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The representation of the knowledge that is used for the specification of affective processes in agents, is almost as diverse as number of approaches that have addressed this issue. This diversity is due, to a large extent, to the need of systematic guidelines and standards that support computer scientists on the creation of affective models and architectures. Our aim is to perform a further step towards the standardization of this process, in order to improve the creation and enhancement of affective agent languages, architectures, and models. We offer a method to build affective BDI (Beliefs, Desires, and Intentions) agents, adapted to the problem to solve, and specifically, adapted to the way affect influences the agent behavior. To this end we offer $GenIA^3$, a General-purpose Intelligent Affective Agent Architecture, which can be committed with specific psychological theories to create the architecture of the final agent. We also offer general guidelines that allow to define the processes performed in the agent architecture. These guidelines allow to select and adapt a BDI agent platform in order to include the processes of the proposed agent architecture and adapt a BDI agent language to include the representation of the required affect-related attributes.

1 Introduction

Emotions and affective characteristics influence human day-to-day decisions and behavior. Computer science and researchers are aware of this and, in the last years, the simulation of human behavior has received a special and increasing interest. New emotion models of intelligent agents are designed and deployed by the affective computing community, which has been mainly motivated by the ambitious purpose of creating intelligent agents that resemble, to the greatest extent, human behavior. In parallel the need of standards and systematic guidelines for that systems has also grown [3]. Nevertheless, only few standards and systematic guidelines have been proposed, and they often don't go beyond a theoretical level that include high level abstract models, generics concepts or tasks, and very few proposals offer a standard agent affective architecture.

Agent language developers and computer scientists often face the challenge of starting from scratch when including affect in the representation of an agent and its behavior. Scientists use their creativity to define the way emotions are appraised, experienced, and their effects on behavior. In fact "the *direct* implementation of an emotion theory as a computer program is usually not the best way to go" and "this is a cumbersome way to proceed" [28]. In this work we make a further step toward the above mentioned standardization process. We start from inspiring psychological theories, which have helped to identify the main affect-related processes in an agent, and the representation of the related knowledge in an agent language, in order to make possible to carry out those processes.

Our goal is to offer a method to build affective BDI agents, since the BDI agent's architecture is a suitable and widely exploited alternative to model intelligent agents. This method relies on general guidelines that cover the main stages of the development of an affective agent. These guidelines start from the problem to solve (where it is emphasized the way affect influences the agent behavior). We present $GenIA^3$ (a General-purpose Intelligent Affective Agent Architecture), which supports these guidelines, and contains the required modules to model affect and related processes in a BDI agent. We also propose a representation of the main affect-related concepts, which results in constructions that are independent of the agent programming language that is used. The identification of the main affect-related processes, and related representation to perform these processes will support the development of affective agent languages regardless of the specific ways those affective processes are performed and what theoretical models support them, i.e. what appraisal theories, emotion dynamic theories, or emotion-effect procedures are used. Same way agent languages and platforms could be compared and improved with the support of a common language and basic-theory elements.

This report is organized as follows. Section 2 presents some related works. The main processes of a BDI agent architecture and the main affective processes are presented in Section 3. Section 3 also presents $GenIA^3$ (which includes those processes). Section 4 shows the representation of the knowledge useful to carry out those affective processes. Section 5 offers general guidelines to develop affective BDI agents, and Section 6 describes how the steps of the guidelines were followed to integrate the processes and representation proposed in the agent language Jason. Section 7 offers the final conclusions.

2 Background and Supporting Theories

When scientists model computationally affect, they face two broad challenges: how to model affect and how to enrich artificial agents architectures and languages to include those affective models [28]. Several psychological theories provide almost complete support for affect-related processes (e.g., emotion generation, and emotions effects on cognition, expression, and behavior) [14]. Consequently, approaches for agent modeling are different considering what psychological theories support them [28]. For a review about computational approaches for modeling emotions see [20], and [28].

Nevertheless, the task of systematically recreating existing emotion theories, and to use the general strategy of building formal languages for this, may be cumbersome. Two more viable strategies can be used: "1) break up existing emotion theories into their component assumptions and 2) reformulate these assumptions in a common conceptual framework"[28]. In line with these strategies Hudlicka proposes some guidelines for designing computational models of emotion [13]. In this work the author deconstructs emotion modeling into two processes: *emotion generation* and *emotion effects*, and describes the computational tasks that are necessary for theses processes. In this article we also propose general guidelines, but our approach differs from [13] in that the processes we propose are built on top of a BDI architecture, with the aim of using BDI agent languages and platforms. Our approach also offers a representation of the knowledge required by these processes in a BDI agent language.

3 Processes of an Affective Agent Life Cycle

In this section we identify the main cognitive processes that are part of $GenIA^3$. These processes are in line with theories of motivation and action generation. According to [28] "nearly all current theories of motivation and action generation are variants of a singly basic theory, the *belief-desire* theory of action". These psychological theories of motivation have inspired computational emotion models, which have been used in cognitive agent architectures. In particular the belief-desire-intention (BDI) architecture [5] is a practical and powerful conceptualization, widely accepted in agent's community which has been the base of numerous computational approaches.

The affective processes addressed in this work are in line with *cognitive-motivational* (or belief-desire) emotion theories, whose constituents or mental causes are both: beliefs and desires [28]. Thus, the motivational function of emotion is to guide goal's priorities and/or to generate new goals. We start from the BDI model to identify the core cognitive processes of the life cycle on an affective agent, due to the dependence of emotions on beliefs and desires, and the constructs for building autonomous and goal-directed agents that BDI logics provide.

3.1 Processes in a BDI Agent

The BDI architecture has its foundations on the philosophical theory of "practical reasoning", where the actions to be performed are decided according to certain goals. According to the BDI theory, rational agents are committed to their intentions, intending to do always what they believe will lead to their desires [4]. Practical reasoning requires both: establishing what goals to achieve (deliberate) and how to achieve them (also called means-end reasoning), what can be summarized in four main processes performed consecutively [36]:

Belief revision function (brf). Determines new beliefs starting from a perceptual input and the agent's current beliefs.

Option generation function (options). Takes the agent's current beliefs and intentions to determine its desires (options or courses of actions available), i.e. the means to achieve its intentions.

Filter function (filter). Determines the agent's intentions, i.e. what to do, through a deliberation process that uses previously-held intentions, and the agent's current beliefs and desires. The new set of intentions will contain either newly adopted or previously-held intentions.

Action selection function (execute). Returns the next action to be executed on the basis of current intentions.

3.2 Agent's Affective Processes

According to [14] the agent's core affective processes can be modeled across four emotions' modalities of biological agents. These emotion modalities are the *behavioral/expressive* (which results in action-oriented characteristics and behavior); the *somatic/physiological* (which has a neurophysiological orientation); the *cognitive/interpretive* emotions (which are manifested as the result of the agent's evaluation according to its goals, preferences, and the current situation); and the *experiential/subjective* (which results in an idiosyncratic and conscious experience of emotions). We focus on the *cognitive* emotion modality, and hence, on the corresponding processes for emotion generation and effects. We also focus on the *behavioral/expressive* emotion modality, specifically on the processes for emotion effects related to action selection.

There is a wide consensus in computer science, with a solid theoretical background, of the main affective processes that should be considered when building appraisal-based models for affective agents [1, 14, 20]. These processes include both: affect generation and affect effects. The set of processes we propose is inspired on the Open Affective Agent Architecture (O3A) [1]. These processes are:

Appraisal. Is the process whereby a set of appraisal variables are derived as the result of a transformation of the agent's current situation, concerns, and cognitive state. This process can be triggered for example if a change is produced on the environment, although this is not the only cause that triggers appraisal. It can also be part of a continuous appraisal-reappraisal process or it can be triggered by other internal cognitive events. Conceiving this process in such a way allows to implement different appraisal theories like Smith and Lazarus' [32], Scherer's [31], Roseman's [29], or Ortony's [26] appraisal theories.

Affect generator. In this process the appraisal variables that result from the *appraisal* process are transformed into a representation of the agent's affective state. In this work we consider that this affective state can be represented by one ore more emotion categories and their intensities, similar to the emotion categories of the OCC model [26] (e.g. joy, hope, anger). The affective state can also have a dimensional representation, where values in a multidimensional space determine a point for the affective state (e.g., the Pleasure-Arousal-Dominance model of Mehrabian and Russell [22]).

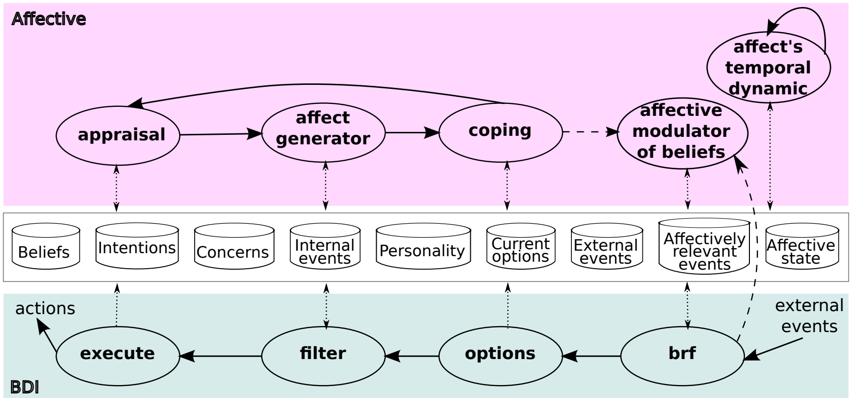

Figure 1: $GenIA^3$: a General-purpose Intelligent Affective Agent Architecture that integrates BDI and affective processes. Sequence (solid line arrows), subprocess (dashed line arrows), and exchange of information (dotted line arrows).

Affect regulator. Through this process, the possible emotional behaviors and coping responses are determined. Emotional behaviors may include body gestures or facial expressions for example. The coping responses may change the environment or the individual's cognitive representation like plans, beliefs, or intentions [19].

Affective modulator of beliefs. Determines if and how the affective state biases the agent's beliefs. This process contributes to the beliefs maintenance according to the affective state. It is known for example that a negative affective state makes us questioning our beliefs and makes us to be more prone to accept new information; also a positive affective state makes us to rely more on our current beliefs [27]. The influence of affective states on the maintenance of beliefs, has been computationally modeled in several ways [18, 27, 15]. Even though it is not represented in other works (e.g., the idealized computational appraisal architecture of Marsella *et. all.* [20]), we consider relevant to include in our approach a representation for modeling the impact of the affective state on the agent's beliefs. Emotions influence the "content and the strength of an individual's beliefs, and their resistance to modification" and this influence "has traditionally been considered to be one of the most important things to be said about emotions" [9].

Affect's temporal dynamic. This process doesn't depend of any other process and no other process depends on it. It determines the duration of the affective state's components as well as how their intensities decay over time. We include this process as an independent process for modeling the affect's temporal dynamic since theories of mood and affect emphasize this issue [11, 35, 34, 17].

We have found the implementation of the processes of sections 3.1 and 3.2 essential according to our view of what a rational and affective agent should be. But we are aware that such general specification admits many possible ways of modeling an agent.

3.3 Integration of affective and rational BDI processes

In order to establish the relation and sequence of rational BDI and affective processes we propose $GenIA^3$ (General-purpose Intelligent Affective Agent Architecture), which is shown in Figure 1. The sequence of the affective processes is independent from the sequence of the BDI processes. This means that, an agent that is built on top of this architecture may have, at least, one execution thread for each set of processes. Moreover there is an affective process which is "disconnected" from the others: the *affect's temporal dynamic*, because its function of controlling variations on the affective state intensity doesn't depend on other processes.

The sequence of the affective processes takes place as follows. When internal or external events are triggered, they are evaluated in the *appraisal* process. Other parameters are also used in the *appraisal* process that are related to the cognitive information of the agent (e.g., its concerns, beliefs, or the agent's personality). The resulting appraisal variables are used by the *affect generator*, which updates the current affective state of the agent. By varying the agent's affective state, the *coping* process checks if some action is necessary in order to either taking back the affective state to a desired state, or to perform some reactive action. Optionally, the *coping* process may require updating the agent's beliefs if this is one of the agent's "coping strategies"[26]. This update is performed by the *affective modulator of beliefs* process. The *appraisal* process can be triggered again after the *coping* process, even when there isn't an event to be processed. For example, if *appraisal* complies with Sherer's theory (which is one of the more complex theories of appraisal), the appraisal is conceived as a multilevel sequential checking where a set of evaluation checks are performed in sequence [31]. The Gratch and Marsella's EMA model [19] also fits in this structure, because, in this model, affect is derived from a continuous cycle of appraisal, coping and re-appraisal. In general most appraisal theories can be represented in this way.

On the other hand, the BDI processes in the $GenIA^3$ architecture maintain their original functions, however some of them include new ones. After the agent perceives its environment it updates its beliefs in the *brf* process, which includes the *affective modulator of beliefs* process in order to evaluate how the current affective state influences the content and the strength of the beliefs. Then, the available options are selected in order to determine the new course of actions in the *options* process. The *filter* process determines what to do by selecting the next intention, including the agent's affective state as a parameter. Finally the selected intention is executed in the *execute* process.

In the $GenIA^3$ architecture the interaction between affective and BDI processes is produced by using and updating the information related to the agent's cognition. These concepts become agent attributes including: the agent's `beliefs` (i.e., the information the agent has about the environment, about himself, or about others); the agent's `concerns` (the agent's personal values, such as its interests, motivations, standards, norms, or ideals); `internal events` (events that take place during the agent execution and that may generate changes on the agent state, for example, in the agent's affective state); `personality` (a representation of the agent's personality); `current options` (the options of the agent for facing the current situation, which is in line with the "desires" concept of the BDI model); `external events` (events perceived from the environment); `affectively relevant events` (those events that have produced important changes on the affective state of the agent); `affective state` (a representation of the affective state of the agent).

Some of these attributes may not vary along the whole life time of the agent, such as the agent's `personality` and its `concerns`. Other attributes, in turn, have a bigger frequency of variation, for example, the `affectively relevant events`. The rest of the agent attributes can vary in every reasoning cycle, such as the agent's `beliefs`, `internal events`, `current options`, `external events`, and `affective state`. Table 1 shows the precise interaction of BDI and affective processes with these attributes. A more detailed description of these attributes can be found in Section 4.

4 Representation of the agent attributes for BDI and Affective Processes

This section explains in more detail the agent attributes introduced in Section 3.3, (also shown in Table 1). It is also discussed why they are considered as inputs or outputs for the processes of $GenIA^3$. The representation of the agent attributes that are related to the BDI processes has been a widely studied issue. Therefore, we begin this section by describing the representation of these concepts.

4.1 Representation for BDI processes

Current `beliefs` are both inputs and outputs of the *brf* process, since its function is to revise beliefs. Likewise a representation of `external events` is created in this process, which are the events perceived from the environment. In order to determine the possible actions at a certain moment of time, the *options* process takes the current `external events`, `internal events`, and the agent's `beliefs`. Then the `current options` are updated. The next action to be performed is selected from the `current options` by the *filter* process, and then, `intentions` are updated. This process is influenced by the current `affective state`. Different agents have different propensities to be influenced by their affective state when making decisions. Therefore, this aspect of the agent's `personality` can also be an input for the *filter* process[1]. The next action to be performed is determined by the *execute* process, which uses the current `intentions` and generates `internal events` like the intention's failure or success.

4.2 Representation for affective processes

The *appraisal* process is included in the affective side of the agent. We understand it as part of a continuous appraisal-affect generation-coping cycle that may or may not process certain event. The goal of this configuration of the architecture is to make it flexible enough to represent most appraisal theories. Thus, those appraisal theories that argue for a relation event-appraisal variables [26, 29] fit in the *appraisal* process of the architecture, since it has both `external` and `internal events` as inputs. On the other hand, appraisal theories that use processes with several steps [32, 31], can also be represented in this architecture. In Lazaru's theory [32], for example, *primary* and *secondary* appraisals are performed in two different stages[2]. During *primary* appraisal the relevance and congruence of an event is evaluated starting from

[1] Some tests like the Cognitive Reflexion Test (CRT) [8] are used in psychology to determine this issue.

[2] Lazaru's theory also argues that *primary* and *secondary* appraisals are not necessarily sequential, but we limit it to be sequential in our architecture in order to have as much compatibility as possible.

Table 1: Inputs and outputs for the processes of $GenIA^3$.

Process	Inputs	Outputs
Appraisal	beliefs, concerns, internal events, external events, affectively relevant events, intentions, current options	affectively relevant events
Affect generator	affective state	affective state
Coping	personality (coping strategies), affective state	current options, intentions
Affective modulator of beliefs	affective state, beliefs	beliefs
Affect's temporal dynamic	affective state, personality	affective state
brf	beliefs	external events, beliefs
options	beliefs, external events, internal events	current options
filter	personality (e.g. rationality level), current options, affective state	intentions
execute	intentions	internal events

the agents `concerns`, `current options`, and `intentions`. During *secondary* appraisal, the event is evaluated according to the agent's capacities and resources. We argue that such issues (i.e. capabilities and resources), could be represented by using the probabilities of the `beliefs`, the probabilities that an action can be performed, and the probability that an agent performs an action[3]. For example, the agent's capabilities and resources to perform an action, can be expressed as the probability that the agent can perform such action. Other issues like the memory of `affectively relevant events` may influence the *appraisal* process as well [6]. Our idea of memory is in line with the psychological concept of "autobiographic memory" in psychology [24], and it stores meaningful experiences of an individual. Optionally, and depending on the structure of the particular architecture that is used (based on $GenIA^3$), `affectively relevant events` can be updated. For example, if some event causes a strong emotional impact, it can be saved as an event that has been significant from an affective point of view.

The main outputs of the *appraisal* process are the appraisal variables[4]. These variables vary from one computational appraisal model to another but they have in common that these variable represent the agent's judgments, and they produce changes in the `affective state`. The way these changes are produced is determined by the *affect generator* process which uses the appraisal variables. The *coping* process acts as an affect regulator, modifying the agent's `current options`, `beliefs`, or `intentions`, i.e. altering "the nature or content of cognitive processes" [20] in order to take the current `affective state` to a desired state or to an "equilibrium state". This process can also generate intentions oriented to perform reactive physical actions such as body gestures or facial expressions, for example, as a way to mitigate negative emotions. Each agent may have particular ways of reacting to changes of its af-

[3]We make a review of psychological theories in other work (to be published), where it is shown how these probabilities allow to represent a variety of inputs of appraisal theories.

[4]Although appraisal variables are an output of the *appraisal* process, they are not considered in Table 1 because this table only represents inputs and outputs that are persistent during the agent's life cycle or that are used by two or more processes in the architecture.

fective state, so we state that these individual "coping strategies" are part or the agent's `personality`, and they are used by the *coping* process. In order to determine the way the agent's `beliefs` can be modified to cope with certain appraisals, the *coping* process can invoke the *affective modulator of beliefs* process. This process contains the mechanisms whereby certain `affective state` may or may not influence `beliefs`. Finally the *affect's temporal dynamic* process, is in charge of controlling the duration and decay of certain `affective state`. It can also use traits of the agent's `personality` as input, as shown in computational approaches like [30]. Certainly the need of a balance between the temporal dynamic and the structural dynamic of the affective state is implicit in $GenIA^3$, so each particular committed architecture should pay attention and take care of this issue. Similarly, committed architectures need to care about the balance between the frequency of the cycle for affective processes and the BDI cycle, since this design allows to give different priorities to each cycle.

4.3 Representation of affect-related attributes in an agent language

After identifying the processes that we consider more relevant when modeling affective agents, it is necessary to address what should be represented when programing the agent in order to make all this "machinery" work. Current BDI-based agent languages include well established structures to represent and manage `beliefs`, `options` (or desires), `intentions`, as well as `states`, `actions`, `internal` and `external events`. Therefore we focus on the representation of the knowledge used by affect-related processes. In this direction the distinction is made through three stages: affect generation, experience and effect.

4.3.1 Affect Generation

In our proposal affect generation is supported by the appraisal theory. In order to be able to perform the *appraisal* process in a way that is consistent with most appraisal theories, a BDI agent language needs new structures to represent some affect-related attributes. We summarized these attributes in: `concerns`, `probabilities of beliefs`, and `personality`.

Concerns One of the most recurrent ideas on appraisal theories is the important role of individual `concerns` (e.g., motivations, standards, ideals) in the agent's appraisal of events. According to N. Frijda "a concern is what gives a particular event its emotional meaning" [11]. Appraisal variables like "desirability of an event" of Ortony's *et. al.* appraisal theory [26], or "motivational relevance" and "motivational congruence" of Smith and Lazarus' theory [32], completely depend on the agent's concerns.

Personality In most affect-related theories, as well as the computational approaches that they support, the need of individual characteristics that differentiate the behavior of agents is addressed. Thus we believe that this is an important affective concept which needs a representation in an agent language. `Personality` can take several forms. Individual traits can be represented through dimensions (in line with dimensional theories of personality [23, 7, 21]). Also, `personality` may include concepts like `coping strategies` or `rationality level`. `Coping strategies` define the way an individual reacts to an event that involves emotional changes, and those reactions can be either involuntary manifestations or more planed actions. Reactions can be oriented to change beliefs, goals, or intentions of an individual. We also propose a `rationality level` to represent the propensity of an agent to be influenced by its affective state when making decisions. This value allows to establish mechanisms to implement agents that can be more or less emotional when making decisions according to their personality.

Beliefs' probabilities Computational approaches that model agent's affect, often use formalization theories based on BDI logics, since "most (at least most 'higher') emotions are thought to depend on beliefs and—directly or indirectly—on desires"[28]. Nevertheless emotions also arise as the result of constructed representations of "what it could be" either in the present or in the future (also defined as *prospects based* emotions by Ortony *et. al.* in the OCC model [26]). This is the case, for example, of *hope* or *fear*. In [33] *hope* is formalized as "being pleased about a prospective consequence (of an event)" and *fear* is formalized as "being displeased about a prospective consequence (of an event)". Also by being able to compare reality with "what it could have been, might have been, or should have been" [16], an agent may experience emotions like *frustration* or *regret*. The representation of these future states (such as "what it could be") can be done by assigning probabilities to beliefs for a certain time `t` in the future. This representation also allows to evaluate the probability of the state of the world (that those beliefs conform) at time `t`. Thus, the agent language that supports approaches using these kind of emotions, should have useful structures for agents to perform "prospective reasoning" and for representing future states. An agent able to perform "prospective reasoning" can evaluate what a future affective state could be.

4.3.2 Affect Experience

In order to associate the agent's actions to specific affective states, the ***Affective state*** needs a representation in the agent language. This representation can adopt a qualitative or cuantitative way of expressing values of individual appraisal variables, emotion categories, values for dimensions of mood, or a combination of them.

4.3.3 Affect Effects

In our architecture we consider that the influence of affect on the agent's behavior can be of two kinds: 1) by leaning the agent's decisions towards options biased from the optimal options, and 2) through responses of the agent in order to either adequate its emotional state for it to be more desirable or to make the current situation become more controllable. The functions that are needed for the first kind of influence are performed by the *filter* process of $GenIA^3$, and the functions for the second kind are performed by the *coping* process. Ortony called these responses: "response tendencies" [25]. He grouped the response tendencies in behavioral (automatic and difficult to control), information-processing (involuntary responses that produce changes on the way information is processes), and coping (strategies that transform the emotional state or the situation to be more favorable). Each specific committed architecture based on $GenIA^3$, should define the way the responses are created. Each particular agent language that complies with this architecture should provide structures to allow the affective state to generate action tendencies by assigning "states of readiness" to actions or plans [10]. These responses and actions can be cognitive, expressive, or behavioral.

5 Guidelines to include affect in a BDI agent

We propose some guidelines in order to build affective BDI agents using an architecture compliant with $GenIA^3$. We start by analyzing the characteristics of the domain of application and the problem to solve. Next, the agent architecture and agent language should be designed, selected, and/or improved in order to satisfy the requirements of the problem.

1. **Describe the problem to be solved, and determine weather affect influences agent's cognition, expression, or behavior, and how this influence takes place.** In this step it is necessary to clarify some issues such as: how the current affective state influences the agent's decisions, weather and how the affective state generates responses in the agent, weather it is required to differentiate agents according to their personality, weather personality should be represented through `personality traits`, `coping strategies` and/or a `rationality level`, or how personality influences cognition, expression, or behavior.
2. **Determine what affective processes of the architecture should be included**. This selection should be based on the affect's effects previously defined. Table 2 shows a guide for this step. For example, consider a virtual character, whose goal is to perform long interactions with humans, and, whose affect influences the selection of the dialogs to use and also the agent's responses through facial expressions. This domain may require the processes *appraisal*, *affect generator*, and *coping*. Processes *affective modulator of beliefs* and *affect's temporal dynamic* can be optional. On the other hand, if the problem only requires to model how affect influences cognition on the agent's perception, it is required to include the processes *appraisal*, *affect generator*, and *affective modulator of beliefs*. The remaining processes would be optional.
3. **Define specific steps for each affective process included in the architecture. Select supporting theories, if available**. For example, for the *appraisal* process it is necessary to define the appraisal theory that supports it. Some other decisions are implicit such as: decide how many appraisal-reappraisal cycles should be performed in order to comply with the supporting appraisal theory.
4. **Select or improve the agent language and agent platform to use.** The agent language should include a representation of the attributes shown in Section 4.3. If the appraisal theory used generates prospects-based emotions, and the agent is able to reason about future states, then it will be necessary to represent the probabilities of beliefs. This representation should be based on a temporal logic that allows to represent the temporal validity of beliefs and emotions. Also, if affect influences the agent's decisions or the agent's cognition in perception, then it is necessary that the language includes a representation of the `affective state`.
5. **Design and implement these process of the committed architecture that are not included in the agent platform**. In this step it is

Table 2: Required (checkmark) and optional affective process according to affect's effects.

	Affect's influence in			
	Agent perception (brf)	Agent decisions	Agent responses: Cognition	Agent responses: Expression & Behavior
appraisal	✓	✓	✓	✓
affect generator	✓	✓	✓	✓
affect's temporal dynamic	?	?	?	?
coping	?	?	✓	✓
affective modulator of beliefs	✓	?	✓	?

necessary to integrate the process of the committed architecture created in the agent platform if it doesn't include them originally.

6. **Implement the agents to solve the problem, as well as their environment and other supplementary tools**.

6 Integrating affect representation and processes in Jason

We used the guidelines of Section 5 for creating an example of an agent implemented in Jason [2]. We will refer to the steps of the guidelines in the description of the example. The selected example simulates an agent 'father' in a scenario where he observes his son playing a baseball game. The 'father' has three rounds to bet or not that his son will make a home run (during his bat turn). Following the step 1 of the guidelines, we determined that, in this example, we wanted to simulate how affect influences decisions. According to step 2, we also need to determine the affective processes of $GenIA^3$ that should be included. Thus, according to Table 1, the affective processes of $GenIA^3$ that need a representation in this problem are *appraisal* and *affect generator*.

The step 3 of the guidelines requires to define the supporting theories for each affective process used. In our example we used the appraisal theory of the EMA model [19] for implementing emotion generation as part of the *appraisal* process. We used the ALMA model [12] to implement the mapping from emotions to affect, as part of the *affect generator* process. Thus, affect is expressed according to the three dimensional PAD model of mood (Pleasure, Arousal, and Dominance) of Mehrabian [22]. The agent personality was represented through the OCEAN model of personality (Openness, Conscientiousness, Extroversion, Agreeableness, and Neuroticism) [21].

The next step of the guidelines (step 4) refers to the selection or improvement of the agent language. We selected Jason as the programming agent language. It includes constructions for a BDI agent architecture and needs new constructions for affect-related attributes (the attributes of section 4.3). We didn't consider the agent's personality or prospective emotions in this example. Nevertheless, we proposed a representation for the agent's `personality` and for the `probabilities of beliefs`.

We represented agent's `concerns` trough a Jason rule that expresses the agent's utility function in this particular scenario. The rule has the form

```
plateAppearance(son,2)[pr__(0.8,t4)].
plateAppearance(son,1).
strikesOut(son,1).
maxturn(3).
bets([6,8,10]).
utility__(Value):-
   plateAppearance(son,PA)& strikesOut(son,SO)&
   ((SO==0 & Value=0) | (Value = PA/SO)).

@p1[affect(insecure)]
+!decideBet : maxturn(MT) & currTurn(T) & T<MT
       .print("I don't bet.").

@p2[affect(verysecure)]
+!decideBet : maxturn(MT) & currTurn(T) & T<MT & bets([B|T])
       -+currentBet(Bet3);
       .print("I bet ",B," euros.");
       !bet(B).
```

Figure 2: Extract of the code for agent 'father'.

`utility__(Value):-`, where `utility__` is a reserved word, and `Value` represents a variable that stores the numerical value for the agent's utility in the current state. We represented the beliefs' probabilities by using annotations. This is a construct that Jason provides which allows to add details to a belief. The probability of a belief is represent using the term `pr__(Number, Time)`, where `Number` is a value representing the numerical value for the probability and `Time` can be an atom or a numerical value representing the moment of time corresponding to this probability. We propose to set the agent personality in the multi-agent system (MAS) definition, specifically when declaring the agents of the MAS. We use a new attribute for the agent with the form `personality [ListOfValues]`. In this representation `personality` is a reserved word and `ListOfValues` is a numerical list of values that contains the strength of each personality trait[5].

Affect is represented in both, the agent definition and the MAS definition. The MAS definition can contain a list of affective categories. An affective category is a literal with the form ⟨`label`⟩`(ListOfRanges)`, where `label` is the description of the affective category (e.g., "insecure"), and `ListOfRanges` is a list that contains the ranges of values for each affective variable[6]. Finally, an affective state is represented through a literal with the form `affect__` `(`⟨`AffectiveCategory`⟩`)`, where `affect__` is a reserved word and `AffectiveCategory` must be one of the affective categories declared in the MAS definition. The association between an affective state and an agent plan is done through an annotation in the plan label, which is another construct that allows to associate the meta-level information of the plan. This annotation has the form of a specific affective state.

The step 5 of the guidelines requires the design and implementation of the affective processes (originally not included in the Jason platform). This step is not shown due to space limits.

Figure 2 and 3 show an extract of the code for the agent 'father' and the

[5]The number of traits depends on the supporting personality theory.

[6]The number of variables depends on the supporting theory.

```
1 agents:
2 father agentClass emAgent personality [0.3,-0.3,0.5,0.4,-0.6];
3 affect_categories:
4    insecure(<0:0>,<0.8:0.9>,<0.1:0.3>),
5    secure(<0.6:0.8>,<0:0.2>,<0:0>),
6    verysecure(<0.8:1>,<0:0>,<0:0>),
7    fearful(<0:0>,<0.8:0.9>,<0.2:0.4>);
```

Figure 3: Extract of the code for the MAS.

MAS respectively (following the step 6 of the guidelines). In Figure 2 lines 1-5 contain the agent's beliefs. We discretized the time by innings of the baseball game, so `t4` represents the 4^{th} inning. The belief of line 1 represents how many plate appearances the 'father' thinks that his son will have at inning 4 with a probability of 0.8. Lines 2 and 3 represent the plate appearances and the strikes out at the current inning respectively. Lines 4 and 5 represent the maximum number of turns for betting, and possible bets (in descending order) respectively. Line 6-8 is the rule that represents the utility of the current state for 'father'. This value represents the proportion between the number of plate appearances and the number of strikes out.

In Jason the selection of the next actions to be executed, corresponds to the selection of an applicable plan (see [2]). This is also the function of the *filter* process of $GenIA^3$. The code of Figure 2 also shows two plans (`p1` and `p2`), represented in lines 10-12 and lines 14-18. Plan `p1` will be selected when the affective state is `insecure` and when the current bet turn is under the maximum bet turn (in the context of the plan). In plan `p1` the agent doesn't bet. In the plan `p2` the agent bets (a goal is added in line 18 that leads to the selection of the plan for betting). The bet is maximum since the agent affect will be `verysecure` for this plan to be selected.

Figure 3 shows the code of the MAS definition. The agent's personality is represented through a list of values of each one of the traits of the OCEAN model (line 2). The list of affective categories is shown in lines 3-7. There is a range of values for each one of the dimensions of the PAD model and for each category[7].

7 Conclusions

In this work we offer a global view of the development process of affective BDI agents. In [28] it is stated that "most theories of emotion generation seem to be compatible with rather different assumptions about the nature of emotions and their effects", what makes possible to establish different links between emotion generation, experience and effect. $GenIA^3$ is a suitable tool in order to precisely define those links, and hence, in order to create an affective agent based on an architecture that fits specific requirements and specific supporting theories. We cover the most important affective processes, including the *affective modulator of beliefs* (whose role is one of the most important and less addressed [9]). We also have identified those affect-related concepts whose

[7]Ranges can overlap but this doesn't affect the selection of plans. It means that more than one affective category matches with the current affective state, and, hence, plans with this affective categories are more prone to be selected.

representation is required when defining the affective BDI agent.

Our proposal is not a formal model (although a formal model is needed). It is a way of avoiding designers of BDI affective agents to start from scratch, simplifying the creation of a computational affective model. This also avoids to make irrelevant commitments to implementation details. The terms that are used across computational approaches and their supporting theories, to characterize affect-related concepts and processes, is wide and diverse. We unified them in a common terminology that allows the comparison of existing computational models. Also the identification of implementation-independent constructions that should be included in an affective BDI agent language, offers a common language that allows to perform language-independent formalizations. We make a step toward the standardization of the development of affective agents.

Due to the space limit we didn't provide enough details of how the different processes addressed in this work can be implemented. We focused on offering a broad view of how the different stages of the design of the affective agent could be addressed, and, the links between these stages. It is a task of the designer to perform more specific commitments for each process involved. Nevertheless, as part of our future work, we will provide a default implementation for those processes.

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