type Indicator (Myers, 1962) to define the personality using the types *ISTJ*, *ISFJ* and *INFJ* we can define each type as follows:

```
personality_types:
ISTJ
ISFJ
INFJ
```

This is only used to define the personality types allowed to define the agent's personality. For each type we can define different behaviors as we do with profiles. Therefore, we have also extended the agent personality model to allow the use of personality theories based on types. For example, an agent can have a personality defined as:

```
personality__: { types__: [ISTJ] }
```

In this example the agent's personality type is *ISTJ*. To make this type of representation possible, the

agent specification includes the personality defined as a list of types or traits (see Figure 3).

```
personality → "personality__:""{"
              (traits|types)  ["," rat_level]
              ["," "coping_strats]"}"
types       → "types__:"
              "[" <ATOM> ("," <ATOM>)* ) "]"
```

Figure 3: Extension of *GenIA*^{3} agent syntax to allow the use of type theories.

3.3 Improving the Personality Management in the Default Design of *GenIA*^{3}

As we said in section 2.1, personality has a relevant effect on cognitive and affective processes. So if we want to simulate human behavior using affective agents, it is necessary that personality influences these processes. We have also modified the *GenIA*^{3} architecture to make the personality affect the cognitive and affective processes.

The modules that are affected by the incorporation of our personality model are (see Figure 1): the Appraisal process, where the personality affects the generation of emotions; and the Affect Generator process where we propose a model where the personality affects the displacement of the mood. In the proposed model, intentions and affective events related to personality profiles are generated.

Finally, we have modified the personality on the platform incorporating the use of theories based on types and a model that allows the use of personality profiles to define different behaviors. For this purpose, we have modified the agent selection of plans process generating new intentions related to personality profiles. Therefore, users can define different intentions for each profile allowing to create different behaviors according to agent's personality in a simple way.

In *GenIA*^{3}, the selection of plans is done through two processes: The *Jason plan selection process* which returns the list of possible actions sorted according to their priority, and the *selecting affective actions process* which returns a list of possible affective plans sorted by priority. A *GenIA*^{3} affective plan is any plan including the annotation *affect__()* in the plan's label[3]. This annotation is used to determine the affective state that the agent must have to select that plan. For example, in the following plan:

```
@plan1[affect__(sadness)]
!event :  true <- .print("I'm sad")
```

the plan's annotation is *affect__(sadness)*, so this plan will be only chosen if the agent is in a sadness state. The lists obtained by these two processes are used to decide the plan to be executed based on the level of rationality of the agent. A plan is selected using the Formula 1 proposed in (Alfonso, 2017).

$$\min_{i \in I} Rl * Rr_i + (1 - Rl) * Ar_i \quad (1)$$

were I is the set of intentions, Rl is the rationality level of the agent, Rr_i is the priority of the intention i in the rational list of plans, and Ar_i is the priority of the intention i in the affective list of plans.

Our proposal for the selection of intentions includes a new annotation for the selection of affective plans:

$$personalityProfiles\_\_(profile_1, profile_2, ..., profile_n)$$

This new annotation allows to modify the process of selection of plans based on the agent's personality profile. Therefore, this annotation allows the user to define different behaviors for each personality profile in a simple way. The introduction of this new annotation improves the usability of *GenIA*^{3}, allowing to easily implement studies like (Gebhard, 2005; Santos et al., 2011).

The default design of *GenIA*^{3} has an evaluation process in which the emotions are selected and the mood is updated. The default design includes six different emotions: surprise, hope, joy, fear, sadness, and anger, but can be easily extended by the user. In order to facilitate the use of emotions, our proposal incorporate the intensity of emotions. The intensity of the emotions allows to differentiate the way in which the cognitive processes work and allows to determine which emotions affect the individual in function of his personality (Santos et al., 2011). The intensity of positive and negative emotions also have an impact on decision-making processes (Ristvedt and Trinkaus, 2005). In addition, our design allows to define how the personality will affect the emotions according to their intensity.

Our new default design allows the personality to affect the mood. Initially *GenIA*^{3} updated the mood based on the model proposed in *ALMA* (Gebhard, 2005). According to that model the mood was moved towards a theoretical point of the PAD space obtained by the emotions selected in the appraisal process. They called this point the virtual emotion center

[3]In Jason, plans have a label that allows, in addition to naming the plan, to add annotations that can be later used in the system.

(VEC). The mood was updated following a fixed displacement without taking into account the agent personality. But, personality should affect mood (Watson and Naragon-Gainey, 2014; John and Srivastava, 1999; Derryberry and Reed, 1994): people with high levels of extraversion tend to have more positive mood than people with high levels of neuroticism, while people with high levels of neuroticism and lows level of extraversion tend to more negative mood. Therefore, to simulate this natural human behavior it is necessary to consider the personality to update the mood, as for example is proposed in (Gomes et al., 2014). We propose to modify the current displacement of the mood according to personality traits following the Formula 2 in function of the neuroticism and extraversion traits. This is defined as

$$personalityDisplacement = \left| \frac{pe}{npe} * e - \frac{ne}{nne} * n \right| \quad (2)$$

were *pe* is the number of active positive emotions (i.e. the positive emotions that have been calculated in the appraisal process), *ne* is the number of negative active emotions, and *npe* and *nne* represent the total number of positive and negative emotions respectively. Finally *e* and *n* are the levels of extraversion and neuroticism. This equation is bounded between zero and one because the personality traits are also bounded between zero and one. By this formula we simulate the effect of the personality in the mood according to different theories (Derryberry and Reed, 1994; John and Srivastava, 1999; Ditto et al., 2006). This allows to adjust the mood displacement according to different personality traits getting closer to the way it happens in humans (Zelenski, 2007; Watson and Naragon-Gainey, 2014). For example, if the number of positive emotions is zero, the number of negative emotions is greater than zero, and the level of neuroticism is high, the mood displacement will be negative and greater than the mood displacement when the level of neuroticism is low.

4 RESULTS

In order to test our proposal, we have developed an experiment with sixty agents playing the Blackjack game. These agents have different personalities, and are induced with positive and negative emotions to analyze the evolution of the mood. As we saw in Section 3.1, the default design of *GenIA*^{3} uses the FFM to represent the personality and PAD to represent mood. We have created two personality profiles: Profile One consists of agents with low level of extraversion and high level of neuroticism, while Profile Two represents agents with high level of extraversion and low level of neuroticism. We have established the equilibrium mood at the point [0.0, 0.0, 0.0] so that all agents start with the same mood. This decision allows to easily compare the evolution of the mood in both personality profiles.

To simplify the experiment we have chosen only two emotions: joy and sadness. The main concern

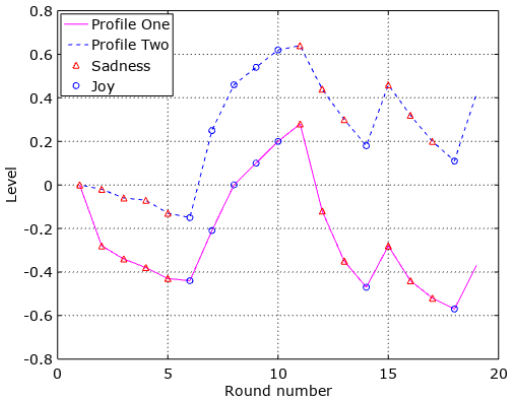

Figure 4: Average evolution of pleasure for Profile One and Two.

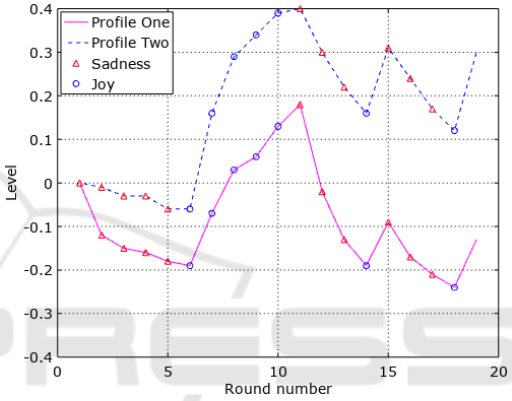

Figure 5: Average evolution of arousal for Profile One and Two.

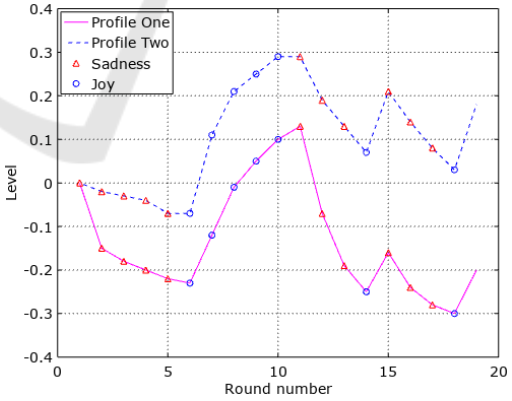

Figure 6: Average evolution of dominance for Profile One and Two.

of the agents is to win. Therefore, winning a game causes the *joy* emotion in the agent while losing a game causes *sadness*. Agents play eighteen rounds: seven have a winning result and eleven have a losing result. Therefore, we have alternated the two emotions over time and checked the mood evolution for the two different profiles. As Figures 4, 5, and 6 show, the mood of agents classified in Profile One tends to decrease, while mood of agents classified in Profile Two tends to increase. We can also see that the final mood is different for each profile in all dimensions of the PAD. This is consistent with the psychological theories that determine the individual differences produced by the personality when dealing with a particular emotion (Zelenski, 2007; Tong, 2010).

We can also see that negative emotions have a greater impact on Profile One, and positive emotions have a greater impact on Profile Two. For example, the first iteration produces a negative emotion and the effect is greater in Profile One than in Profile Two.

5 CONCLUSIONS

Personality is a crucial factor in understanding the individual differences that affect the way human beings perceive the environment and emotions, and that has an impact on mood and on cognitive processes. We have seen different ways of representing personality. We have also seen how different personality traits can directly influence certain emotions and behaviors. In this paper we have used the FFM focusing on neuroticism and extraversion as the most important factors that influence the affective and cognitive processes. Our proposal is based on different psychological theories that argue that extraversion and neuroticism are the factors with greatest relevance in affective and cognitive processes.

We have presented an extension for the architecture of affective agents *GenIA*^{3}. Our extension enlarge and generalizes the use of the personality within this architecture extending its adaptability employing personality theories based on types and traits. We have modified the cognitive processes of the agents to allow the personality to influence the process of reasoning and decision making. We have also proposed a formula for updating the mood according to the different parameters of the personality, based on different theories that relate neuroticism to negative emotions and mood and extraversion to positive emotions and mood. Our proposal allows the use of personality profiles that are very useful when modeling different behaviors grouping individuals with a similar personality. Therefore, personality profiles allow the user to abstract from the different personality traits when modeling different behaviors. We have tested our proposal by an example where sixty agents classified into two personality profiles have been induced to negative and positive emotions. The obtained results are consistent with the psychological theories mentioned in this paper.

One of the future extensions of this work has its origin on the effect of the temporal dynamics process. Currently, this process calculates the decay of the mood towards the equilibrium state using a fixed and constant value for all the agents. One possible improvement would be to investigate how the personality traits affect this process and to propose a formula, such as the one we have proposed for the updating of the mood, that allows to calculate the way in which mood must be updated in function of personality.

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