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ABC-EBDI: A cognitive-affective framework to support the modeling of believable intelligent agents.

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ABC-EBDI: A COGNITIVE-AFFECTIVE FRAMEWORK TO SUPPORT THE MODELING OF BELIEVABLE INTELLIGENT AGENTS.

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DOCTORAL THESIS

ABC-EBDI: A cognitive-affective framework to support the modeling of believable intelligent agents.

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Resumen y conclusiones

El Grupo de Investigación de Interfaces Avanzadas (AffectiveLab), es un grupo reconocido por el Gobierno de Aragón (T60-20R) cuya actividad se enmarca en el área de la Interacción Humano-Computadora (IHC). Su actividad investigadora se ha centrado, en los últimos años, en cuatro temas principales: interacción natural, informática afectiva, accesibilidad e interfaces basadas en agentes inteligentes, siendo esta última en la que se enmarca esta tesis doctoral. Más concretamente, la realización de esta tesis doctoral se enmarca dentro de los proyectos de investigación nacionales JUGUEMOS (TIN2015-67149-C3-1R) y PERGAMEX (RTI2018-096986-B-C31). Una de sus líneas de investigación se centra en el desarrollo de arquitecturas cognitivo-afectivas para apoyar el modelado afectivo de los agentes inteligentes. El AffectiveLab tiene una sólida experiencia en el uso de agentes de interfaz incorporados que exhiben expresiones afectivas corporales y faciales (Baldassarri et al., 2008). En los últimos años, se han centrado en el modelado del comportamiento de los agentes inteligentes (Pérez et al., 2017).

La definición de agente inteligente es un tema controvertido, pero se puede decir que es una entidad autónoma que recibe información dinámica del entorno a través de sensores y actúa sobre el medio ambiente a través de actuadores, mostrando un comportamiento dirigido a un objetivo (Russell et al., 2003). El modelado de los procesos cognitivos en los agentes inteligentes se basa en diferentes teorías (Moore, 1980; Newell, 1994; Bratman, 1987) que explican, desde diferentes puntos de vista, el funcionamiento de la mente humana. Los agentes inteligentes implementados sobre la base de una teoría cognitiva se conocen como agentes cognitivos. Los más desarrollados son los que se basan en arquitecturas cognitivas, como Soar (Laird et al., 1987), ACT-R (Anderson, 1993) y BDI (Rao and Georgeff, 1995). Comparado con Soar y otras arquitecturas complejas, BDI se destaca por su simplicidad y versatilidad. BDI ofrece varias características que la hacen popular, como su capacidad para explicar el comportamiento del agente en cada momento, haciendo posible una interacción dinámica con el entorno. Debido a la creciente popularidad del marco BDI se ha utilizado para apoyar el modelado de agentes inteligentes (Larsen, 2019; (Cranefield and Dignum, 2019). En los últimos años, también han aparecido propuestas de BDI que integran aspectos afectivos. Los agentes

inteligentes construidos en base a la arquitectura BDI que también incorporan capacidades afectivas, se conocen como agentes EBDI (Emotional BDI) y son el foco de esta tesis.

El objetivo principal de esta tesis ha sido proponer un marco cognitivo-afectivo basado en el BDI que sustente el modelado cognitivo-afectivo de los agentes inteligentes. La finalidad es ser capaz de reproducir un comportamiento humano creíble en situaciones complejas donde el comportamiento humano es variado y bastante impredecible. El objetivo propuesto se ha logrado con éxito en los términos descritos a continuación:

- Se ha elaborado un exhaustivo estado del arte relacionado con los modelos afectivos más utilizados para modelar los aspectos afectivos en los agentes inteligentes.
- Se han estudiado las arquitecturas de BDI y las propuestas previas de EBDI. El estudio, que dio lugar a una publicación (Sánchez-López and Cerezo, 2019), permitió detectar las cuestiones abiertas en el área, y la necesidad de considerar todos los aspectos de la afectividad (emociones, estado de ánimo, personalidad) y su influencia en todas las etapas cognitivas. El marco resultante de este trabajo doctoral incluye también el modelado de la conducta y el comportamiento comunicativo, que no habían sido considerados hasta ahora en el modelado de los agentes inteligentes. Estos aspectos colocan al marco resultante entre EBDI los más avanzados de la literatura.
- Se ha diseñado e implementado un marco basado en el BDI para soportar el modelado cognitivo, afectivo y conductual de los agentes inteligentes, denominado ABC-EBDI (Sanchez et al., 2020) (Sánchez et al., 2019). Se trata de la primera aplicación de un modelo psicológico muy conocido, el modelo ABC de Ellis, a la simulación de agentes inteligentes humanos realistas. Esta aplicación implica:
    - La ampliación del concepto de creencias. En el marco se consideran tres tipos de creencias: creencias básicas, creencias de contexto y comportamientos operantes. Las creencias básicas representan la información general que el agente tiene sobre sí mismo y el entorno. Las conductas operantes permiten modelar la conducta reactiva del

agente a través de las conductas aprendidas. Las creencias de contexto, que se representan en forma de cogniciones frías y calientes, se procesan para clasificarlas en creencias irracionales y racionales siguiendo las ideas de Ellis. Es la consideración de creencias irracionales/racionales porque abre la puerta a la simulación de reacciones humanas realistas.

    - La posibilidad de gestionar de forma unificada las consecuencias de los acontecimientos en términos de consecuencias afectivas y de comportamiento (conducta). Las creencias de contexto racionales conducen a emociones funcionales y a una conducta adaptativa, mientras que las creencias de contexto irracionales conducen a emociones disfuncionales y a una conducta maladaptativa. Este carácter funcional/disfuncional de las emociones no se había utilizado nunca antes en el contexto del BDI. Además, el modelado conductual se ha ampliado con el modelado de estilos comunicativos, basado en el modelo Satir, tampoco aplicado previamente al modelado de agentes inteligentes. El modelo de Satir considera gestos corporales, expresiones faciales, voz, entonación y estructuras lingüísticas.

- Se ha elegido un caso de uso, "I wish a had better news" para la aplicación del marco propuesto y se han realizado dos tipos de evaluaciones, por parte de expertos y de usuarios. La evaluación ha confirmado el gran potencial del marco propuesto para reproducir un comportamiento humano realista y creíble en situaciones complejas.

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CHAPTER 1: Motivation and Objectives

Introduction

In this first chapter, the context and motivation that led to this doctoral thesis are explained. The proposed objectives and the structure of this document are also presented.

1.1 Context

The Research Group on Advanced Interfaces (AffectiveLab), is a group recognized by the Government of Aragon (T60-20R) whose activity is framed in the area of Human-Computer Interaction (HCI). Its research activity has focused, in recent years, in four main topics: natural interaction, affective computing, accessibility and interfaces based on intelligent agents, being the latter one in which this doctoral thesis is framed. More specifically, the realization of this Doctoral Thesis began in the context of the JUGUEMOS research project (TIN2015-67149-C3-1R) a national coordinated project leaded by the AffectiveLab with the collaboration of the GEDES group of the University of Granada and the group UGIVIA of the University of Balearic Islands. One of its research lines focuses on the development of cognitive-affective architectures to support the affective modeling of intelligent agents. The AffectiveLab has a strong background in the use of embodied interface agents that exhibit body and facial affective expressions (Baldassarri et al., 2008). In the last years, they have been focused in the modeling of the behavior of intelligent agents (Pérez et al., 2017).

The definition of intelligent agent is a controversial issue, but it can be said that is an autonomous entity that receives dynamic surrounding information through sensors and acts on the environment through actuators, showing a goal-directed behavior (Russell et al., 2003). The modeling of the cognitive processes in intelligent agents is based on different theories (Moore, 1980; Newell, 1994; Bratman, 1987) that explain, from different points of view, the functioning of the human mind. Intelligent agents implemented over the base of a cognitive theory are known as cognitive agents. The most developed ones are those based on cognitive architectures, such as Soar (Laird et al., 1987), ACT-R (Anderson, 1993) and BDI (Rao and Georgeff, 1995). In fact, Soar was the base of a previous PhD developed in the AffectiveLab (Marco, 2017), that focused in the Soar architecture. Compared to Soar and other complex architectures, BDI stands out for its simplicity and versatility. It was born on the basis of the theoretical foundation of Michael Bradman's practical reasoning

(Bratman, 1987) and it is based on three fundamental mental attitudes: beliefs (that represent the information about the environment and oneself), desires (that represent the motivational state of the agent) and intentions (actions plans that have been selected and are committed to achieve and that provide the deliberative character to the model). BDI offers several features that makes it popular, like its capability to explain agent's behavior at every moment, making possible a dynamic interaction with the environment. To support it, several programing tools have been developed to allow high level programming of complex systems in a more simple way. Due to the growing popularity of the BDI framework it has been used to support the modeling of intelligent agents (Larsen, 2019), (Cranefield and Dignum, 2019). In the last years, BDI proposals that integrate affective aspects have also appeared. Intelligent agents built on the basis of the BDI architecture that also incorporate affect, are known as EBDI (Emotional BDI) agents and are the scope of this thesis. Several affective aspects have been considered to model affective issues in EBDI agents which are explained next.

1.2 Motivation: The consideration of affective aspects in the modeling of believable intelligent agents

On behalf of achieving a more realistic human-like behavior one of the major challenges in AI (Artificial Intelligence) is the incorporation of affective issues into intelligent agents (Reisenzein et al., 2013a). Firstly, because emotions can enhance the agent's autonomy and effectiveness, particularly in complex and uncertain environments, by biasing the agent's behavior towards a selection of particular goals and actions, producing a more adaptive behavior. Secondly, because emotions can enhance the agent's believability, awarding affective and social realism to the agent. Not only will the agent exhibit more realistic behavior (showing anger, tiredness or relief depending on the situation) but will be capable of reacting differently to the same situation or event depending on changing moods and goals. Emotions may also play a significant role in social and interpersonal domains, as different types of emotions could be exhibited depending on the relationship with the user or other agents. In this sense, not only emotions come to play, but also personality, mood and affective capabilities such as coping, emotional regulation and empathy. All of them play an important role to model a believable human-like behavior since they directly affect human's cognitive processes like perception and

decision making and determine how humans cope with a particular situation, therefore affecting their adaptation capacity.

In fact, and in spite of the effort done, reproducing believable human behavior is still a challenge, in special in those situations where human behavior is very varied and quite unpredictable. To understand the kind of situations we are talking about, let's consider the following bad news scenario. A young doctor is going to meet Susan, one of his patients. Susan is a 50-year-old woman that has hypertension and hyperlipidemia. As she was not feeling lately very well an ultrasound of her abdomen has been done; it shows several target lesions in the liver suggestive of metastasis. So, he will have to tell her that she has cancer and little can be done. What can the doctor expect from Susan? How is she going to react? Will she become just sad and ask for guidance or would she become angry and react aggressively? In this case, her affective regulation abilities will also come into play. Her reactions, which can be very varied, would depend on several factors, such as her personality, her knowledge, her current affective state, but also on her prior experiences and her family history. All these factors will condition her conduct (what she says, but also how she says it), her feelings and her thoughts during the encounter with the doctor. So far, most of proposals in the literature are focused on modeling just what she says, some of them also on what she feels, but it is also interesting to model which are the underlying thoughts that make her say something in a particular way and make her feel a particular emotion. These related aspects (feelings, thoughts and conduct) make up the variety of reactions of a human being in such a situation which are certainly very difficult to reproduce by a machine. To model believable human behavior in that kind of complex situations is still a challenge and this is why, the objective of this doctoral thesis is the modeling on how an individual feels, what he/she thinks and how he/she behaves in complex situations.

1.3 Thesis objectives

The main objective of this thesis is to propose a BDI-based cognitive-affective framework to support the cognitive-affective modeling of intelligent agents. The aim is to be able to reproduce believable human-like behavior in complex situations where human behavior is varied and quite unpredictable. The proposed framework has to be implemented and validated.

The phases of the doctoral work have been the following:

- Elaboration of an exhaustive state of the art related to the most used affective models to model affective aspects in intelligent agents.
- Study of the BDI architecture and previous EBDI proposals.
- Proposal of an EBDI framework capable of supporting cognitive-affective-behavioral modeling in complex situations.
- Selection of a use case for the application of the proposed framework.
- Implementation of a prototype to support the use case and to validate the feasibility of the proposed framework to simulate believable human-like behavior in complex situations.
- Writing of the dissertation.

1.4 Thesis structure

The structure of this document is as follows:

- Chapter 2 presents the state of the art related to affective models and BDI cognitive-affective frameworks used to model intelligent agents.
- Chapter 3 presents the proposed cognitive-affective-behavioral framework, called ABC-EBDI.
- Chapter 4 presents the framework implementation.
- Chapter 5 presents use case and evaluations.
- Chapter 6 presents conclusions and future work.

CHAPTER 2: Related work

2.1 Introduction

The aim of this chapter is to review the literature on BDI emotional agents, and, based on this, to identify common findings, good practices and open research questions. First, an overview of how affective aspects are modeled in intelligent agents is presented. Second, the affective theories most used in intelligent agent modeling are presented and, finally, the most relevant works based on BDI agent's architecture are reviewed. The content of this chapter has been published in (Sánchez-López and Cerezo, 2019).

2.2 Modeling affect in Intelligent Agents

The design of intelligent agents has focused in the last years on the modeling of emotions and their influence on the cognitive process, pursuing a more believable and humanlike behavior. The modeling of emotions and their influence on the cognitive process is not the only aspect that has attracted the attention of researchers, but also the modeling and influence of other affective states such as mood, personality and other affective capacities like empathy, emotional regulation and coping. The works aimed to incorporate emotional mechanisms into intelligent agents can be grouped into three categories (Reisenzein et al., 2013a): formalizations, specialized affective architectures and extensions of existing cognitive and agent's architectures.

Formalizations consists of translating a psychological emotion theory (or selected assumptions of one or more emotion theories), into a precise, but implementation-independent language. They can be very useful to fundament and verify computational models (or at least part of them) and to compare existing computational models of emotions. Among the best known are formalizations of psychological models by set theory (Broekens et al., 2008; Reisenzein and Junge, 2012) and by using agent logics (Hughes and Cresswell, 1996). The latter are the most popular, since, although they are more restrictive in the form of representation, they are usually more useful for a specific application context. One of the most used agent logics are those based on BDI terms (belief-desire-intention), which are known as BDI logics. They are formal logic languages that arise from the combination of several modal logics: a temporal or a dynamic logic used to capture the dynamic nature of agents, and logics for the mental states of beliefs, desires and intentions (Reisenzein et al., 2013b).

Specialized affective architectures are those specifically designed for the creation of affective agents. They are composed of several modules (perception, memory, appraisal, and actuation) and are suited to model different affective theories. In this group, the affective architectures FLAME (El-Nasr et al., 2000), FAtiMA (Dias et al., 2014), Cathexis (Velásquez and Maes, 1997), ALMA (Gebhard, 2005) and MAMID (Hudlicka, 1998), (Hudlicka, 2004) stand out.

Extended cognitive architecture systems make use of existing general cognitive architectures, such as Soar and ACT-R, or existing agent's architectures such as BDI, to model emotions. Their use has the practical advantage of reliving the modeler of the need to solve numerous implementation problems and focus on modeling emotions. Besides, they may help to bridge the gap between psychological emotion theories and computational emotion modeling, as well as they may increase the comparability of different computational emotion models. EMA (Marsella and Gratch, 2009), Sigma (Rosenbloom, 2013) and EVOX (Pérez et al., 2016) are based on Soar. Other works such as Fun and Stocco (Fum and Stocco, 2004) and Cochran (Cochran, 2006) are extensions of the ACT-R architecture. The emotional extensions of the BDI architecture are often called Emotional BDIs or EBDIs and are in the scope of this thesis. Besides their psychological foundations, the existence of logical models (BDI logics) that allow to define, and reason about BDI agents in a precise manner, make them very interesting for the creation of intelligent affective agents. The existence of several software systems for programming BDI agents that are close to these logical specifications have also greatly contribute to their spreading. To review the literature on BDI emotional agents, we will consider both those works based on BDI formalizations as well as those that are extensions of the BDI agent's architecture. But first, in the next section we review, the affective theories most used in the modeling of emotional intelligent agents.

2.2.1 Affective theories

In the literature the term affect is frequently used as a general category that includes short-term emotional states such as emotions, long-lasting mood, and more permanent states such as personality. The modeling of affect in intelligent agents has not only focused on the generation of these affective states but also on their influence on the cognitive process. Other aspects that are also often included in the development of affective intelligent agents are the ability to empathize with others

and to regulate emotions and behavior. Empathy is the ability to feel, imagine and support the experiences and emotions of another person (Gibson, 2006); it develops gradually throughout life, and depends on the degree of contact with the person to empathize. In the field of intelligent agents, empathy has been used as a powerful tool to improve their cooperative and communicative social skills with human users. Regarding regulation, there are two fundamental approaches: emotional regulation and coping. Emotional regulation refers to the way individuals modify the emotions they experience and how they express them. Coping is oriented to affront stressing situations. Next, the main affective theories regarding each affective aspect will be reviewed.

2.2.2 Emotions

In the last decades, diverse theories have demonstrated the influence of emotion in the cognitive process (Damasio, 1994). The definition of emotions is a controversial issue since there are more than 92 definitions in the literature (Kleinginna Jr and Kleinginna, 1981). In general, it is said that emotions can be defined as the "evaluative judgments of the environment, the self and other social agents, in light of the agent's goals and beliefs" (Hudlicka, 2008).Emotions are short-lived affective states that arise suddenly in the context of a specific stimulus, having significant psycho-corporeal repercussions and producing physiological changes. Three fundamental characteristics of emotions are their high intensity, their short duration and that they are tied to a particular event. There are two principal aspects to take into account in emotion modeling: emotional representation and emotional elicitation.

Regarding emotional representation, some dimensional theories have been used in intelligent agents modeling such as the one of Russell (Russell, 1980a) and Mehrabian (Mehrabian, 1996a) theories. In these models affective states are not independent from one another, rather, they are related in a systematic manner (Gunes et al., 2011). In the case of Russel it is a bidimentional model that represents emotional states according to two universal values: valence and arousal. The proposal of Mehrabian presents the PAD theory that is a tridimensional model used, not only to represent emotional states, but also to represent mood (see section 2.1.3).

Emotional elicitation is the most studied aspect in emotional agent modeling, therefore, several theories of emotion have been used (Zajonc et al., 1989; LeDoux,

1996; Damasio, 1994; Plutchik, 2001; Ortony Andrew et al., 1990; Smith and Lazarus, 1991; Frijda, 1987; Roseman et al., 1990; Sherer, 1999). In general, according to the emotion elicitation process, they can be grouped into cognitive and non-cognitive theories (Reisenzein et al., 2013a). In general, non-cognitive theories of emotions follow two main perspectives regarding the elicitation of emotions. Some of them claim that certain kinds of affect (i.e., sensory-pleasure for smelling a rose) are non-cognitively generated, because they presuppose only non-propositional or even non-conceptual representations (Reisenzein, 2006). Other theories claim that even prototypical emotions (i.e., fear, anger, joy) can be non-cognitively caused, given that they can be elicited by the visual or acoustic appearance of danger (i.e., visualize a fierce animal), without mediating any thoughts (Reisenzein et al., 2013a). In any case, these theories have been lees used in intelligent agent modeling, being the cognitive ones the most used.

In the case of non-cognitive theories, emotions in a broad sense are always elicited by stimuli via a more direct route that circumvents a higher cognitive process. On the contrary, in cognitive theories the emotion elicitation requires certain "higher-order" mental representations (beliefs and desires) (Green and Green, 1992). Cognitive theories are the most used and, in most of them, a cognitive evaluation process (appraisal) of the stimulus precedes emotion (Ortony Andrew et al., 1990; Smith and Lazarus, 1991; Frijda, 1987; Roseman et al., 1990; Sherer, 1999). Cognitive appraisal theories attempt to explain why a certain event results in one emotional-response rather than another and why a certain emotion can be elicited by different events. The key concept is that the subjective cognitive evaluation of events, in relation to the agent's goals, is responsible for emotion (Roseman and Smith, 2001). More generically, events have to be evaluated as having personal meaning or relevance (Van Reekum, 2000). This evaluation is the so-called appraisal. The most popular of the cognitive theories is the OCC theory (Ortony Andrew et al., 1990). This is due to its tree structure that allows implementing it in a simple way, and also because it works with concepts (beliefs, desires and standards) well-studied in agent's theories. It is important to emphasize that the OCC theory does not specify the influence of the emotions in the cognitive process, but only their elicitation. The theory bases its foundations on the way individuals perceive the world and it defines three aspects in which the individual can focus its perception: events,

agents, and objects (see Fig. 2.1). If the focus is put on the consequences of events, fortune-of-others, prospect-based and well-being emotions may be elicited. If the focus is put on the actions of the agents, attribution emotions may be elicited. If the focus is put on the properties of objects attraction emotions are obtained. This way, OCC defines twenty-two emotions describing their elicitation as a result of the cognitive appraisal process of the stimulus, guided by some evaluation variables (appraisal variables). The theory also defines the global and local variables that influence the intensity of the emotions. As said before, the success of this theory lies in its easy transfer to a computational model.

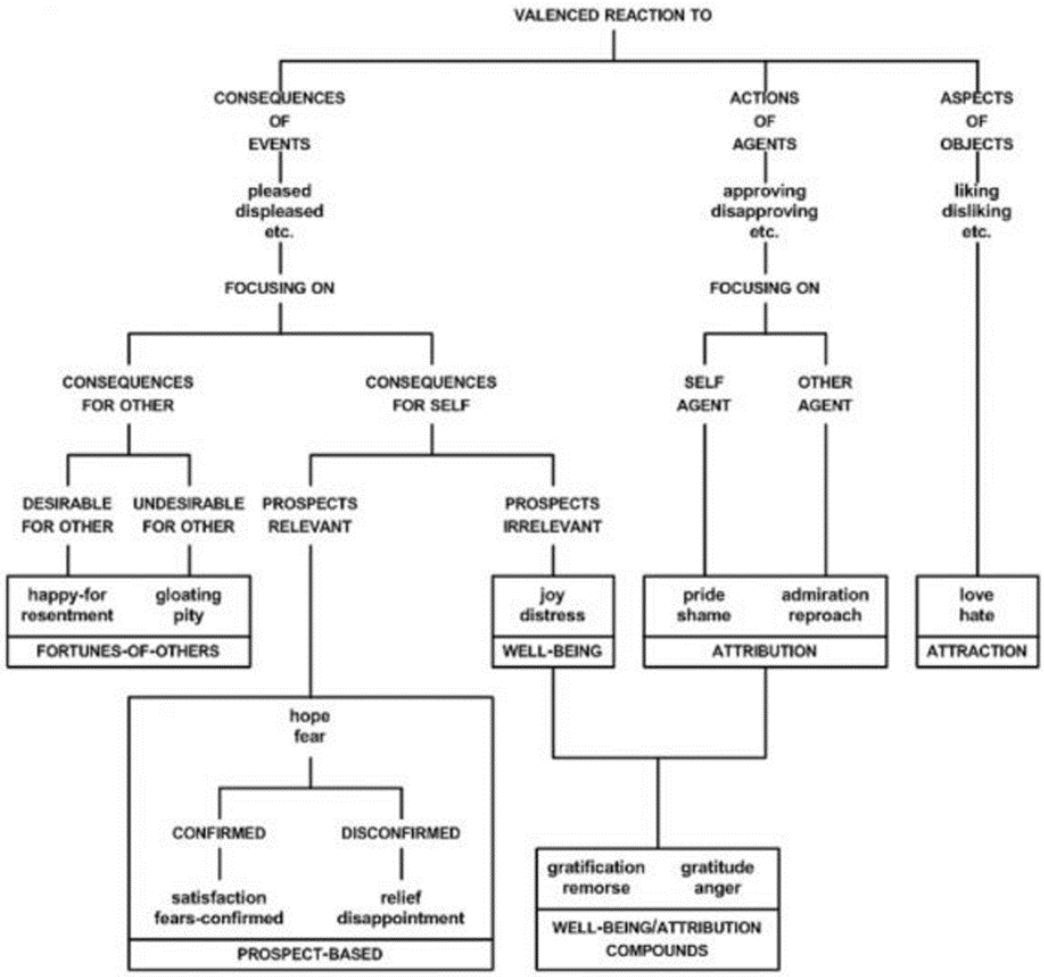


Fig. 2.1. Global structure of the emotions of the OCC theory. Taken from the book "The Cognitive Structure of Emotions" (Ortony Andrew et al., 1990)

An interesting aspect of the modeling of emotions is that they have been usually classified into three main types: primary, secondary and tertiary emotions (Damasio, 1994; Sloman, 2000). Primary emotions (being startled, terrified, sexually stimulated) are innate responses to an external event. Secondary emotions (anxious, apprehensive, relieved, pleasantly surprised) generation involve primary emotions and a more complex cognitive appraisal. Tertiary emotions are disturbing states (feeling humiliated, infatuated, guilty) that reduce self-control. Primary emotions generation have usually been modeled in intelligent agents by using a cognitive reactive layer whereas secondary emotions require a deliberative cognitive layer in addition to the reactive machinery of the primary emotions. The case of tertiary emotions is more complex and has not yet been successfully implemented since it depends on the existence of a mechanism that controls the partial loss of control of attention in the intelligent agent, requiring a sophisticated information processing architecture (Sloman, 2000).

Another interesting question is the ability to measure the intensity of which an emotion is experienced, since it is a quantitative measure that defines a separation between affective reactions and emotions. According to (Ortony Andrew et al., 1990) an emotion only occurs when its intensity achieves a specific threshold; this means that an intelligent agent not always will experiment an emotion. The intensity also determines how strong the response of an individual is (Scherer, 2000). An affective state that depends on the intensity of the emotions is mood, which will be discussed in the next section.

2.2.3 Mood

Mood is recognized as the global affective state of an individual (Desmet, 2015). This affective state tends to vary in time due to emotions, returning afterwards to its initial state. Compared with emotions, mood lasts longer, has lower intensity and often appears without being associated with a specific event or object (Larsen, 2000). Gratch and Marsella (Gratch and Marsella, 2004) refer the importance of modeling moods as “they have been shown to impact a range of cognitive, perceptual and behavioral processes, such as memory recall (mood-congruent recall), learning, psychological disorders (depression) and decision-making” (Gratch and Marsella, 2004).

Relevant mood theories are the Larsen (Larsen, 2000), Mehrabian (Mehrabian, 1996a), Watson and Tallagen (Watson and Tellegen, 1985), Circumplex theory of affect (Russell, 1980b) and PAD (Mehrabian, 1996a) theory. Most of the theories model mood in a bi-dimensional way, by means of two edges universally recognized as fundamental to characterize mood values: valence and arousal. In this regard, the PANAS theory (Watson and Tellegen, 1985) and the Circumplex theory of affect (Russell, 1980b) stand out. In the case of Circumplex theory (Russell, 1980b), it postulates that the underlying structure of an affective experience can be characterized as an ordering of affective states on the circumference of a circle (Remington et al., 2000). That way, sixteen mood states are defined in terms of valence and arousal. The valence variable is related to negative or positive affect and the arousal value measures the excitement level. The PANAS theory proposed by (Watson and Tellegen, 1985) does not specify particular mood states but mood categories also defined in two dimensions: valence (pleasant-unpleasant) and arousal (high energy-low energy). Four categories of mood arise in this model: energized-unpleasant, energized-pleasant, calm-unpleasant and calm-pleasant. In the case of the PAD model, mood is modelled in a three-dimensional way. The Pleasure-Displeasure dimension that is an evaluation of predominance of positive versus negative affective states; Arousal-Non arousal dimension is the level of physical activity and mental alertness, and Dominance-Submissiveness dimension is a measure of feelings of control vs. lack of control. The PAD theory is the most widely used in intelligent agents. Mood is generally considered influenced by personality, commented in the next section.

2.2.4 Personality

Personality refers to characteristic thought patterns that persist through time and situations and that distinguish one person from another. It influences the emotional response of each individual as well as its mood. Personality and emotions are different in terms of focus and duration. Emotions are always tied to a particular event or object and are short-term. Personality remains constant in time and is not tied to a particular event. It can be said that an emotion is a specific and short-lived modification of personality.

In the field of intelligent agents, the most widely used personality theory is the Big Five theory (McCrae and John, 1992), also known as Five Factor Model (FFM). The

model establishes five factors that are universally considered as the basic dimensions of personality: Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism, frequently grouped under the OCEAN acronym. The model has been implemented in several intelligent agents' proposals (Durupinar et al., 2008; André et al., 2000; Yu and Choi, 2005). One popular example is ALMA (Gebhard, 2005) where the personality is used to calculate the initial mood of the agent. To do so, the work of Mehrabian (Mehrabian, 1996b) that proposes a mapping between PAD and Big Five is used.

There are other personality theories such as The Four Temperaments theory (Merenda, 1987), the P-E-N theory (Eysenck, 1967) and the Interpersonal Circumplex or IPC model (Wiggins, 2003), but they have been scarcely used in the modeling of intelligent agents. The Circumplex model defines a broad set of inter-Personal relationships that have a direct relation with behavior in the affective and cognitive area. It is a bidimensional model that defines two orthogonal axes: a vertical axis (of status, dominance, power, or control) and a horizontal axis (of solidarity, friendliness, warmth, or love). The Four Temperaments model is one of the oldest personality models in the world and it's also known as the Hippocrates-Galen temperaments theory (Merenda, 1987). The model defines four temperaments: sanguine, choleric, melancholic and phlegmatic. Another interesting one is the P-E-N (Psychoticism-Extraversion-Neuroticism) theory of Eysenck (Eysenck, 1967). The psychoticism trait is related to normality which means that individuals with higher P scores are prone to engage in irresponsible behavior (i.e., aggression, egocentrism and impulsiveness) and to contravene social norms, motivated by a need for immediate gratification, in spite of its consequences. Extraversion trait is modeled according to the two extremes of spectrum, i.e. introversion and extroversion, according to the related concepts of inhibition and excitation. Neuroticism is explained with regard to the psychological concept of emotionality, where high scores on N factor reveals a low threshold of emotionality, while lower scores indicated a high threshold of emotionality (Eysenck, 1991). This theory is considered, together with the Big Five theory, one of the "giants" in personality modeling (Scholte and De Bruyn, 2004), but in spite of this, it has been scarcely used in intelligent agents.

2.2.5 Empathy

The most common definition of empathy is “put yourself in someone else’s shoes to understand his emotions” (Pacherie, 2004). An important feature of empathy is that it has two dimensions: cognitive and affective. The cognitive dimension is about understanding the situation of the other and the affective one is about feeling an emotion produced by the other´s situation. Both may or may not appear together: an empathic cognitive emotion can be felt without feeling an affective one. The modeling of empathy in intelligent agents has been considered from two perspectives: the empathy evoked by the intelligent agent (into the user) or the empathy that the intelligent agent "feels". There are proposals to model both perspectives: those that seek to evoke empathy in users (Paiva et al., 2004) and those that focus on the empathy that the agent feels (McQuiggan and Lester, 2006; Reilly, 1996; Ochs et al., 2008). The latter ones are those of interest here. Usually these works are not based on specific models but on empirical works or theoretical approaches such as the mentioned OCC theory (Ortony Andrew et al., 1990). In fact, OCC describes the elicitation of two empathic emotions when a goal of another intelligent agent or the user is achieved: happy-for and sorry-for. To consider them, the intelligent agent needs to have a representation of other agent’s (or user) goals. In the next section, other important affective processes are discussed.

2.2.6 Emotional regulation and coping

Emotional regulation is defined as “the processes by which individuals influence which emotions they have, when they have them, and how they experience and express these emotions” (Gross, 1998). Other authors define it as “the extrinsic and intrinsic processes responsible for monitoring, evaluating and modifying emotional reactions, especially their intensive and temporal features, to accomplish one’s goals” (Thompson, 1994).

Another concept regarding regulation is coping; its more accepted definition is given by (Lazarus and Folkman, 1984) who express that coping “consists of cognitive and behavioral efforts to manage specific external or internal demands (and conflicts between them) that are appraised as taxing or exceeding the resources of the person”. It should be noted that emotional regulation focuses on the increase or decrease of positive and negative emotions (Gross, 1998) whereas coping is more about diminishing negative emotions in stressful situations (see (Lazarus and

Folkman, 1984); (Scherer, 1984)). The most used models in the field of agent modeling are the one of Lazarus and Smith (Smith and Lazarus, 1991), oriented to coping, and the Gross theory (Gross, 1998) oriented to emotional regulation.

In Smith and Lazarus (Smith and Lazarus, 1991), coping is related to the way the individual interprets its relation with the environment. The theory proposes two fundamental coping strategies: problem focused, that consists of altering the adverse situation, and emotion focused, that consists of coping distressing emotions that arise in situations where the circumstances are not going to change. An example of the use of this model in intelligent agents is EMA (Marsella and Gratch, 2009), a proposal to create agents that are able to cope with negative affect.

In Gross (Gross, 1998), emotions can be regulated in five different phases during the emotion generation process: Situation Selection (avoidance of people, places, or objects), Situation Modification (active efforts to modify the situation in order to alter its emotional impact), Attentional Deployment (selection of where to put the focus on), Cognitive Change (modification of the cognitive evaluation of the situation) and Response Modulation (expression of the emotion elicited). Each phase takes part in the process according to the emotional dynamics and it is able to regulate positive as well as negative affect. CoMERG (Bosse et al., 2007) and S-model (Soleimani and Kobti, 2012) are two computational models of emotion regulation that follow Gross's paradigm.

Both coping and emotional regulation are oriented to the regulation of emotions but there are also theories to regulate more medium-term affective states like mood, such as the theory of Larsen (Larsen, 2000). In fact, the Affective Regulation term has been proposed as a global category that includes emotional regulation, coping and mood regulation. Moreover, there are works that address the subject of Empathic Emotion Regulation (EER) and define it as "an interpersonal regulation system in which an empathic response to another person's emotional state aims to regulate both emotion within the provider and across interaction partners" (Hamburg et al., 2014). Nevertheless, this kind of issues has not yet been modeled yet in intelligent agents.

2.2.7 Affective influence in the cognitive process

The influence of emotions in the cognitive process is a field of interest in many research areas (philosophy, psychology, neuroscience)(Blanchette and Richards,

2010; Angie et al., 2011). Studies have shown that emotions influence the human decision-making process (Damasio, 1994) and may influence all the phases of the cognitive process: perception (Zadra and Clore, 2011), beliefs (Nico H Frijda et al., 2000; Glore and Gasper, 2000) and behavior (Dolan, 2002).

Emotions, mood and personality are the affective aspects whose influence on the cognitive processes has been studied. As commented before, emotions and mood are two strongly related concepts, this is why in many works about affective influence are treated interchangeably (Zadra and Clore, 2011).

Regarding the specific influence of emotions on the cognitive processes, there is no general consensus among researchers. There are studies that show that emotions influence mediating information processing (attention, perception, memory), situation assessment, decision-making, goal management, planning and learning (Nico H Frijda et al., 2000; Angie et al., 2011; Dolan, 2002). For example, positive emotions induce global focus, whereas negative emotions induce a moral local focus and analytical thinking. Also, anxiety states reduces attentional and working memory capacities and biases attention toward the detection of threatening stimuli (Jeon, 2017) .

Regarding the influence of mood, it has been studied its impact on a range of cognitive, perceptual and behavioral processes, such as memory recall (mood-congruent recall), learning, psychological disorders (depression) and decision-making (Gratch and Marsella, 2004). Particularly, its influence on judgment is mediated by the individual's subjective (positive or negative) experience about the object of judgment. This means that, when evaluating objects or belief statements, individuals act accordingly to how they feel about them, using that information for the judgment in a mood congruent way (Schwarz and Clore, 1983).

Regarding personality, studies have been focused mainly on its influence on behavior (McEachan et al., 2010), (McEachan et al., 2010), (Lönnqvist et al., 2001). For example, a growing number of researchers have concluded that neurotic (as compared to non-neurotic) individuals have stronger negative affective reactions to undesirable stimuli, whereas extraverts (as compared to introverts) have stronger positive affective reactions to pleasant stimuli (i.e., (Larsen and Ketelaar, 1989),(Larsen and Ketelaar, 1991)).

In the next section, the BDI proposals that deal with the affective aspects studied in this section will be analyzed. First, the main BDI concepts will be reviewed.

2.3 Emotional BDI agents

2.3.1 The BDI agent's architecture

BDI (Belief Desire Intention) architecture was born on the basis of the theoretical foundation of Michael Bratman's practical reasoning (Bratman, 1987). Until then, there were models that only considered beliefs and desires; BDI introduces future-direct intentions providing the deliberative character to the model. The intentional feature was introduced by Bratman and is inspired by the "intentional instance" term of the philosopher Daniel C. Dannett (Dennett, 1989). BDI is known for their simplicity and efficiency in shaping human behavior and is based on three fundamental mental attitudes:

- *beliefs*: That represent the information about one self and the environment.
- *desires*: That represent the motivational state.
- *intentions*: That represent the commitments to achieve desires and provides the deliberative character to the model.

Fig. 2.2 shows the interaction between the three main components of the BDI:

- When an event (either internal or external) happens, it is perceived by the agent through the input sensors (*pers(Env)*).
- With the new perceived information beliefs are updated (*brf(B,p)*).
- Based on the set of updated beliefs, desires are generated (*options(B,I)*).
- Intentions are obtained to fulfill the objectives outlined (*filter(B,D,I)*).
- Finally, plans of actions are executed (*action(I)*).

BDI offers several features that makes it popular:

1. Beliefs provide a powerful tool to remind past events.
2. Plans are not fully defined and may consist of a set of sub-objectives, which provides adaptability to the framework.
3. The reconsideration of the plans that are being executed allows dealing with a dynamic environment because it allows to meet more urgent needs or to discard intentions that have no reason to be.
4. It is based on goals and not on tasks. This allows knowing at every moment not only *what* but *why* the agent is doing something. This way it is possible

to explain its behavior at every moment, giving the system the possibility to recover from failures and seize opportunities that arise dynamically.

5. The programming is at a high level and allows the development of more complex systems in a simple way.

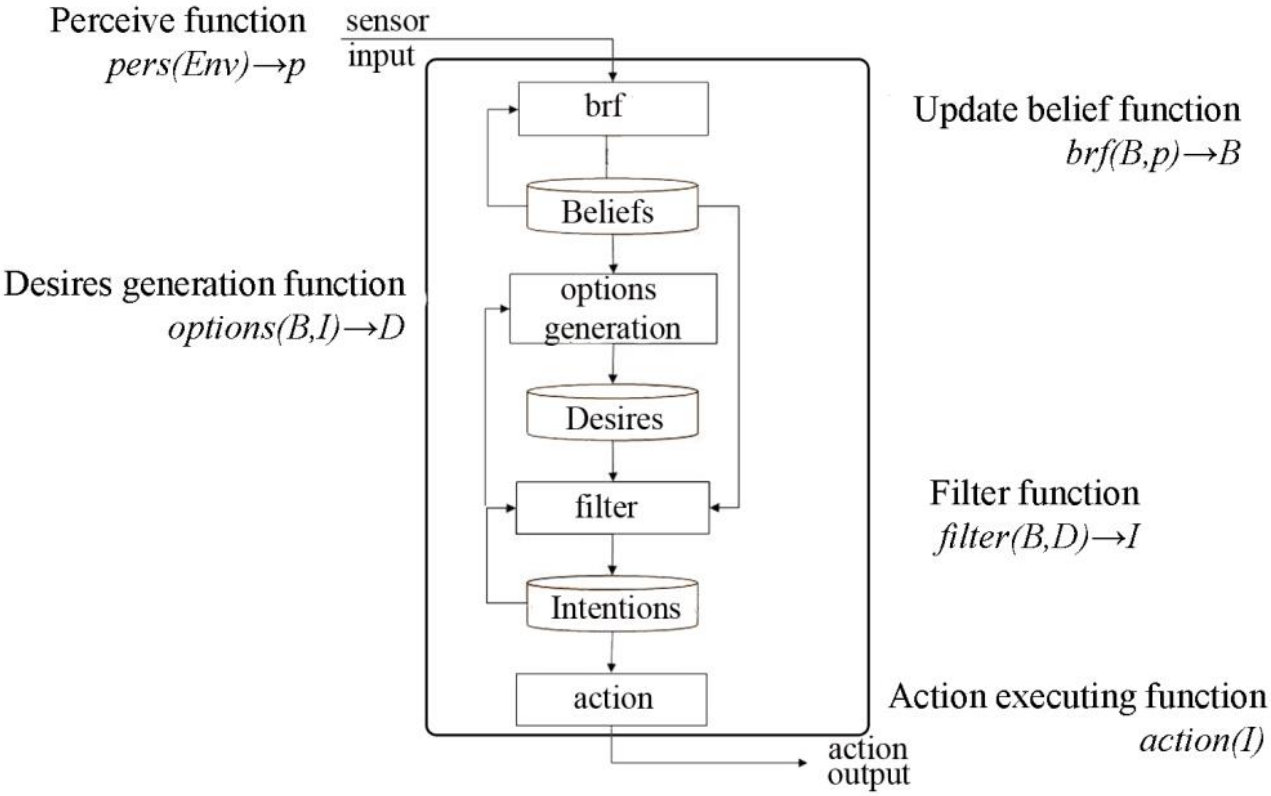


Fig. 2.2. Generic BDI schema adapted from Weiss (1999).

Anand S. Rao and Michael P. Georgeff (Rao and Georgeff, 1995) are among the first developers to put the BDI architecture into practice implementing an air-traffic management application, an air-combat simulation system and an autonomous mobile robot (Georgeff and Lansky, 1987). Since then, BDI agents have been created and used in several application such as the tourist guide of (Corchado et al., 2004) or the virtual humans training system of (Van Oijen et al., 2011).

The growing popularity of the BDI architecture has led to the development of several implementation tools that support it. The first generation of languages that emerged was PRS (Procedural Reasoning System) (Ingrand et al., 1992), followed by its successor dMARS (D'Inverno et al., 2004) continued by its third generation JACK Intelligent Agents (Winikoff, 2005) and AgentSpeak(L) (Rao, 2009) that emerged

as a new approach to formalize the operational semantics of PRS and dMARS. The AgentSpeak (L) language is one of the most influential languages in the implementation of BDI agents and has been developed up to its free version implemented in Java, JASON (Bordini and Hübner, 2007), which, being an open source interpreter, allows it to be completely configurable and easy to implement. Other languages that also support BDI agents are JAM (Huber, 1999), 3APL (Hindriks et al., 1999), SPARK (Morley and Myers, 2004), and JADEX (Braubach et al., 2003). In fact, JADEX is one of the most attractive due to its adaptability to run on several platforms, in addition to being implemented in Java and also being open source.

In last years, the growing interest in incorporating affect into intelligent agents has given rise to several emotional BDI proposals that are reviewed in the next section.

2.3.2 Emotional BDIs: classification

In this section, we will present the most relevant proposals related to the modeling of affective aspects in BDI agents. A systematic bibliographic search was done. From the 978 works initially obtained we restricted them to those published in the last 20 years in English that presented original BDI proposals (no revision or comparisons or new applications) prioritizing those with a medium or high relevance (in terms of citations). First, the present a general classification of the selected works. Then, we review them in terms on how the different affective aspects are considered and how they influence the general cognitive BDI process.

Following the classification presented in section 2.2, the proposals found can be grouped into two main categories: BDI formalizations and extensions of the BDI architecture. The works are presented in Table 2.1 indicating the affective aspect they consider (emotions, mood, personality, empathy and regulation). The level of application is also indicated: some proposals are no implemented at all, other present just an experimental scenario or application to test its viability. Only a few present a full application with a specific objective.

The first group of proposals is formed by those belonging to the formalization group. It is quite a diverse group. Most of them are based on agent logics languages, in particular, in BDI logics. But others extend existing agents specification frameworks or agent modelling languages as it is commented next.

Table 2.1

A classification of the proposals reviewed in this section showing the affective aspects modeled (mood, personality and regulation), and the application type (Exp_app: Experimental application; Exp_scenario: Experimental scenario; Real_app: Real application).

	Proposals	Emotions	Mood	Personality	Empathy	Regulation	App type
BDI Formalizations	Adam et al. (2006)	✓	-	-	-	-	-
	Steunebrink et al. (2012)	✓	-	-	-	-	-
	Gluz and Jaques (2017)	✓	-	-	-	-	Exp_scenario
	Meyer (2006)	✓	-	-	-	-	-
	Dastani and Lorini (2012)	✓	-	-	-	✓	-
	Bosse and Zwanenburg, (2009)	✓	-	-	-	-	Exp_app
	Bosse and de Lange (2008)	✓	-	-	-	✓	Exp_app
	Bosse and Höhle (2011)	✓		-	-	-	Exp_app
	Pereira et al. (2005)	✓	-	-	-	✓	-
	Van Straalen et al. (2009)	✓	-	-	-	✓	-

Table 2.1 (Continued).

	Proposals	Emotion	Mood	Personality	Empathy	Regulation	App type
Extension of BDI architectures	Alfonso et al. (2014)	✓	✓	✓	-	✓	-
	Dyke Parunak et al., (2006)	✓	-	-	-	-	-
	Jiang et al. (2007)	✓	-	-	-	-	Exp_app
	Lejmi-Riahi et al. (2014)	✓	-	-	-	-	-
	Hernández et al. (2004)	✓	✓	-	-	-	Exp_app
	Jones et al. (2009)	✓	-	✓	-	-	-
	Puica and Florea (2013)	✓	-	✓	-	-	Exp_scenario
	Neto and da Silva (2012)	✓	✓	✓	-	-	Exp_app
	Boukricha and Wachsmuth (2011)	✓	✓	✓	✓	-	Real_app
	Ochs et al. (2010)	✓	-	-	✓	-	Real_app
	De Rosis et al. (2003)	✓	✓	✓	-	✓	Real_app
	Becker-Asano and Wachsmuth (2010)	✓	✓	✓	✓	✓	Real_app

The proposals of (Steunebrink et al., 2012) and (Meyer, 2006) extend the BDI-based KARO agent specification framework (Meyer et al., 1999). The KARO framework is based on a blend of dynamic logic with epistemic logic, enriched with modal operators for beliefs and desires concepts (Meyer and Van Der Hoek, 2004). No application or scenario is presented.

The works of (Adam et al., 2009), (Dastani and Lorini, 2012) and (Gluz and Jaques, 2017) use BDI logic languages: the ABC, DL-GA and AfPL logics, respectively. The ABC logic is an extended version of one the first BDI logics proposed by Cohen and Levesque (Cohen and Levesque, 1990). It formalizes the concepts of action, time, belief, and choice in a simple propositional modal logic (Herzig and Longin, 2004). The DL-GA (Dynamic Logic of Graded Attitudes) logic is designed to represent with special operators the beliefs, goals, and intentions of the agent, where beliefs and goals have degree of plausibility and desirability, respectively. The AfPL logic is a propositional logic with the traditional logic operators that manage the beliefs, goals intentions concepts. As we will see in next section, in all there cases they formalize the OCC theory, combined with (Oatley and Jenkins, 1996) theories in the case of (Adam et al., 2009) and the (Lazarus, 1991) and (Frijda, 1986) theories in the case of (Dastani and Lorini, 2012). Agent logic languages facilitate the transformation from specification to implementation. Nevertheless, (Gluz and Jaques, 2017) is the only of them that presents an experimental scenario (a vacuum cleaner robot), but without implementation.

Finally, in this group the proposals of (Bosse and de Lange, 2008), (Bosse and Zwanenburg, 2009), (Bosse and Höhle, 2011) can also be found. In this case, they use as formalization tool an agent-based modeling language, called LEADSTO (T. Bosse et al., 2007). LEADSTO language allows to model dynamic processes in terms of both qualitative and quantitative concepts, by either logical or mathematical means, or a combination thereof. They formalize three Ekman's emotions, the expectation-based emotions of (Castelfranchi and Lorini, 2003) and two emotions based on the appraisal theory presented in (Gratch and Marsella, 2004). They present three experimental applications (simulation environment with two Intelligent Virtual Agents, a dice game with an embodied agent and a game based on RobCop, respectively) to test the viability of the proposals.

As we see, these works have focused mainly in emotional formalization, and mostly in formalizing the OCC theory. Only three of them have consider other aspects such as mood (Bosse and Höhle, 2011) and regulation (Dastani and Lorini 2012; Bosse and Zwanenburg 2009). Details on how they consider these three aspects are presented in the next sections. Empathy and personality have never been formalized.

The second big category is formed by those works that are extensions of existing BDI cognitive architectures. They follow the generic BDI schema (see section 2.2.1) extended with affective modules that influence different cognitive phases (as it will be explained in section 2.2.8). Although OCC is also widely used, many more theories are applied (as it will be commented in next section). Mood and personality are also considered in about half of them. On the contrary, empathy (just treated in three of them) and regulation (only in two) are scarcely considered. In this category, as it was commented in previous section, the existence of several implementation tools facilitates their development and application. In spite of this, some of them do not present any application or example scenario. Other just present experimental applications or scenarios to test the architecture's viability. This is the case of (Jiang et al., 2007), that present an application developed in the Tileword platform (Pollack and Ringuette, 1990), to compare the behavior of emotional and non-emotional BDI agents. In (Puica and Florea, 2013) an experimental scenario of an agent situated in a 2D map with artifacts and traps., is presented. In (Hernández et al., 2004) a more elaborate experimental application based on a humanoid robotic head with vision and audio sensor capabilities to evaluate the reaction of the robot to certain colors and the activation of primary emotions (surprise, fear) and secondary emotions (happiness, sadness and anger) given the image's luminance value, is presented. In (Neto and da Silva, 2012) two games as experimental applications; Iterated Prisoner's Dilemma and a Memory card game, are presented; they focus on evaluating the influence of the affective state in the activities of perception, memory and decision-making. In the case of (Boukricha and Wachsmuth, 2011), the experimental application is an embodied agent, called EMMA, integrated as third pattern into Max's virtual environment (Becker-Asano and Wachsmuth, 2008); they focus in the assessing EMMA's capability of empathizing with Max's emotions during the interaction with a human user. Four of the proposals present full applications. In all the cases an ECA (Embodied Conversational Agent) is used but within different application scenarios. The work of (De Rosis et al., 2003) has been

used as the base of an interactive listening agent (Bevacqua et al., 2008) and an Interactive Storyteller (Bevacqua et al., 2010). In (Ochs et al., 2010), the application is 3D talking head that shows facial expressions according to the intensity of the elicited emotions, in order to empathize with the user. In the case of (Boukricha and Wachsmuth, 2011) and (Becker-Asano and Wachsmuth, 2008), they present two different systems; the first one focuses on empathic emotion elicitation and the second one in primary and secondary emotion elicitation. The application developed by (Becker-Asano and Wachsmuth, 2008) is a virtual human named Max, that plays the role of museum guide. The application has been implemented in several scenarios (robotics, chat boot agent) and, more recently, it has been extended with memory retrieval functions of the ACT-R cognitive architecture (Becker-Asano, 2014).

2.3.3 Emotion modeling

Emotion is the most commonly treated emotional concept in intelligent agents. As it has been analyzed in section 2.1.2, there are many emotion elicitation theories that have been used in this context and they can be grouped into cognitive and non-cognitive theories. In cognitive theories the emotion elicitation requires certain "higher-order" mental representations whereas in the case of non-cognitive theories, emotions are elicited by stimuli via a more direct route that circumvents higher cognitive processes (Reisenzein et al., 2013b). The emotional BDI proposals selected to be reviewed will be classified into those two groups.

Only three proposals follow non-cognitive theories. In this group the work of (Jiang et al., 2007) stands out and is the basis of other proposals. They follow the theory of Damasio (Damasio, 1994) but the concept of emotion is implemented in general way, without specifying the elicitation of any particular emotion. They provide the cognitive affective reasoning needed for eliciting both primary and secondary emotions in the general BDI process. Primary emotions are modeled as the first feeling that an individual experiences when an event occurs and secondary emotions may be caused directly by primary emotions, or come from more complex chains of thinking. Current beliefs and intentions originate primary emotions and the generation of secondary emotions is influenced by beliefs, intentions, and primary emotions. In contrast with the other examples, beliefs can be acquired through perception, contemplation or communication. In the case of (Jones et al., 2009),

they maintain the cognitive and emotional modeling of Jiang et al. adding personality and physiology, which is their main contribution. Physiology (stress, hunger/thirst, tiredness, temperature, injury and contamination) is used as a moderator of the cognitive-affective process that directly influences the elicitation of primary emotions. Personality modeling is another important aspect that differences these proposals as it will be explained in section 2.2.5.

In the case of (Bosse and de Lange, 2008), their modeling of emotions is based on (Ekman et al., 1972) and just three basic human emotions (anger, happiness or fear) are elicited. In contrast to the other proposals in this group, beliefs can only be acquired from observations and only one emotion can be experienced simultaneously. Besides, each emotion has an associated emotional response level (ERL) directly influenced by agent's beliefs. In spite of the simplicity of their emotional modeling they address an interesting and practically unexplored field in intelligent agents modeling, emotional regulation, as it will be analyzed in section 2.2.7.

The proposals based on cognitive theories are the more numerous and have been divided into formalization and extension proposals. In the formalization category four of them are based on the OCC theory, and the others in (Lazarus, 1991), (Oatley and Jenkins, 1996) and (Castelfranchi and Lorini, 2003), respectively.

The proposals that formalize the OCC theory have in common the way emotions are elicited, because they consider that emotions depend on beliefs and—directly or indirectly—on desires. In (Adam et al., 2009) emotion elicitation involves two types of beliefs (strong beliefs, that are those that are truth without doubt, and weaker beliefs , that are those that are related to the probability of an event yo be true) and goals that are related to the desirability/undesirability of the consequences of events. They manage intensity, but they do not deferenciate between emotion elicitation and emotion experience. This means that in the case that the conditions for an emotion are met, the agent will always experience it. In addition, they do not distinguish between emotions of the same OCC branch as anger and irritation. Finally, their formalization is restricted to their own BDI-based logical framework. The proposal of (Steunebrink et al., 2012) is a first attempt to differentiate between affective reactions and experienced emotions: an emotion triggered is experienced only if it has already been experienced in the past and the overall emotion intensity is positive.

To do so, they implement an intensity assignment process but without detailing the complete intensity calculation. In contrast to (Adam et al., 2009), their formalization of the OCC theory it's not tied to a particular framework, because they provide a formalization into dynamic doxastic logic an later they translate it into a logical implementation. In contrast with the precedent works, (Gluz and Jaques, 2017) present a probabilistic formalization of the OCC emotion elicitation process. They also distinguish between emotion elicitation and emotion experience managing intensity, but providing all the detailed calculations of the variables affecting intensity (potential and threshold). As the other works, they formalized the process of appraisal that depends on agents' beliefs, goals and desirability but adding a new desirability operator. In the proposal of (Dastani and Lorini, 2012) emotions are defined in terms of graded beliefs, graded goals, and intentions and intensity is considered. Their implementation of coping strategies represents a step forward in including affective aspects into formalizations and it will be discussed in section 2.2.7. All the precedent proposals formalize OCC emotions but they differ in the number of emotions they consider: (Steunebrink et al., 2012)-22 OCC emotions, (Adam et al., 2009)-20 emotions, (Gluz and Jaques, 2017)-8 emotions (event-based emotions with consequences for self-based) and (Dastani and Lorini, 2012)-4 of the prospect-based emotions.

In the formalization group, there are also proposals based on different theories of emotion, not OCC. This allows them to model other types emotions not usually considered. The proposal of (Meyer, 2006) is based on the emotional theory of (Oatley and Jenkins, 1996) and models the elicitation of free-floating emotions, whose elicitation is not always directly related to a particular object or situation. They formalize four type of them: happiness, sadness, anger and fear. The elicitation of emotions is shaped by the success or failure of a plan and by the achievement or abandoning of the pursued goal. They do not manage the intensity of emotion. The (Bosse and Zwanenburg, 2009) proposal is based on the emotional theory of (Castelfranchi and Lorini, 2003) and considers expectation-based emotions (before-emotions and after-emotions). Modeling this kind of emotions allows the agent not only to "feel" an emotion when an event happens, but also by anticipating future events (before-emotions) and evaluating past events (after-emotions). Expectation-based emotions are generated by the combination of beliefs and desires in a particular state, considering also the intensity related to the importance of the desire.

The proposal of (Bosse and Höhle, 2011) is based on (Gratch and Marsella, 2004) work. Emotions are generated as a result of the evaluation of events through desires and are influenced by beliefs. Two types of emotion are modeled, happiness and sadness, but the model can also be used to model emotions like anger and fear. They do not differentiate between emotion elicitation and emotion experience but they work with the concept of intensity proportional to the strength of the desire. Their proposal differentiates from all the other because they include mood modeling as it will be discussed in section 2.2.4.

As most of the proposals in the formalization group are based on BDI logics, they may be not expressive enough to accommodate all assumptions of psychological emotion theories. For example, most of them are purely qualitative; however, emotions differ not only in quality but also in intensity, which is important to explain certain effects of emotions. In this regard, proposals like the one of (Dastani and Lorini, 2012), that combines a dynamic knowledge logic with a logic for graded beliefs and desires can provide a more wide range of constructs to enrich the modeling of emotions. Most of them miss also another important issue: the emotional influence on cognitive reasoning, i.e., how the emotions can help agents to choose the most rational action to be performed, and how the emotions can improve the way agents reason, decide or act.

Regarding the proposals that are BDI extensions, they are mainly (all except two of the selected proposals) based on the OCC theory either alone or combined with other theories. Proposals based only on the OCC theory, manage the process emotional elicitation in a similar way: an event is appraised in terms of beliefs, desires and intentions and a certain score regarding its valence (negative/positive, displeasure/pleasure) and arousal (intensity of the elicited emotion) is returned. Their main differences consist of the emotions they model and the consideration of additional concepts that directly affect the cognitive and affective process. The proposal of (Neto and da Silva, 2012) is the only that models the 22 OCC emotions. The other proposals focus on modeling a specific branch of the OCC emotions, like the case of (De Rosis et al., 2003) that models the event-driven category and of (Dyke Parunak et al., 2006) that models only two emotions. Other works like (Ochs et al., 2010) and (Boukricha and Wachsmuth, 2011) are based on the OCC theory but their main objective is empathy modeling, therefore they will be discussed in section 2.2.6.

Among the BDI extensions that are based only in the OCC theory the proposal of (De Rosis et al., 2003) is probably the most relevant since it is one of the first emotional BDI proposals and it is one the most cited. They propose the use of a belief network to represent the agent's mental state. They model the elicitation of a subset of the emotions: the event-driven categories of fortune of others and wellbeing and prospect-based emotions. The elicitation of emotions is determined by the variation of the agent's beliefs about whether a goal can be threatened or achieved, depending on the importance (weight) assigned to the goal. They manage the intensity of an elicited emotion using the weight of the goal. This idea of assigning weights to desires is similar to the ideas of probability of (Gluz and Jaques, 2017) and graded goals of (Dastani and Lorini, 2012). The main problem is the complexity of the proposed beliefs network, since the number of nodes increases considerably with the number of emotions modelled. Nevertheless, they make up for this problem, reducing the time required to propagate evidence and update the emotion intensities, thanks to the effectiveness of the algorithm employed. They also take into account mood, personality and regulation as discussed in sections 2.2.4, 2.2.5 and 2.2.7, respectively.

Some other OCC based proposals stand out because they consider new concepts, providing the agent with a wide range of information and resources that improve its performance in a dynamic environment. The work of (Dyke Parunak et al., 2006) include the concepts of Dispositions, Triggers and Tendencies. They extend the appraisal reasoning processes with an analysis process. The appraisal process assesses the beliefs in the context of agent disposition and returns the elicited emotion. Beliefs are mapped to digital pheromones, which inform the presence of other agents (or objects) in the environment. These pheromones act as Triggers for emotions. The analysis process determines the intentions to be committed by the agent, drawing on the pheromone vector. As it can be seen, their emotional modeling is tied to a particular situation (domain-dependent) and only two emotions are modeled.

The proposal of (Neto and da Silva, 2012) manages a memory component for past events and a memory filter that retrieves those beliefs that are aligned with the agent's current emotional state. They also consider that the emotional state of the agent is not only determined by the elicited emotions caused by an event, but also by

the agent's perception. To do so, every possible perception has associated a vector of 22 emotions, and the sum of its intensities has to be equal or greater than a minimum value so they can be taken it into account in the emotional state of the agent. Another interesting aspect is that the affective output of the emotional component is the agent's mood and not the elicited emotions.

As it was mentioned before, only two proposals are not based on OCC theory. (Lejmi-Riahi et al., 2014) emotional BDI is based on the emotional theory of (Loewenstein and Lerner, 2003) and it is oriented to deal with expected and immediate emotions. Expected emotions are predictions about the emotion that will be experienced if the decision is taken, and immediate emotions refer to the emotions felt at the time of the decision-making. In contrast with the proposals that model OCC, they propose three appraisal process: incidental stimulus appraisal (for immediate emotions elicitation), and emotional option and cognitive option appraisal (for expected emotions elicitation). Immediate emotions generation is influenced by beliefs and intentions and expected emotions generation is influenced by immediate emotions, desires, and intentions. The proposal of (Pereira et al., 2005), unlike all the previous ones, is open to the implementation of any emotional theory; they do not detail how emotions are modeled, but just the interaction between the emotional component and the BDI process. Their main contribution is the introduction of two interesting concepts: Capabilities and Resources. The idea of introducing these concepts comes from identifying some disadvantages of the BDI model such as the lack of information about resource bounds, of a dynamic deliberation process and of the consideration of other mental states different than beliefs, desires and intentions. They define capabilities as a library of available abstract plans that the agent owns and resources as the way of converting these abstract plans into action plans. Resources can be either physical (disk space, available memory, etc.), virtual (energy sources on a virtual world, other agents, etc.), or both. The emotional component manages both the resources and the capabilities and the availability or unavailability of capabilities depends on the availability of the required resources.

The proposals that combine different cognitive and non-cognitive theories of emotion are oriented to model the elicitation and representation of a high diversity of emotions (primary, secondary and tertiary) and to consider additional affective concepts such as mood, personality and regulation. Three of the proposals are based

on the Damasio and OCC theories and they model primary and secondary emotions. Of them, the proposal of (Becker-Asano and Wachsmuth, 2008) stands out for being one of the most cited and being used in different applications domains. Their model combines the OCC and the Damasio theory for emotion elicitation and the PAD model for emotional representation. Primary emotions are modeled as inborn affective states that are triggered by reflexes in the case of harmful stimuli, determining the reactive behavioral responses of the agent. Secondary emotions are model as a more complex affective state and their elicitation depends much more on the situational and social context than that of primary emotions. The proposal of (Puica and Florea, 2013) focus on simulating human mechanisms of internal resource usage and agent personality following the ideas of (Pereira et al., 2005) and of (Jones et al., 2009), respectively. They combine the theory of Damasio to represent primary and secondary emotions, the OCC theory for emotion elicitation and the Russell's theory for emotion representation. Alfonso et al. (Alfonso et al., 2014) also follow the theories of emotion of (Ortony Andrew et al., 1990) and Damasio (1984). They include the modeling of the surprise emotion, not considered in OCC, which can be either a primary or secondary emotion. (Hernández et al., 2004) combines Damasio (Damasio, 1994) with Sloman (Sloman, 2002) theory (not OCC). They propose an emotional component composed of a three-level belief system that generates three emotional levels: primary, secondary and tertiary. Although tertiary emotions are not implemented, this is the first attempt to consider them. They use also model emotional representation in a dimensional space (valence; arousal) based on the ideas of (Breazeal, 2002).

As a conclusion, most of the proposals are based on just one theory (being OCC very prominent) but the idea of combining several theories is interesting and should be further explored. It would allow widening the type of emotions considered to some of them that are practically unexplored, such as Sloman's tertiary emotions. Another interesting aspect is the combination of elicitation and representation emotion theories. In this sense, the OCC theory combined with the PAD model is often used, but other interesting theories such as the Russell and PANAS theories for emotional representation may also be used. Moreover, the consideration of new concepts (resources, capabilities, triggers, tendencies, information not only acquired by perception) provides the agent with a wide range of information and resources and may improve its performance in dynamic environments.

In Table 2.2 the revised proposals are presented showing the emotional theory they are based on and the specific emotions modeled. The way these works consider the other affective aspects will be commented in next sections.

Table 2.2

The proposals reviewed showing the theory in which the emotional modeling is based on and the emotions they model. (F: Formalization; Ex: BDI extension).

	Proposal	Category	Emotional theory	Emotions modeled
Non-Cognitive	Bosse and de Lange (2008)	F	Ekman et al. (1972)	anger, happiness and fear
	Jiang et al. (2007)	Ex	Damasio (1994)	primary and secondary emotions Unspecified
	Jones et al. (2009)	Ex	Damasio (1994)	fear/hope, anger/gratefulness, shame/proud and reproach/trust
Cognitive	Meyer (2006)	F	Oatley and Jenkins (1996)	free floating emotions: happiness, sadness, anger and fear
	Bosse and Zwanenburg, (2009)	F	Castelfranchi and Lorini (2003)	expectation-based emotions: before-event (hope and fear) and after-event (surprise, (dis)satisfaction, relief, and disappointment)
	Adam et al. (2009)	F	OCC theory (Ortony et al., 1990)	event-based and agent-based emotions
	Bosse and Höhle (2011)	F	Based on Gratch and Marsella (2004)	Happiness and sadness
	Dastani and Lorini (2012)	F	OCC theory (Ortony et al., 1990)	prospect-based emotions: hope, fear, joy, sadness and distress

Table 2.2. (Continued)

	Proposal	Category	Emotional theory	Emotions modeled
Cognitive	Gluz and Jaques (2017)	F	OCC theory (Ortony et al., 1990)	event-based emotions with consequences for self-based
	De Rosis et al. (2003)	Ex	OCC theory (Ortony et al., 1990)	event-based emotions
	Dyke Parunak et al. (2006)	Ex	OCC theory (Ortony et al., 1990)	event-based (fear) and agent-based (anger) emotions
	Van Straalen et al. (2009)	Ex	OCC theory (Ortony et al., 1990)	Unspecified
	Ochs et al. (2010)	Ex	Own model of emotions, based on theoretical approach	satisfaction, frustration, irritation, sadness, and anger as empathic emotions
	Boukricha and Wachsmuth (2011)	Ex	OCC theory (Ortony et al., 1990)	primary emotions (happy, surprised, angry, annoyed, bored) and empathic emotions related
	Steunebrink et al. (2012)	Ex	OCC theory (Ortony et al., 1990)	event-based, agent-based and object-based emotions
	Neto and da Silva (2012)	Ex	OCC theory (Ortony et al., 1990)	event-based, agent-based and object-based emotions
	Lejmi-Riahi et al. (2014)	Ex	Loewenstein and Lerner (2003)	immediate emotions and expected emotions Unspecified
	Pereira et al. (2005)	Ex	Open to any theory	Unspecified

Table 2.2 (Continued).

	Proposal	Category	Emotional theory	Emotions modeled
Cognitive and non-cognitive	Hernández et al. (2004)	Ex	Damasio (1994) and Sloman (2002)	primary (fear and surprise) and secondary (happiness, sadness and anger) emotions based on Damasio and tertiary (shame or pride) emotions based on Sloman
	Becker-Asano and Wachsmuth (2010)	Ex	Damasio (1994), OCC theory (Ortony et al., 1990), Ekman et al. (1972)	primary (bored, annoyed and depressed Ekman's basic emotions) and secondary (OCC prospect-based emotions)
	Puica and Florea (2013)	Ex	Damasio (1994), OCC theory (Ortony et al., 1990), Russell (1980)	primary emotions and secondary emotions based on Damasio unspecified
	Alfonso et al. (2014)	Ex	Damasio (1994), OCC theory (Ortony et al., 1990)	primary and secondary emotions distress, excitement, contentment, depression, misery, pleasure, arousal and sleepiness

2.3.4 Mood modeling

Mood is generally recognized as the global affective state of an individual (Section 2.2.3). In spite of this, just seven of the 22 proposals reviewed model mood, being

one (Bosse and Höhle, 2011) a formalization and all other extended BDI architectures. In Table 2.3 those proposals are shown.

Table 2.3.

Proposals reviewed that model mood showing the affective theory they follow and the mood states they model.

Proposal	Affective theory	Moods modeled
De Rosis et al. (2003)	-	Not independent state
Hernández et al. (2004)	-	Not independent state
Bosse and Höhle (2011)	-	Positive and negative
Becker-Asano and Wachsmuth (2010)	PAD	Positive and negative
Boukricha and Wachsmuth (2011)	(De Vignemont and Singer, 2006)	Positive and negative
Neto and da Silva (2012)	PAD	Exhuberant, dependent, relaxed, sweet, bored, arrogant, anxious, hostile
Alfonso et al. (2014)	PAD	Exhuberant, dependent, relaxed, sweet, bored, arrogant, anxious, hostile

As it can be seen, the proposals that deal with mood in the simplest way (De Rosis et al., 2003; Hernández et al., 2004) do not follow any mood theory and do not model mood as an independent state but rather as the decay of the emotions in time. Bosse and Höhle (Bosse and Höhle, 2011) treat mood as an independent state that depends on the previous mood in combination with the weighted sum of the different emotional intensities, but without applying any explicit affective theory.

In the other four proposals mood is modelled as an independent state applying an affective theory, being the dimensional ones, and more specifically, the PAD theory the most extended. In some cases, mood is modeled directly derived from PAD space (Neto and da Silva, 2012; Alfonso et al., 2014) whereas in other it is modeled as the

agent's overall positive or negative feeling (Becker-Asano and Wachsmuth, 2010; Boukricha and Wachsmuth, 2011).

In all proposals, mood persistence in time is modeled as a decay factor that is applied in the absence of another input stimulus. In some cases, the decay factor is determined directly by the agent personality as well as mood's initial or default value (De Rosis et al., 2003; Alfonso et al., 2014). In other cases, the decay factor is determined by a linear function (Becker-Asano and Wachsmuth, 2010), as a change rate (Bosse and Höhle, 2011), or as an amount by which the current emotional state is divided (Hernández et al., 2004).

All proposals also agree in the interconnectivity between mood and emotions which results in an "emotion dynamics": emotions influence mood updating and mood influences emotion elicitation. This is empirically supported by (Neumann et al., 2001), who found that individuals in a positive mood are less likely to experience negative emotions and vice versa. The influence of mood in the emotional elicitation process is generally named mood–congruency. This bidirectional relationship has been particularly modeled in those proposals that model primary and secondary emotions. In most of the cases mood influences the elicitation of primary emotions (Alfonso et al., 2014) and in some cases, it is used directly to elicit them (Becker-Asano and Wachsmuth, 2010). In the case of (Becker-Asano and Wachsmuth, 2010) mood-congruency of secondary emotions is also considered. Other proposals model the mood-emotion relationship as a modulation factor, as is the case of (Boukricha and Wachsmuth, 2011), that implement a empathizer-mood component where a negative mood increases the potential of eliciting a negative empathic emotion and decreases the potential of a positive one. In contrast, a positive mood increases the potential of a positive empathic emotion and decreases the potential of a negative one. In the proposals that do not follow any theory this relationship is modeled through a decay factor.

As a conclusion, the consideration of mood as an independent state, modeled with an appropriated theoretical base that ties it to the emotional process, guarantees a mood-congruent emotions elicitation and, therefore, more believable intelligent agents. The consideration of personality is also essential, and is reviewed in the next section.

2.3.5 Personality modeling

Personality refers to characteristic thought patterns that persist through time and situations and that distinguish one person from another (section 2.1.4). Personality modeling is an important aspect to take into account when modeling believable affective agents. Nevertheless, personality is only considered in 8 of the 22 reviewed proposals. All of them are BDI extensions: personality is not modeled in any BDI formalization. In Table 2.4 the proposals that considered personality are presented.

Table 2.4.

The proposals reviewed in this section showing the affective theory in which the mood modeling is based on and the mood states they model.

Proposal	Personality theory	Personality modeling/specific traits or temperament or disposition
De Rosis et al. (2003)	Carbonell (1980), Ortony (2002)	Dispositions/pessimistic, optimistic
Parunak et al. (2006)	-	Dispositions/cowardice, irritability
Jones et al. (2009)	-	Traits/docility, curiosity, leadership, stressability, normativity
Becker-Asano and Wachsmuth (2010)	-	Temperaments/sluggish, moody
Boukricha and Wachsmuth (2011)	-	Temperaments/temperamental, lethargic
Neto and da Silva (2012)	Big Five (McCrae and John, 1992)	Traits/neuroticism, extroversion, openness, cordiality, agreeableness
Puica and Florea (2013)	Hippocrates-Galen 4 temperaments theory (Merenda, 1987) and Eysenck's theory (Eysenck 1967)	Temperaments/sanguine, choleric, melancholic, phlegmatic
Alfonso et al. (2014)	Big Five (McCrae and John, 1992)	Traits/neuroticism, extroversion, openness, cordiality, agreeableness

They have been grouped depending on whether they model personality as traits (i.e., neuroticism), temperaments (i.e., lethargic) or behavioral dispositions (i.e., irritability). Half of them follow domain-independent theoretical approaches (McCrae and John, 1992; Merenda, 1987; Eysenck, 1967; Carbonell, 1980; Ortony, 2002) which means that the considered traits/temperaments/dispositions are not tied to a particular type of situation, and can be used to model several scenarios. Proposals that do not detail any affective theory are prone to model traits/temperaments/dispositions as domain-dependent. This is the case of (Jones et al., 2009) and (Dyke Parunak et al., 2006), that model specific traits and behavioral disposition tied to crisis and combats simulation situations, respectively. In the other cases, such as in (Becker-Asano and Wachsmuth, 2010) and (Boukricha and Wachsmuth, 2011), personality is modeled just as a parameter value that determines how emotional the agent is.

Personality modeling is related to emotion and mood modeling. The relationship between personality and mood is quite close, as it is generally modeled based on the idea that mood changes depending on the individual personality traits. In this regard, in most of the proposals the agent's default or initial mood value is set according to the agent's personality traits, directly influencing its updating and decay factor during the interaction.

On the contrary, (Puica and Florea, 2013) just model personality and emotions. In this case, the relationship is modeled through two variables, emotion intensity, and decay, linked to introversion/extraversion and stable/unstable traits respectively (Eysenck, 1967). Finally, the proposal of (Neto and da Silva, 2012) models the three affective aspects interconnected. In this case, the relationship is modeled through the well-known ALMA model (Gebhard, 2005), that allows the mapping between emotions, mood and personality (see section 2.2.4).

As a conclusion, the use of a theoretical approach allows the obtaining of domain-independent solutions and a more realistic modelling of the relationships between emotions, mood and personality. Nevertheless, these relationships need to be more intensively explored. Only the PAD and the Big Five theory have been used to model the personality-mood relationship, but as commented in section 2.2.4, there are others interesting proposals such as Russell and PANAS theories that can be connect to Big Five, or even to another personality theory such as (Eysenck, 1967). The same happens with emotion-mood-personality relationship where OCC-PAD-Big Five has

been the only molded through the (Gebhard, 2005) work. Thus, a formalized approach as well as a more interconnected modeling of personality in BDI agents remain to be done.

2.3.6 Empathy modeling

It is generally accepted that the modeling of the empathy in intelligent agents is very important in order to improve their human-like behavior, especially the human-user interaction. In spite of this, most of the works just model empathy through the OCC emotional theory or based on simple empirical rules, as explained in section 2.2.5. In this section we will comment the two BDI extensions that were found that deal with empathy modeling (see Table 2.5).

Table 2.5.
The reviewed proposal that model empathy, showing the empathic theory in which they are based on and the empathic emotions they model.

Proposal	Empathy theory	Empathic emotions modeled
Ochs et al. (2010)	Own model of emotions, based on theoretical approach (Scherer, 1988; Ortony et al., 1990; Frijda et al., 1992; Lazarus, 1991)	satisfaction, frustration, irritation, sadness, and anger as empathic emotions
Boukricha and Wachsmuth (2011)	(Hoffman, 2000; Davis, 1994; De Vignemont & Singer, 2006; Ortony et al., 1990)	primary emotions (happy, surprised, angry, annoyed, bored) and empathic emotions related

The proposal of (Ochs et al., 2010) is based on empirical and theoretical approaches (Scherer, 1988; Ortony Andrew et al., 1990; Frijda et al., 1992; Lazarus, 1991). They make us of their own emotional model where the emotion generation process is related to a particular event and the emotional intensity corresponds to the emotional impact of the event. To model empathy the intelligent agent has a mental representation of other's mental state. The agent deduces user's intentions from the enunciation of user's communicative acts. Agent´s empathic emotions elicitation

depends on the success or failure of user's intentions: when events that affect user´s intention occur, the agent feels an empathic emotion.

The proposal of (Boukricha and Wachsmuth, 2011) presents a more complete mechanism to model intelligent agents' empathic emotions. The emotional state and empathic emotions of the agent are represented in the PAD space and primary and secondary emotions are modeled. The proposal is based on theoretical approaches (Hoffman, 2000; Davis, 1994; De Vignemont and Singer, 2006; Ortony Andrew et al., 1990) and presents three processes to model empathy: Empathy Mechanism, Empathy Modulation and Expression of Empathy.

The Empathy Mechanism is responsible for the outcome of the empathic emotions based on perceived emotional facial expressions of others. They define a predefined saliency threshold that represents agent´s responsiveness to the other's situation. If the elicitation of the empathic emotion takes place, it is affirmed as belief and the second and third process occur. The second process is the modulation of the empathic emotion intensity (Empathy Modulation component) based on several predefined factors: mood, personality and social relationship to the other. Finally, the third process (Expression of Empathy) occurs and the empathic emotion expression is triggered.

As a conclusion, empathy is scarcely modeled in BDI extensions and not modeled at all in formalizations: it remains an open research question.

2.3.7 Regulation modeling

As mentioned before (section 2.2.6), there are two concepts related to regulation: coping, directed to negative emotions regulation, and emotional regulation, oriented to both positive and negative emotions. Following that distinction, the reviewed proposals are presented in Table 2.6. Most of the review proposals in this section are BDI extensions, but also two formalizations can be found: one related to coping, (Dastani and Lorini, 2012), and the other, (Bosse and de Lange, 2008), related to emotional regulation.

Regarding coping, the proposal of (Becker-Asano and Wachsmuth, 2010) presents a simple coping mechanism, not based on any theory, that just considers reappraisal in the emotion module. The other three proposals deal with coping in different ways as they are based on different theories. (Van Straalen et al., 2009) model coping in

Table 2.6.

The reviewed proposals that model emotional regulation, the regulation theory they apply and the regulation strategies modeled.

Proposal	Regulation theory	Regulation type (ER or C)/Strategies
De Rosis et al. (2003)	-	ER/Masking emotions mechanism
Bosse and Lange (2008)	Gross (1998)	ER/ a parameter that measures the emotional regulation speed to its original or default state
Van Straalen et al. (2009)	(Kübler-Ross, 2009)	Coping/Denial, Isolation, Anger, Bargaining, Depression, and Acceptance
(Becker-Asano and Wachsmuth, 2010)	-	C/ simple mechanism related to emotional reappraisal process
(Dastani and Lorini, 2012)	Lazarus (1991)	C/ related to beliefs, goals and intentions
Alfonso et al. (2014)	Castelfranchi (2000)	C/ plans prioritization strategy

*ER: Emotional regulation; C: Coping

bad news scenarios. They propose a categorization of coping strategies based on the theory of (Kübler-Ross, 2009) about terminal patients: Denial and Isolation, Anger, Bargaining, Depression, and Acceptance. The emotional BDI proposed by (Alfonso et al., 2014) is based on the ideas of (Castelfranchi, 2000); they propose a coping component that determines if the changes on current mood deserve to take actions in cognitive processes. In those cases, the way intentions are selected is changed using a plan prioritization strategy. In the formalization proposed by (Dastani and Lorini, 2012) coping modeling is based on (Lazarus, 1991) theory. Three coping strategies are modeled: strategies affecting intentions (removing/generating them), strategies affecting beliefs (increasing/reducing their strength) and strategies affecting goals (increasing/reducing their strength).

Regarding emotional regulation, juts two proposals have been found. (De Rosis et al., 2003) present a simple mechanism of masking emotions formalized with context-dependent rules without explicit theoretical foundation. They consider aspects such as the interlocutors' personalities, their relationship and the social

interaction context. In the case of (Bosse and de Lange, 2008), the regulation process is modeled following (Gross, 1998) theory. They introduce a parameter that measures the speed to return the emotional response level to its default state. For example, after an unpleasant event an agent may stay in an emotional state (i.e., angry) for a long time or leave the event behind quickly, depending on the values of the regulation parameter.

As we see, coping has been modeled far more than emotional regulation. The latter has only been modeled in very simple ways that represent a starting point in this unexplored line of investigation.

2.3.8 Affective influence on cognitive process

As commented in section 2.2.7, nowadays it is clear that the individual affective state affects the cognitive process. Due to this connection, it is important the consideration of the affective influence on the cognitive process when modelling intelligent agents.

Only three of the proposals reviewed (Adam et al., 2009), (Steunebrink et al., 2012) and (Gluz and Jaques, 2014) do not consider the affective influence on the cognitive process. All of them are based on the OCC theory that does not describe this emotional influence. The other works implement the affective influence on different steps of the BDI cognitive process. In Table 2.7 the emotional BDI proposals and the affective influence on the BDI cognitive process are shown. The first column shows the theoretical base of the affective influence management. In half of them, the modeling of the affective influence is not based on theoretical foundations but just on intuitive evidences learned from psychological literature. On the contrary others are based on affective theories well-known in intelligent agent modeling such as (Castelfranchi and Lorini, 2003), (Damasio, 1994), (Lazarus, 1991) and (Loewenstein and Lerner, 2003) and (Frijda, 1987).

As it was explained in section 2.2.7, the affective influence can be modeled in several steps of the cognitive process such as beliefs, perceptions, decision-making, memory and behavior. In emotional BDIs this is done following the steps of the BDI cognitive process (section 2.3.1): perception, belief updating, options generation, intention filtering, and actuation. In the proposals reviewed, intention filtering is the BDI cognitive process most influenced. This influence is mainly done by emotions, but in two cases mood and coping alter the process. Another cognitive aspect in which affective influence has been widely modeled is

Table 2.7.

The proposals reviewed and the influence of agent's emotions (E) or (Other's) emotion, mood (M), personality(P), empathy (Emp), coping (C) and emotional regulation (ER) on the BDI cognitive processes, as well as the theoretical bases of these influences.

Proposal	Theoretical basses	Perception	Belief updating	Options generation	Intension filtering	Actuation
De Rosis et al. (2003)	-	-	-	E/P	-	E/ER
Hernández et al. (2004)	Castelfranchi (2000), Canamero (2000)	-	E	E	-	-
Pereira et al. (2005)	-	E	E	E	E	E
Parunak et al. (2006)	-	-	-	-	E	-
Meyer (2006)	-	-	-	-	E	-
Jiang et al. (2007)	Damasio (1994), Frijda, Manstead, and Bem (2000)	-	E	E	E	-
Bosse and de Lange (2008)	Gross (1998)	-	-	E	-	-
Jones et al. (2009)	-	-	E/P	P	E	-

Table 2.7. (Continued).

Proposal	Theoretical basses	Perception	Belief updating	Options generation	Intension filtering	Actuation
Bosse and Zwanenburg, (2009)	Castelfranchi and Lorini (2003)	-	-	-	-	E
Van Straalen et al. (2009)	Folkman and Lazarus (1980), Carver, Scheier, and Weintraub (1989)	-	-	-	-	C
Becker-Asano and Wachsmuth (2010)	-	-	-	-	E	-
Ochs et al. (2010)	-	Other's E	-	Emp	-	-
Boukricha and Wachsmuth (2011)	-	Other's E	Emp	-	-	-
Bosse and Höhle (2011)	-	-	E	E/M	E	M
Neto and da Silva (2012)	Gazzaniga and Heatherton (2006), Izard (1993), Damasio (1994)	M	M	-	M	-

Table 2.7. (Continued).

Proposal	Theoretical basses	Perception	Belief updating	Options generation	Intension filtering	Actuation
Neto and da Silva (2012)	Gazzaniga and Heatherton (2006), Izard (1993), Damasio (1994)	M	M	-	M	-
Dastani and Lorini (2012)	Lazarus (1991)	-	C	C	E/C	-
Puica and Florea (2013)	-	E	E	-	E	-
Lejmi-Riahi et al. (2014)	Loewenstein and Lerner (2003)	E	E	E	E	-
Alfonso et al. (2014)	Niedenthal and Setterlund (1994), Castelfranchi (2000)	M	-	-	M/C	-

beliefs updating. In this case, emotions are also the affective aspect that influences the most, but mood, personality and affective capacities (coping and empathy) influences have also been modeled. The other cognitive aspect widely considered in the literature is the motivational state of the agent. In the case of the BDI architecture, this corresponds to the options generation process where the agent's desires/goals are generated. Even though it is true that emotional influence is also the aspect most considered, this is the only step where the

influence of all the affective aspects has been modeled, including affective capacities such as empathy, emotional regulation and coping. Perception (influenced by emotions and mood) and actuation (influenced by emotions, mood and affective regulation) are the processes in which the affective influence has been less considered.

As it has been already commented, emotional influence is the most widely aspect considered in the literature. It is modeled by directly affecting the way perception is achieved, by directing attention towards belief-relevant information, by prioritizing desires and/or by helping to select intentions. In our review, the proposals of (Pereira et al., 2005), (Jiang et al., 2007), and (Lejmi-Riahi et al., 2014) stand out. They are the most referenced ones that consider the emotional influence on most of the BDI process. The proposal of (Pereira et al., 2005) takes into account the emotional influence on all the cognitive process. Nevertheless, they do not explicitly detail how the influence is implemented: they make an overview on how the emotional state of the agent modulates the decision-making process according to the availability of resources and capabilities. In the case of (Jiang et al., 2007), they take into account the influence of primary and secondary emotions on belief updating, option generation and intention filtering. They use emotions to set the priority of desires and help to decide intentions. To do so, they follow the idea of some researchers (Camerer et al., 2003) that point out that decision making may actually be driven by emotions, since people with emotional impairments have trouble making decisions. The proposal of (Lejmi-Riahi et al., 2014) takes into account the influence of secondary emotions in almost all the BDI cognitive processes. They follow the theory of (Loewenstein and Lerner, 2003) that establishes two ways in which emotions can influence at the time of decision making: as anticipated consequences (expected emotions) and as feelings experienced at the time of decision making (immediate emotions). Immediate emotions influence all cognitive processes except actuation. In the case of expected emotions, the influence is modeled in the options generation process. This way, they propose a complex cognitive-affective processing that makes it possible to model other types of behaviors that are not directly product of decision.

Another way to influence decision making is through a more permanent affective state such as mood. Only three of the reviewed proposals consider this influence. In the case of (Bosse and Höhle, 2011) (that is the only that presents a formalization) they do not detail the theoretical foundation of their modeling. Mood and emotional influence are modeled in the same way: as rules that are mostly domain-specific and define the impact of emotions and mood on the BDI cognitive process; for instance, a positive mood increases the desire to cooperate with teammates, and a negative mood increases the desire to behave aggressively. The other two proposals model mood's influence independently of emotional influence. Their mood's influence modeling is based on theoretical foundations and focuses on perception and decision making and in memory in the case of (Neto and da Silva, 2012). Both proposals model the influence on perception based on the same idea: mood can intensify or blur perceptions: depending on agent's mood the same sensation may generate different perceptions. Regarding the mood's influence on decision making, they model it in different ways. In (Neto and da Silva, 2012) proposal it is modeled in the updating beliefs and intention filtering processes. This is implemented through emotional markers (Damasio, 1994) that allow tagging actions with emotional states, in such a way that actions can be selected through the corresponding emotional states that tag them, and vice-versa. In contrast, (Alfonso et al., 2014) only model mood influence on the intention filtering process: if the changes experimented in the current mood deserve to take actions, this will determine the intentions selected.

Regarding personality, there are two proposals (BDI extensions) that model its influence on the BDI cognitive process: (De Rosis et al., 2003) and (Jones et al., 2009). In both proposals the personality influences the options generation process, but in different ways. In the case of (De Rosis et al., 2003), personality traits are related to certain goal weights directly affecting the intensity of the elicited emotions. In (Jones et al., 2009) they consider the influence of the agent's physiological state but it is not detailed. They also model the influence of personality (and emotions) on the belief updating process, in particular, in the way new beliefs are interpreted.

Affective capabilities also influence the BDI cognitive processes. As in precedent sections, we will analyze affective regulation and empathy.

Proposals that consider regulation (coping and emotional regulation) influence have all a strong theoretical foundation. In general, both emotional regulation and coping have direct influence on agent decision making and final behavior. Coping modeling has been modeled as a mechanism that directly affects the intention filtering and/or actuation process, determining various types of responses. In (Alfonso et al., 2014) coping influences the intention filtering process through a mechanism of plan's prioritization according to the agent's current mood. In the case of (Van Straalen et al., 2009), as their particularly interested in the way the agent responds to bad news, coping alters the actuation process, both influencing the behavior selection and the manifestation of the selected behavior. (Dastani and Lorini, 2012) present a more complete model. Following the idea that coping can be seen as a cognitive mechanism whose aim is to discharge a certain emotion by modifying one or more of the mental attitudes that triggered the emotion, they consider it in beliefs updating, options generation and intention filtering. This is done by looking over an intention, by changing the agent's interpretation of the situation, by changing a belief or a goal's strength.

Regarding emotional regulation influence, just one proposal has been found that models it. In (De Rosis et al., 2003) the influence of emotional regulation is in the actuation process: it affects directly agent's expression, masking elicited emotions. This does not necessarily imply the elimination of an emotion but the variation of its intensity or its duration. In the case of (Bosse and Lange, 2008), that also consider emotional regulation, they do not model a direct influence of regulation on the agent's cognitive process. The influence is indirect on the agent emotional response level, which in turn, influences the motivational state of the agent.

The influence of empathy in the cognitive process is modeled in the two proposals that consider empathy modeling (section 2.2.6). In both of them, the other's emotions influence the cognitive process in the perception process. Besides, the agent empathic emotions influence the option generation process in the case of (Ochs et al., 2010), and the belief updating in (Boukricha and Wachsmuth, 2011) proposal.

As a conclusion, the BDI cognitive phases influenced and how this influence is modeled varies greatly from one proposal to another. Emotions influence is taken into account in most of the proposals, mood and personality to a lesser extent. The belief updating process and the intention filtering process are the processes most influenced by emotions, mood and, in a lesser extent, by personality. Options generations process is frequently influenced by a combination of some affective aspects such as emotions and mood or emotions and personality. The influence of affective capacities (affective regulation and empathy) is scarcely modeled and remains nowadays an open line of research. In general, the actuation process is the most influenced by coping and emotional regulation as it's related to the final behavior of the agent. Empathy has been modeled to influence the belief processing and the options generations processes.

2.4 Conclusions: good practices and open questions

After the review presented in the last section some common features, good practices and open questions can be extracted. We present them grouped by affective aspect.

Emotions

Emotions are short-lived affective states that arise suddenly in the context of a specific stimulus. Nowadays it is recognized as mandatory to endow the agent with an emotional model if believability is sought. In most of the proposals, emotions influence the cognitive process in several ways: in perception, motivation and decision-making processes or at least a combination of them.

Good practices:

- Emotional modelling should be based on an established emotional theory. It is recommended that emotional modeling includes both primary and secondary emotions.
- It is recommended to combine emotional elicitation theories with dimensional theories to allow a more complete emotional modeling and to facilitate the modeling of emotion-mood dynamics.
- It is important to quantify emotions in terms of their intensity, to be able to differentiate between emotions of the same type such as irritation, anger, rage. It makes it possible also to consider if an emotion is actually experienced once elicited.

- Emotions should influence perceived information and all processes of BDI reasoning (updating beliefs, generating desires and obtaining intentions). To do so, several theories of emotion have to be combined.

Open questions:

- It is still missing a proposal that allows managing the emotional influence on all the BDI phases.
- Tertiary emotions' modeling is missing.
- It is still a challenge an efficient modeling of mood-congruent emotion elicitation.

Mood

Mood, as a more durable affective state, has been shown to impact a range of cognitive, perceptual and behavioral processes, and the emotional elicitation (mood-congruent emotions). Nevertheless, in many of the proposals, it is just considered as an unattributed affective basis to which emotions decay.

Good practices:

- Mood should be modeled as an independent affective state rather than just as the decay of emotions.
- Mood should influence all the phases of the BDI process.
- The relationship between mood and other affective states such as emotions and personality should be considered:
    - It is common to consider personality when calculating the agent's initial mood or mood "by default".
    - Mood updating process should be influenced be the elicited emotions. A good practice is to relate it to the intensities of the emotions experienced.
    - The mood of the agent should be taken into account in the emotion generation, in particular, in the calculation of the intensity of the elicited emotions.

Open questions:

- It is still missing a proposal that models, an in efficient way, the mood's influence on the emotion elicitation process to obtain mood-congruent emotions.
- The modeling of the influence of mood on every BDI cognitive phase is still missing.

Personality

Personality is considered a long-term affective state that does not change over time. This way personality can be used to differentiate one agent of another.

Good practices:

- Even though the Big Five model is the most used personality model, others such as The four temperaments and the one proposed by (Carbonell, 1980) should be also considered depending on the agent´s context.
- Personality should be taken into account in the emotional generation process and mood decay time.
- Personality should influence the BDI cognitive process together with other affective states.

Open questions:

- It still missing an efficient modeling of personality's influence on cognitive and affective processes.

Empathy

Empathy is the capacity to understand or feel what another person is experiencing from within his or her frame of reference. Empathic experience is related to the other's cognitive-affective state. Empathy should be considered if believable agent-user interaction is sought.

Good practices:

- To model empathy it is necessary to have the representation of other's mental attitudes.
- Empathy should be modeled in its two variants: cognitive and affective.
- Empathic emotions should influence the decision process as do non-empathic ones.

Open questions:

- A complete and theoretically based modeling of empathy in emotional BDI agents is still missing.

Regulation

Regulation modeling is focused on coping with stressing situations and regulating both negative and positive emotions. In the proposals that model coping, the

regulatory process influences the selection of the agent's behavior and how it is expressed. On the other hand, the proposals that model emotional regulation are focused on the regulation of the emotional response.

Good practices:

- The regulation process should influence not only the emotions displayed by the agent but its behavior.
- Both coping and emotional regulation should be implemented. To do so, the Gross theory (Gross, 1998) stands out as it allows coping strategies to be integrated into the emotional regulatory process.

Open questions:

- The works that consider regulatory mechanisms are scarce and it still an open question how to integrate these issues in the general BDI scheme.
- Empathic emotion regulation aiming to regulate emotion both within the provider and across interaction partners has not been yet considered in any proposal.
- Mood regulation modelling is missing. Larsen theory (Larsen, 2000) could be a good starting point. The consideration of mood regulation would open the door to a more wide consideration of regulation (the so-called Affective Regulation).

As it can be seen, in spite of the great advances in the modeling of affective intelligent agents, there is no proposal that models the influence of emotions, mood and personality in all the BDI phases. In this regard, it is interesting to highlight, that in some of the works, the affective state of the agent is a component composed by personality, mood and emotions, and it is the result of this interaction what influences the cognitive BDI process. This an interesting point of view that allows the modeling of emotion-mood-personality dynamics and its influence on BDI cognitive process. Other relevant affective capabilities such as regulation and empathy still require a strong research effort. It is true that in many cases the open research questions detected are related to open psychological questions without generally accepted models. In this regard, a more intense inter-disciplinary exchange between psychology and computer science could make it possible to significantly advance in the challenge of understanding and modelling human emotions. As we see, several open questions remain and a complete and integrated emotional BDI proposal is still missing. This is why the scope of the thesis has focused on the cognitive-affective

modeling of emotional in BDI agents. Our proposal, includes emotions, mood, personality and affective capabilities, such as emotional and mood regulation modeling, what puts the framework among the most advanced EBDIs.

CHAPTER 3: The proposed cognitive-affective framework: The ABC-EBDI framework

3.1 Introduction

The main objective of this chapter is to presented the proposed cognitive-affective-behavioral framework named ABC-EBDI. First of all, the ABC model on which it is based is presented, next all the components of the proposed framework are described. Finally, conclusions are presented. The content of this chapter has been published in (Sanchez et al., 2020) and (Sánchez et al., 2019).

3.2 The ABC model

This thesis focuses in the modeling on how an individual feels, what he/she thinks and his/her conduct in adverse situations. To do so, we propose the ABC-EBDI framework, which is the result of applying a psychotherapeutic model, the ABC model (Ellis, 1962), (Ellis and Harper, 1975), (Ellis, 1980), (Ellis, 1994) intensively used in the therapeutic ambit, to the EBDI scheme. The proposed EBDI framework models affect taking into account emotions, mood and personality, and affective capacities such as affect regulation. The choice of the ABC model is based mainly on the following reasons:

- When the ABC model emerged, it became a landmark as it presented cognition and affect in a unified manner. The application of the model to a BDI scheme would allow integrating cognition, emotion and conduct in the simulation of the behavior of intelligent agents.
- A correspondence can be established between the BDI concepts of beliefs, desires and intentions and the ABC concepts of a beliefs system, desires and conduct.

The ABC model is one of the most widely accepted theories in the psychological therapeutic field and is the main guide in the practice of Rational Emotive Behavior Therapy (REBT) (David, 2003). This model has served as the basis of most of the psychotherapeutic models existing today and its success lies in the connection between the individual´s beliefs (cognitions) and their emotional and behavioral consequences. This relationship is specified as follows: when an event A (adversity) occurs, the beliefs (B) held over A can be irrational or rational. Irrational beliefs lead to consequences (C) that are behaviorally maladaptive and emotionally dysfunctional, and rational ones lead to consequences (C) that are behaviorally adaptive and emotionally functional. Both types of emotions

(dysfunctional and functional) can be either negative or positive. The acronym to refer to irrational beliefs is IB (Irrational Belief) and to rational beliefs RB (Rational Belief). Fig. 3.1 shows the basic scheme of the ABC model.

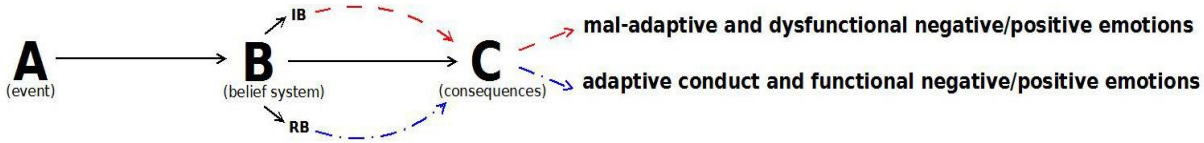


Fig. 3.1. Basic schema of the ABC model.

For a better understanding of the model, next section provides an overview of what each element (A, B and C) means, and how they relate to each other.

3.2.1 A, B, and C: Meaning and relationship

In the ABC model, A is understood as an event that can be an objective situation, feelings, conduct or past or future thoughts and memories, which are in some way related to the current situation. The belief system (B) represents the individual's beliefs, but in a broad sense as it includes thoughts, memories, images, assumptions, inferences, attitudes, attributions, norms, philosophy of life, etc. (CATREC, 2013). In fact, the beliefs system is the core of the ABC theory. Thus, B represents the beliefs (cognitions) about (A) which are determined by their directional source (self, other, or world/life conditions) and can be either rational or irrational. The irrational or rational content of beliefs leads to emotional and behavioral consequences (C). For a better understanding of how the model works, we will use an example: suppose a patient receives a diagnosis of cancer. In this case, the event (A) is: The doctor informs the patient that he has terminal cancer. If the patient's belief about this event is: "I have cancer, but I have to face it" (rational), the consequences would be adaptive conduct and negative functional emotions such as sadness. If, on the contrary, if the belief is: "I have cancer and I cannot stand it" (irrational), the consequences would be maladaptive conduct and negative dysfunctional emotions such as depression.

The consequences (C) may give rise to a new activating event A1, related to beliefs B1 leading to consequences C1, and so on. In this process, beliefs B1 are known as meta-cognitions (e.g. irrational or rational reflections on the agent's own

thoughts), and C1 as meta-consequences (e.g. concern about being sad). In Fig. 3.2, the dynamic of the process is shown.

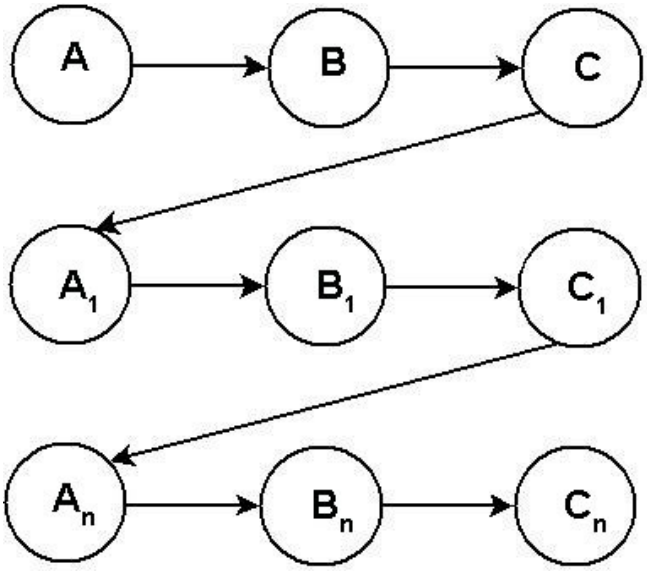


Fig. 3.2. The dynamic process of the ABC model.

Beliefs are the most important component in the model, so they are detailed next.

3.2.2 Beliefs (B)

Ellis argues that beliefs (cognitions), emotions, and conduct are interconnected (Ellis et al., 2010). According to Ellis, people **believe** they want something, they **desire** to do so, and they **act** to implement their beliefs and desires. Desires represent the individual's motivational state, and following this, Ellis argues that beliefs are assertions of desires. Beliefs are determined by their directional source (self, other, or world/life/conditions) and their evaluative content (Irrational or Rational). Irrational belief content is rigid, illogical, and/or has no empirical support, or is non-pragmatic (i.e., "*I cannot have cancer*"). The content of rational beliefs is flexible, logical and/or has empirical support or is pragmatic (i.e., "*I wish I didn't have cancer*") (Ellis et al., 2010). Emotions and conduct that derive from irrational beliefs are dysfunctional and maladaptive, respectively. Irrational beliefs are the most widely studied in the field of psychotherapy. Initially, Ellis (Ellis, 1980) defined only two irrational beliefs but these were later

extended to eleven. Table 3.1 shows the eleven general irrational beliefs established by Ellis (Ellis, 1994).

Subsequently, the eleven irrational beliefs were classified into four fundamental categories:

- **Demandingness** (*DEM*): These are absolutist demands, expressed in the form of "must", "should" and "ought". They include two evaluative components of how desirable it is and what can really be expected. An example of an irrational belief with a demanding character could be: "*I must be be able to face a cancer diagnosis*" (Corresponds to general irrational belief V in Table 3.1).
- **Awfulizing** (*AWF*): This refers to the evaluation that an individual makes about a situation as something very bad or catastrophic and evaluates it as the worst that can happen. An example of a catastrophic irrational belief would be: "*I cannot do anything; this is only the beginning of the end. I will die inevitably!* "(Corresponds to general irrational belief VI in Table 3.1).
- **Global evaluation/self or other-downing** (*GE/SD*): This refers to how an individual tends to make an excessively negative evaluation of himself, of others or the world in general. An example of an irrational belief of this type would be: "*Maybe, because of this, they will stop loving me and I won't stand it.*" (Corresponds to general irrational belief I in Table 3.1).
- **Low frustration tolerance** (*LFT*): This refers to the inability of an individual to face the situation. An example of an irrational belief of this type could be: "*I don't feel able to face this by myself. I will put myself in their hands*"(Corresponds to general irrational belief VIII in Table 3.1).

Demandingness (DEM) is considered as the main category within the irrational beliefs classification. Demanding beliefs are considered primary beliefs since they are those that directly provoke maladaptive conduct and dysfunctional emotions. Thus, when processing the content of beliefs to identify their irrational character and categorize them, a sequence is established (Ellis et al., 2010): first the demanding character (DEM) is determined, and secondly, if it is related to catastrophism (AWF) and/or low tolerance to frustration (LFT), and/or global evaluation (GE/SD).

As mentioned before, demanding beliefs (DEM) are the core of the irrational evaluative process and that is why they have been the most extensively studied.

Table 3.1

Ellis's general irrational beliefs (Ellis, 1994).

General Irrational Beliefs (IBs)
IB-I - It is an extreme need, for the adult human being, to be loved and approved by every significant person in his environment.
IB-II - To consider myself as a valid person, I must be very competent, sufficient and able to achieve anything that I propose.
IB-III - People who do not act as they "should" are vile, evil and infamous and should be punished for their evil.
IB-IV - It is terrible and catastrophic that things do not work out as one would like.
IB-V - Human disgrace and discomfort are brought about by external circumstances, and people have no ability to control their emotions.
IB-VI - If something is or can be dangerous, I must be terribly worried about it and I must constantly think about the possibility of it happening.
IB-VII - It is easier to avoid the responsibilities and difficulties of life than to confront them.
IB-VIII - I must depend on others and need someone stronger to trust.
IB-IX - What happened to me will always continue affecting me.
IB-X - We must be very concerned about the problems and disturbances of others.
IB-XI - There is a perfect solution to every problem and if we do not find it, it would be catastrophic.

According to Ellis (Ellis et al., 2010) there are three fundamental types of demanding beliefs (DEM) :

- Demands for Comfort (DEM comfort): those related to comfort and equity/rights. An example could be: "*I am worried that with this hanging over me, my family might not love me anymore*" (Corresponds to general irrational belief I in Table 3.1).
- Self-related demands of achievement and competence (DEM achievement and competence): those related to oneself, one's achievements and personal competence. An example could be: "*I cannot afford to be weak in this situation*" (Corresponds to general irrational belief II in Table 3.1).

- Demands for control (DEM control): those related to rigid and dominant conduct. An example could be: "*I have cancer because of the kind of life that circumstances force me to live*" (Corresponds to general irrational belief V in Table 3.1).

On the other hand, rational beliefs, because they guide adaptive conduct and functional emotions, have been less widely studied. In the literature, rational categories can be found, but not explicit beliefs alternative to the irrational beliefs presented in Table 3.1. The rational categories (Ellis et al., 2010) are:

- **Preferences**: These refer to preferentially desiring something and they are expressed in the form of "*I want*" and "*I wish*". An example could be: *"I wish I had no cancer"*.
- **Non-awfulizing** (*non-AWF*): This refers to a flexible negative evaluation done by an individual for not having satisfied his or her preferences. Recognizing the bad side of the situation can help you find positive aspects. An example could be: *"I want to concentrate on what I have to do now"*.
- **Unconditional acceptance** (*non-GE/SD*): This is the antidote to the irrational belief/global/critical evaluation (GE/SD). The individual accepts him/her self, others or the world unconditionally and evaluates only very specific aspects of him/her self (what we are doing, thinking, feeling), others and the world. An example could be: *"Life does not always turn out as one would wish"*.
- **High frustration tolerance** (*FT*): This refers to the tolerance capacity of an individual when preferences are not met. An example could be: *"I am the one who decides what is the best for me and I know all the possibilities"*.

Preferences are the main rational category (primary). If a belief is evaluated as preferential, it is classified as rational, and subsequently (secondary) the non-awfulizing (non-AWF), high tolerance to frustration (FT) and/or unconditional acceptance (non-GE/SD) categories are analyzed.

The impact of an event (A) that results in emotional and behavioral consequences, (C) is mediated by an appraisal process of the beliefs (B) that is explained next.

3.2.3 Appraisal process

The ABC model establishes that there is an appraisal process of (B) over (A) that leads to emotional and behavioral consequences (C). Beliefs about an event (A) are represented in the form of cognitions in the human mind. In the literature, the terms "cold" and "hot" are used to distinguish between what is known and what is evaluated (Abelson and Rosenberg, 1958). Thus, the two basic types of cognitions most commonly used in the literature are referred to by the terms “cold cognitions” and “hot cognitions”. Cold cognitions (also known as automatic thoughts) refer to the way in which individuals develop representations of relevant events. An example of cold cognitions are descriptions (i.e., It's raining) and inferences (i.e., If it rains there is no party). Cold cognitions may generate operant behaviors, learned conduct under our voluntary control, having a direct impact on the environment (Spiegler et al., 1993). Hot cognitions are a type of evaluative cognition that refers to the way individuals appraise cold cognitions (consciously and/or unconsciously) in terms of their personal well-being. Hot cognitions are those that directly influence the emotional generation process, since cold cognitions do not generate emotions by themselves (Ellis et al., 2010). Examples of hot cognitions are Ellis’s irrational and rational beliefs.

Ellis's original work does not detail the appraisal process, so we rely on later works such Ellis and Policy (Ellis and Policy, 2012) to examine it. In Ellis and Policy (Ellis and Policy, 2012) a general appraisal process that follows the ABC model is explained. The work describes the type of consequences (C) that are obtained: negative or positive dysfunctional/functional emotions and maladaptive or adaptive conduct. According to this work, the appraisal process has two phases: a primary and a second secondary appraisal.

In the primary appraisal process, **desires** are generated from irrational or rational beliefs. Desires generated by irrational beliefs are irrational, and those generated by rational beliefs are rational. The first step of the process involves the consideration of three appraisal components:

- **Demandingness** vs **Preferences**: This determines whether the desire is demanding or preferential. In the previous example: *"I can’t have cancer"* (demanding) vs *"I would prefer not to have cancer, but I know it is something that can happen"*(preferential).

- **Motivational relevance**: This determines if the event is relevant to an individual according to his or her life goals. In the previous example, a life goal could be *"To be healthy"* and, following this, the fact of having cancer is a relevant event because it conflicts with a life goal.
- **Acceptation** vs **Non-acceptation**: This determines whether or not an individual accepts the situation. In the previous example, it could be: *"I accept that sometimes life doesn't turn out the way I want"* vs *"I cannot accept being sick"*.

The motivational relevance component is the most important since it determines whether the individual is going to experience emotions or not. When an individual faces an event, he/she experiences emotions if the event is relevant according to his or her desires and personal well-being, otherwise he/she doesn't experience emotions at all.

The second step of the first appraisal process analyzes whether or not the event fits the desires. This is known as **motivational congruence**. It is defined as the way an even fits or not human desires. Motivational congruence is a key component since it determines the character (negative or positive) of the emotions that the individual will experience. If the event fits the individual's desires (motivational congruence), the emotions that are experienced are positive (either dysfunctional or functional). On the contrary, if the event doesn't fit desires, there is no motivational congruence (motivational incongruence) and the secondary appraisal process begins and negative (either dysfunctional or functional) emotions will be experienced. Notice that motivational congruence and motivational relevance are both related to desires, but are different concepts since an event can be motivationally relevant, but incongruent at the same time (i.e., lethal cancer).

The secondary appraisal process is carried out from three perspectives: self, others and/or life and also involves three evaluative components:

- **Low frustration tolerance** (*LFT*) vs **High frustration tolerance** (*HFT*): This determines whether or not an individual tolerates a situation according to the nature of his or her formulated desires. For example, "*I cannot bear to have cancer*" vs "*I don't like to have cancer, but I' ll face it*".

- **Awfulizing** (*AWF*) vs **Non-awfulizing** (*non-AWF*): This determines if a situation is the worst that could happen vs a nuanced negative evaluation. For example, "*To have cancer is the worst thing in the world*" vs "*It's really bad to have cancer, but it's not the end of the world.*"
- **Global evaluation** (*GE/SD*) vs **Unconditional acceptance** (*non-GE/SD*): This determines if a situation is evaluated as totally bad or if it is accepted by evaluating only specific and discrete aspects. For example, *"It's life's fault" vs "It's bad to have cancer, I do not take enough care of my health."*
- The irrational or rational character of beliefs not only determines the nature of the generated desires but also the nature of the emotional and behavioral consequences, as explained next.

3.2.4 Consequences (C): Conduct and emotions

Consequences (C) resulting from the ABC model can be emotional or behavioral. Behavioral consequences can be maladaptive or adaptive depending on the irrationality or rationality of underlying beliefs. Since irrational beliefs are the most widely studied in the field of psychotherapy, many maladaptive conducts have been identified. Table 3.2, based on the work of Ellis et al. (Ellis et al., 2010), shows the main maladaptive conducts derived from irrational beliefs. In the table, the irrational beliefs are shown according to the categories mentioned before (*DEM, LFT, AWF, GE/SD*) together with the possible maladaptive conduct. The emotional and behavioral consequences deriving from rational beliefs have been less widely studied, since they represent the desirable conduct of individuals when facing an adverse situation.

The resulting emotions can be dysfunctional or functional depending on the irrationality or rationality of the beliefs, and positive or negative depending on the motivational congruence, as seen in the previous section. Originally Ellis and Harper (Ellis and Harper, 1961) suggested that dysfunctional and functional emotions could be differentiated by their intensity, but a subsequent review of the theory (Ellis and Harper, 1975) established that the distinction between dysfunctional and functional emotions was fundamentally qualitative and not quantitative.

Table 3.2

Maladaptive conducts relative to categories of irrational beliefs (based on (Ellis et al., 2010)).

Maladaptive Conduct	Category of irrational beliefs
I - Hostile dominant interpersonal style	DEM control
II - Behavioral avoidance, procrastination, reduced anger control, overspending, increased anger expression, relational problems	DEM comfort
III - Increased anger expression, social avoidance and isolation, decreased performance in social context	DEM achievement and competence
IV - Submissive interpersonal style, social isolation, increased anger expression	Awfulizing (AWF)
V - Decreased anger control, increased anger expression, increased anger suppression, social isolation, behavioral avoidance	Low frustration tolerance (LFT)
VI - Defensiveness to negative feedback, increased anger suppression, aggressive anger expression	Global evaluation/self or other-downing (GE/SD)

Consistent with this view, David et al. (David et al., 2004) concluded that it is their qualitative character (negative vs. positive) and the nature of the cognitive content (*irrational vs. rational*) of the emotions, and not their intensity, that differentiates them. The ABC model does not detail the generation of specific emotions but establishes a relationship between beliefs, emotions and human conduct. Several works have been developed on the theoretical basis of the ABC model to investigate and validate the role of irrational and rational beliefs in the emotion-cognition relationship, and the elicitation of specific emotions (David et al., 2005), (Master and Gershman, 1983), (Kassinove et al., 1993), (Cramer and Fong, 1991). Among the different paradigms used to validate the model, the works based on appraisal theories of emotions stand out, such as the proposal of David et al. (David et al., 2002), based on Smith and Lazarus (Smith and Lazarus, 1993).

David et al. (David et al., 2002) propose the validation of the ABC model as a theory of emotional generation and describe the elicitation of four specific negative dysfunctional emotions and four specific negative functional emotions. The framework presented in this thesis is based on that work, so a broader explanation of it is given within the framework explanations in next section.

3.3 The ABC-EBDI framework

The proposed ABC-EBDI framework is an EBDI framework, that is, an extension of the BDI cognitive framework, to support affective modeling, including emotions, mood, personality and affect regulation. The objective of this section is to give a general overview of the conceptual model of the framework, as well as to detail the processing of beliefs and the obtaining of the behavioral and affective consequences.

3.3.1 General overview

First of all, the mapping between the concepts of the ABC model and the cognitive-affective-behavioral process of the ABC-EBDI framework is explained (see Table 3.3). To establish the connection between the BDI process and the ABC model we follow the idea of Ellis (see section 3.2.2): *People **believe** they want something, they **desire** to do so, and they **act** to implement their beliefs and desires*. What "*people believe*" in the ABC model is the beliefs system. In the present framework the original BDI concept of beliefs is extended and defined as the agent Beliefs system which is composed of what the agent believes about an activating event, the information about self and the environment and its operant behavior. What the agent believes about an activating event is represented as context beliefs that are processed in the framework to establish their irrational or rational character. The information about self and the environment (original BDI belief concept) is represented as basic beliefs in the framework. The agent's reactive behaviors are represented as operant behaviors that define preconfigured conducts.

What "*people desire"* is the motivational state of the agent. As in the original BDI, it is represented by desires (goals), but they are also classified into irrational or rational following the ABC model. The "*actions that people perform to implement their beliefs and desires*" are the behavioral consequences together with their related emotional state in the ABC model.

Table 3.3

ABC-EBDI concepts regarding BDI and ABC models.

Concepts	BDI model	ABC model	ABC-EBDI model
Beliefs	Information about self and the environment	What people believe about an event, defined as belief system. It includes mainly individual's irrational/rational beliefs.	-The information about self and the environment (basic beliefs) -What the agent believes about the activating (context beliefs) - Reactive conducts of the agent (operant behaviors)
Desires	Motivational state, goals	Motivational state expressed in demanding or preferential way	Motivational state, goals. Classified as irrational or rational. They can be generated in demanding or preferential way according to irrational or rational beliefs.
Intentions	Commitments to achieve desires or goals	-	Commitments to achieve irrational/rational desires.
Conduct	-	What an individual experiences when an activating event occurs. It can be emotional, cognitive, behavioral, and physiological in nature. Classified as maladaptive or adaptive depending on beliefs' irrationality or rationality	The way the agent behaves when an activating event occurs. It comprises how actions are performed, either in a maladaptive or adaptive way, and how the those actions are expressed (body gestures, facial expression and voice).
Actions	Set of actions plans for achieving desires or goals	Set of actions that people perform to implement their beliefs and desires	Set of actions plans to achieve irrational/rational desires.

These behavioral consequences comprise not only the actions, but also how those actions are performed (in a maladaptive or adaptive way) according to the underlying behavior derived from irrational/rational beliefs, and how those actions are expressed in terms of body gestures facial expressions, voice, etc.). Following this idea, in the ABC-EBDI framework, the concept of the agent's conduct is introduced: it comprises how actions are performed and how those actions are expressed. Intentions, like the original BDI model, are the commitments to implement what the agent believes and desires. Each intention has a set of action plans to fulfill irrational/rational desires. In Fig. 3.3 the relationship between a generic EBDI framework the ABC model and the proposed ABC-EBDI framework is presented. In the figure, it can be seen that the proposed framework, extends EBDI's cognitive and emotional components, with the concepts of the ABC model. The cognitive components are extended with the irrational/rational concepts and a new component is added, Conduct, to consider the behavioral dimension. The emotional component is also extended, with the dysfunctional/functional concepts, and includes personality, mood and affective regulation, based on well-known affective theories.

In the ABC-EBDI framework (see Fig. 3.4), components and processes have been defined to allow integrating affect, affective capacities and behavioral modeling in the logical reasoning process of the BDI agents. Components and processes explanation follows.

COGNITIVE MANAGEMENT COMPONENTS

- Percepts (perc): What the agent perceives objectively.
- Beliefs system (B): They comprise what the agent believes about an event, the information about itself and the environment, and the reactive behavior of the agent. The system starts with three sets: basic beliefs (B_o), context beliefs (B_c) and those that represent operant behaviors (B_{op}).
- Irrational/Rational Beliefs ($B_{I/R}$): They are defined as the set resulting from evaluating context beliefs (cold cognitions) by hot cognitions (irrational/rational general beliefs of Ellis).
- Desires (D): They represent the motivational state of the agent and are obtained in a demanding or preferential way based on the irrational/rational character of beliefs ($B_{I/R}$). This way, they are classified

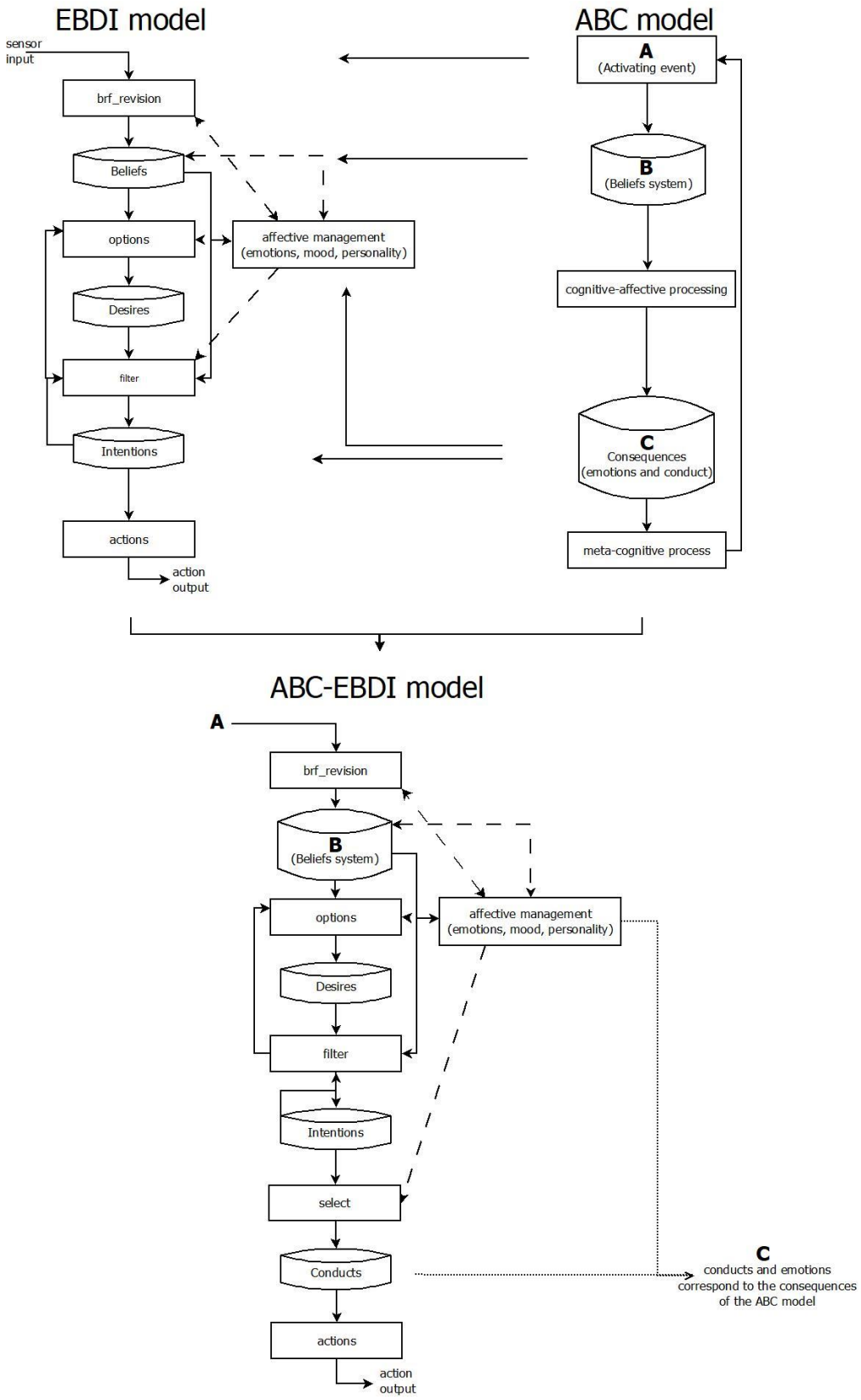


Fig. 3.3. Relationship between an EBDI generic model, the ABC model and the proposed ABC-EBDI model.

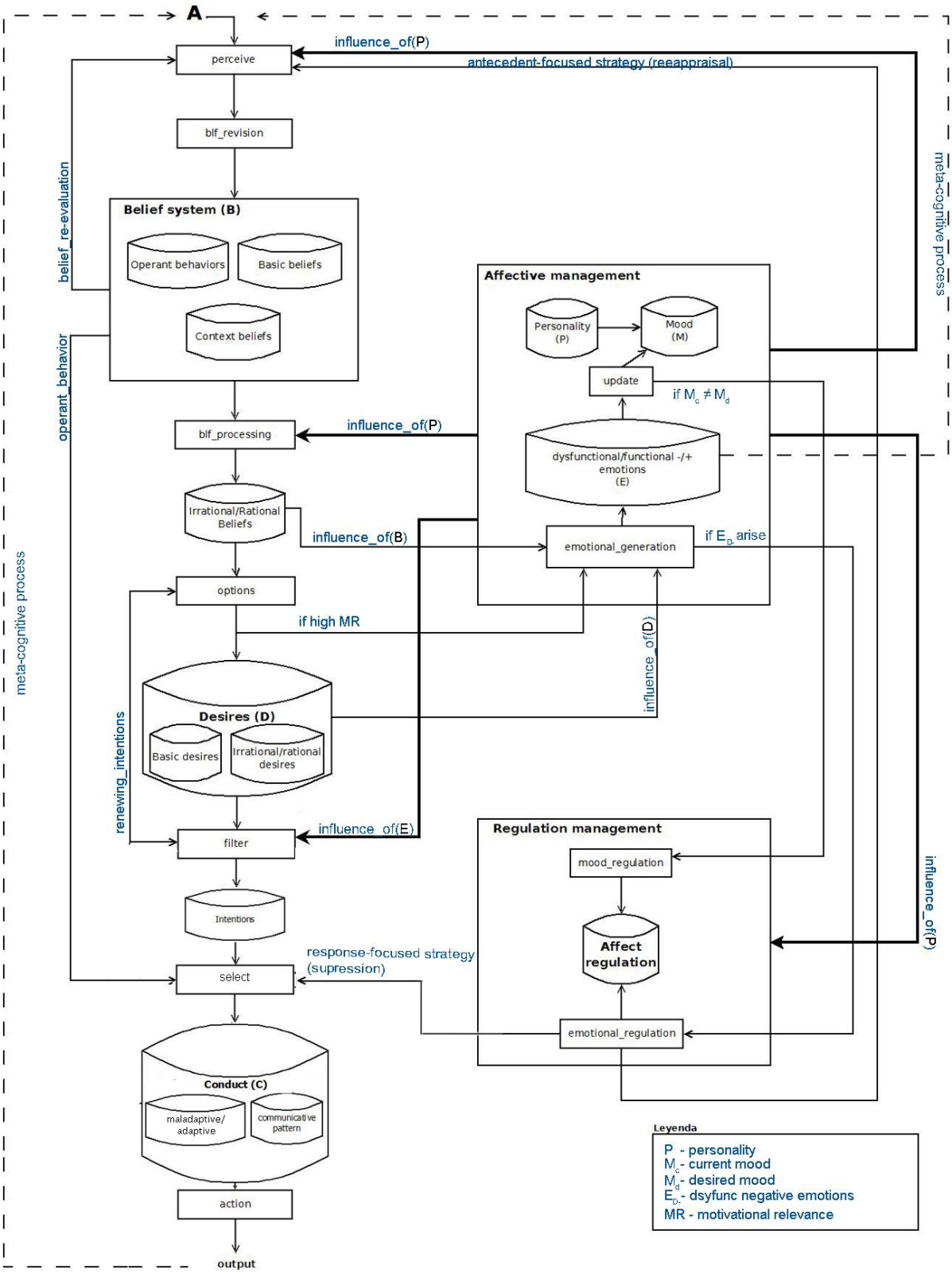


Fig. 3.4. The proposed ABC-EBDI framework.

as irrational or rational (D_I or D_R) depending on the nature of beliefs ($B_{I/R}$). The system starts from two sets: basic desires (D_o) and context desires (D_c).

- Intention (I): They represent the options that the agent has to achieve its desires ($D_{I/R}$), as in classical BDI.
- Conduct (C): It comprises two perspectives, subjective (based on ABC consequences model) and objective (based on Satir's communicative patterns (Andreas and Satir, 1991)), explained in section 3.3.3. Subjective conduct refers to how actions are performed (maladaptive (C_M) or adaptive (C_A)) and objective conduct refers to how those actions are expressed (body gestures, facial expressions and how are expressed verbally), depending of the irrationality or rationality of context beliefs. The system starts from two sets: conducts related to the operant behaviors (C_{op}) and context conducts (C_c) related to context desires.

AFFECTIVE MANAGEMENT COMPONENTS

- Personality (P): It is defined according to the OCEAN model (McCrae and John, 1992) that defines the agent personality through five traits: openness (O), consciousness (C), extraversion (E), agreeableness (A), neuroticism (N).
- Mood (M): It is defined according to the two-factor model (also known as PANAS (Watson and Tellegen, 1985)), which establishes two axes for its definition (valence and arousal). Two mood states are considered: current and desired. The initial value of current mood (M_c) is determined according to the context and the desired mood (M_d) according to the agent's personality.
- Emotions (E): They are classified as dysfunctional or functional and negative or positive following the ABC model (E_{D-}, E_{D+}, E_{F-}, E_{F+}).

REGULATION MANAGEMENT COMPONENTS

- Affect regulation: It is defined as a general category of regulation that includes mood regulation and emotional regulation:
    - Mood Regulation (MR): It follows Larsen's model (Larsen, 2000), and it is activated if the current mood changes with respect to the desired mood (M_d).

- Emotional Regulation (ER): It follows the Gross model (Gross, 1998) and two strategies are modeled: an antecedent-focused strategy (reappraisal) and a response-focused strategy (expression suppression).

PROCESSES

The functions that allow the agent cognitive-affective-behavioral processing are the following:

- *perceive*: It processes the information perceived by the agent and returns the perceptions (perc) about the event A.
- *blf_revision*: Returns beliefs about A according to the perceived information. There are three sets: basic beliefs, context beliefs (B_c) and operant behaviors (B_{op}).
- *blf_processing*: Processes context beliefs (B_c) to classify them as irrational/rational ($B_{I/R}$) (influenced by personality (P)).
- *options*: Determines the irrational/rational character of desires ($D_{I/R}$) and also whether emotions are elicited or not.
- emotional_generation: Generates dysfunctional/functional emotions ($E_{D/F}$). Involves two processes:
  - *primary_appraisal*: Determines the dysfunctional/functional nature and the negative and positive character of the emotions(E_{D-}, E_{D+}, E_{F-}, E_{F+}) that will be elicited.
  - *secondary_appraisal*: Determines the specific emotions that will be elicited.
- *mood_regulation*: Regulates agent's mood; influenced by agent personality (P).
- *emotional_regulation*: Regulates agent's emotions; influenced by agent personality (P).
- *filter*: Filters intention (I) to achieve irrational/rational desires ($D_{I/R}$).
- *select*: Selects the agent conduct ($C_{M/A}$) (comprises if actions are performed/executed in maladaptive or adaptive way and how they are expressed; influenced by emotions ($E_{D/F}$)).
- *action*: Executes actions.

The process is as follows: When an event (**A**) occurs, the agent perceives (***perceive***) the environment or its internal state, and perceptions (***perc***) about A arise. Later on, beliefs are reviewed (***blf_revision***) based on the new information. Depending on the activating event type (adversity or not), from the reviewing process three types of beliefs about A can be obtained: operant behaviors (B_{op}) or basic beliefs (B_o) and context beliefs (B_c). If beliefs related to operant behaviors (B_{op}) arise, the cognitive process directly selects (***select***) the conduct (how actions are performed and how they are expressed), to finally execute the action (***action***). Basic beliefs (B_o) represent the general information that the agent has. Context beliefs (B_c) are processed (***brf_processing***) and classified as irrational/rational beliefs ($B_{I/R}$). The process is influenced by the agent's personality and determines the irrational or rational tendency of the evaluation process (see section 3.3.2). Beliefs may be reviewed (***belief_reevaluation***) depending on the dynamics of the environment.

After the belief's revision process, irrational/rational desires (D_I and/or D_R) are obtained (***options***). The system starts from two sets of desires: basic desires (D_o) and context desires (D_c), obtained in a demanding or preferential way. The process follows the original BDI idea; desires' irrational/rational nature depends on beliefs irrationality/rationality and their evaluation is as follows:

- If the context beliefs set is irrational (B_I), context desires are obtained in a demanding (**DEM**) way and are, therefore, irrational (D_I).
- If the context beliefs set is rational (B_R), context desires are obtained in a preferential (**Preferences**) way and are, therefore, rational (D_R).

In this stage (options) the event is also evaluated to know if it is motivationally relevant (according to the desires) to elicit emotions. Motivational relevance defines the agent's affective level of involvement when facing an event (A). An event evaluated with low motivational relevance does not generate any emotion and the agent acts without an emotional component. On the contrary, if the event is evaluated with high motivational relevance (***if high MR***), the agent will "feel" emotions and the emotional generation process (***emotional_generation***) starts (see section 3.3.4).

The emotional generation process (***emotional_generation***) involves two evaluative processes: ***primary and secondary appraisal***. In the first

evaluative process (***primary_appraisal***) the component of motivational congruence is evaluated to determine the negative/positive character, and the dysfunctional/functional nature of the elicited emotions. The secondary evaluative process (***secondary_appraisal***) determines the specific emotions that will be elicited. Eight dysfunctional/functional negative emotions (anger/annoyance, guilt/remorse, anxiety/concern and depression/sadness) and three positive emotions (gratitude, happiness and pride) (see section 3.3.4.1) are modeled. Besides, the agent mood (M) is updated (***update***) according to the elicited emotions (see section 3.3.4.2).

A fundamental feature of the framework is the modeling of affect regulation mechanisms that, in our case, includes emotional regulation and mood regulation.

Emotional regulation modeling follows the Gross model and uses its two more relevant strategies: reappraisal (***antecedent_focused_strategy***) and emotion-expressive suppression (***response-focused strategy***). The agent chooses one or another depending on the agent's personality (section 3.3.4.3). An emotional regulation mechanism (***emotional_regulation***) focused on antecedent emotion regulation (***antecedent_focused_strategy***) starts if dysfunctional negative emotions are elicited (***if E_{D-} arise***). In that case strategy the agent chooses a different meaning for the event (***reappraisal***) which initiates a reassessment of beliefs (***belief_reevaluation***) to change the dysfunctional negative emotions into functional negative or positive ones. In the case of an emotional regulation mechanism focused on response (***response_focused_startegy***), the agent suppresses the outgoing emotional behavior, by means of the suppression strategy (***suppression***).

Mood regulation modeling is based on the Larsen model. According to Larsen, the agent's desired mood state (M_d) is determined by its personality (see section 5.4.2). Every time that the agent current mood changes (***update***) it is checked if there are discrepancies between current mood (M_c) and the desired mood (M_d) (***if $M_c \neq M_d$***). If this is the case, the agent executes the regulatory mechanism (***mood_regulation)*** to reduce discrepancies (see section 3.3.5.2). The regulation process is detailed in section 3.3.5.

Afterwards, intentions (I) are filtered (***filter***) according to the irrational/rational desires ($D_{I/R}$) generated. The process is the same as in the original BDI processing and provides the deliberative character to the model.

Finally, conducts are selected (**select**) and actions are performed and expressed according to the selected conduct. The process is influenced by the irrational/rational character of desires and the dysfunctional/functional nature of emotions. This means that if desires are irrational (D_I) and emotions are dysfunctional, the conducts will be maladaptive (C_M) and, on the contrary, if desires are rational (D_R) and emotions are functional, the conduct will be adaptive (C_A). As stated before, the agent conduct involves how actions are perfomed or executed (in maladaptive or adaptive way) and how the agent will express those actions (body gestures, facial expressions, linguistics structures and voice). Conduct modeling is detailed in section 3.3.3. Once the conduct is selected, actions are executed (***action***).

During the process, the agent pays attention to the changing dynamics of the environment to detect if intentions are no longer needed. In this case, the agent must consider abandoning them, restarting the deliberation process and renewing intentions (***renewing_intentions***). The agent also takes into account its internal state as a new activating event, which means that the emotional state of the agent can be another activating event. In this case, the agent reasons about their own feelings and thoughts, which generates beliefs about their beliefs (meta-cognitions), that will lead to emotions and conducts (meta-consequences) (i.e., being angry for being anxious).

Once the general overview is given, more in depth explanations follow.

3.3.2 Beliefs system and beliefs processing

In the present framework, as in the original BDI, the agent's beliefs system is what it believes about an activating event and also the information about self and the environment. Beliefs cognitive processing results in a set of irrational/rational beliefs that condition the agent's emotional and behavioral consequences. The agent's belief system is defined based on three perspectives (self, other, life) and it is composed of basic beliefs (B_o), context beliefs (B_c) and operant behaviors (B_{op}):

- Basic beliefs (B_o): They define the general information of the agent about itself and the environment. A basic belief is represented by two dimensions: semantic content and perspective. For example, semantic content: *I am 57 years old,* perspective: *self*.
- Context beliefs (B_c): They represent what the agent believes about an activating event and are represented in the form of cold cognitions. They are evaluated to determine the irrational or rational character. The two basic forms of cold cognitions are inferences (if A then B) and descriptions (objective description of the event). For example, an objective description of an event could be: *Peter hasn't greeted me* and an inference could be: *If Peter hasn't greeted me, then Peter doesn't like me*. A context belief is represented by three dimensions: semantic content, perspective and context. For example, in the previous inference, the semantic content is: *If he hasn't greeted me, then he doesn't like me*, its perspective: *other* and its context*: Peter*.
- Operant behavior (B_{op}): They define how the agent reacts to an event without mediating a complex cognitive processing because it is something predefined. An operant behavior is represented by two dimensions: event type and action. For example, when an event of imminent danger (*event type*) occurs, the agent knows that it has to run away (*action*), so the agent reacts directly and runs.

In our framework, the process of evaluating context beliefs is called *belief processing*. Beliefs processing (***belief_processing***) determines the beliefs irrational or rational character and their categorization. The process of evaluating context beliefs consists of the semantic evaluation of its content, taking into account whether their content is rigid/flexible, illogical/logical and not pragmatic/pragmatic. To do so, the general irrational beliefs of Ellis (Table 3.1) and the complementary rational beliefs shown in Table 3.4 are used. Complementary rational beliefs are obtained identifying the opposites of the irrational beliefs from three global perspectives: self, other and life.

Rational and irrational general beliefs (hot cognitions) can be further classified (see Table 3.5). The categorization we propose is based on the work of (Ellis et al., 2010) and it is fundamental in the subsequent processes of eliciting emotions and

selecting conducts. For example, an inference of the type of: *If I have cancer my family will stop loving me* (self), has a rigid, illogical and non-pragmatic evaluative semantic content that corresponds to the first Ellis' irrational belief (see Table 3.1) which, following Table 3.5 corresponds to a DEM Comfort primary category related to self-downing (SD). On the other hand, if the inference is more general, related to other/life (*If I have cancer no one will love me*), it also corresponds to the first Ellis' irrational belief but it falls into the secondary category of global evaluation (GE). The process results in the set of irrational/rational beliefs ($B_{I/R}$) that are those that lead to dysfunctional/functional emotions and maladaptive/adaptive conducts. The process is influenced by the agent personality (***influence_of (P)***) because an individual with a high value of neuroticism (N) has a strong tendency to have cold cognitions (context beliefs) with rigid, illogical and non-pragmatic content about an event A, whether an agent with a high value of extraversion (E), will tend to be more flexible, logical and pragmatic (see section 3.3.4.3).

Table 3.4

General rational beliefs.

General Rational Beliefs (*RBs*)
RB-I - I accept my own limitations and mistakes, and my behavior is not conditioned by the continuous search for recognition and approval of others (self).
RB-II - Each person has the right to act according to his or her criteria, without me having to expect them to behave according to what I expect, need, or consider right (other).
RB-III - Life and its circumstances happen in an independent way to my needs and it is me who must adapt to manage the possibilities and difficulties that arise (life).

The process of evaluating context beliefs results in a set of irrational/rational beliefs ($B_{I/R}$) composed of the original context beliefs and their corresponding irrational or rational categorization. The irrational or rational character of the beliefs conditions, not only the cognitive components (Desires, Intentions), but also the emotional and behavioral outputs.

Table 3.5

Proposed irrational/rational beliefs categorization.

General Irrational beliefs (IB)	Primary and Secondary Categories
IB-I - It is an extreme need, for the adult human being, to be loved and approved by every significant person in his environment.	Primary - DEM comfort Secondary - Global evaluation/self or other-downing (GE/SD)
IB-II - To consider myself as a valid person, I must be very competent, sufficient and able to achieve anything that I propose.	Primary - DEM achievement and competence Secondary - Global evaluation/self or other-downing (GE/SD)
IB-III - People who do not act as "should" are vile, evil and infamous and should be punished for their evil.	Primary - DEM control Secondary - Global evaluation/self or other-downing (GE/SD)
IB-IV - It is terrible and catastrophic that things do not work out as one would like.	Primary - DEM achievement and competence Secondary - Awfulizing (AWF)
IB-V - Human disgrace and discomfort are brought about by external circumstances, and people have no ability to control their emotions.	Primary - DEM control Secondary - Global evaluation/self or other-downing (GE/SD)
IB-VI - If something is or can be dangerous, I must be terribly worried about it and I must constantly think about the possibility of it happening.	Primary - DEM comfort Secondary - Awfulizing (AWF)
IB-VII - It is easier to avoid the responsibilities and difficulties of life than to confront them.	Primary - DEM comfort Secondary - Low frustration tolerance (LFT)

Table 3.5 (Continued).

General Irrational beliefs (IB)	**Primary and Secondary Categories**
IB-VIII - I must depend on others and need someone stronger to trust.	Primary - DEM comfort Secondary - Low frustration tolerance (LFT)
IBIX - What happened to me will always continue affecting me.	Primary - DEM comfort Secondary - Global evaluation/self or other-downing (GE/SD)
IB-X - We must be very concerned about the problems and disturbances of others.	Primary - DEM comfort Secondary - Global evaluation/self or other-downing (GE/SD)
IB-XI - There is a perfect solution to every problem and if we do not find it, it would be catastrophic.	Primary - DEM achievement and competence Secondary - Awfulizing (AWF)
General rational beliefs (RB)	**Primary and Secondary Categories**
RB-I - I accept my own limitations and mistakes, and my behavior is not conditioned by the continuous search for recognition and approval of others.	Primary – Preferences Secondary - Unconditional acceptance (non-GE/SD)
RB-II - Each person has the right to act according to his or her criteria, without me having to expect them to behave according to what I expect, need, or consider right.	Primary – Preferences Secondary - High frustration tolerance (non-LFT)
RB-III - Life and its circumstances happen in an independent way to my needs and it is me who must adapt to manage the possibilities and difficulties that arise.	Primary - Preferences Secondary - Non-awfulizing (non-AWF)

3.3.3 Modeling conduct

Human conduct is subjectively conditioned by underlying factors behind human actions and how those actions are objectively expressed in term of specific body gestures and facial and verbal expressions. The factors that conditions the subjective part of human conduct are culture, attitudes, emotions, thoughts (beliefs), ethics, and/or even, genetics. At the same time, human conduct has the objective part, that refers to how human actions are expressed regarding body gestures, facial expressions, also how they are expressed verbally. In the proposed framework we model conduct as a component that involves both perspectives in terms of how agent's actions are performed (subjective conduct) and how they are expressed (objective conduct). To model them, the ABC and the Satir model (Andreas and Satir, 1991) are used, respectively.

To model how intentions are performed (subjective conduct), we follow the ABC model idea of behavioral consequences that can be maladaptive or adaptive depending on the irrationality or rationality of beliefs (see section 3.2.4). Therefore, the agent conduct is classified either as maladaptive or adaptive: maladaptive conducts are derived from irrational beliefs and adaptive ones from rational beliefs. To model how intentions are expressed (objective conduct) the communicative patterns, defined by the Satir model, are used. They allow the definition of the specific,body gestures, facial expressions, voice, intonation and linguistic structures used by the agent. The agent subjective conducts (maladaptive/adaptive and related to operant behaviors) that have been considered are explained first, and later, the communicative patterns to model objective conduct will be presented.

Maladaptive conducts related to the irrational beliefs are shown in Table 3.2. In the case of adaptive conducts, they are not well documented, and in this work they have been defined as the opposite of some of the main maladaptive behaviors related to irrational beliefs. In Table 3.6, adaptive behaviors in relation with the rational beliefs categories are presented.

As stated before, in the framework, not only the conduct related to an irrational or rational cognitive process is modeled, but also the one related to operant behaviors. The conduct related to an operant behavior (C_{op}) is defined according to the normal expected conduct that the agent should perform. For example, in the case of an

operant behavior of: *In the light of greeting,* the action of *To Greet* would be performed and expressed in the normal or expected way in situations of this type. Therefore, the conduct related to operant behavior will be always, adaptative performed and expressed with a leveling communicative pattern as explained next.

Table 3.6

Adaptive conducts relative to rational beliefs category.

Category of rational beliefs	**Adaptive conduct**
Preferences	Controlled conduct
Unconditional acceptance (non-GE/SD)	Non-aggressive conduct
Non-awfulizing (non-AWF)	Fluid, open conduct
High frustration tolerance (FT)	Facing conduct

To model how actions are expressed (objective conduct), the communicative patterns defined by the Satir model (Andreas and Satir, 1991) are used (see Fig 3.5).

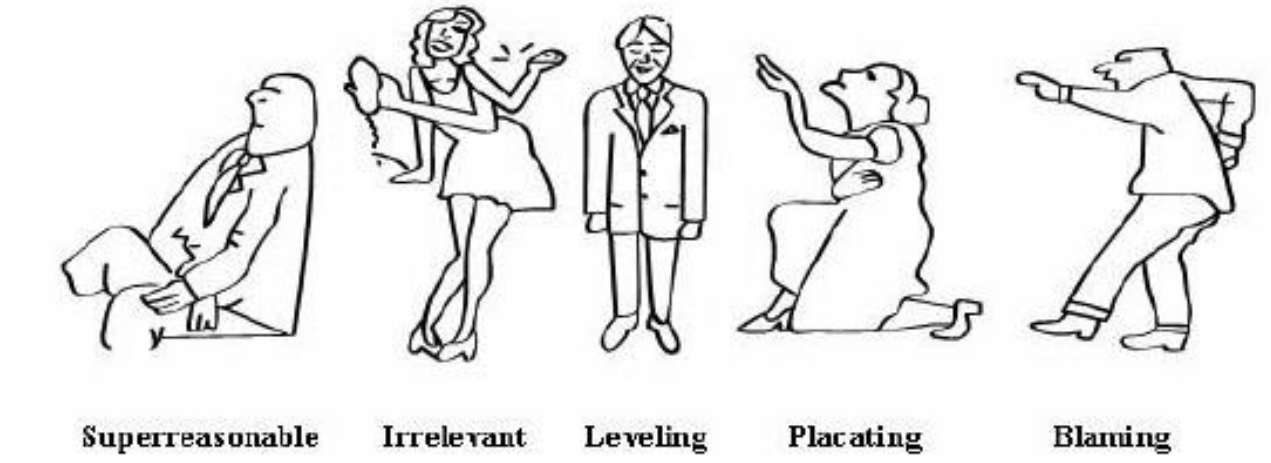


Fig. 3.5. Satir's patterns: Superreasonable, irrelevant, leveling, placating and blaming. Adapted from (Andreas and Satir, 1991).

Satir states that, "people meet in four ways the negative effects of stress or tension". She states that in stress situations involving the self-esteem, most of the people adopt one of these four communication styles to hide their feelings:

1. Placating: apologetic, eager to please (hides fear).
2. Blaming: fault-finding, critical (hides pain).

3. Superreasonable: super-reasonable, abstract (afraid of feelings).
4. Irrelevant: irrelevant, talkative (afraid of reality).

The system has a fifth pattern, leveling, that represents the common normal communicative human behavior. These five communicative patterns (superreasonable, irrelevant, leveling, placating and blaming) are universally recognized and widely used in family therapy but they have never been used in the modeling of intelligent agents. For each pattern the model defines several communication characteristics that allow the individual's behavior to be personalized. Each pattern defines the body posture, facial expression, voice and linguistic structure as shown in Table 3.7.

Table 3.7

Satir's patterns and their communication styles (Andreas and Satir, 1991).

Pattern	**Body posture**	**Facial expression**	**Voice(V) and Linguistic structures(L)**
Blaming	Pointing with a finger	Tense facial muscles, pursed lips, expand nasal passages, annoyed look	V: Scream with a hard voice, tense, shrill L: Everyone, everything, always, every time
Placating	Body in low position, as kneeling begging, and saying yes to every- thing	Sad facial gesture, look to the floor	V: Gangosa, which nasal resonance, with complacent tone L: Yes, only, even
Superreasonable	Straight body posture, feeling of tranquility and control	Does not finch, does not show emotions, direct gaze	V: Monotonous and dry L: Omission of nominative arguments. Use the longest possible words, even if you are not sure of the meanings. At least it will look smart
Irrelevant	The body goes in different directions, joining the knees in an exaggerated manner, bending the shoulders	Distracted, lazy, entertaining, distracted gaze	V: Singsong that clashes with words L: Words without meaning and irrelevant
Leveling	Freedom of movement	Neutral expression, look into the eyes	V: Warm L: Direct answer

Satir model goes into the detail of the type of thoughts that emerge in each pattern, thoughts that are based on irrational/rational beliefs. Those beliefs are the way of linking both models, Satir and ABC. Thoughts related to the four patterns linked to stress and tension are based on irrational beliefs (related to dysfunctional emotions and maladaptive behaviors) and in the case of the leveling pattern, it is based on rational beliefs and therefore, linked to functional emotions and adaptive behaviors. The proposed mapping (see Table 3.8) is based on the categorization of the general irrational/rational beliefs presented in Table 3.5 and on the relationships between irrational/rational categories and maladaptive/adaptive conducts proposed in Table 3.2.

Table 3.8

Proposed mapping between irrational/rational beliefs categories, conducts and communicative patterns. Conducts are referenced according to Table 3.2.

General Irrational beliefs (IB)	**Category**	**Possible Conducts** / **Satir's pattern**
IBI - It is an extreme need, for the adult human being, to be loved and approved by every significant person in his environment.	Primary - DEM comfort Secondary - Global evaluation/self or other-downing (GE/SD)	II, VI placating
IBII - To consider myself as a valid person, I must be very competent, sufficient and able to achieve anything that I propose.	Primary - DEM achievement and competence Secondary - Global evaluation/self or other-downing (GE/SD)	III, VI blaming
IB-III - People who do not act as "should" are vile, evil and infamous and should be punished for their evil.	Primary - DEM control Secondary - Global evaluation/self or other-downing (GE/SD)	I, VI superreasonable
IB-IV - It is terrible and catastrophic that things do not work out as one would like.	Primary - DEM achievement and competence Secondary - Awfulizing (AWF)	III, IV blaming

Table 3.8 (Continued).

General Irrational beliefs (IB)	Category	Possible Conducts / Satir's pattern
IB-V - Human disgrace and discomfort are brought about by external circumstances, and people have no ability to control their emotions.	Primary - DEM control Secondary - Global evaluation/self or other-downing (GE/SD)	I, VI superreasonable
IB-VI - If something is or can be dangerous, I must be terribly worried about it and I must constantly think about the possibility of it happening.	Primary - DEM comfort Secondary - Awfulizing (AWF)	II, IV placating
IB-VII - It is easier to avoid the responsibilities and difficulties of life than to confront them.	Primary - DEM comfort Secondary - Low frustration tolerance (LFT)	II, V irrelevant
IB-VIII - I must depend on others and need someone stronger to trust.	Primary - DEM comfort Secondary - Low frustration tolerance (LFT)	II, V placating
IB-IX - What happened to me will always continue affecting me.	Primary - DEM comfort Secondary - Global evaluation/self or other-downing (GE/SD)	II, VI placating
IB-X - We must be very concerned about the problems and disturbances of others.	Primary - DEM comfort Secondary - Global evaluation/self or other-downing (GE/SD)	II, VI placating
IB-XI - There is a perfect solution to every problem and if we do not find it, it would be catastrophic.	Primary - DEM achievement and competence Secondary - Awfulizing (AWF)	III, IV blaming

Table 3.8 (Continued).

General rational beliefs (RB)	Category	Possible Conducts / Satir's pattern
RBI - I accept my own limitations and mistakes, and my behavior is not conditioned by the continuous search for recognition and approval of others.	Primary – Preferences Secondary - Unconditional acceptance (non-GE/SD)	Congruence, direct and unique message, fluency, confidence, openness
RBII - Each person has the right to act according to his or her criteria, without me having to expect them to behave according to what I expect, need, or consider right.	Primary – Preferences Secondary - High frustration tolerance (non-LFT)	leveling
RBIII - Life and its circumstances happen in an independent way to my needs and it is me who must adapt to manage the possibilities and difficulties that arise.	Primary - Preferences Secondary - Non-awfulizing (non-AWF)	

Following the ABC model, the consequences of events in our framework are not only behavioral but emotional, as it will be explained next.

3.3.4 Affect modeling

Emotions, mood and personality, modulated through affective regulation, determine the affective behavior of ABC-EBDI agents. Each affective aspect will be explained independently.

3.3.4.1 Modeling emotions

In the ABC-EBDI framework dysfunctional and functional emotions, both negative and positive, are modeled. It should be noted that the dysfunctional nature of an emotion is established taking into account if it takes the agent away from its personal goals and if it has maladaptive consequences on agent's behavior. Saving the fact that

some of the dysfunctional emotions modeled may have adaptive consequences on different scenarios, which is the case, for example, of guilt in the context of transgression of social norms (i.e., a person feeling guilty because he/she is conscious that the action done was bad, may act to correct the negative situation caused).

The original ABC model does not describe the elicitation of specific emotions, but other later works go deeper into the emotion elicitation process such as the one of David et al. (David et al., 2002) that validate the ABC model. The proposed framework follows that work and proposes an emotional generation process composed of a primary and a secondary appraisal (see Fig. 3.6) as it is detailed in this section.

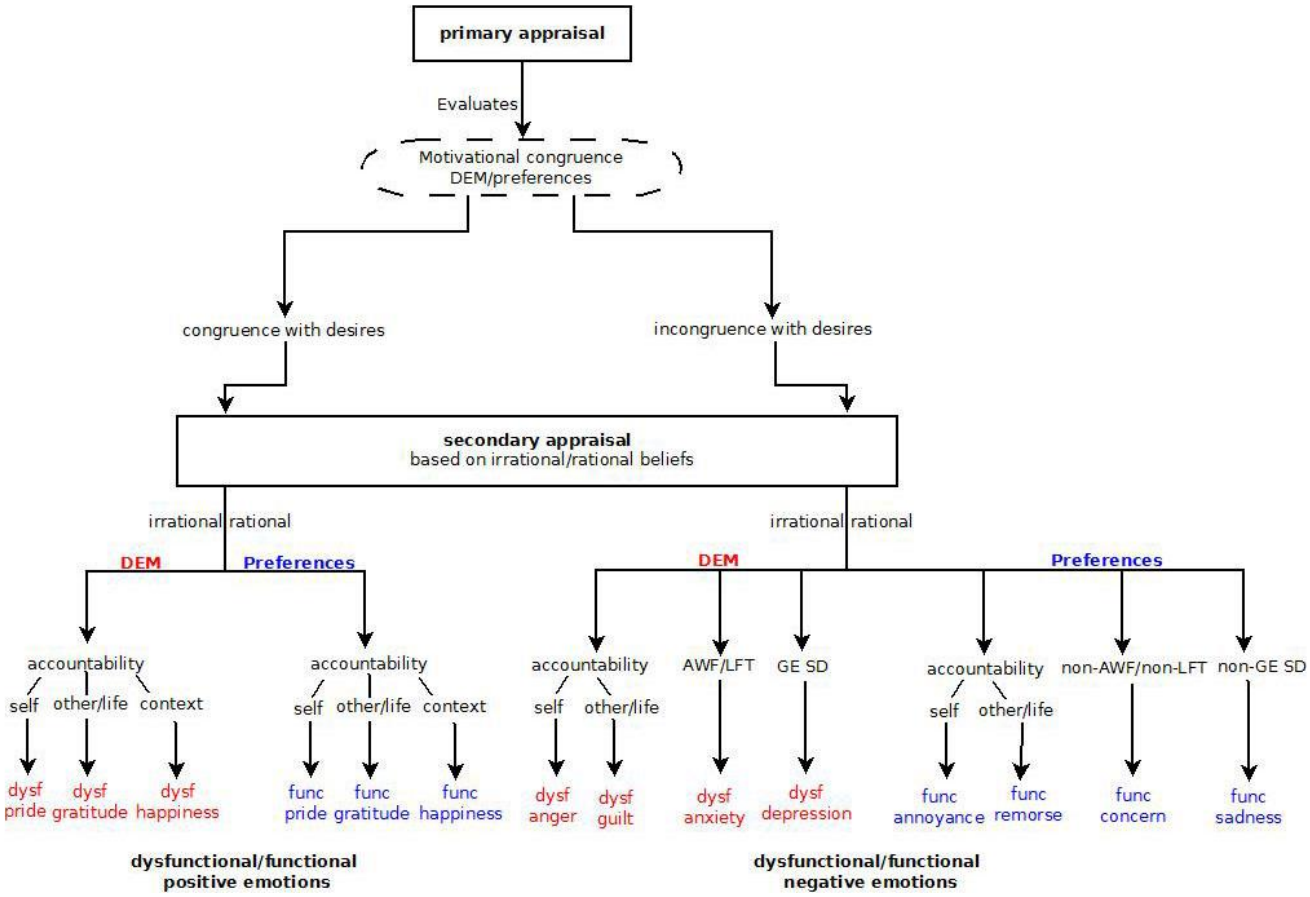


Fig. 3.6. Emotional generation process in the ABC-EBDI framework.

Primary appraisal: It determines the dysfunctional/functional nature of emotions and its negative or positive character. Two components are evaluated, the motivational congruence and the demanding or preferential (DEM/preferences) character of the irrational/rational generated desires ($D_{I/R}$).

- Motivational congruence: Evaluates if the event fits irrational/rational desires ($D_{I/R}$). An event is evaluated as congruent if it fits both initial (D_o) and contextual ($D_{I/R}$) desires and incongruent if it doesn't fit them. The result of the evaluation (congruent or incongruent) determines the negative or positive character of the emotions that will be elicited. If it is congruent, dysfunctional/functional positive emotions emerge; otherwise dysfunctional/functional negative emotions are elicited.
- DEM/Preferences: Evaluates the demanding (DEM) or preferential (Preferences) character of the process based on the irrational/rational character of the desires ($D_{I/R}$). If the desires are irrational (D_I), then emotions will be dysfunctional, otherwise (D_R) the emotions will be functional.

Secondary appraisal: It determines the specific emotions elicited. To do so, the irrational/rational context beliefs ($B_{I/R}$) that lead to the desires are categorized. First, they are categorized as demanding or preferential (main categories). Afterwards, a secondary categorization is carried out in terms of:

- **Accountability** (self, other/life): Evaluates if the event (A) is related to self, other/life or the context.
- **AWF/non-AWF**: Evaluates if context beliefs ($B_{I/R}$) contain beliefs classified as the worst that can happen (AWF) or classified as a flexible negative (non-AWF).
- **LFT/non-LFT**: Evaluates if context beliefs ($B_{I/R}$) may be classified as low frustration tolerance (LFT) or as high frustration tolerance (non-LFT).
- **GE SD/non-GE SD**: Evaluates if context beliefs ($B_{I/R}$) contain beliefs classified as global evaluation/self or other-downing (GE SD) or classified as unconditional acceptance (non-GE SD).

Negative emotions will lead to the dysfunctional emotions of anger (self), guilt (other/life), anxiety (AWF/LFT) or depression (GE/SD), and to the functional emotions of annoyance (self), remorse (other/life), concern (non-AWF/non-LFT) or sadness (non-GE/SD).

The dysfunctional/functional nature of positive emotions has been less studied. In the proposed framework three positive emotions are modeled: pride, gratitude and happiness, based on the work of (Smith, 1991) and the idea of (David et al., 2002). Positive emotions are elicited when there is motivational congruence with agent's desires (see Fig. 3.6) and its dysfunctional or functional nature comes from the irrational or rational character of the underlying beliefs. This means that a positive emotion with a dysfunctional nature is experienced if the context beliefs are irrational (B_I). For example, if we rigidly believe that we do not deserve to win a certain prize and we desire not to win, if we don't win, we feel a dysfunctional positive emotion of happiness. The elicitation of one or the other emotion will depend on whether it is a motivational congruent event related to the context, in the case of happiness, or a motivational congruent event related to self (self-credit), in the case of pride or if it is a motivational congruent event related to others (other-credit) in the case of gratitude. The elicited emotions decay over time, being the agent permanent emotional state its current mood state.

3.3.4.2 Modeling mood

In our framework two types of mood are considered: current mood (M_c), which varies over time, and desired mood (M_d) which is determined by the agent's personality. Mood modeling is based on the two-factor model proposed by (Watson and Tellegen, 1985) that represents mood states in two dimensions that are universally recognized as fundamental: ***valence*** *(pleasant-unpleasant)* and ***arousal*** *(high energy-low energy)*. Four categories of mood arise in this model: *energized-unpleasant, energized-pleasant, calm-unpleasant* and *calm-pleasant*. This model may be seen as too basic but we think that it is adequate in the context of virtual agents. It must be taken into account that, although much progress has been made in the facial and body expression of emotions, the expression of mood is much more complex and has scarcely been studied. In any case, it can be established a relationship with other models such as the PAD model (Mehrabian, 1996a), the Circumplex model (Russell, 1980b), (Russell, 2003), and the two-factor model (Watson & Tellegen, 1985). Fig. 3.7 shows the different mood states that can be modeled through the PAD and Russell models categorized according to the two-factor model.

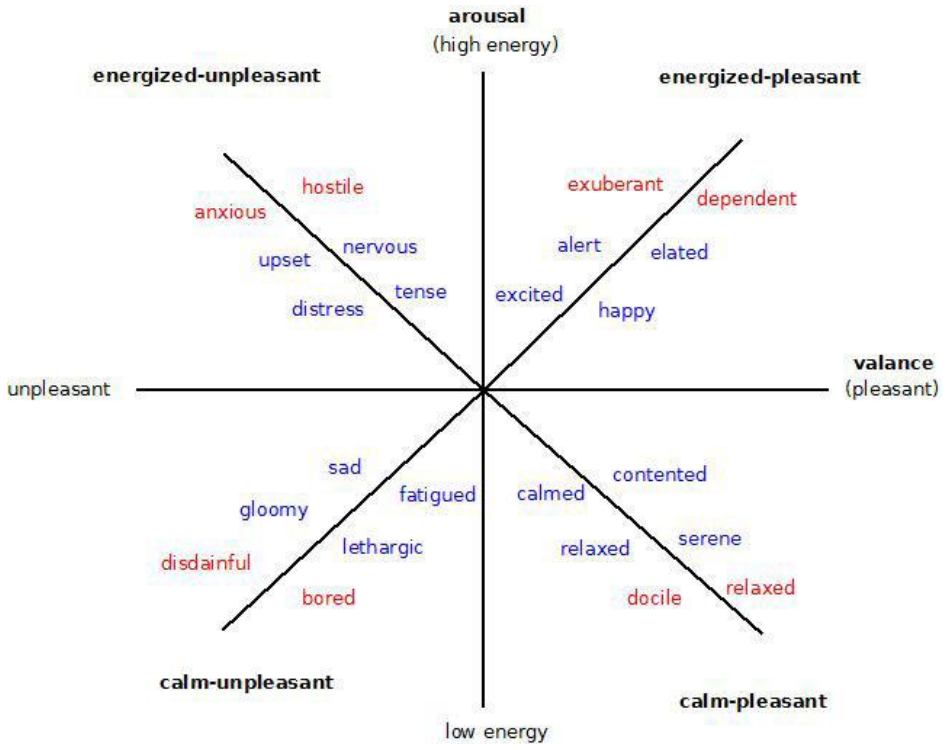


Fig. 3.7. Relationship between the two-factor model (Watson and Tellegen, 1985) and other mood models (Mehrabian, 1996a), (Russell, 2003).

Once the initial value of the current mood is established, it will vary over the time according to the elicited emotions. The process involves two types of mood: previous mood (M_{prev}) and expected mood (M_{exp}). Previous mood is the current mood value when emotions are elicited and the expected mood is the mood value according to the elicited emotions: every elicited emotion has an expected mood value associated. Thanks to the works of (Russell, 1980b), (Russell, 2003) that study the relationship between dysfunctional/functional negative/positive emotions and the two-factor model, the value of the expected mood associated to an emotion can be established (see Fig. 3.8).

As it can be seen, positive emotions are associated to pleasant moods, independent of their dysfunctional (E_{D+}) or functional (E_{F+}) nature. Happiness and gratitude that are experienced with a high arousal, will lead to energized-pleasant mood, whereas pride will lead to calm-pleasant mood. In the case of negative emotions, they are associated with unpleasant moods. Negative emotions such as anger and annoyance are experienced with a higher arousal, leading to energized-unpleasant moods,

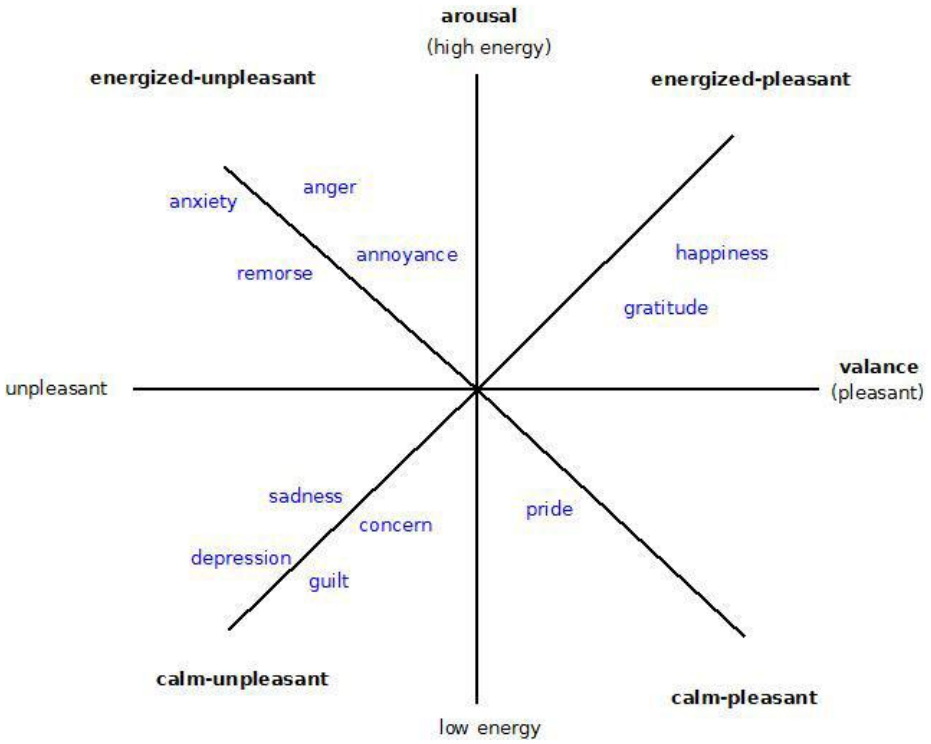


Fig. 3.8. The relationship between the dysfunctional/functional negative and positive emotions, and the mood two-factor model (Russell, 1980b), (Russell, 2003).

whereas depression and concern, will lead to calm-unpleasant moods. Current mood is updated by calculating the midpoint between the previous current mood and the expected mood. When the emotion elicited is just one the expected mood will be the one associated with that emotion, as it has been explained before. When several emotions are elicited the expected mood will be selected according to the agent's personality, as it will be explained in next section. Current mood can be also regulated as it will be explained after (see section 3.3.5.2). The current mood updating process it's not the only thing influenced by the agent's personality but also the desired mood (M_d) value as it will be explained next.

3.3.4.3 Modeling personality

Personality modeling is based on the OCEAN model (McCrae and John, 1992) that makes use of five universally recognized traits: *openness (O), conscientiousness (C), extraversion (E), agreeableness (A) and neuroticism (N)*. In our framework, the determining traits are those of extraversion and neuroticism, since they are directly related to the irrational/rational behavioral tendency of individuals (Spörrle et al., 2010). Thus, in our framework personality directly influences the context beliefs (B_c)

processing, defining the irrational or rational tendency of the cognitive-affective process. Based on (Spörrle et al., 2010), we consider that an agent with a high degree of neuroticism (N) will have a dysfunctional emotional and maladaptive behavioral tendency. On the contrary, an agent with low neuroticism (N) will tend to behave in an emotionally functional and behaviorally adaptive way. Therefore, if the agent has a high level of neuroticism (N) and a low extroversion (E) the process has an irrational tendency, but if the agent has a high level of E and low N, the process has a rational tendency. In the case of high N and high E, the trend is considered irrational since there are works (Gray, 1987) that state that it is highly probable that these values guide impulsive conduct or anxiety. Table 3.9 summarizes the irrational or rational tendency of beliefs processing according to agent's personality.

Table 3.9

Relationship between personality traits and belief tendency.

Personality Traits	**Irrational/Rational belief tendency**
High neuroticism(N), Low extraversion(E)	IBs
Low neuroticism(N), High extraversion(E)	RBs
High neuroticism(N), High extraversion(E)	IBs
Low neuroticism(N), Low extraversion(E)	RBs

As commented before, another aspect influenced by the agent personality is the desired mood (M_d). In our framework this influence is based on the relationship that can be established between the two-factor model and the OCEAN model thanks to works such as Zanon et al. (Zanon et al., 2013) and Costa and McCrae (Costa and McCrae, 1980), that seek the connection between the personality traits and negative and positive affect. In these works, the personality traits that influence negative and positive affect are neuroticism (N) and extraversion (E): neuroticism is strongly linked to negative affect and extraversion to positive affect. In our framework the agent's desired mood is determined according to the values of neuroticism (N) and

extraversion (E) traits, for both edges (*valance-arousal*). The value of the valence is established taking into account that a high degree of N is linked to displeasure (*unpleasant*) and a high degree of E is linked to pleasure (*pleasant*). The combination of high degrees of both traits (high degree of N and E) leads to anxiety, which is unpleasant. The arousal value is established considering that a high degree of N is related to more energized negative states, and in the opposite case (low degree of N and high degree of E), more energized positive states are felt. Table 3.10 summarizes the values of the agent's desired mood (M_d) according to its personality.

Table 3.10

Relationship between desired mood values and agent's personality traits.

Personality traits	Desired Mood
High neuroticism(N), Low extraversion(E)	energized-unpleasant
Low neuroticism(N), High extraversion(E)	energized -pleasant
High neuroticism(N), High extraversion(E)	energized-unpleasant
Low neuroticism(N), Low extraversion(E)	calm-pleasant

The agent's personality also influences the expected mood (M_{exp}) when several emotions arise. The personality determines the agent predisposition to negative or positive affect (Zanon et al., 2013). Individuals with a high degree of neuroticism (N) are prone to negative emotional states; therefore, if several emotions are elicited, the expected mood will be the one associated with the emotion with lowest valence value. Individuals with a high degree of extroversion (E) are prone to positive emotional states; therefore, if several emotions are elicited, the expected mood will be the one associated with the emotion with highest valence value. The influence of personality on the expected mood is shown in Table 3.11.

Table 3.11

Relationship between affective tendency, expected mood and personality traits.

Personality traits values	Affective tendency	Expected Mood
High neuroticism(N), Low extraversion(E)	To negative affect	Lowest valence value
Low neuroticism(N), High extraversion(E)	To positive affect	Highest valence value
High neuroticism(N), High extraversion(E)	To negative affect	Lowest valence value
Low neuroticism(N), Low extraversion(E)	To positive affect	Highest valence value

3.3.5 Affect regulation modeling

In the ABC-EBDI framework emotional regulation and mood regulation are considered. Even though the ABC model proposes a regulatory process, it is oriented to psychological therapy. Therefore, the Gross model (Gross, 1998) oriented to regulate emotions during the emotional generation process, was chosen. Additionally, Larsen's model (Larsen, 2000) has been used for mood regulation.

3.3.5.1 Emotional regulation

The Gross model (Gross, 1998) establishes five regulation strategies that can be used at two different moments of the emotional generation process: before the emotion is elicited (*antecedent-focused*) and after the emotion is elicited (*response-focused*). Antecedent-focused strategies comprise:

- Selection of the situation: Refers to avoiding certain people, places, or objects.
- Modification of the situation: Refers to active efforts done to directly modify the situation to alter its emotional impact.
- Deployment of attention: Refers to selecting which aspect of a situation an individual focus on.
- Change of cognitions: Refers to modifying the cognitive evaluations individuals make depending on their capacity to manage the situation.

Response-focused strategies comprise:

- Modulation of responses: Refers to influencing the final (physiological, experiential, or behavioral) response.

The proposed framework makes use of two strategies: the change of cognitions strategy (antecedent-focused) and the response modulation strategy (response-focused). In particular, among the different change of cognition strategies, *reappraisal* (Balzarotti et al., 2010) has been chosen. It involves the transformation of the situation from the cognitive point of view to alter the emotional impact caused by it. Likewise, among the different modulation of response strategies, the expressive suppression strategy has been selected (Gross, 2002). It consists of attempting to inhibit the outgoing emotional behavior.

In our framework, the regulated emotions are the negative dysfunctional ones that are the ones that guide to maladaptive conducts. The reappraisal strategy can be activated during the process of emotional generation to give a new meaning to the event, changing irrational beliefs that give rise to negative dysfunctional emotions into rational alternative ones, which will guide to negative (or positive) functional emotions and adaptive conducts. Regarding the expressive suppression strategy, it can be activated during the process of selecting the outgoing conduct; in that case, the agent will not show any emotion. The agent will use one or another regulation strategy depending on its personality. The management of the influence of personality on the regulation strategy is based on the work of John and Gross (John and Gross, 2004). They propose that the reappraisal strategy is related to a low degree of neuroticism (N) and the expressive suppression strategy is related to a low degree of extraversion (E). According to this, we consider that, if the agent has a low degree of N, it will regulate emotions through reappraisal strategy, promoting adaptive conduct and more functional emotions. In the case of having a low degree of E, it will regulate emotions applying the expressive suppression strategy. On the other hand, if both traits are high, the agent does not have the ability to regulate emotions and shows its elicited emotions and related conduct. In the particular case that both personality traits (N and E) are low, the agent's cognitive-affective-behavioral process will be rational, functional and adaptive (respectively), so the agent won't regulate its emotions. Table 3.12 shows the relationship between the personality of the agent and the regulation strategy applied.

Table 3.12

Relationship between regulation strategies and personality traits.

Personality traits	Regulation Strategy
High neuroticism(N), Low extraversion(E)	Suppression
Low neuroticism(N), High extraversion(E)	Reappraisal
High neuroticism(N), High extraversion(E)	No regulation
Low neuroticism(N), Low extraversion(E)	No regulation (rational process)

3.3.5.2 Mood regulation

The Larsen's model (Larsen, 2000) establishes that every individual has a desired mood (M_d) in which he/she wants to be, so, when the current mood differs from the desired one, actions are taken to regulate how he/she feels and how to return to the desired one. The actions may be oriented to direct changes in the environment (Focus on situation) or in the person (Focus on itself). In turn, for both mechanisms, there are several behavioral ("Things to do") and cognitive ("Ways to think") strategies, which are activated to return to the desired mood. Table 3.13 shows the main strategies that can be used in mood regulation, both from the cognitive and behavioral point of view.

Mechanisms that individuals use to regulate mood depend greatly, among other factors, on their personality. In (Gray, 1994) it is argued that a high degree of neuroticism (N) inhibits the behavior system, so it is highly probable that the individual chooses mechanisms focused on itself (Focus on itself) applying both behavioral and cognitive strategies. In the case of the extraversion trait (E) in (Gray, 1994), it is also postulated that an individual with a high degree of E tends to activate the behavioral system, so, in this case the individual will probably choose strategies focused in the situation.

Table 3.13

Mechanisms and some possible strategies for mood regulation. Adapted from (Larsen, 2000).

Mechanisms	**Strategies**	
	Behavior ("Things to do")	**Cognitive ("Ways to think")**
Focus on situation	Direct action	Reinterpret the situation so it is not so bad
	Trying harder	Comparing the situation with another worse
	Avoidance	Thinking of success in other areas of life
	Talking to friend	Fatalism-What will be will be
Focus on itself	Distraction/stay busy	Mediation
	Helping others	Fantasy-daydreaming to forget the problems
	Inhibit the expression	Refuse to think about it
	Self-reward	Stoicism
	Socializing	Future thinking-focuses on when you will be free from the problem

Table 3.14 summarizes the relationship between regulation mechanisms and personality, and possible strategies in each case. These strategies have been chosen as the most plausible in the case of virtual agents: their modeling is more viable than those that are more subjective (i.e., fantasy, traying harder) and, therefore, becomes more to implement.

Table 3.14

Relation between personality traits and mood regulation mechanisms and corresponding strategies.

Personality traits	**Mechanisms**	**Strategies**
High neuroticism(N), Low extraversion(E)	Focused on itself	Inhibit the expression (Behavior), Refuse to think about it (Cognitive)
High extraversion(E), Low neuroticism(N)	Focused on the situation	Direct action (Behavior), Reinterpret the situation (Cognitive)
Low neuroticism(N), Low extraversion(E)	Focused on itself	Self-reward (Behavior), Stoicism (Cognitive)
High neuroticism(N), High extraversion(E)	Focused on the situation	Avoidance (Behavior), Thinking on success in other areas of life (Cognitive)

3.4 Conclusions

In this chapter, the ABC-EBDI framework has been presented. The framework is the first application of a well-known psychotherapeutic model, Ellis's ABC model, to the simulation of realistic human intelligent agents. It is able to manage, in a unifying way, the consequences of events in terms of affective and behavioral consequences. It is an EBDI whose affective component considers emotions, mood and personality as well as affective capacities such as affect regulation. In the framework affect influences the cognitive processing in all its stages (Beliefs, Desires and Intentions). This puts the framework among the most advanced EBDIs.

The ABC model allows considering the underlying human beliefs that conditions human's thoughts (what the agent thinks), emotions (what the agent feels) and conduct (how the agent behaves) in complex situations. Its application to an EBDI scheme involves the introduction in the management of beliefs and desires of an aspect not previously considered in the AI context: their rational or irrational character. This irrational or rational aspect of beliefs and desires is what determines, in the ABC model, the human dysfunctional/functional emotions and maladaptive/adaptive conducts when facing life events. The framework includes the management not only agent's maladaptive/adaptive conduct, but also how the agent expresses those behaviors thanks to consideration of Satir's model (Andreas and Satir, 1991) and its general communicative patterns. These patterns open the door to the consideration of body gesture, facial expressions, voice and linguistic structures which makes it very useful for embodied virtual agents modeling. In the next chapter, framework implementation details are given.

CHAPTER 4: Framework implementation

4.1 Introduction

This chapter describes the implementation of the ABC-EBDI framework. First, we present a general implementation overview of the proposed framework. Then, we present the different layers of the architecture, detailing the corresponding modules per layer. Finally, conclusions are presented. The content of this chapter has been partially published in (Sanchez et al., 2020) and (Sánchez et al., 2019).

4.2 General implementation overview

To carry out the implementation of the proposed framework we have designed a 3-layers architecture (see Fig. 4.1):

1- Presentation layer: The user-agent interaction interface.
2- Functional layer: The agent application logic.
3- Data layer: The configuration files.

The presentation layer consists of the user-agent interaction interface. This interface communicates with the other layers through API calls, services, or sockets. In this first version of the framework, a chat-based console application and sockets to communicate layers (presentation → functional) have been used.

The functional layer (also known as application layer) contains the logic of the agent application. It has been organized in seven modules that handle the agent cognitive-affective-behavioral process and the user-agent dialog interaction.

The modules are:

1. Initialization module: Manages the agent's initialization.
2. Perception-Dialog module: Manages the agent's environment perceptions and user-agent interaction dialog.
3. Cognitive module: Manages agent's BDI behavior.
4. Affective module: Manages agent's affective state including personality, mood, emotions and affective regulatory process.
5. Behavioral module: Manages agent's conduct.
6. Response module: Manages output information regarding cognitive and affective dimensions and also agent's response.

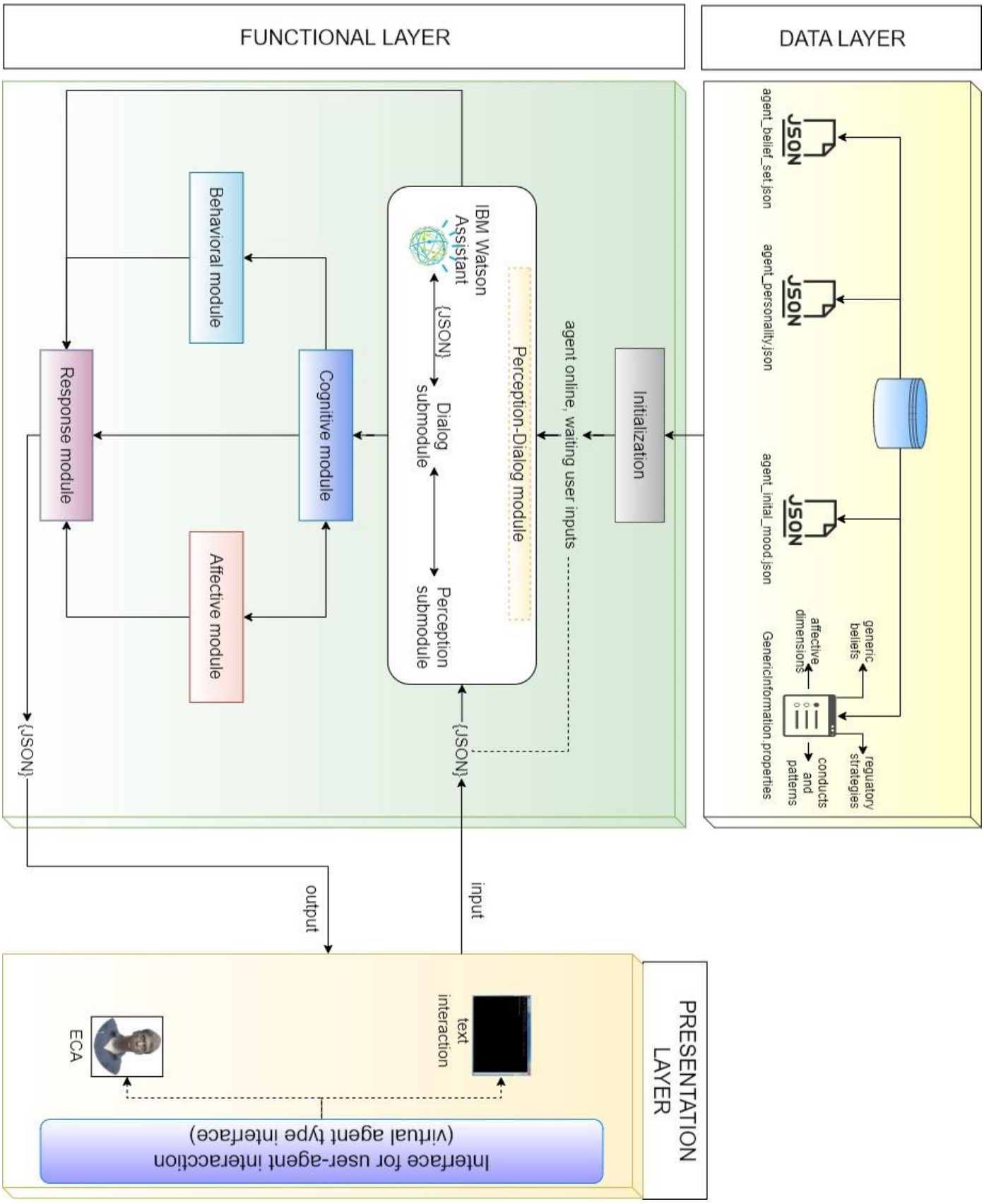


Fig. 4.1. High-level view of the proposed architecture.

To support the BDI agent behavior management the Jadex platform (Pokahr et al., 2013) is used. Jadex is a BDI reasoning engine to process intelligent agents. It facilitates using the BDI model in the context of mainstream programming by introducing beliefs, goals and plans as class objects that can be created and manipulated inside the agent. To define a BDI agent in Jadex platform several issues need to be considered: how to define the BDI agent, how to initialize it and how to use BDI concepts. These aspects will be explained in sections 4.3 and 4.5.

The Data layer manages the stored information that can be accessed by the agent. In this case, it consists of text and java properties files that contain agent's characterization values regarding cognitive dimensions (beliefs and desires), affective dimensions (personality, mood and available regulatory strategies), behavioral dimensions (available conducts and patterns) and generic information needed for the cognitive-affective-processing. Agent information related to cognitive dimensions (agent belief and desires) and affective dimensions (personality and current mood value) are stored as text files. Generic information is stored as java properties files with key/value format, where value is serialized to json format. Modules that contain the agent main logic are explained next.

4.3 Initialization module

The initialization module involves two processes:

a. Agent initialization.
b. Socket connection initialization.

In Fig 4.3 a work flow diagram of the initialization module is presented.

Agent initialization involves two processes: platform initialization and agent characterization. Platform initialization starts the Jadex BDI V3 kernel and is carried out by configuring the PlatformConfiguration and Starter objects provided by the Jadex API:

```
PlatformConfiguration config = PlatformConfiguration.getDefaultNoGui();
config.addComponent("Package.BDI.class");
Starter.createPlatform(config).get();
```

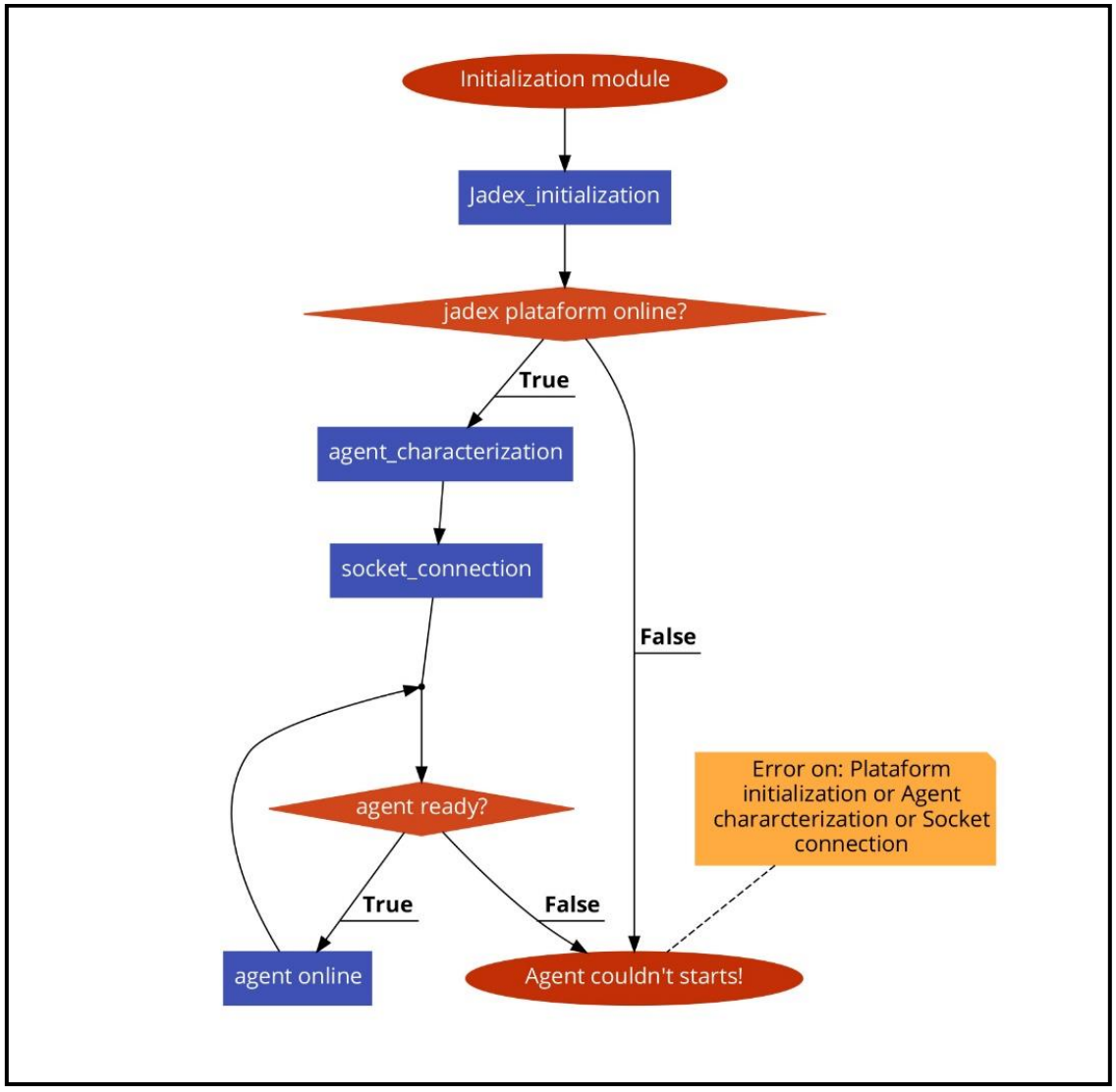


Fig. 4.3. Initialization work flow diagram.

Once the Jadex platform has started, the agent characterization process is carried out to initialize agent's cognitive and affective dimensions (beliefs base, desires, agent personality, and mood) and to set some context information and some initial behavioral values. This is made through the init() method defined in the BDI agent class. The characterization process involves two steps:

1- Uploading information stored in json files and java properties:
   a. Generic information stored as java properties:
      i. Generic irrational/rational beliefs with its corresponding categories;
      ii. Affective information related to mood and emotions;

iii. Available affect regulation strategies;
iv. Mapping between generic irrational/rational belief categories and conduct (maladaptive/adaptive and communicative patterns);

b. Agent information stored as json files:
i. Agent cognitive dimensions: The agent belief base and desires information;
ii. Agent affective dimensions: The agent's personality and initial mood value.

2- Offline agent characterization that involves:
a. Processing belief's content to establish their DEM/Preferential category;
b. Establishing agent desired mood regarding its personality.

The uploading process consists of reading the files and setting agent's cognitive (beliefs set and desires information) and affective (personality and mood) dimensions, and generic information needed for the cognitive-affective-behavioral processing. In the case of agent information, json files are read and parsed to java object using the Gson library. To load the generic information, the Properties java class is used. Generic information and agent cognitive dimensions are stored in HasMap objects. Affective dimensions related to agent information are defined as class objects. In section 4.5 and section 4.6, cognitive and affective dimensions modeling are explained.

The belief content processing in the offline characterization step consists in classifying beliefs according to their irrational or rational nature. This process corresponds to the *blf_processing* step in Fig 3.4 (see chapter 3), and has been implemented in two steps: offline processing implemented in the initialization phase and online processing implemented in the cognitive processing phase (see section 4.5). The offline processing consists in the categorization of each belief regarding the generic irrational/rational belief categories identified in chapter 3 (Table 3.1), if the belief is not already categorized. In our first implementation approach, we decided to start with the agent beliefs already categorized.

The second process performed in the offline agent characterization is to establish the agent desired mood, using the relationship between mood and personality

presented in Table 3.10. Once the agent's characterization ends, socket connection is set up. The socket connection has been implemented using the native java.net.Socket class. If the two processes are carried out without error, the agent is online, which means that it is ready to establish a conversation with the user (Fig 4.4). Each time a user input is received it is processed by the Perception-Dialog module to manage agent percepts and agent text response, as it is explained in next section.

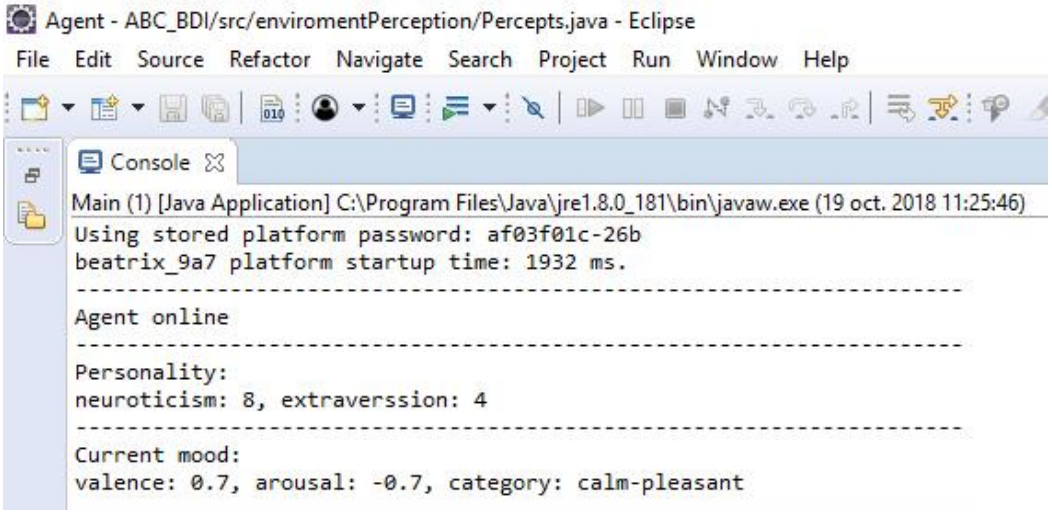


Fig. 4.4. Online agent: the figure shows the state of the agent after initilization including the personality and current mood initial values.

4.4 Perception-Dialog module

The perception-dialog module manages the user-agent interaction (see Fig 4.5), and it is composed of two submodules: perception and dialog. The perception submodule manages the inputs from the environment perceived by the agent. In the user-agent interaction scope, these inputs could comprise text communication, facial recognition, voice recognition, eye tracking, etc. In this first version of the framework only text communication has been considered. In the perception submodule a perception list is built, in which each percept object has four attributes:

- Content: Is the input information perceived, in this case, text information.
- Clasification: A clasification according to the content.
- Context: Is the context related to the perceived content.
- Impact: Is about how percept impacts agent behavior.

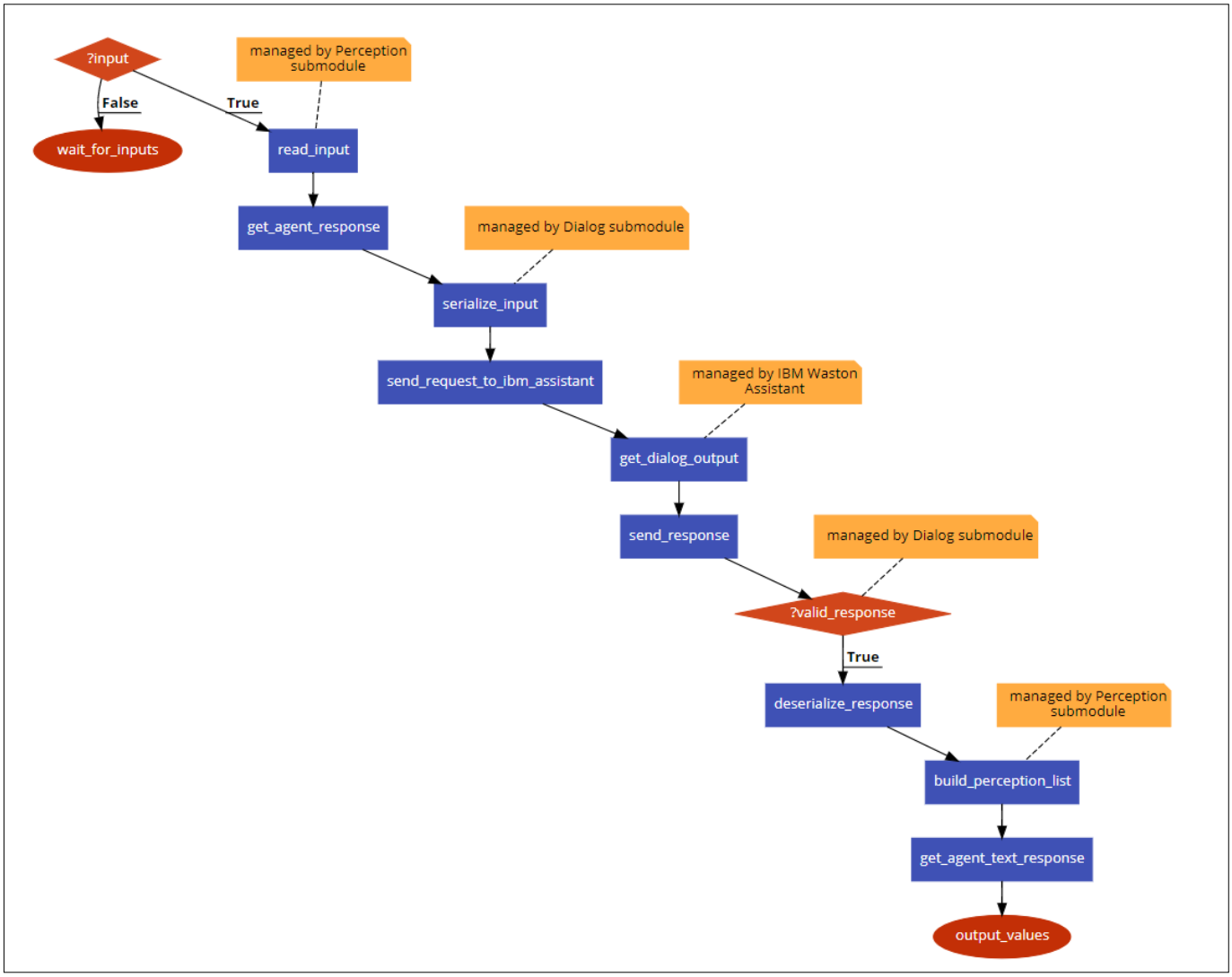


Fig 4.5. Perception-Dialog module flow.

The Dialog submodule manages dialog interaction and is also used to define how user inputs impact the agent affective behavior. To clasify, contextualize and set the percept's impact, the output of the Dialog submodule is used. For example, a user input like "Good morning, how are you today?" is read by the perception submodule and passed to the Dialog submodule to get the related output. The Dialog submodule output consists of the agent text response, like "Good morning, I am great", and also information related with the context of the input, its classification and if it is neutral, good or bad for the agent. To retrieve this information the Dialog submodule uses the IBM Watson Assistant platform (Watson Assistant | IBM Cloud, n.d.). The IBM Watson Assistant is a question-and-answer system that provides a dialog interaction between the conversation

system and users. It is a powerful tool that facilitates the support of conversational interactions and has an out-of-the-box chat interface which makes it easy to build a conversational experience (Comerford et al., 2001)(Goel and Polepeddi, 2016). The IBM Watson Assistant allows; to build conversational interfaces into any application, device, or channel it is offered as a service that can be requested once it is initialized. To use the IBM Watson Assistant an IBM Cloud account must be created. To the development of this project the free plan has been used, which provides access to develop, track, plan, and deploy apps (see (Building a complex dialog, n.d.), to know more about IBM Watson Assistant configuration and service api usage).

To process the agent's response the Dialog submodule serializes the input passed by the perception submodule as text to the appropiated format. Besides, to use the IBM Watson Assistant, its components have to be configured: skills, assistant, dialog, intents, entities, context variables and content catalog. In Table 4.1 these components and their definitions are presented.

In our framework, an assistant component named BDIAgent has been created to define the user-agent interaction in the IBM Assistant tool. To provide the agent with the ability to respond coherently according to a context, a skill has to be defined. We have defined a skill that contains the intents, entities, dialog flow and context variables that are needed to provide the agent with the ability to answer generic inputs about personal information (name, age), greetings (good morning, hello) and endings (see you later, say good bye). If more contextualized dialog abilities are needed, intents and entities, as well as dialog nodes and context variables have to be added to the BDIAgent skill. Three intents related to generic behaviors such as greetings, endings and some basic information such as name and age, are defined:

1. #General_Greetings: To manage inputs related to basic greetings such as *Good morning, Good afternoon, Good night, Hello, Hi, How are you?*
2. #General_About_You: To manage inputs related to basic information such as *What your name?, How old are you?, Where are you from?*
3. #General_Ending: To manage inputs such as *Thanks for everything, Take care your self, See you later, Bye, Good afternoon, Good night*.

Table 4.1.

IBM Watson Assistant components and their definitions.

Component	Definition
Assistant	Directs requests down the optimal path for managing user-agent interaction. You can add skills so that your assistant can provide a direct answer to a common question or reference more generalized search results for something more complex.
Skills	A container for the artificial intelligence that enables an assistant to answer the user.
Dialog	Defines what your assistant says in response to users, based on what it believes the user wants. The dialog flow is represented graphically in the tool as a tree.
Intents	A goal that you anticipate your users will have when they interact with your assistant. It is identified by a # character before the intent name.
Entities	A object that provides context for an intent. For example, an entity might be a name that helps your dialog to distinguish which type of input is received. It is identified by a @ character before the entity name.
Context variables	A variable tied to a dialog node; optionally it specifies a default value. Other dialog nodes or application logic can subsequently set or change its value. It is identified by a $ character before the variable name.
Content Catalog	An easy way to add common intents to your Watson Assistant dialog, for example, common ways of greeting.

These intents are adapted according to the agent's desired behavior: for each intent possible inputs are configured. Regarding entities, two of them have been defined to contextualize the input according to the defined intents: @reactive entity related to generic inputs such as greet and endings and @identity entity related to more personal information. To define this contextualization, keywords and related synonyms that can be identified in inputs are configured. Moreover, for entity matching, AI mechanisms (fuzzy matching) can be configured to

increase the engine ability to recognize misspelled values. In our case, one context variable, $impact, its used to define if an input has a neutral, good or bad impact for the agent. In Table 4.2, the defined intent and entities and context information is presented.

Table 4.2.

Defined intent, entities and context information.

Intent	**Intent value**	**Entity**	**Entity value/synonyms**
#General_About_You	What's your name, How old are you	@identity	-what's your name/tell me your name, tell me your full name -how old are you/what's your age
#General_Greetings	Good morning, Good afternoon, Good night, Hello, Hi, How are you	@reactive	-good afternoon -good morning -good night/good evening -hello/hi -how are you
#General_Ending	Bye, See you later, Good bye	@reactive	-bye/good bye -see you/see you later

Once intent and entities are defined, the Dialog submodule manages the user-agent dialog flow, where all possible agent's responses for each intent according to its entities, are defined. The dialog component is composed by nodes that are connected according to a logical flow that the interaction should follow. In the dialog flow each #intent is linked to a node and to each defined @entity:input combination, related to the intent, a response is configured and if it is the case the context variable(s) value is/are set.

A user's input can be recognized by its value or its defined synonyms. For each @entity:input combination, more than one response can be configured which

would be selected in sequential or random way. In Fig 4.6, an overview of a node flow configuration is shown.

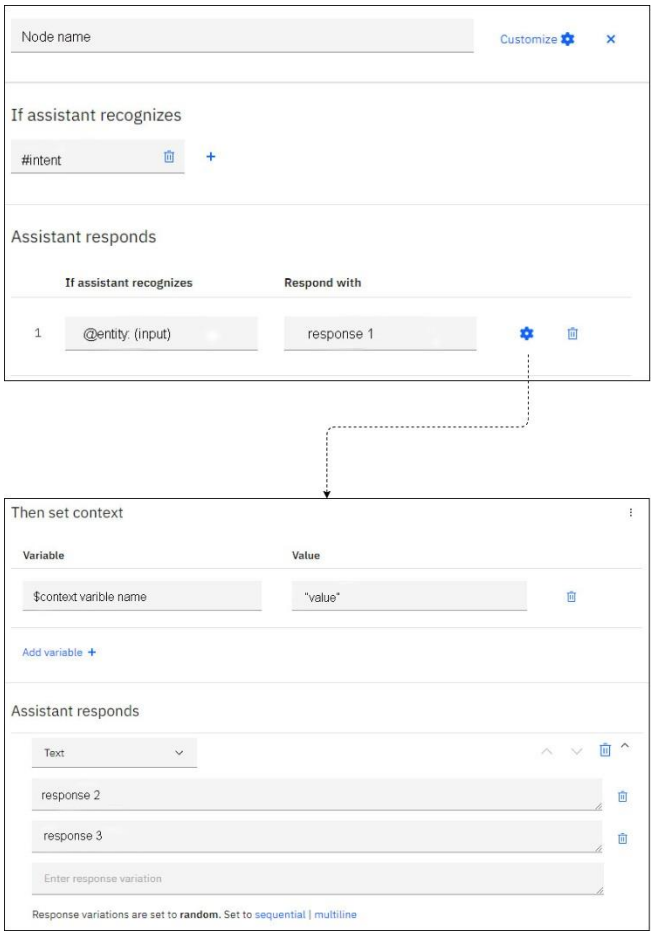


Fig. 4.6. Overview of a node flow configuration in the IBM Watson Assistant tool.

In this first implementation, three nodes according to the three intents shown in Table 4.2 and one additional node to manage non-identified input, have been defined:

1. Greet: To manage agent response related to #General_Greeting intent.
2. About_You: To manage agent response related to #General_About_You intent.
3. Ending: To manage agent response related to #General_Ending intent.
4. Anything_Else: To manage agent response to any not identified input (i.e., agent response: Can you express yourself in other words? Sorry, I have not understood).

For each node the @entity:input combinations with their possible responses and the value that takes the $impact variable, are configured. For each combination the value of the $impact context variable is set according to how relevant the input for the agent is. In the case of the four nodes, impact variable is set to neutral. The selection of the responses is set to random to provide more versatility to agent's responses. In the case of the Anything_Else node, that has neither intents nor entities, only the context variable value and the possible responses are defined. In Table 4.3, @entity:input combinations, responses and $impact variable value, to each defined node are shown.

Table 4.3.

Defined @entity:input combinations, responses and $impact variable value.

Node	**#intent**	**@entity: input combination**	**Responses**
Greet	#General_Greeting	@reactive:(hello)	- Hi - Hello
		@reactive:(how are you)	- I am fine, thanks - Fine, thanks
		@reactive:(good afternoon)	- Good afternoon
		@reactive:(good morning)	- Good morning
		@reactive:(good night)	- Good night
About_You	#General_About_You	@identity:(what's your name)	- My name is Susan - Susan - Is Susan
		@identity:(what's your full name)	- My name is Susan Lopez
		@identity:(what's your age)	- I am 35 years old - 35 years old - 35
Ending	#General_Ending	@reactive:bye	- Bye - Good bye
Anything_Else	-	-	- I have not understood - Could you repeat please? I have not understood

Once the IBM Watson Assistant is configured and initialized it, is ready to support the dialog interaction. When a request is received by the IBM Watson Assistant service, it recognizes the intent expressed in a user's input and chooses the correct dialog flow that corresponds to it. For example, if an input like *What's your name?* is perceived by the agent, the assistant service recognizes it and maps it to the #General_About_You intent that is managed by the About_You node, in which one of the possible responses configured for the @identity:(what's your name) combination is selected in random way. As we mentioned before, an input can be recognized by its value or its synonym, therefore in this case, if the input were *Tell me your nam*e, which is a synonym of *What's your name*, the dialog flow processing would be the same.

The IBM Watson Assistant output is a json object that contains the value of response, #intent, #entities and $impact context variable. The value of the json is deserialized by the Dialog submodule and returned to the perception submodule that uses it to build the perception list and the agent text response. Intent, entity information and context variable ($impact) are used to set percept classification, percept context and percept impact, respectively. In the case of percept classification and context, a tag related to intent and entity names are dynamically defined as value. They are constructed removing the @ symbol of the entity name. In Table 4.4, the defined intent, entities and context variable value and its relationship with the perception cognitive concepts are presented.

Table 4.4.

Defined intent, entities and context variable values and its relationship with the cognitive concepts (Percept clasification, Percept context and Percept impact).

#intent -> percept classification tag	**@entity-> percept context tag**	**$context variable-> percept impact value**
#General_greetings -> general_greeting	@reactive -> reactive	$impact(neutral) -> neutral
#General_about_you -> general_about_you	@identity -> identity	$impact(neutral) -> neutral
# General_Ending -> general_ending	@reactive -> reactive	$impact(neutral) -> neutral
#Anything_else -> anything_else	@reactive-> reactive	$impact(neutral) -> neutral

*->: relationship

The output values (text_response and perception_list) of the perception-dialog module are used by subsequent modules. Text response is used by the Response module to set the agent's answer (see section 4.8). Perceptions are used to check the agent's beliefs and select which of them are involved in the cognitive process, and if they are motivationally relevant or not according to agent desires and if so, the affective processing is triggered. This process is managed by the Cognitive module as it is explained next.

4.5 Cognitive module

The Cognitive module manages the agent's BDI cognitive processing (following what was explained in section 3.3). As it was mentioned before, the Jadex plataform has been chosen due to its simplicity and its fast integration into Java's platforms. In particular, the Eclipse Java's IDE and the Jadex's engine, version 3.3 rc have been used. Jadex platform uses a goal-oriented reasoning mechanism to implement the full BDI reasoning cycle including the selection of goals to pursue (goal deliberation) and the realization phase, in which different plans can be tried out to achieve a goal. In Jadex agents have beliefs, which can be any kind of Java object, that are stored in a belief base. Goals represent the specific motivations (e.g. states to be achieved) that influence agent's behavior. To achieve its goals the agent executes plans, which are procedural recipes coded in Java. On the one hand, the agent reacts to incoming messages, internal events and goals by selecting and executing plans (means-end reasoning). On the other hand, the agent continuously deliberates about its current goals to decide which consistent subset should be pursued.

Jadex BDI concepts and processing can be injected into Java code by means of annotations in the following way:

- BDI agent class: Represents the agent's logic. It is defined as a class annotated as @Agent and has an init method annotated as @AgentCreated where agent fields (i.e., beliefs base) are initialized and an execute method annotated as @AgentBody to carry out the agent cognitive-affective-behavioral process. Also, to inject the BDI processing two features need to be defined: IBDIAgentFeature and IExecutionFeature:

```
@Agent
@Description(value = "Agent ABC EBDI")
@AgentFeature
protected IBDIAgentFeature bdiFeature;
@AgentFeature
protected IExecutionFeature execFeature;
public class AbcEBDI {
@AgentCreated
public void init() { // agent initialization }
@AgentBody
public void body(){ // cognitive-affective-behavioral processing }
}
```

- Beliefs: An agent's belief base represents its knowledge about the world and controls the ongoing behaviour by determining when a goal is achieved or by rendering plans. They can be modeled with a common field (i.e, List, Map) or with a getter/setter method that can be implemented or not. They are annotated as @Belief.
- Goals: Agent's goals show the fact that an agent commits itself to a certain objective and may try all the possibilities to achieve its goals. There are different kinds of goals: achieve goal, query goal and maintain goal. They are annotated as @Goal.
- Plans: Agent's plans encapsulate the recipe for achieving some state of affair (goals). A plan defines two aspects: head, that contains meta information about it and body that contains the specific instruction that should be carried out. They are annotated as @Plan.

To implement the proposed framework the BDI concepts managed by our proposal have been adapted to Jadex's BDI concepts. Based on Jadex concepts, the belief base is used to define the three type of beliefs (operant, context, basic), the goals to define both set of desires (context, basic) and the plans to represent intentions. In Table 4.5, the relationship between the ABC-EBDI cognitive concepts and Jadex BDI concepts, and the way they are implemented, are presented.

Table 4.5.

Relationship between the ABC-EBDI cognitive concepts and Jadex BDI concepts and their implementation.

ABC-EBDI cognitive concepts	**Jadex concepts**	**Implementation**
Belief set (context beliefs, basic beliefs and operant behaviors)	belief base	Belief set implemented as fields Full set: agentBeliefSet: Map<int,BeliefType> @Belief Map<int,BasicBelief> activeBasicBeliefs @Belief Map<int,ContextBelief> activeContextBeliefs @Belief Map<int,OperantBehavior> activeOperantBehaviors
Desires (context and basic)	achieve goals , query goals, maintain goals	Basic desires set implemented as a generic goal Context desires set is implemented as context desires triggered by beliefs @Goal ContextDesire inner class
Intentions	represented implicitly by the runtime stack of plans to be executed	Plans related to each desire and to operant behaviors @Plan method
Conduct	-	As java classes
Action	Specific instruction inside plans to pursuit a goal	Specific instruction inside plans to pursuit goal in neutral, maladaptive or adaptive way

The agentBeliefsSet field contains BeliefType objects. The BeliefType is an abstract class that defines belief's generic behavior and has three attributes: *content, perspective and context*. Context belief, operant behavior and basic belief are classes that extends the BeliefType abstract class. In the case of context belief, two additional attributes are considered as *nature* and *category*, which

defines irrational/rational belief nature and its related irrational/rational category. Perspective field can take *self, other, life or context related* value. Context field defines the type of events that will be simulated and it is set according to the percept context values. In this way when a percept with the same context value of a defiend belief is received, the related belief is activated. In the case of operant behaviors, the context value should be defined as *reactive* and in the case of basic belief should be defined as *identity*. Context values related to context belief depend on the use case that will be modeled as in the case of percept context values (see section 4.4).

To carry out the specific cognitive processing in each step of the dialog, three Map structures are defined, annotated with @Belief, to manage the type of belief, activated in each step:

```
@Belief
protected Map<Integer, ContextBelief> activeContextBeliefs;
@Belief
protected Map<Integer, OperantBehavior> activeOperantBehaviors;
@Belief
protected Map<Integer, BasicBelief> activeBasicBeliefs;
```

Two set of desires have been defined: basic desires (D_o) and context desires(D_c). Each basic desire is implemented as a generic goal that is triggered when it is needed as top-level goal. Basic desires are triggered during cognitive processing when needed, by a dispacthTopLevelGoal instruction provided by the Jadex engine:

```
(BasicDesire)bdiFeature.dispatchTopLevelGoal(new BasicDesire().get();
```

Context desires are related to context beliefs and are triggered according to the active beliefs. A context desire is modeled as an inner class, named ContextDesire, and has two string fields: content (i.e., “No to have cancer”) and nature (irrational or rational). Context desires are closely related to belief nature, so every time a context belief is added into the activeContextBeliefs, a new context desire of

irrational or rational nature is created. To support this processing the constructor of the ContextDesire class should be annotated as:

```
@GoalCreationCondition(beliefs="activeContextBeliefs")
```

Intentions are modeled as methods that represent plans. Three plans are modeled: one related to execute operant behavior and two to achieve basic and context goals. The plan related to operant behavior is elicited in a dynamic way when the agent's activeOperantBehaviors collection is updated; then the agent executes the plan. The plans modeled are:

```
@Plan(trigger=@Trigger(goals=BasicDesires.class))
@Plan(trigger=@Trigger(goals=ContextDesires.class))
@Plan(trigger=@Trigger(beliefs=activeOperantBehaviors))
```

Each plan contains the specific instructions (actions) to achieve goals that include selecting a conduct (maladaptive/adaptive and communicative pattern), building the response and, finally, executing the action, that is, sending to the user the output (text and cognitive-affective-behavioral information).

The agent cognitive processing is defined in the agent body method annotated as @AgentBody and its functioning is explained next (see Fig. 4.7). With the information related to each percept (classification, context and impact), each element of the agent's belief set (agentBeliefsSet) is reviewed (*blf_revision*) to determine which belief(s) is/are activated. In this version of the framework, only one belief can be activated according to the perceived percept. Each context information related to the belief is compared with the context information of the percept and if they match, it is added into the corresponding active belief collection. Later, the online processing, which is part of the *blf_processing*, starts. The online belief processing consists of determining what type of belief is activated (basic, operant or context). If context beliefs are activated the activeContextBeliefs collection is iterated to define its irrational or rational nature, which depends on the amount of irrational and rational beliefs activated:

$CB_I = \sum B_I$ and $CB_R = \sum B_R$, (amount of irrational and rational beliefs):
If $CB_I > CB_R$, the process has an irrational tendency,
If $CB_I < CB_R$, the process has a rational tendency.

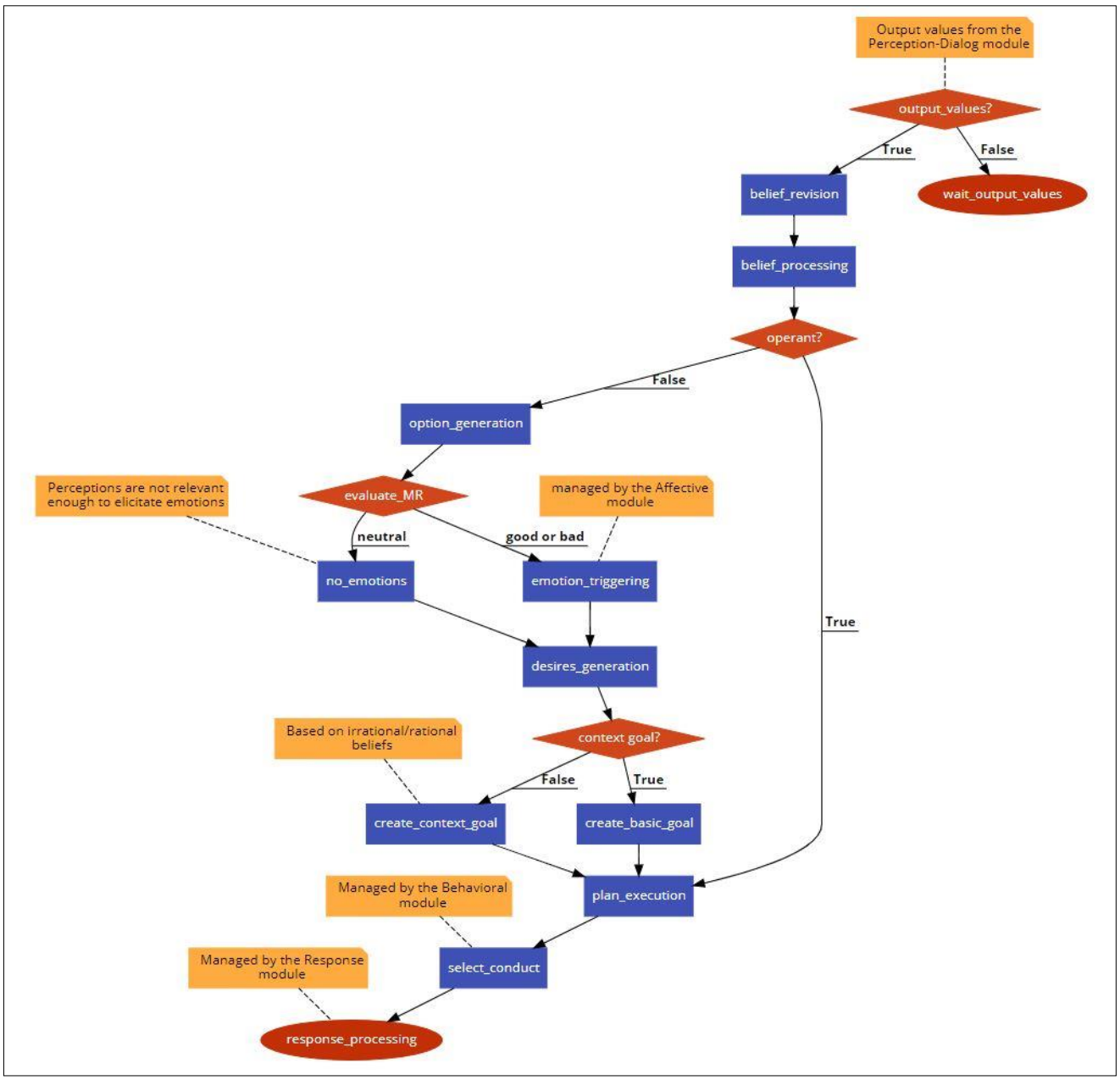


Fig 4.7. Cognitive module work flow diagram.

In the case of CBI = CBR, the Table 3.9 is used and the irrational or rational tendency depends on the agent's personality.

Once *belief_processing* ends, if an operant behavior is activated, its related plan is executed and the agent returns to be online ready to receive new user's inputs. If basic beliefs or context beliefs are activated, the options generation (*option_generation*) process stars. The process consists in triggering the emotional processing and creating a goal related to active beliefs. First, the motivational relevance (MR) is evaluated to decide if the affective processing

including emotions elicitation, mood updating and affective regulation starts. Affective processing is triggered only if motivational relevance (MR) is high. In this first version, if perceptions have non-neutral impact are relevant enough to elicit emotions. Therefore, perceptions with good or bad impact have a high MR and the emotional process is triggered; perceptions with neutral impact have low MR and not emotions are elicited. Affective processing is carried out by the Affective module that is explained 4.6. Later, the goal creation process starts based on active beliefs. If basic beliefs are activated, a basic goal is created and triggered with the dispatchtoplevelgoal instruction. In the case of context beliefs, if the cognitive process has an irrational or rational tendency a goal is created (@GoalCreationCondition) and will be pursuit in an irrational or rational way. Once the emotional processing is triggered (or not) and a goal is created, plans related to goals are triggered (*plan_execution* process, see Fig 3.4) and actions inside plans are executed. In both cases, operant behavior or basic/context beliefs, plan execution will consist of:

1. Selecting a conduct (maladaptive/adaptive and communicative pattern) according to the activated operant behavior or basic/context beliefs. Conduct is managed by the Behavioral module explained in section 4.7.
2. Processing the cognitive-affective-behavioral responses: cognitive information (beliefs), affective state (emotions, mood and regulation) and behavioral information (conduct) of the agent in each step of the dialog (i.e., the category of the belief that has been activated, the emotion elicited, mood state, regulatory strategies, maladaptive/adaptive conduct and communicative pattern. Agent response is managed by the Response module explained in section 4.8.

As it can be seen, the cognitive processing is the manager process where the affective, behavioral and response processing are invoked. These processes are explained next.

4.6 Affective module

The affective module manages both affective dimensions and affective regulation. In Fig. 4.8 the work flow diagram regarding affective processing is presented.

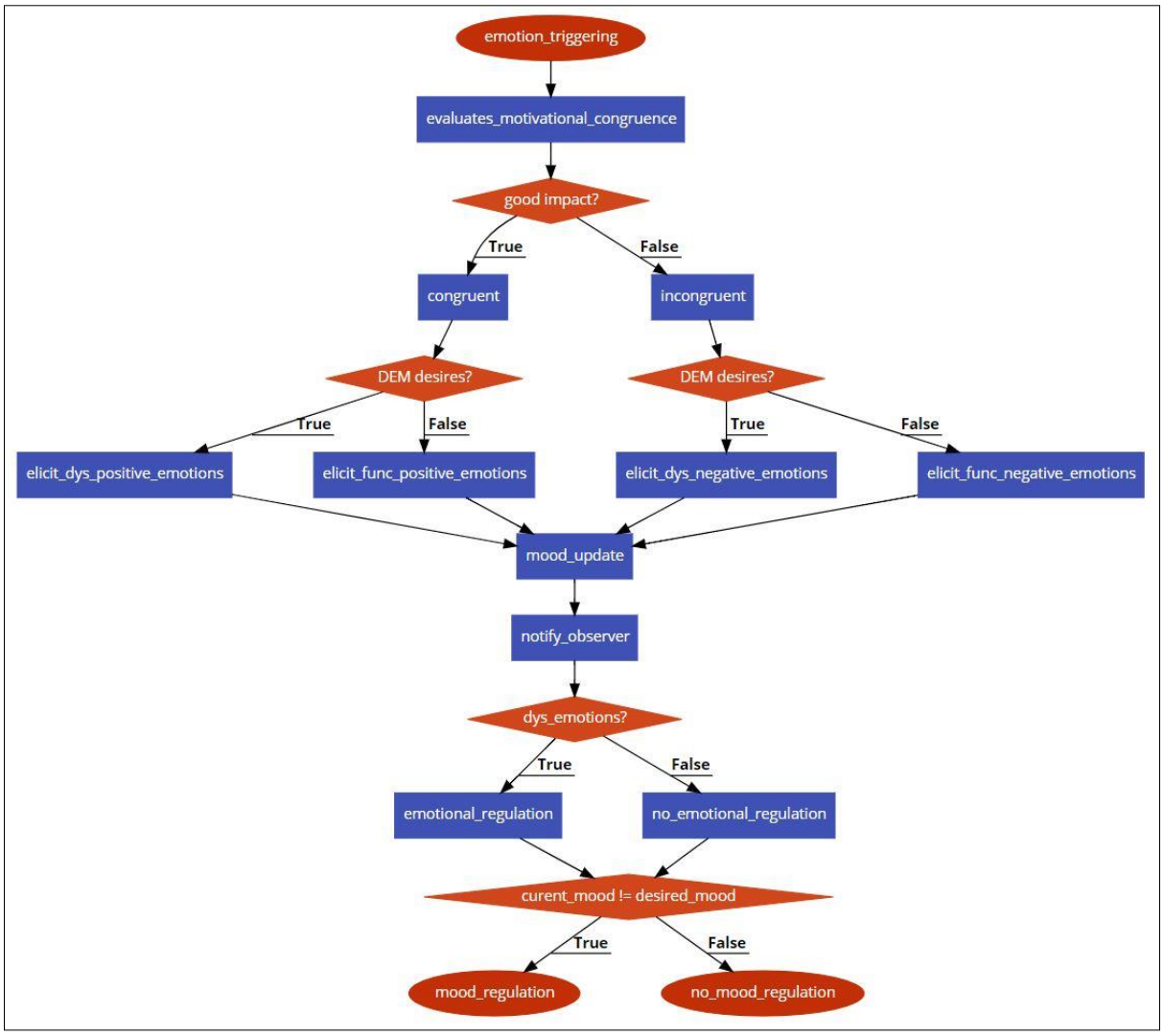


Fig. 4.8. Affective processing work flow diagram.

The affective dimension management involves emotions, mood and personality. A personality object has two integer fields to represent neuroticism (N) and extroversion (E) traits in the range from 1 to 10 (values under 5 are considered low and over 5, high). In the case of emotion and mood, both have been modeled as classes. An abstract class Mood has been defined with two fields: description (i.e. annoyed anxious, sadness, etc.) and value. The value field is modeled as a Point object where **x** defines arousal and **y** defines valence. Two classes that extend the mood abstract class have been defined to represent agent's current and desired mood. The agent's current mood value can be one of the 24 moods that has been modeled (see Fig. 3.7).

The agent's desired mood value is defined regarding the agent personality and both current and desired mood are established in the initialization module as explained in section 4.3.

Emotions have been modeled with the following class hierarchy: an abstract class to define a generic emotion (Emotion), and two child classes to define dysfunctional and functional emotions (DysEmotion, FuncEmotion, respectively). An Emotion has three fields: description (i.e. guilt, angry, etc.), character (1,-1) represents positive/negative, and expected value regarding mood (arousal; valence). The expected mood field has been also modeled as a Point object like mood value field and it is used to establish the emotion-mood relationship (see section 3.3.4.2). DysEmotion and FuncEmotions classes represent dysfunctional and functional emotions, respectively. The dynamic of an affective state is modeled as an interface IDynamic that represents the ability of an affective dimension to change over time. Therefore, both emotion and current mood classes implement this interface (see Fig 4.9).

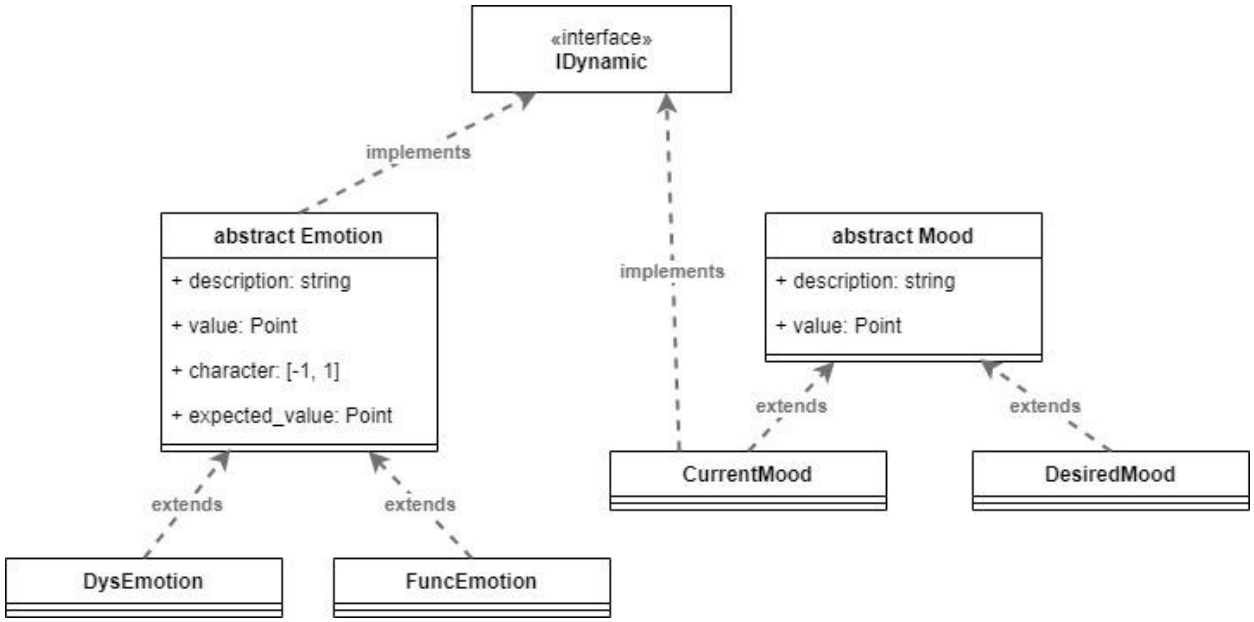


Fig. 4.9. Class diagram regarding mood and emotion dimensions.

The different moods and emotions considered with their predefined values of arousal and valence (see Fig. 4.10) are stored in an affective dimension file and

preloaded in the initialization module (see section 4.3). Following the appraisal process explained in section 3.3.4.1, three main stages are considered:

1- Primary appraisal: Determines the negative or positive character of the emotions by determing the motivational congruence (MC) and their dysfunctional and functional nature (DEM/Preferences) of emotions by means of the irrational/rational nature of the generated desires.
2- Secondary appraisal: Determines which specific emotions are elicited.
3- Mood updating: Updates mood value considering the emotions elicited.

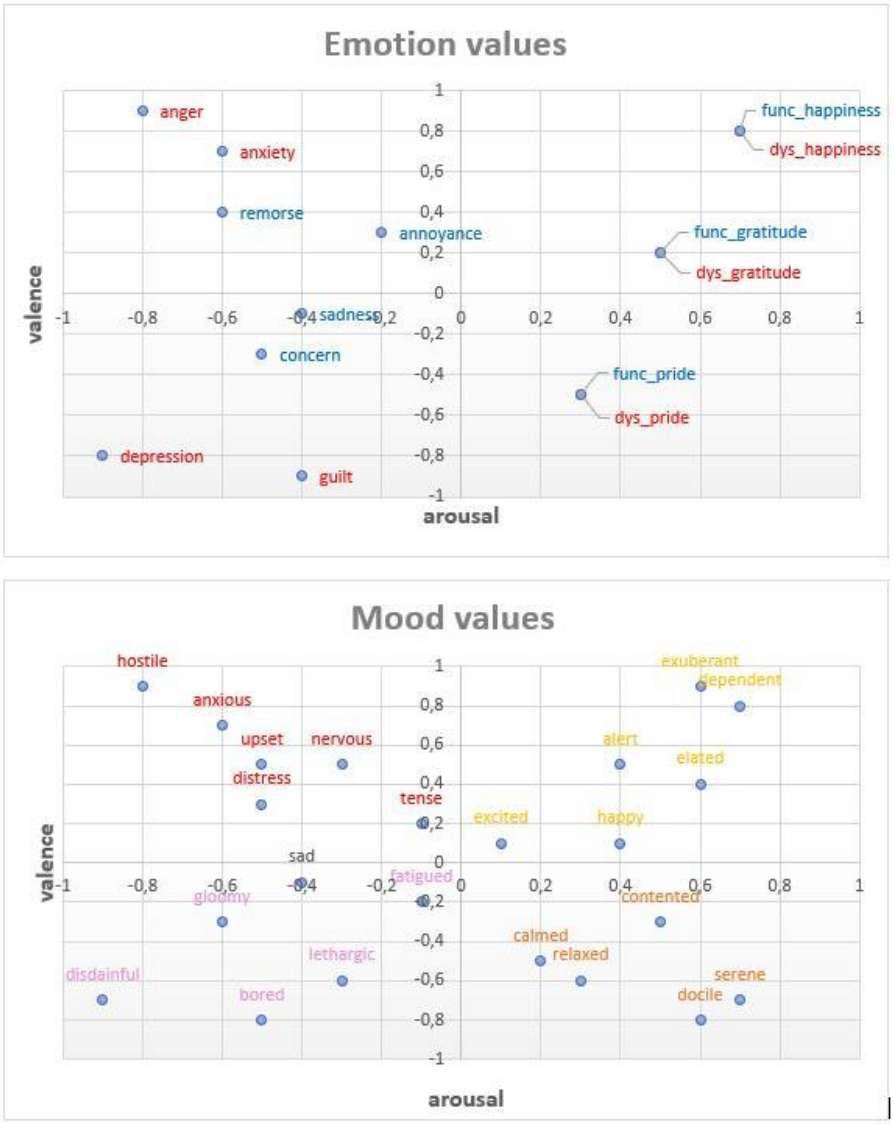


Fig. 4.10. Predefined emotion and mood values.

In the *primary_appraisal* process, the motivational congruence (MC) defines if the input, that is relevant for the agent, fits agent's desires. To do so, the percept impact information is used:

A bad impact → MC is evaluated as incongruent
A good impact → MC is evaluated as congruent

Once primary appraisal is over, secondary appraisal starts to determine the specific emotions that will be elicited. To do so, the information (perspective, nature) related to the active context beliefs is used. Following the definition explained in section 3.3.4.1, eleven dysfunctional/functional emotions (3 positive and 8 negative) can be elicited (see Fig 3.6) depending on the DEM/Preferences character of desires generated dysfunctional/functional emotions will be elicited (section 3.3.4.1). Each elicited emotion is stored in an eEmotions list (List<IDynamic>).

One important affective processing is the mood updating process. As it has been explained in section 3.3.4.2, the process involves: previous mood and expected mood and is influenced by the agent's personality and desired mood, (established in the initialization module). Agent's current mood is updated as follows:

$$Mc = \frac{previous\_mood}{Eexp\_value}$$

The above expression is used if just one emotion is elicited, where *previous_mood* is related to the current mood value when the emotion was added into the elicited emotion list (eEmotions) and the *Eexp_value (expected value)* is the one related to the elicited emotion. If more than one emotion is elicited, the agent personality comes into play. Therefore, following Table 3.11, with a high degree of N (neuroticism), the *Eexp_value* will be the one associated with the emotion with lowest valence value, and with a high degree of E (extraversion), it will be the one associated with the emotion with highest valence value. In this first stage of implementation, only one belief at the time is activated, coexistence of emotions is not managed.

The affective regulation management involves both mood and emotion regulation. To model the affect regulation mechanism a State and Observer pattern have been used. During the affective processing, when an emotion is elicited (added into the eEmotions list) or the mood is updated (change of the mood current value), the AffectRegulationEngine object is notified and the IDynamic (Emotion or CurentMood objects) that have changed their state are passed to it. Emotional regulation strategies are triggered only when dysfunctional emotions arise.

Therefore, if a dysfunctional emotion is elicited or mood is updated, the appropriate regulatory strategy is then triggered, depending on agent's personality values (see Tables 3.12 and Table 3.13). The State pattern is use to model which affect regulation strategy (emotional or mood) is executed according to the affective dimension that has been updated. The Observer pattern has been used to notify to the observers (regulation engine) when the affective state of the agent has been changed, regarding both, emotional and mood states.

To regulate emotion two strategies have been modeled: reappraisal and suppression. Reappraisal strategy involves the transformation of the situation from the cognitive point of view to alter the emotional impact caused by it (see section 3.3.5). In this case, the impact information related to percept is used (i.e., change percept impact value from bad to good) and the agent revaluates its perceptions that provoke a belief reevaluation (*belief_reevaluation*). The suppression strategy consists of attempting to inhibit the outgoing emotional behavior; therefore, to implement it, the agent will behave with a normal conduct. If no regulatory process is carried out, an informative message is shown. In Table 4.6, the emotional regulation strategies, regarding the agent personality values and how they have been implemented, are shown.

Table 4.6

Emotional regulation strategies, related personality values and their implementation.

Personality traits	**Regulation Strategy**	**Implementation**
High neuroticism (N), Low extraversion (E)	Suppression	The agent will not express emotions, to do so a conduct related to an operant behavior is selected.
Low neuroticism (N), High extraversion (E)	Reappraisal	Alter the percept impact information from bad to good, which triggers the cognitive affective processing and functional emotions and adaptive conducts arise.
High neuroticism (N), High extraversion (E)	No regulation	No action. An informative message is shown: "The agent does not have the ability to regulate his emotions"
Low neuroticism(N), Low extraversion(E)	No regulation (rational process)	No action. An informative message is shown: "The agent has rational response".

Mood regulation is triggered if current mood value is different from desired value; therefore, the agent will be most of the time regulating its mood state. This is why, during affective processing, both strategies may overlap. If dysfunctional emotions are elicited and the agent personality has a high degree of N and Low degree of E, mood behaviour strategy is *Inhibit the expression* and emotional strategy is *Suppression*, which refers to the same action. This is also the case of the reappraisal emotional regulation strategy and the reinterpret the situation mood strategy (high E and Low N case).

In fact, for the moment and, regarding mood regulation, only the strategies that coincide with the emotional strategies have been implemented. The rest are implemented just in an informative way (no action is carried out, only a message is shown), as they are more oriented to abstract or subjective behaviors (i.e., Avoidance, Thinking on success in other areas of life), or are very subjective (i.e., Self-reward, Stoicism, Fantasy). In Table 4.7, the agent personality values, the mood regulation mechanism, strategies and how it has been implemented, are shown.

Table 4.7

Mood regulation mechanisms and strategies, related personality values and implementation.

Personality traits	**Mechanisms**	**Strategies**	**Implementation**
High neuroticism (N), Low extraversion (E)	Focused on itself	Inhibit the expression (Behavior), Fantasy (Cognitive)	*Behavior*: The agent will not express emotions, to do so a conduct related to an operant behavior is selected. *Cognitive*: No action. An informative message is shown -> "Fantasy to forget the problems"
High extraversion (E), Low neuroticism (N)	Focused on the situation	Direct action (Behavior), Reinterpret the situation (Cognitive)	*Behavior*: No action. An informative message is shown -> "Direct action" *Cognitive*: Alter the percept impact information from bad to good, which triggers the cognitive affective processing and functional emotions and adaptive conducts arise.

Table 4.7 (Continued)

Personality traits	Mechanisms	Strategies	Implementation
Low neuroticism(N), Low extraversion(E)	Focused on itself	Self-reward (Behavior), Stoicism (Cognitive)	*Behavior*: No action. An informative message is shown -> "Self-reward" *Cognitive*: No action. An informative message is shown -> "Stoicism"
High neuroticism(N), High extraversion(E)	Focused on the situation	Avoidance (Behavior), Thinking on success in other areas of life (Cognitive)	*Behavior*: No action. An informative message is shown -> "Avoidance" *Cognitive*: No action. An informative message is shown -> "Thinking on success in other areas of life"

The affective information is used by the response module to build the agent response. Once the affective process ends, the agent conduct is selected by the behavioral module, which is presented next.

4.7 Behavioral module

Behavioral module (see Fig. 4.11) manages conduct (maladaptive/adaptive and communicative patterns).

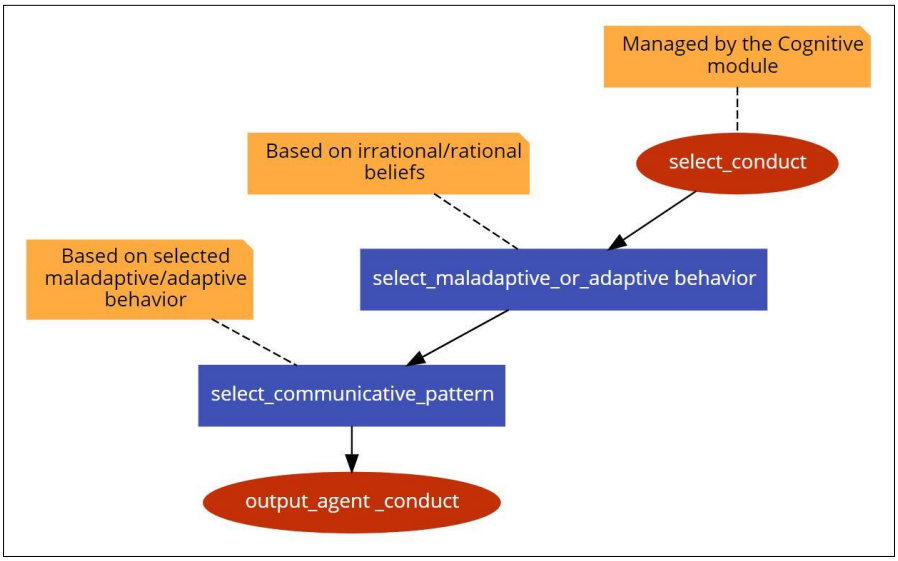


Fig. 4.11. Behavioral module flow.

Agent conduct involves how actions are performed and how the agent will express them. Actions can be performed in maladaptive or adaptive way (hostile, submissive) according to the agent active beliefs. According to the maladaptive or adaptive behavior, the related communicative pattern is selected (see Table 3.8). From the four characteristics defined for each pattern (body gesture, facial expression, voice and linguistic structures, see Table 3.7), in this first implementation approach, linguistic structures have not been considered.

To model conduct a class named Conduct with two fields type (maladaptive, adaptive) and expression (i.e., hostile, submissive) has been defined. To model the communicative behavior an abstract class, Pattern, with five fields, description, body gestures, facial expression, linguistic structures and voice, has been defined. For each pattern type (blaming, placating, irrelevant, leveling and superreasonable) a class that extends the Pattern class, has been defined: BlamingPattern, PlacatingPattern, IrrelevantPattern, LevelingPattern and SuperreasonablePattern. Fields related to physical and verbal expressions have been modeled as string values that describe them. For example, a BlamingPattern object has the following values:

body_gesture: "pointing with a finger"
facial_expression: ["tense_facial_muscles", "pursed_lips",
"expand_nasal_passages", " annoyed_look"]
voice: ["scream_hard", " tense", "shrill"]

The conduct selection process is the first statement inside of the *plan_excecution* process of the Cognitive module. To select if actions (agent response) are performed in maladaptive or adaptive way and how the agent will express those actions, the mapping proposed in Table 3.8 is used. Therefore, if an irrational belief is activated a maladaptive conduct related to the irrational belief category is selected with its corresponding communication pattern, using the activeBeliefsSet information. Otherwise, if a rational belief is activated, an adaptive conduct related to its rational belief category is selected with its corresponding communication pattern. Conducts related to basic beliefs and operant behaviors are modeled according to a rational process, therefore the agent will behave with an adaptive behavior (confidence, openness, unique message) and express it with a leveling pattern.

The cognitive-affective-behavioral processing ends with the output of the information managed by the Response module presented next.

4.8 Response module

The Response module is responsible of building the agent output response. It parses the affective, cognitive and behavioral information into a json format. In Fig 4.12, the basic work flow of the Response module is presented.

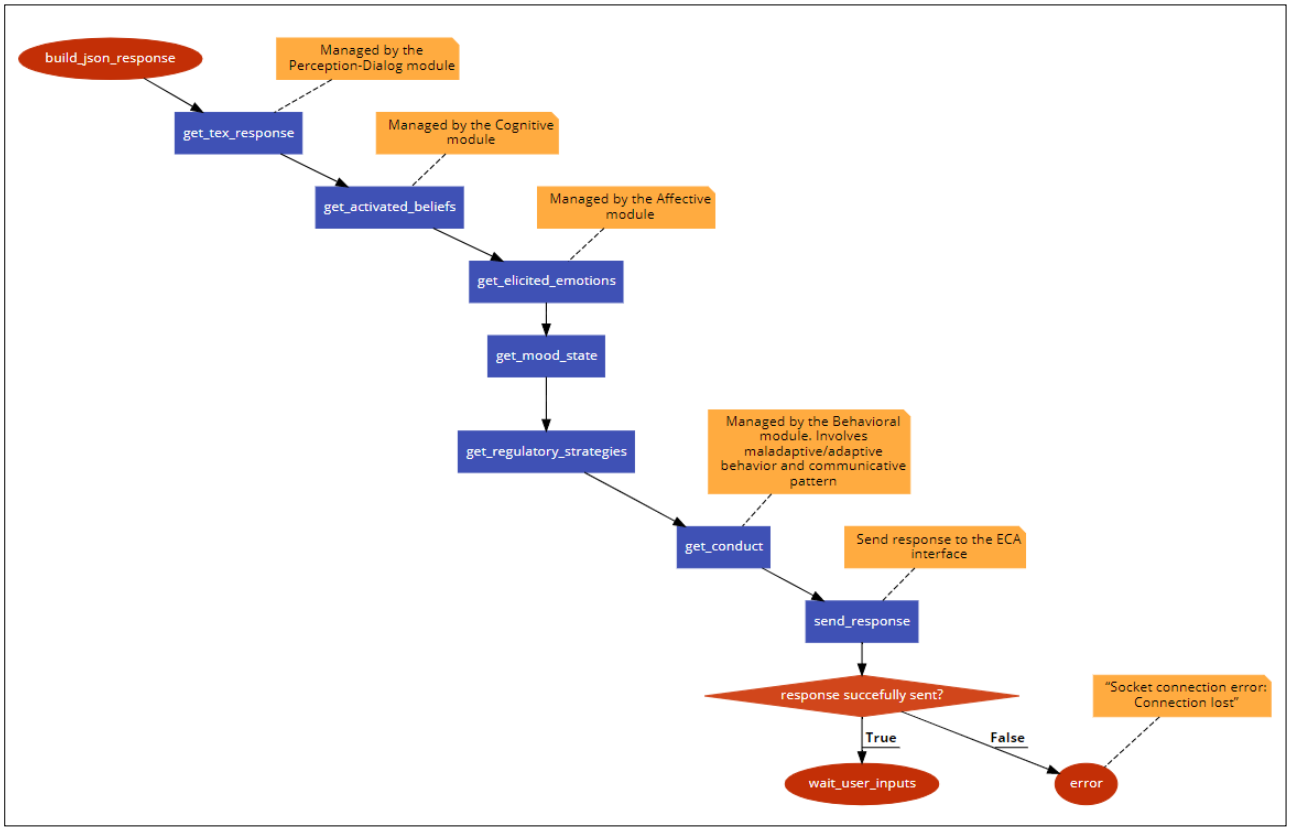


Fig. 4.12. Response module basic work flow diagram.

In each step of the interaction between the agent and the user, the information returned in the output is presented to the user in the following way:

1- Text response: Agent's answer.
2- Cognitive Response (what the agent thinks): Characterization of the irrational/rational beliefs about (A) and of the desire's nature. This determines the type of thoughts the agent will have. In the case of operant behavior, or basic beliefs, no information is shown.
3- Affective information (what the agent feels): Emotions and current mood.

4- Conduct (how the agent behaves): Information about how the agent behaves regarding maladaptive/adaptive conduct and expression (i.e., with hostile interpersonal style and a blaming pattern (body gestures, facial expressions and voice)).

5- Affect regulation: Affective regulatory strategies related to emotions and mood that are triggered during the cognitive-affective processing.

In Fig 4.13, an example of the output information is presented.

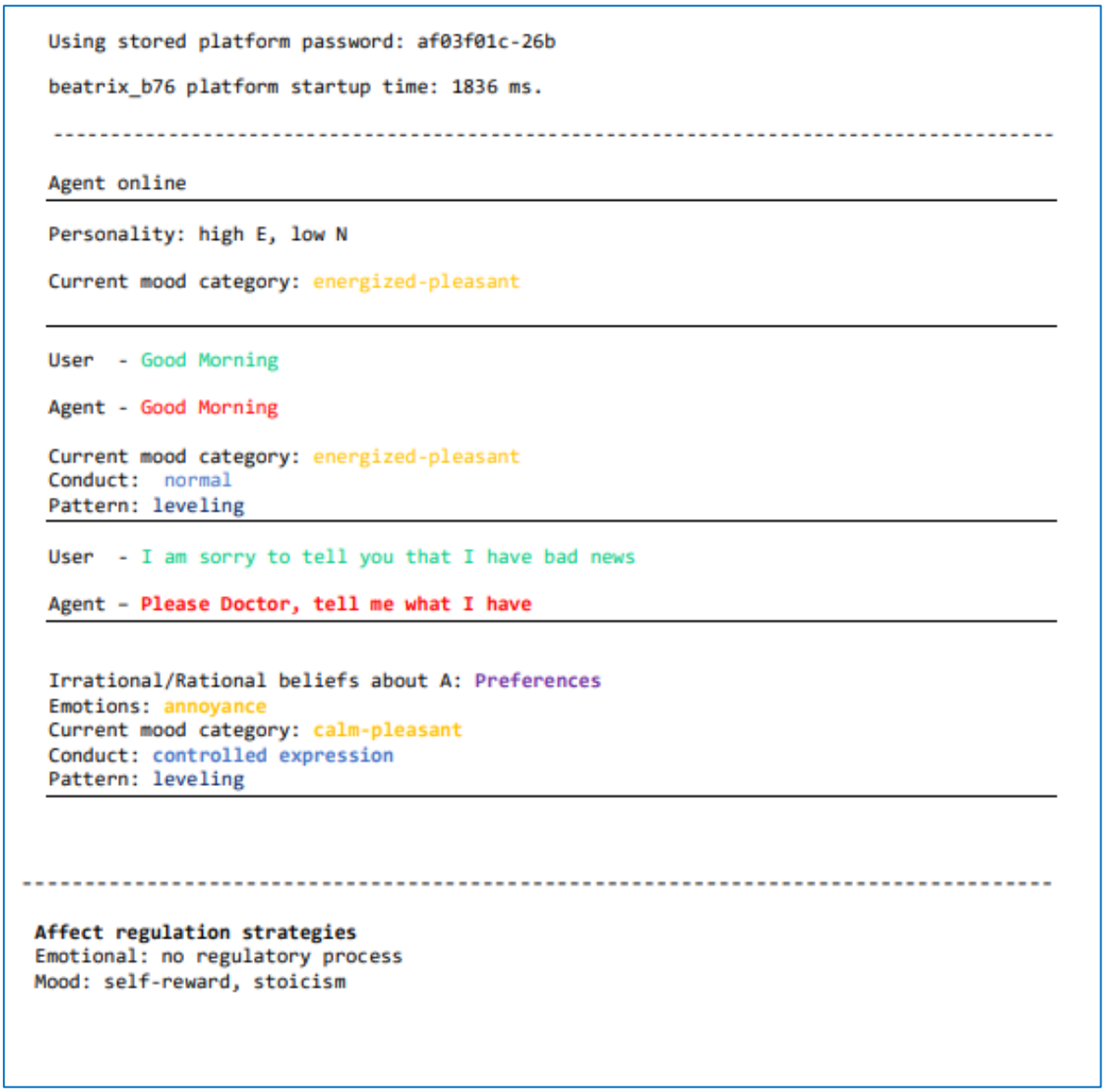


Fig. 4.13. Example dialog with the cognitive-affective-behavioral outputs (from the use case presented in Chapter 5).

To carry out the evaluation of the framework, the output of the cognitive-affective- behavioral and communicative behavior of the agent can be presented to the user in a more friendly format, as it will be explained in next chapter.

4.9 Conclusions

In this chapter, the implementation of the proposed affective ABC-EBDI framework has been presented. The different layers of the architecture, detailing the corresponding modules per layer, have been explained. The framework has been implemented in Java, in particular the Eclipse Java's IDE has been used. To support the BDI reasoning cycle, the Jadex's engine, version 3.3 rc has been chosen due to its simplicity and easy integration into the Java platform. The framework is able to simulate user-agent dialogs (text-based) and makes use of IBM Watson Assistant tool. In each step of the dialog, the system output comprises cognitive (what the agent thinks), affective (what the agent feels), behavioral (how the agent behaves) and communicative (facial expressions, body gestures and voice) information.

To understand the potential of the proposed framework to simulate believable human-like behavior, the simulation of a use case and its evaluation will be presented in next chapter.

CHAPTER 5: Use case and Evaluation

5.1. Introduction

This chapter describes the evaluation that have been carried out to assess the potential of the proposed framework to simulate believable human-like behavior in situations where human behaviors are quite unpredictable. To do so, a bad news scenario has been chosen. The chapter is organized as follows. First, the use case and its simulation based on the proposed framework are explained. Then, the evaluation and its results are presented. Finally, conclusions are presented.

5.2. Use case: The "I wish I had better news" scenario.

The ABC-EBDI framework can be used in different application domains, but as it is based on a therapeutic model, it is especially well-suited to manage adverse situations that generate negative emotions and maladaptive conducts as it is the case in healthcare application domains. Moreover, as it was mentioned in Chapter 1, we focuse on situations where human behavior is varied and unpredictable, this is why a bad news scenario in medical diagnosis (like the one presented in section 1.1) has been chosen (see Fig 5.1). The scenario has been adapted from research about bad news comunications (Saab, 2005), and we have called it "I wish I had better news". Its description follows.

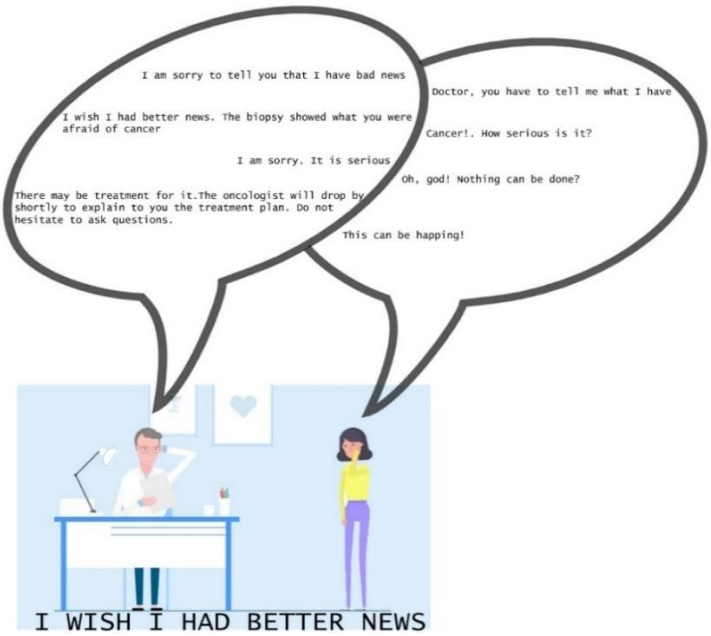


Fig. 5.1. Bad news sacenario in medical diagnosis: *"I wish I had better news"* .

Susan has a history of breast cancer in her family: her mum and aunt died because of it and she knows that little can be done if detected late. She knows that she has

a high chance to have it, because genetics plays an important role in cancer disease. Due to her experience with cancer disease, she is worried about how it could affect her family and how they would react to a news like that. This is way she is stressed when entering doctor's office. There, the following dialog between Susan and the doctor happens:

- *Doctor: I am sorry to tell you that I have bad news.*
- *Susan: Doctor, you have to tell me what I have.*
- *Doctor: Do you remember why we did the biopsy?*
- *Susan: Yes, to see if the mass is cancerous.*
- *Doctor: Judging from what I know of you, you seem to be a person who wants to know what is there irrespective of how serious the condition is.*
- *Susan: I am a believer; I accept God's will.*
- *Doctor: I am sorry. I wish I had better news. The biopsy showed what we were afraid of: cancer.*
- *Susan: Cancer! How serious is it?*
- *Doctor: It is serious.*
- *Susan: Oh, god! Nothing can be done?*
- *Doctor: There may be treatment for it. The oncologist will drop by shortly to explain to you the treatment plan. Do not hesitate to ask questions.*
- *Susan: This can't be happening!*

A simulation where the user plays the role of the doctor and the agent plays the role of the patient has been carried out. As mentioned in previous chapter, some initial configurations have to be made according to the use case:

1- To configure the IBM Watson assistant to support the dialog.
2- To configure the agent cognitive and affective dimensions.

The proposed dialog (adapted from (Saab, 2005)) follows the standard structure identified in the field of bad news communication:

1- Preparing opening statement.
2- Checking patient's knowledge.
3- Checking for patient's preference.
4- Breaking bad news.
5- Avoiding minimization of the problem.

6- Instilling realistic hope.

Therefore, in IBM Watson Assistant, the corresponding six intents have been defined: #openning_statement, #checking_knowledge, #checking_preferences, #breaking_news, #avoiding_minimization and #relalistic_hope. Besides, input phrases are added to their corresponding intent and entities are created to define the agent responses related to each input. In the dialog flow, the *$impact* context variable is set to neutral, bad or good according to the impact of each input in the agent behavior. In Table 5.1 the defined intents, entities and context information of the bad news dialog agent are shown.

Table 5.1.

Defined intents, entities and context information of the bad news dialog agent.

Input	**Intent**	**Related entities**	**Context variable**	**Agent response**
I am sorry to tell you that I have bad news.	#Opening_statement	@opening_bad	$impact (bad)	Doctor, you please to tell me what I have.
Do you remember why we did the biopsy?	#Checking_knowledge	@checking_knw	$impact (neutral)	Yes, to see if the mass is cancerous.
I am sorry. I wish I had better news. The biopsy showed what we were afraid of cancer.	#Breaking_news	@bad_news	$impact (bad)	Cancer! How serious is it?
It is serious.	#Avoiding_minimization	@avoiding_minimization	$impact (bad)	Oh, god! Nothing can be done?
There may be treatment for it. The oncologist will drop by shortly to explain to you the treatment plan. Do not hesitate to ask questions.	#Realistic_hope	@realistic_hope	$impact (bad)	This can be happing!

Similar inputs to each phrase are defined as synonyms. For example, for *"I am sorry to tell you that I have bad news"*, the following synonyms are defined: *I have bad news/I need to tell you something bad*. Later, the dialog flow is defined.

To each intent, a node dialog is created and its content information and possible agent responses, regarding entities, are defined (see Fig 5.2).

Regarding agent's configuration, the texts files related to agent cognitive and affective dimensions have to be settled (see section 4.3):

1- Agent cognitive dimensions: beliefs and desires sets related to the use case.
2- Agent affective dimensions: personality and initial current mood value.

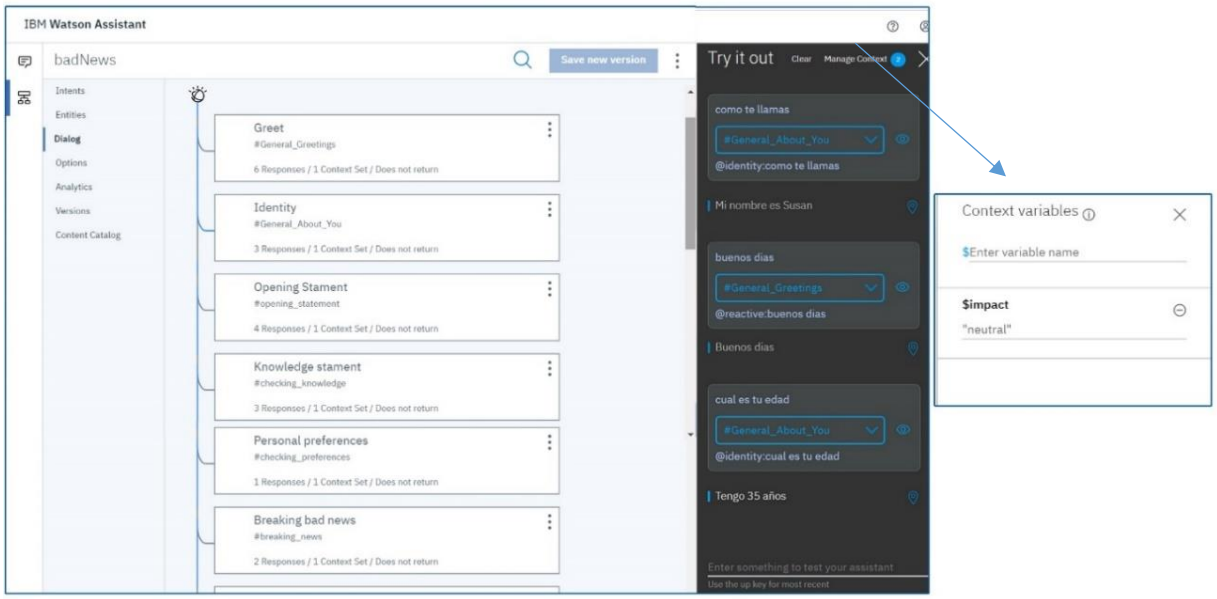


Fig 5.2. IBM Watson Assistant dialog flow for bad news communication.

Beliefs set is defined according to Susan's personal information and life experience. For the use case simulation, context beliefs are defined already categorized with their corresponding generic category. Each defined belief set has the following generic structure:

$$B_{o/op/c}\ (content;\ perspective;\ context)$$

Content: It is set according to the semantic value of the belief, for example, *I am Susan* or directly *Susan* in the case of basic beliefs. In the case of, operant behaviors, it refers to the type of event, for example, *In light of greeting*. In the case of belief context, is related to the thougths that an individual could have, for example, *Having cancer is the worst that can heppning to me.*

Perspective: It is set according to if the belief content refers to self, life or other.

Context: It is defined according to the percept context values, therefore, basic belief context is defined as identity and operant behaviors context as reactive. In the case of context beliefs, they are set according to the percepts context tagging

constructed from the defined @entities in relation with the scenario that is going to be simulated. Therefore, the possible values are: *opening_bad, checking_knw, bad_news, avoiding_minimization and realistic_hope*.

In the case of context beliefs, also the irrational/rational category (DEM, AWF, LFT, GE/SD, Preference, non-AWF, non-LFT, non-GE/SD) is defined. Therefore, context beliefs will have the form of B_c *(content; perspective; context;category)*.

The agent beliefs set is composed by:

- Basic beliefs (B_o): Defined according to Susan's personal information. In this case, two basic beliefs, *name -> Susan and age -> 50 years old,* have been defined. Both have self perspective and identity as context value.
- Operant behaviors(B_{op}): No extra operant behaviors are defined, just generic, such as to greet and to say good bye, are used. All of them have self perspective and reactive as context value.
- Context beliefs (B_c): Defined according to Susan's life experience. In the scenario Susan's main thoughts are about her family and how a bad diagnosis could affect them. It can be deduced that her family approval and comfort it is very important for her. This type of thoughts can be found in Table 3.5 and are related to beliefs linked to comfort like IB-I, IB-VIII, IB-IX and IB-X. Therefore, irrational beliefs regarding those irrational categories can be defined. Morover, from those categories, several implicits beliefs related to the LFT, GE, SD or AWF, can also be defined. For example: she probably has rigid thoughts about the fact that genetics plays an important role in cancer disease (GE) and also, she could be prone to frustration (LFT). Perspective values have been defined according to the belief content and context values are defined according to the percept context tagging. For example, if an irrational belief has the category DEM comfort, and the opening_bad (derived from @opening_bad entity name tag) is assigned to it, when a perception with the same context value is received by the Cognitive module the belief is activated.

Regarding the desires set, it will have the form of $D_{B/C}$ *(content;type)*. The **content** value refers to the semantic content of the desires and the **type** refers to the types of desires supported: basic or context. In this case, two basic and one context desires have been defined:

1- Basic Desires: D_{B1} -> No to died and D_{B2}-> To be happy.

2- Context desire: D_{C1} -> Not to have cancer.

In Table 5.2, agent beliefs and desires values are presented.

Table 5.2.

Agent initialization values.

	Simulation
P	High N, High E
M_c	Nervous, energized-unpleasant category
B_o	B_o(Susan; self; identity), B_o(50 year; self; identity)
B_{op}	B_{op1}(In light of greeting; other; reactive) B_{op2}(In light of say good bye; other; reactive)
B_C	B_{I1}(I need my family approval and a cancer diagnosis could affect them; self; opening_bad; DEM comfort) B_{I2}(I'd rather not be a burden for my family; self; bad_news; GE) B_{I3}(Serious diseases always have to do with the genetics that one brings and it is impossible to change it; life; avoiding_minimization; DEM comfort) B_{I4}(I am incapable to cope with this situation, I need someone to trust; life; realistic_hope; LFT)
D_B	C_{B1}(Not to died; basic) C_{B1}(To be happy; basic)
D_C	C_{C1}(No to have cancer; context)

B_o : Basic beliefs; B_{op}: Operant Behaviors; B_c: Context beliefs; C_B: Basic desires; C_C: Context desires; M_c:Initial mood; P:Personality.

Initial mood and personality are set according to the context of the scenario. In this case, initial current mood value (M_c) has been defined according to how Susan could feel at the time she gets into the doctor's office. In this case, Susan was nervous, therefore: M_c → energized-unpleasant (see Fig.3.7, in section 3.3.4.2). Personality has been defined as one of those personalities characterized for being extreme and prone to lead to unpredictable behaviors: high neuroticism and high extraversion. In Table 5.2, agent mood and personality initialization values are presented.

Once the configurations are set, the agent is inizialized and ready to interact with the user. In each step, during the dialog, the system inputs are the doctor (user) entries and the outputs are the following:

1- Agent text response.
2- Agent thoughts: Correspond to the cognitive information related to the characterization of the irrational/rational beliefs. The information presented to the user is the one related to the belief category name (see Table 3.2).
3- Agent affective state: Corresponds to the agent emotions about the event and how its mood state has been changed according to them. The information presented to the user is the one related to the emotions and the mood names (see Fig. 3.6 and 3.7).
4- Agent conduct: Corresponds to how the agent behaves. The information is presented to the user is the one related to the maladaptive/adaptive conduct name (see Table 3.2) and the communicative pattern name (see Table 3.8).
5- Affect regulation strategies: Correspond to how the agent regulates its affective state during the dialog. The information presented to the user is the strategy name (see Table 3.12 and 3.14).

Simulation ends when the agent receives one of the general endings defined in the IBM Watson Assistant (see Table 4.2) from the user. In Fig 5.3, the simulation output related to the use case is presented.

As it can be seen, during the dialog, the agent experiences anger, depression and anxiety. These elicited emotions are dysfunctional negative emotions, due to the irrational beliefs set of the agent and its personality. The agent mood changes from energized-unpleasant state to calm-unpleasant state, as the result of the elicited emotions and the agent's tendency to feel negative states. Finally, the agent feels anxiety and the mood changes to an energized-unpleasant state. The agent conduct during the dialog is maladaptive, since it is related to demand desires such as $D_c \rightarrow$ (Not having cancer) and to its dysfunctional emotions such as anger and anxiety. Therefore, during the interaction, the conduct of the agent goes through several stages such as defensiveness, avoidance and, finally, social isolation.

```
Using stored platform password: 283ca33f-986

ZAZ-8SB9MQ2_fa8 platform startup time: 2234 ms

Agent online
```

```
Personality: neuroticism: 7, extraversion: 9

Current mood: nervous, valence: -0.3, arousal: 0.5, category: energized-unpleasant
```

```
User  - Good Morning

Agent - Good Morning
```

```
Current mood category: energized-unpleasant
Conduct:  normal
Pattern: leveling
```

```
User  - I am sorry to tell you that I have bad news
Agent – Please Doctor, tell me what I have
```

```
Irrational/Rational beliefs about A: DEM comfort
Emotions: anger, depression
Current mood category: energized-unpleasant
Conduct: defensiveness
Pattern:
```

```
User   - I am sorry. I wish I had better news. The biopsy showed what you were afraid of cancer
Agent  - Cancer! How serious is it?
```

```
Irrational/Rational beliefs about A: GE
Emotions: depression
Current mood category: calm-unpleasant
Conduct: defensiveness
Pattern:
```

```
User   - I am sorry, it's serious

Agent  - Oh my god, I am going to die!
```

```
Irrational/Rational beliefs about A: DEM comfort
Emotions: anger
Current mood category: energized-unpleasant
Conduct: procrastination
Pattern:
```

```
User   - There may be treatment for it. The oncologist will drop by shortly to explain to you the treatment
         plan
Agent  - This can’t be happening!
```

```
Irrational/Rational beliefs about A: LFT
Emotions: anxiety
Current mood category: energized-unpleasant
Conduct: social insolation
Pattern:
```

```
Affect regulation strategies
Emotional: no regulatory process
Mood: no regulatory process
```

Fig 5.3. I wish I had better news simulation output.

Simulations, as the one explained here, have been used to assess the framework capability to simulate human-like behavior in that type of situations as it is explained next.

5.3. Evaluations

Among the diferent forms of evaluations, the triangulation technique has been widely used due to its usefulness to enhance the validity of research findings (Mathison, 1988). Triangulation involves the employment of multiple external data collection methods concerning the same events and may be enhanced by multiple external analysis methods. There are five fundamental types of triangulations (Denzin, 2017; Begley, 1996):

1. Data triangulation: Referes to using several data sources, for example, the inclusion of more than one individual as a source of data.
2. Specialists or investigator triangulation: Involves multiple researchers in an investigation.
3. Method triangulation: Involves using more than one method to gather data, such as interviews, observations, questionnaires, and documents.
4. Theory triangulation: Involves using more than one theoretical scheme in the interpretation of the phenomenon.
5. Multiple triangulation: Involves the combination of two or more tringulation techniques (Begley, 1996).

To evaluate the proposed framework, the multiple triangulation technique has been used. In this case, the data and specialist tringulation techniques are combined. The data technique is used to collect data from a nonspecialized point of view, in this case from user perspective. The specialist triangulation has been used to collect information from a specialized point of view. The combination of both perspectives have been chosen because we think is suitable to validate the capability of the framework of simulating complex human-like behavior, not only according to the criteria of experts, but also from individual self perspective.

More specifically, the objective of the evaluation has been to assess whether the cognitive-affective-behavioral consequences of the agent are realistically simulated in the bad news communication scenario previously presented. These consequences comprise:

1. What the agent thinks: The agent irrational/rational beliefs.
2. What agent feels: The agent emotional and mood state.
3. How the agent behaves: The agent maldaptive/adaptive conduct.

How the agent communicates (Satir patterns) and regulates its emotions have been not included in the evaluation, and would require a specific evaluation (i.e, to assess the agent's regulatory and communicative abilities) (see future work in section 6.2).

As stated before, two types of evaluations have been carried out, one with experts and one with users (general public). Both evaluations are presented next following this presentation scheme:

1. Method, participants selection and procedure.
2. Bad news scenario simulations.
3. Assessment result.

A general discussion about the results will also be presented.

5.3.1. Evaluation by experts (Specialist triangulation)

5.3.1.1. Method, participants selection and procedure

The triangulation of specialists involves the use of several evaluators in the process. To carry out this technique, it is necessary to align different specialists in the same field of study, so that each evaluator examines the "program" with the same qualitative or quantitative method (questionnaire, interview, observation, case study or focus groups). In this case, the questionnaire method is used. The questionnaire given to the experts ask them to evaluate: what the agent thinks (beliefs), what it feels (emotions and mood) and how it behaves (maladaptive/adaptive conduct). As measurement method, a qualitative scale is defined: Not realistic at all-1, Not very realistic-2, A little realistic-3, Somewhat realistic-4, Quite realistic-5 and Very realistic-6.

An essential part of the process is the selection of the participants as they must be specialists in the field of study to be evaluated. In our case, the inclusion criterion has been based on their direct relationship with the bad news communication scenario. The specialists involved in the study are three experts currently working as clinical psychologists, two of them in ASPANOA (Asociación de Padres de niños con cáncer en Aragón/Association of Parents of Children with

Cancer in Aragon) and another in the San Juan de Dios Hospital, in the province of Zaragoza in Spain. All of them are directly related to the communication of bad news to both patients and their families.

The evaluation procedure was:

1- Specialist were contacted and the evaluation was explained to them.
2- Two simulations were carried out to reproduce a bad news scenario. The situation was the same, but the life experience and personality of the patient (agent) changed.
3- A document with the results of the simulations and the questionnaires were mailed to the specialists.
4- After evaluating the simulations, specialists returned the filled questionnaire by email. In ANNEX I the questionnaire is presented.

5.3.1.2. Bad news scenario simulations

Two different simulations for the same scenario were presented to the specialists. The general scenario is the one presented in previous section. In both simulations, Susan is a patient who goes to the doctor's office to receive a positive cancer diagnosis result. She has a history of breast cancer in her family: her mum and aunt died because of it. Simulations correspond to two types of patient's personalities, chosen because they are extreme and lead to quite unpredictable behaviors:

1. Simulation 1 corresponds to a high neuroticism (N) and high extraversion (E) personality.
2. Simulation 2 corresponds to a low neuroticism (N) and low extraversion (E) personality.

Besides the personality, initial mood values and belief sets are also different in both scenarios. Beliefs set is defined according to her life experience and personality (irrational/rational tendency), and the initial current mood value (M_c), according to how she could feel at the time she gets into the doctor's office.

In the first simulation Susan life experience is focused in having her family comfort and approval, since Susan's main thoughts are about her family and how a bad diagnosis could affect them (see section 5.2). Therefore, and based on her personality (tendency to irrationality), Susan's beliefs set is composed by

irrational beliefs, related to DEM Comfort, LFT and GE/SD. As Susan was stressed before talking to the doctor, her initial current mood (M_c) was set to energized-unpleasant (see Fig.3.7, in section 3.3.4.2).

In the case of simulation 2, Susan's beliefs set is different since her life experience changes. In this case, also her mum and aunt died because of it, but she knows that if it is detected late little can be done but if detected early a lot may be done. She also knows that the best way of facing cancer is being objective and stating focused in treatments. She is also aware of the role of genetics in cancer disease, and that it is something that is out of her control. This is why she is excited, alert when entering doctor's office. Based on it and her personality (tendency to rationality), it can be deduced that Susan's thoughts about having cancer are flexible since she knows that a cancer detected early can be cured and she also thinks that stating focused in the treatment is very important to beat it. So, her main thoughts are rational, have a preferential nature and are related to the RB-I, RB-II, RB-III categories found in Table 3.5. Rational beliefs related to those rational categories can be defined. Moreover, from those categories, implicit beliefs related to the non-LFT, non-GE/SD or non-AWF, can also be defined (see Table 3.4). In spite of Susan's general tendency to rational thoughts about cancer, she also has rigid beliefs about the fact that genetics plays an important role in cancer disease (IBV, IB-III). Regarding the initial current mood value (M_c), as Susan was excited and alert at the time she gets into the doctor's office, it is set to energized-pleasant (see Fig.3.7, in section 3.3.4.2).

In Table 5.3, the agent (Susan) initialization values for both cases, including the different sets of beliefs, are shown. The simulation outputs shown to the specialists are the following:

1- Agent text response.
2- Agent thoughts: The agent irrational/rational beliefs about the event. The information is presented to the user in a more readable format. So, in the output instead of the category of the belief (i.e., AWF, see Fig 5.3 in section 5.2), the related thought (i.e., "Having cancer is the worst that can be happen") is presented to the specialist.
3- Agent affective state: The agent emotions and mood state during the dialog (i.e., it feels anger, it feels excited, respectively).

4- Agent non-verbal behavior: The agent conduct during the dialog. The information presented to the user is the maladaptive/adaptive conduct and communicative pattern names.

In Fig. 5.4, both simulation outputs are shown.

Table 5.3

Agent initialization values.

	Simulation 1	**Simulation 2**
P	High N, High E	Low N, Low E
M_c	Stressed, energized-unpleasant	Alert, energized-pleasant
B_o	B_o(Susan;self; identity), B_o(50; self; identity)	[a]Same
B_{op}	B_{op1}(In light of greeting; other; reactive) B_{op2}(In light of say good bye; other; reactive)	[a]Same
B_c	B_{I1}(I need my family approval and a cancer diagnosis could affect them; self; opening_bad; DEM comfort)	B_{R1}(I want to be focused and not to get carried out by others; self; opening_bad; Preferences)
	B_{I3}(I'd rather not be a burden for my family; self; bad_news; GE)	B_{R2}(If I have cancer will face it on my own way; self; bad_news; non-LFT)
	B_{I4}(Serious diseases always have to do with the genetics that one brings and it is impossible to change it; life; avoiding_minimization; DEM comfort)	B_{R3}(If I have cancer I want to know every possible treatment; self; avoiding_minimization; non-LFT)
	B_{I5}(I am incapable to cope with this situation, I need someone to trust; life; realistic_hope; LFT)	B_{I1}(Situations that are out of my control, can't happen; self; realistic_hope; DEM control)
D_B	C_{B1}(Not to died; basic) C_{B1}(To be happy; basic)	[a]Same
D_C	C_{C1}(No to have cancer; context)	[a]Same

B_o : Basic beliefs; B_{op}: Operant Behaviors; B_c: Context beliefs; C_B: Basic desires; C_C: Context desires; M_c:Initial mood; P:Personality; [a]Same: The same value than simulation 1.

Simulation 1

Características del Paciente

Personalidad- optimista y directa, no se anda con rodeos. Es algo propensa a la ira y a estados depresivos.

Estado de ánimo inicial- Al entrar en la consulta del médico se encuentra algo estresada por la incertidumbre que genera el resultado de la biopsia.

Diálogo *(en morado lo que piensa/siente, en azul la comunicación no verbal)*

Doctor - Buenos días

Paciente - Buenos días

- Se siente estresada
- Se muestra neutral

Doctor - Lamento decirle que tengo malas noticias

Paciente - Doctor, hable sin rodeos

- Piensa que esto podría afectar mucho a su familia
- Siente ira y depresión
- Su expresión muestra un alto grado de ira, y se comporta de forma defensiva

---

Doctor - Lo siento mucho… aunque me gustaría tener mejores noticias, la realidad es que la biopsia muestra claramente que el tumor es cancerígeno

Paciente - ¡Cáncer! Pero… ¿Es muy grave?

- Piensa que prefería no ser una molestia para su familia
- Siente depresión
- Se muestra triste, desdeñosa, y se comporta de forma defensiva

---

Doctor - Lo siento, realmente es muy agresivo

Paciente - ¡Oh Dios mío! ¿Pero… podrán hacer algo?

- Piensa que las enfermedades graves siempre tienen que ver con la genética que uno trae y es imposible cambiarlo
- Siente ira
- Se muestra tensa y molesta, está abatida

Doctor - Hay posibilidad de tratamiento. El oncólogo la va a citar lo antes posible para explicarle el plan a seguir en estos casos

Paciente – ¡Esto no me puede estar pasando a mí!

- Piensa que en estas situaciones lo único que se puede hacer es confiar en los que saben.
- Siente ansiedad
- Se muestra ansiosa, nerviosa… ahora mismo lo que quieres es estar sola y aislarse del resto del mundo

---

Fig. 5.4. Simulations outputs. In each step of the interaction the following aspects are visualized: what the agent thinks (Irrational/Rational beliefs, what the agent feels (Emotions and Current mood) and the agent non-verbal behavior (conduct).

Simulation 2

Características del Paciente

Personalidad- Es reservada, solitaria. No es propensa a la ira, ni estados depresivos.
Estado de ánimo inicial- Al entrar en la consulta del médico se encuentra algo exaltada por la incertidumbre que genera el resultado de la biopsia.

Diálogo (*en morado lo que piensa/siente, en azul la comunicación no verbal*)

Doctor - Buenos días
Paciente - Buenos días

- Se siente emocionada, algo nerviosa
- Se muestra neutral

Doctor - Lamento decirle que tengo malas noticias
Paciente – Dígame lo que tengo

- Piensa que ahora es importante no dejarse llevarte por los demás
- Siente molestia, enojo
- Se muestra excitada, pero sin ser hostil (expresión emocionada pero controlada)

Doctor - Lo siento mucho… aunque me gustaría tener mejores noticias, la realidad es que la biopsia muestra claramente que el tumor es cancerígeno
Paciente - ¡Cáncer! ¿es muy grave?

- Piensa que lo importante es encontrar "su propia forma" para poder afrontar bien estas cosas
- Siente preocupación
- Se muestra tensa, y a la vez decidida a hacer frente a la situación (afronta la situación)

Doctor - Lo siento, realmente es muy agresivo
Paciente - ¿Pero hay algún remedio… aunque no sea fácil?

- Piensa que en esta situación lo que hay que hacer es preguntarlo todo para poder elegir qué tienes que hacer y tener claras las posibilidades
- Siente preocupación
- Se muestra desdeñosa, triste, pero está centrada en lo que es importante (afronta la situación)

Doctor - Hay posibilidad de tratamiento. El oncólogo la va a citar lo antes posible para explicarle el plan a seguir en estos casos
Paciente – ¡Esto no me puede estar pasando a mí!

- Piensa que hay determinadas cosas que pueden estar fuera de su control.
- Siente ira
- Se muestra tensa, estresada, nerviosa …ahora mismo lo que quieres es estar sola

---

Fig. 5.4. (Continued).

As it can be seen, the agent experiences different cognitive, affective and behavioral changes. As it was explained in previous section, in Simulation 1 the agent emotional experience has a dysfunctional negative nature leading to anger, anxiety and depression. This is due to the agent beliefs set, irrational due to her personality. The agent mood flow goes from energized-unpleasant to calm-unpleasant and finally back to energized-unpleasant, due to the agent's tendency to feel negatives states.

In simulation 2, the agent experiences annoyance, concern and anger. The two first elicited emotions are functional negative emotions, due to the rational beliefs set of the agent and its personality. But finally, the agent feels angry, due to its irrational belief about the role of genetics in cancer disease. The agent mood changes from energized-pleasant state to energized-unpleasant state as the result of the elicited emotions, but decays to calm-unpleasant due to the agent's personality tendency to feel positive states. Finally, due to the dysfunctional emotions, the agent mood final state is energized-unpleasant, which means that she feels nervous and anxious (see Fig. 3.7). The agent conduct for the most part of the dialog is adaptive (facing behavior, fluid open behavior), since they are related to its preferential desires such as Dc → (Not having cancer), and also to its functional emotions such as annoyance and concern (Fig. 3.6). But, at the end, the agent behaves in maladaptive way (avoidance) due to the change in her emotional state (anger).

Both simulations were sent to the experts. The experts filled the questionnaires (see ANNEX I) and returned them by e-mail.

5.3.1.3. Assessment results

Once the specialists returned the questionnaires, they were analyzed. In Fig. 5.5 the evaluations of the specialists regarding each of the aspects (what the agent thinks, feels and her conduct) are shown. As it can be seen, results are positive indicating that the ABC-EBDI agent is able to simulate *Quite realistic* human-like behavior regarding the emotional (Feel) and cognitive (Think) aspects. Regarding the agent's conduct, the framework is able to reproduce it in a *Somewhat real way*. The specialists agreed that real patients in situations of this type are prone to experience the cognitive, affective and behavioral changes that were shown in the simulation, even in a short period of time as the one simulated. Nevertheless,

specialists argued that the patient's conduct should be more specifically shown and that it was difficult to assess it from the outputs of the system. They commented that it would be useful to have a graphical output where body gestures, facial expressions and intonation could be used to show agent's conduct. This lead us to consider the use of ECAs as it will be commented later on.

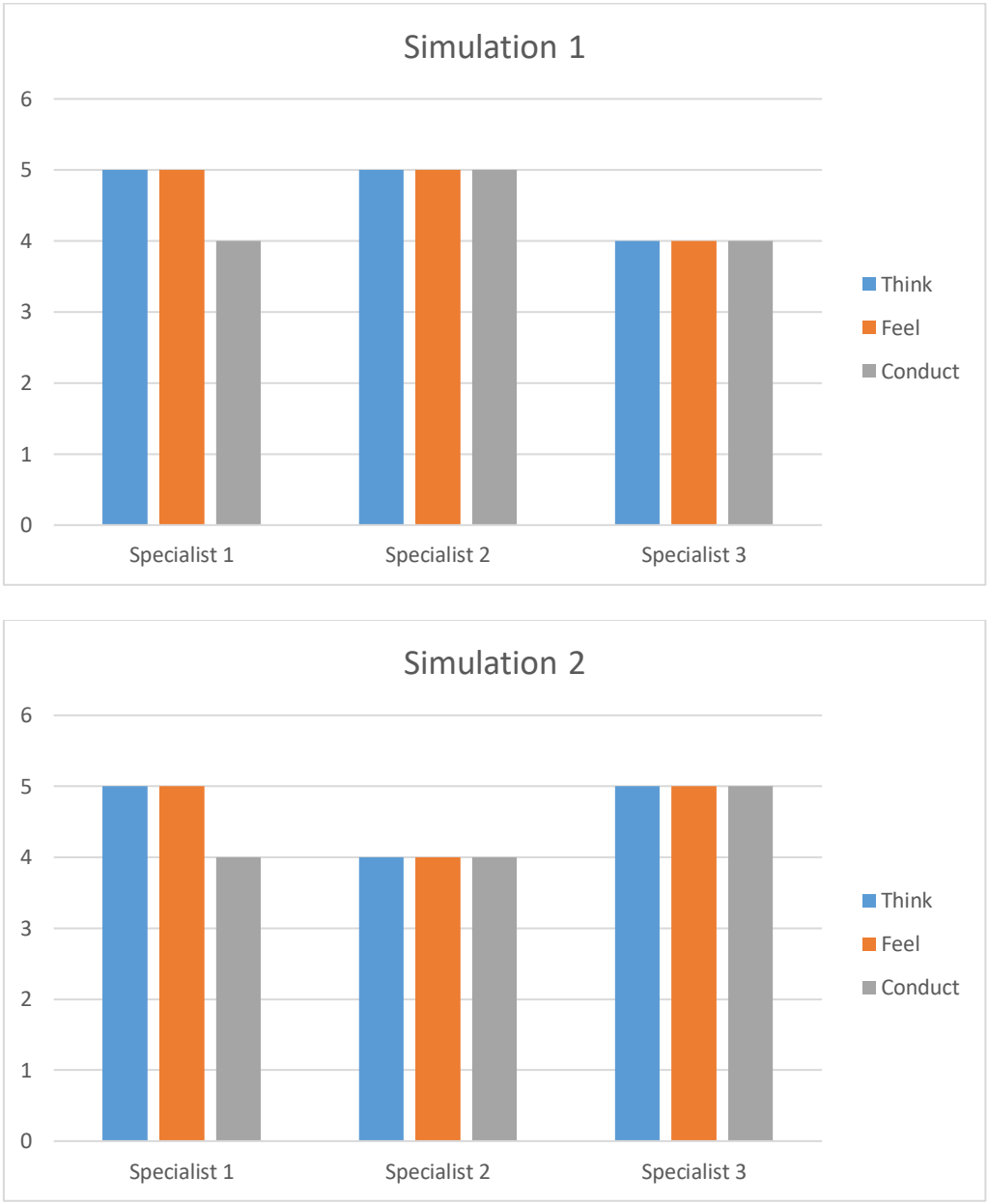


Fig. 5.5. Specialist evaluation results. The following scale has been used: Not realistic at all-1, Not very realistic-2, A little realistic-3, Somewhat realistic-4, Quite realistic-5 and Very realistic-6.

5.3.2. Evaluation by users (Data triangulation)

5.3.2.1. Method, participants and procedure

A second evaluation with users were carried out. It can be seen as a data tringulation, as data from several individuals were collected (Denzin, 1989). This technique is frequently used in exploratory research as a mean of achieving a more complete evaluation of a phenomenon (Fielding, 2012) (Jick, 1979). In this case, the opinion of a set of individuals are used as data source. Each user was asked if the agent cognitive-affective behavior fit with its own expected behavior in a situation like the chosen scenario. A questionnaire (ANNEX I) with the following scale was used: *Does not fit at all(2), Fits a little(3), Fits considerably(4)* and *Fits a lot(5)*.

No special inclusion criteria were applied, so persons of different ages, professional backgrounds and gender were present in the set. Eighteen users (12 women and 8 men) of ages ranging from 28 to 75 participated in the test.

In this case the evaluation required to set the agent cognitive-affective values with the users' cognitive-affective information; therefore, an individual characterization process before simulation had to be made. So, the evaluation procedure was:

1- Each user was provided with a personality, mood and beliefs questionary (ANNEX I) to set the agent cognitive-affective values. These questionaries were sent and returned by e-mail.
2- A simulation for each user was carried out with information collected in the characterization process.
3- The simulation results and a questionnaire were mailed to each participant.
4- After evaluating the simulation, users returned independently the filled questionnaire by e-mail.

5.3.2.2. Bad news scenario simulation

In this case, the agent plays the role of the participant. Therefore, to carry out the simulation of each participant, the agent has to be configured or characterized according to the participant is own information. This means that, to characterize the agent's cognitive and affective dimensions, the user's own cognitive and

affective values regarding personality, initial current mood and beliefs set were used. To do so, Spanish versions of the following questionnaires were provided to the users:

1- NEO-FFI (John and Srivastava, 1999) to establish the user/agent personality value.
2- The Positive and Negative Affect Schedule (PANAS) (Blanco et al., 2014) to establish the user/agent's initial mood value.
3- Aptitudes and Beliefs Test (Lega et al., 2009) to establish the user/agent's belief set.

In ANNEX I the three questionnaires are presented. The NEO-FFI is a Spanish version of the well-known Big Five (Costa, P. T. and McCrae, 1999) personality test. It consists of 60 items to measure the levels of the five traits: openness, extraversion, neuroticism, agreeableness and conscientiousness. The measure scale is the following: very low, low, medium, high and very high. As explained in Chapter 3, only values related to neuroticism and extraversion are used in the simulations. To fill the PANAS questionnaire and set the agent initial mood, the participant was asked to put his/her self in the situation of bad news of cancer just in the moment before receiving the news, just before entering in the consultation. The PANAS questionnaire measures the degree of positive and negative affect in a precisely moment or weekly. In this case, momentary measure was used. The questionnaire is composed by 20 mood states measured in the range of 1 to 5. To establish the agent initial mood, the general measure of positive and negative affect (PA and NA) is used in the following way: in the case of high PA or NA the highest value of the mood related to the PA or NA dimension is used. A random criterion is applied when two or more mood states have the same value. In Table 5.4, the mapping between the PA/NA and the 24 moods considered in the proposed framework is presented.

To set the agent's belief set based on user's cognitions, the Aptitudes and Beliefs Test (Lega et al., 2009) has been used. The questionnaire is composed of 48 items to set up the demanding or preferential (DEM or Preferences) and the extreme or non-extreme (AWF/non-AWF, LFT/non-LFT, GE-SD/non-GE/SD) nature of the participant's beliefs. It allows to measure the level of rationality and irrationality dimensions such as demandingness, catastrophism, low frustration tolerance,

global self-other downing, need for achievement, need for approval and need for comfort. In the case of high degree of rationality, beliefs related to the three rational categories (preferences, non-AWF, non-LFT) are defined. In the case of high degree of irrationality, the mapping shown in Table 5.5 was used.

Simulations output followed the same format as in the expert evaluation. In this case, it was writen in first person to enhance participants involvement and make it easier for the users to put themselves in a bad news situation.

Table 5.4.

Mapping between the PANAS' mood and the 24 moods considered in the proposed framework.

PANAS mood (PA or NA Dimension)	**ABC-EBDI mood**
Interested (PA)	serene
Distressed (NA)	distress
Excited (PA)	excited
Upset (NA)	upset
Scared (NA)	anxious
Hostile (NA)	hostile
Enthusiastic (PA)	exuberant
Irritable (NA)	tense
Alert (PA)	alert
Inspired (PA)	happy
Nervous (NA)	nervous
Determined (PA)	relaxed
Attentive (PA)	elated
Jittery (NA)	nervous
Active (PA)	exuberant
Afraid (NA)	tense

*PA: Positive Affect; NA: Negative Affect.

Table 5.5.

Mapping between the Aptitudes and Beliefs Test irrationality/rationality measures and the defined irrational/rational beliefs.

Aptitudes and Beliefs Test irrational/rational measures	**Defined irrational/rational belief category**
High level of demandingness	Belief(s) categorized as DEM control
High level of need for approval	Belief(s) categorized as DEM
High level of need for comfort	Belief(s) categorized as DEM comfort
High level of catastrophism	Belief(s) categorized as AWF
High level of global self-other downing	Belief(s) categorized as GE/self or other-downing
High level of low frustration tolerance	Belief(s) categorized as LFT
Low level of demandingness or need for approval or of need for comfort or global self-other downing	Belief(s) categorized as Preferences
Low level of catastrophism	Belief(s) categorized as non-AWF
Low level of low frustration tolerance	Belief(s) categorized as non-LFT

5.3.2.3. Assessment results

Once users returned the questionnaires, results were analyzed. In Fig.5.6, the results of the evaluations regarding each of the aspects (cognitive, affective, behavioral) are shown.

It can be seen that users consider that the agent's outputs *Fit considerably* (45% of the answers) or *Fit a lot* (35% of the answers) their own expected outputs. Only the 10 percent of the items are considered to *Fit a little* and just one item is labeled as *Does not fit at all*. It can be noticed that, what the agent feels and thinks, obtains better results than conduct (behaves). This can be due to the difficulty of describing with words such a component.

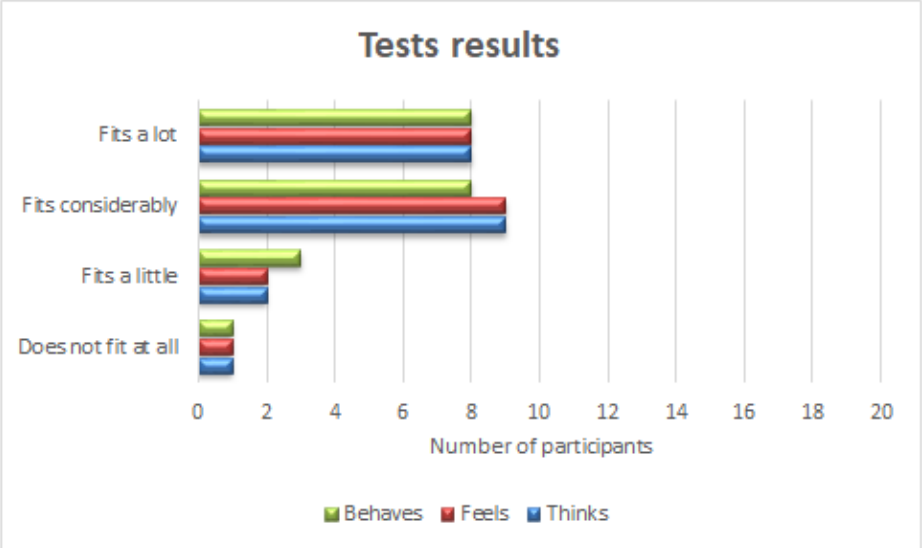


Fig. 5.6. Tests results. In green evaluation of the agent behavior, in red what the agent Feels and in blue of what the agent Thinks.

5.3.3. Discussion: convergence analysis and limitations

In multiple triangulation, the convergence between the chosen triangulation techniques can be analyzed. In this case, Data triangulation (user evaluation) and Specialist triangulation (expert evaluation) have been applied. The convergence is analyzed combining both results according to the three aspects that have been evaluated. To do so, the values of specialists in both simulations have been averaged. Regarding user (data) triangulation, results have been also averaged. In Fig. 5.7, the convergence diagram is presented.

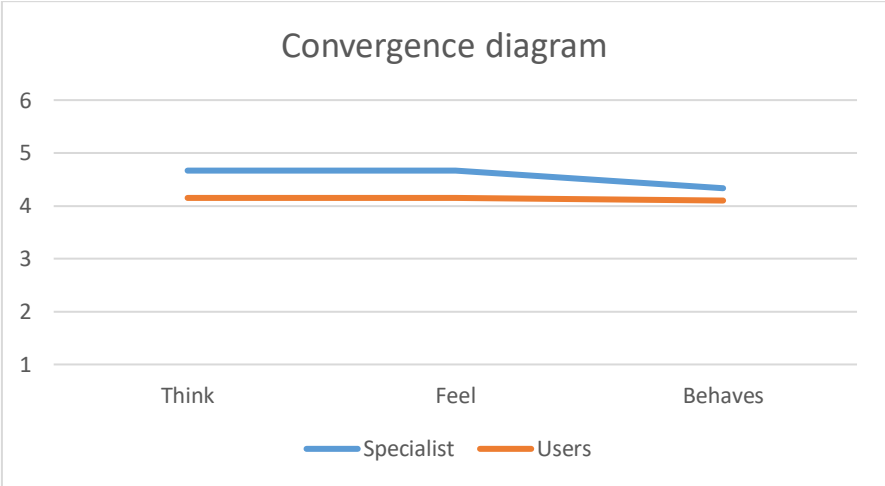


Fig. 5.7. Convergence of data and specialist triangulation in the three evaluated aspects: What the agent Thinks, What the agent Feels and the How the agent Behaves.

As it can be seen, both evaluations converge in the three aspects. This indicates that the ABC-EBDI agent is able to simulate human-like behavior in adverse situations, *Quite realistic/Fit considerably* regarding the emotional (Feel) and cognitive (Think) aspects. Regarding the agent conduct, it is able to reproduce it in *Somewhat real way* in specialist triangulation and *Fit considerably* in user evaluation perspective. In the case of specialists triangulation, they agreed that real patients in situations of this type are prone to experience the cognitive, affective and behavioral changes that were shown in the simulation, even in a short period of time as the simulated. Nevertheless, specialists argued that the patient's conduct should be more specifically shown and that was difficult to assess it from the outputs of the system. They commented that it would be useful to have a graphical output where body gestures, facial expressions and intonation could be used to show agent's conduct. In the same way, in the user evaluation, participants expressed that it was very difficult to evaluate the behavior component. This could be due to the difficulty of describing with words such a component and, probably, this is the reason why what the agent feels and thinks obtains better results than conduct.

As we see, agent's conduct is hard to evaluate without a graphical output. This is why the integration of the ABC-EBDI framework in an ECA-based system such as the ones developed by the group (Baldassarri et al., 2008) would be of great interest. This way, body gestures, facial expressions and intonation could be used to better show agent's conduct. This would help to overcome one of the limitations of the evaluations, the use of text output to assess conduct.

In fact, and in spite of the positive results, we are aware of the limitations of the evaluation presented. The number of experts and users was limited and should be increased in subsequent evaluations. Regulation mechanism were not assessed and should be also added in next evaluations.

5.4. Conclusions

In this chapter the use case chosen and the framework evaluations have been presented. As use case, a bad news scenario, "I whis I had better news", in medical diagnosis scope has been chosen. The selection of this scenario is because in medical diagnosis and, more specifically, in bad news communication, patient behavior is very varied and quite unpredictable. Based on it, two evaluations have

been carried out, one with experts and one with users. In both cases, and spite of their characteristics and limitations, results are positive and have encouraged us to continue the research.

One limitation found has been the kind of framework outputs (just text). This has been the reason to begin to work in a ECA (Embodied Conversational Agent) application. ECAs are computer generated life-like characters that interact with human users in face-to-face conversation. They are generally human-like, but not necessarily. In general, an ECA interfaces allow to support credible human-agent interaction, recognizing and responding to verbal and nonverbal input from the human user, generating verbal and nonverbal outputs and performing conversational functions (Huang et al., 2008). More explanation about the application being developed can be found in ANNEX II. Another limitation lies on the fact that only three experts have been recruited in the evaluation by experts, which may limit the results. Finally, no regulation has been applied which limits the information provided to the participants (experts/users) and the possibility of achieving and evaluating a richer and more varied agent's output to evaluate in a more deep way the agent cognitive-affective processing.

CHAPTER 6: Conclusions and Future work

6.1. Conclusions

In this chapter the conclusions of the present work are presented taking into account the objectives presented in chapter 1, commenting possible application fields and exposing the future lines of work to be followed.

6.2. Objectives fulfilled

The objectives planned for this Thesis and outlined in Chapter 1 (Section 1.4) have been successfully accomplished in the terms described below:

- An exhaustive state of the art related to the most used affective models to model affective aspects in intelligent agents has been elaborated.
- BDI's architectures and previous EBDI proposals have been studied. The study, that resulted in a publication (Sánchez-López and Cerezo, 2019) allowed us to detect open questions in the area, and the necessity of considering all aspects of affect (emotions, mood, personality) and their influence in all cognitive stages. The framework resulted from this doctoral work also includes the modeling of conduct and communicative behavior, that have not been considered so far in the modeling of intelligent agents. These aspects put the resulting framework among the most advanced EBDIs in the literature.
- A BDI-based cognitive-affective-behavioral framework to support the cognitive, affective and behavioral modeling of intelligent agents, named ABC-EBDI, has been designed and implemented (Sanchez et al., 2020) (Sánchez et al., 2019). It is the first application of a well-known psychological model, Ellis's ABC model, to the simulation of realistic human intelligent agents. This application implies:
    - The extension of the concept of Beliefs. In the framework, three types of beliefs are considered: basic beliefs, context beliefs and operant behaviors. Basic beliefs represent the general information the agent has about itself and the environment. Operant behaviors allow modeling the reactive behavior of the agent through learned behaviors. Context beliefs, which are represented in the form of cold and hot cognitions, are processed to be classified into irrational and rational beliefs following Ellis's ideas. The consideration of

irrational/rational beliefs opens the door to the simulation of realistic human reactions.

  - The possibility of managing, in a unifying way, the consequences of events in terms of affective and behavioral consequences (conduct). Rational context beliefs lead to functional emotions and adaptive conduct whereas irrational context beliefs lead to dysfunctional emotions and maladaptive conduct. This functional/dysfunctional character of emotions has never been used before in the BDI context. Also, the behavioral modeling has been extended with the modeling of communicative styles, based on the Satir model, which represents, its first application in intelligent agent's modeling. Satir's model considers body gestures, facial, expressions, voice, intonation and linguistics structures.

- A use case, "I wish a had better news", for the application of the proposed framework has been chosen and two type of evaluations, by experts and users, have been carried out. The evaluation has confirmed the great potential of the proposed framework to reproduce realistic believable human-like behavior in complex situations. It has also detected some questions to be further considered that will be commented as future work.

6.2.1. Application field

The ability of the ABC-EBI framework to simulate human-like behavior in complex scenarios, makes it ideal to develop intelligent agents for healthcare applications. This is the reason of the election of the use case. The integration of the Satir model in the framework makes it specially well-suited to the use of ECAs (Embodied Conversational Agents) in which visual and auditive output in terms of body and facial gestures, voice and intonation are of great importance. In fact, the potential of this type of agents lies in their expression and interaction abilities. ECAs can be found in different domains as virtual assistants, training and educational agents, social companions, and virtual guides (Norouzi et al., 2018). Particulary, ECAs-based tools can be very useful in the health domain as there are studies that show that people may feel more comfortable interacting with a virtual character than with a human doctor (Yoshida et al., 1993). This way, ECAs have been used as a complementary tool by the specialists, acting as interviewers

(Lucas et al., 2017), counselors (Li et al., 2012), virtual coaches (Hudlicka, 2013) or virtual patients (Rizzo et al., 2011). It is in this area of virtual patients where the proposed ABC-EBDI framework could be very useful. In this line, we have began to work in an ECA-based application to support the simulation of human-like behavior specially oriented to build virtual patients to be used in healthcare application domains (see ANNEX VI). In particular, due to ability of the ABC-EBDI framework to simulate cognitive and affective behavior in complex situations, such an application could be a powerful simulation tool used to train and test medical communication skills (Saleh, 2010), (Maicher et al., 2017), (Jung et al., 2005).

6.3. Future work

There are four immediate lines of future work related to the ABC-EBDI framework:

- To build the beliefs set by using NLP (Natural Language Processing) and ML (Machine Learning) techniques to obtain the agent beliefs, from the semantic analysis of the use case description. NLP could be used to extract relevant entities according to identified keywords and/or n-grams from general irrational/rational beliefs (see Table 3.4, Chapter III), such as I must, I need, I wish, I desire, I prefer, Is catastrophic, Is the worst, Is the end, etc. Once the beliefs set is extracted, ML could be used to train a categorical classifier to categorize the agent beliefs set.
- To implement affective regulation strategies that have been considered for the moment just in an informative way.
- To carry out a more in deep evaluation of the framework to overcome present limitations such as the number of experts and users and the consideration of regulation.
- To finish the role-play ECA-based application to train healthcare professionals and to add more conversational capabilities to the agent by adding more skills that allow it to interact with users in several contexts and scenarios.

In the midterm, in order to simulate more complex cognitive-affective behavior some extensions could be added to the framework, such as:

- To consider tertiary emotions elicited by the meta cognitive processing, that will lead to disturbing states (feeling humiliated, infatuated, guilty) that reduce self-control. Its inclusion will allow to explore the most complex affective processing, practically unexplored in intelligent agent modeling, as it depends on the existence of a mechanism that supports the partial loss of control of attention in the intelligent agent, which requires a sophisticated information processing architecture.
- To consider mixed irrational/rational beliefs sets since the coexistence of irrationality and rationality in human mind is a fact. To do so, the irrational or rational degree has to be modeled by belief and not globally as it is implemented at the present time.

ANNEXS

ANNEX I: EVALUATION QUESTIONNARIES

AI.0 - Annex Introduction

In this annex, the questionnaires provided to users (Data triangulation) and specialists (Specialist triangulation), are presented.

AI.1 – Specialist questionnaire

Evaluación del framework ABC-EBDI.

Nombre del evaluador:

_____

Especialidad:

_____

Objetivo: Evaluar si el comportamiento afectivo y conductual (forma de expresarse) de un agente construido sobre la base del framework ABC-EBDI, es realista.

Metodología

Dado un escenario de ejemplo (i.e., diagnóstico de cáncer) donde el agente juega el rol del paciente, teniendo en cuenta la personalidad de éste y el contexto del escenario presentado, cada evaluador debe opinar sobre el pensar/sentir y comportamiento no verbal del agente, atendiendo las preguntas:

-Lo que piensa y siente el paciente, ¿se ajusta a una experiencia real?

-Las expresiones no verbales del paciente ¿se ajustan a las de una experiencia real?

Para valorarla utilizaremos la siguiente escala:

1. Nada reales
2. Casi nada reales
3. Poco reales
4. Algo reales
5. Bastante reales
6. Muy reales

Agradeceremos que se justifique la elección con algún comentario en el espacio disponible para tal fin.

Caso de uso 1: Diagnóstico de Cáncer

La Sra. Y C, de 74 años, tiene hipertensión e hiperlipidemia. Una ecografía del abdomen muestra varias lesiones en el hígado sugestivas de metástasis. El médico debe comunicar un diagnóstico de cáncer al paciente tras haber sido confirmado por una biopsia.

Características del Paciente

Personalidad- optimista y directa, no se anda con rodeos. Es algo propensa a la ira y a estados depresivos.

Estado de ánimo inicial- Al entrar en la consulta del médico se encuentra algo estresada por la incertidumbre que genera el resultado de la biopsia.

Diálogo *(en morado lo que piensa/siente, en azul la comunicación no verbal)*

Doctor - Buenos días
Paciente - Buenos días

- Se siente estresada
- Se muestra neutral

Doctor - Lamento decirle que tengo malas noticias
Paciente - Doctor, hable sin rodeos

- Piensa que esto podría afectar mucho a su familia
- Siente ira y depresión
- Su expresión muestra un alto grado de ira, y se comporta de forma defensiva

---

Doctor - Lo siento mucho… aunque me gustaría tener mejores noticias, la realidad es que la biopsia muestra claramente que el tumor es cancerígeno
Paciente - ¡Cáncer! Pero… ¿Es muy grave?

- Piensa que prefiería no ser una molestia para su familia
- Siente depresión
- Se muestra triste, desdeñosa, y se comporta de forma defensiva

---

Doctor - Lo siento, realmente es muy agresivo
Paciente - ¡Oh Dios mío! ¿Pero… podrán hacer algo?

- Piensa que las enfermedades graves siempre tienen que ver con la genética que uno trae y es imposible cambiarlo
- Siente ira
- Se muestra tensa y molesta, está abatida

Doctor - Hay posibilidad de tratamiento. El oncólogo la va a citar lo antes posible para explicarle el plan a seguir en estos casos
Paciente – ¡Esto no me puede estar pasando a mí!

- Piensa que en estas situaciones lo único que se puede hacer es confiar en los que saben.
- Siente ansiedad
- Se muestra ansiosa, nerviosa… ahora mismo lo que quieres es estar sola y aislarse del resto del mundo

---

Cuestionario 1– Caso de uso 1: Diagnóstico de cáncer

Acorde a las características del paciente, en qué medida crees que la situación está ajustada a la realidad. Marca lo que corresponda:

	Nada	Casi Nada	poco	algo	Bastante	Mucho
Lo que piensa y siente el paciente, ¿se ajusta a una experiencia real?						
Las expresiones no verbales del paciente ¿se ajustan a las de una experiencia real?						

Por favor, justifica tus elecciones

Caso de uso 2: Diagnóstico de Cáncer

La Sra. Y C, de 74 años, tiene hipertensión e hiperlipidemia. Una ecografía del abdomen muestra varias lesiones en el hígado sugestivas de metástasis. El médico debe comunicar un diagnóstico de cáncer al paciente tras haber sido confirmado por una biopsia.

Características del Paciente

Personalidad- Es reservada, solitaria. No es propensa a la ira, ni estados depresivos.

Estado de ánimo inicial- Al entrar en la consulta del médico se encuentra algo exaltada por la incertidumbre que genera el resultado de la biopsia.

Diálogo *(en morado lo que piensa/siente, en azul la comunicación no verbal)*

Doctor - Buenos días
Paciente - Buenos días

- Se siente emocionada, algo nerviosa
- Se muestra neutral

Doctor - Lamento decirle que tengo malas noticias
Paciente – Dígame lo que tengo

- Piensa que ahora es importante no dejarse llevarte por los demás
- Siente molestia, enojo
- Se muestra excitada, pero sin ser hostil (expresión emocionada pero controlada)

Doctor - Lo siento mucho… aunque me gustaría tener mejores noticias, la realidad es que la biopsia muestra claramente que el tumor es cancerígeno
Paciente - ¡Cáncer! ¿es muy grave?

- Piensa que lo importante es encontrar "su propia forma" para poder afrontar bien estas cosas
- Siente preocupación
- Se muestra tensa, y a la vez decidida a hacer frente a la situación (afronta la situación)

Doctor - Lo siento, realmente es muy agresivo
Paciente -¿Pero hay algún remedio… aunque no sea fácil?

- Piensa que en esta situación lo que hay que hacer es preguntarlo todo para poder elegir qué tienes que hacer y tener claras las posibilidades
- Siente preocupación
- Se muestra desdeñosa, triste, pero está centrada en lo que es importante (afronta la situación)

Doctor - Hay posibilidad de tratamiento. El oncólogo la va a citar lo antes posible para explicarle el plan a seguir en estos casos
Paciente – ¡Esto no me puede estar pasando a mí!

- Piensa que hay determinadas cosas que pueden estar fuera de su control.
- Siente ira
- Se muestra tensa, estresada, nerviosa …ahora mismo lo que quieres es estar sola

---

Cuestionario 2– Caso de uso 2: Diagnóstico de cáncer

Acorde a las características del paciente, en qué medida crees que la situación está ajustada a la realidad. Marca lo que corresponda:

	Nada	Casi Nada	poco	algo	Bastante	Mucho
Lo que piensa y siente el paciente, ¿se ajusta a una experiencia real?						
Las expresiones no verbales del paciente ¿se ajustan a las de una experiencia real?						

Por favor, justifica tus elecciones

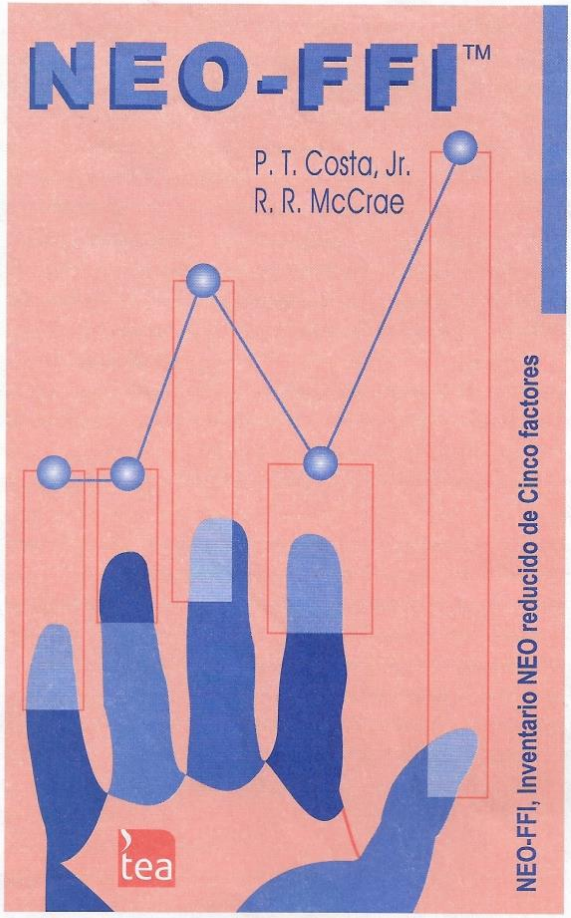
AI.2 – Users' questionnaires

In user's evaluation, two type of questionaries have been used: agent characterization questionnaires and assessment of results questionnaire. The characterization questionaries are:

1- A Spanish version of the Big Five questionnaire, NEO-FFI (John and Srivastava, 1999), used to establish the agent personality value.
2- A Spanish version of the Positive and Negative Affect Schedule (PANAS) (Blanco et al., 2014), used to establish the agent's initial mood value.
3- A Spanish version of the Aptitudes and Beliefs Test (Lega et al., 2009) used to establish the agent's belief set.

The four questionaries (three characterization questionnaires and one of assessment result) are list below.

AI.2.1 – NEO-FFI



INSTRUCCIONES

Por favor, lea cuidadosamente estas instrucciones antes de empezar para marcar bien sus respuestas.

Este cuestionario consta de 60 frases. Lea cada frase con atención y marque la alternativa (A a E) que refleje mejor su acuerdo o desacuerdo con ella. Señale:

- **A** si la frase es completamente falsa en su caso, si está en **total desacuerdo** con ella.
- **B** si la frase es frecuentemente falsa, si está **en desacuerdo** con ella.
- **C** si la frase es tan cierta como falsa, si no puede decidirse, o si Vd. se considera **neutral** en relación con lo que se dice en ella.
- **D** si la frase es frecuentemente cierta, si Vd. está **de acuerdo** con ella.
- **E** si la frase es completamente cierta, si está **totalmente de acuerdo** con ella.

Vea los dos ejemplos (E1 y E2) que vienen aquí debajo y cómo se ha contestado.

E1	Me gustaría pilotar una nave espacial	(A)	B	C	D	E
E2	A la hora de vestir prefiero los tonos obscuros	A	B	C	(D)	E

La persona que ha contestado a estos ejemplos ha indicado que está en **total desacuerdo** (letra A) con la frase E1, porque no le gustaría nada pilotar una nave espacial, y está **de acuerdo** con la frase E2, porque frecuentemente prefiere los tonos obscuros para vestir (letra D).

Por tanto, no hay respuestas «correctas» ni «incorrectas». Conteste de forma sincera y exprese sus opiniones de la manera más precisa posible.

Dé una respuesta a todas las frases. Asegúrese de que marca cada respuesta en la línea correspondiente a la misma frase y en la opción que mejor se ajuste a su manera de ser.

No olvide anotar sus datos personales en la parte superior antes de contestar a las frases.

ESPERE, NO PASE LA PÁGINA HASTA QUE SE LO INDIQUEN.
MUY IMPORTANTE, ESTE EJEMPLAR DEBE ESTAR DESPLEGADO PARA CONTESTAR.

NOMBRE _____ EDAD ___ SEXO VARÓN ___ MUJER ___ FECHA ___-___-___

NEO-FFI

		TOTAL V + M						Varones						Mujeres					
		N	E	O	A	C		N	E	O	A	C		N	E	O	A	C	
MUY ALTO	75	36-48	46-48	44-48	47-48	48	75	36-48	46-48	44-48	46-48	48	75	37-48	46-48	44-48	47-48	47-48	75
	-				46		-						-	36		43	46		-
	-	35		43			-	34-35	45	43	45		-						-
	-	34	45	42	45	47	-	33					-	35	45	42			-
	-	33		41			-	32	44	42	44	47	-	34		41	45	46	-
	70	32	44		44		70	31		41			70	33	44		44		70
	-	31		40		46	-	30			43		-	32		40			-
	-	30	43		43		-	29	43	40	42	46	-	30-31	43		43		-
	-	29		39	42	45	-	28		39	41		-			39		45	-
	-	28	42				-	27	42			45	-	29	42	38	42		-
	65	27		38	41	44	65	26	41	38	40		65	28				44	65
ALTO	-	26	41	37	40		-	25		37	39	44	-	27	41	37	41		-
	-	25	40				-	24	40	36			-	26			40	43	-
	-	24		36	39	43	-	23			38	43	-	25	40	36			-
	-	23	39	35	38	42	-	22	39	35		42	-	24		35	39	42	-
	60	22					60	21	38		37		60	23	39				60
	-	21	38	34	37	41	-	20		34	36	41	-	22	38	34	38	41	-
	-	20	37				-	19	37	33			-						-
	-			33	36	40	-	18	36		35	40	-	21	37	33	37	40	-
	-	19	36	32		39	-	17		32		39	-	20	36		36	39	-
	55	18			35		55		35	31	34		55	19		32			55
MEDIO	-	17	35	31		38	-	16				38	-	18	35	31	35	38	-
	-	16	34	30	34	37	-	15	34	30	33	37	-						-
	-						-	14	33	29			-	17	34	30		37	-
	-	15	33	29	33	36	-				32	36	-	16			34	36	-
	50	14	32	28	32	35	50	13	32	28	31	35	50	15	33	29	33	35	50
	-	13					-	12	31	27			-	14	32	28			-
	-		31	27	31		-	11	30	26	30	34	-		31	27	32		-
	-	12	30	26		34	-						-	13			31	34	-
	-	11			30	33	-	10	29	25	29	33	-	12	30	26		33	-
	45		29	25			45		28	24			45						45
BAJO	-	10	28	24	29	32	-	9		23	28	32	-	11	29	25	30		-
	-						-		27				-		28	24	29	32	-
	-	9	27	23	28	31	-	8	26	22	27	31	-	10				31	-
	-	8	26	22	27		-	7		21	26	30	-	9	27	23	28		-
	40					30	40		25			29	40		26	22		30	40
	-	7	25	21	26	29	-	6	24	20	25		-	8			27		-
	-	6	24	20	25	28	-	5		19	24	28	-		25	21		29	-
	-		23	19			-		23	18	23	27	-	7	24	20	26	28	-
	-	5		18	24	27	-	4	22			26	-	6	23		25		-
	35	4	22		23	26	35	3		17	22	25	35			19		27	35
MUY BAJO	-	3		17		25	-		21	16		24	-	5	22	18	24	26	-
	-		21	16	22	24	-	2	20	15	21	23	-	4		17		25	-
	-	2	20	15	21	23	-		19		20	22	-	3	21		23	24	-
	-		19				-	1	18	14	19	21	-		20	16	22		-
	30	1	18	14	20	22	30		17	13		20	30	2		15	21	23	30
	-		17	13	19	21	-	0	16	12		19	-	1	19		20	22	-
	-			12		20	-				18	18	-			14			-
	-		16		18	19	-		15	11	17	17	-		18	13	19	21	-
	-		15		17	17-18	-		14		16	16	-	0	17	12	18	20	-
	25	0	0-14	0-11	0-16	0-16	25		0-13	0-10	0-15	0-15	25		0-16	0-11	0-17	0-19	25
		N	E	O	A	C		N	E	O	A	C		N	E	O	A	C	

NOMBRE _____ EDAD ☐☐ SEXO VARÓN ☐ MUJER ☐ FECHA ☐☐ - ☐☐ - ☐☐

A En total desacuerdo	B En desacuerdo	C Neutral	D De acuerdo	E Totalmente de acuerdo

1. A menudo me siento inferior a los demás.
2. Soy una persona alegre y animosa.
3. A veces, cuando leo poesía o contemplo una obra de arte, siento una profunda emoción o excitación.
4. Tiendo a pensar lo mejor de la gente.
5. Parece que nunca soy capaz de organizarme.
6. Rara vez me siento con miedo o ansioso.
7. Disfruto mucho hablando con la gente.
8. La poesía tiene poco o ningún efecto sobre mí.
9. A veces intimido o adulo a la gente para que haga lo que yo quiero.
10. Tengo unos objetivos claros y me esfuerzo por alcanzarlos de forma ordenada.
11. A veces me vienen a la mente pensamientos aterradores.
12. Disfruto en las fiestas en las que hay mucha gente.
13. Tengo una gran variedad de intereses intelectuales.
14. A veces consigo con artimañas que la gente haga lo que yo quiero.
15. Trabajo mucho para conseguir mis metas.
16. A veces me parece que no valgo absolutamente nada.
17. No me considero especialmente alegre.
18. Me despiertan la curiosidad las formas que encuentro en el arte y en la naturaleza.
19. Si alguien empieza a pelearse conmigo, yo también estoy dispuesto a pelear.
20. Tengo mucha auto-disciplina.
21. A veces las cosas me parecen demasiado sombrías y sin esperanza.
22. Me gusta tener mucha gente alrededor.
23. Encuentro aburridas las discusiones filosóficas.
24. Cuando me han ofendido, lo que intento es perdonar y olvidar.
25. Antes de emprender una acción, siempre considero sus consecuencias.
26. Cuando estoy bajo un fuerte estrés, a veces siento que me voy a desmoronar.
27. No soy tan vivo ni tan animado como otras personas.
28. Tengo mucha fantasía.
29. Mi primera reacción es confiar en la gente.
30. Trato de hacer mis tareas con cuidado, para que no haya que hacerlas otra vez.
31. A menudo me siento tenso e inquieto.
32. Soy una persona muy activa.
33. Me gusta concentrarme en un ensueño o fantasía y, dejándolo crecer y desarrollarse, explorar todas sus posibilidades.
34. Algunas personas piensan de mí que soy frío y calculador.
35. Me esfuerzo por llegar a la perfección en todo lo que hago.
36. A veces me he sentido amargado y resentido.
37. En reuniones, por lo general prefiero que hablen otros.
38. Tengo poco interés en andar pensando sobre la naturaleza del universo o de la condición humana.
39. Tengo mucha fe en la naturaleza humana.
40. Soy eficiente y eficaz en mi trabajo.
41. Soy bastante estable emocionalmente.
42. Huyo de las multitudes.
43. A veces pierdo el interés cuando la gente habla de cuestiones muy abstractas y teóricas.

A En total desacuerdo	B En desacuerdo	C Neutral	D De acuerdo	E Totalmente de acuerdo

44 Trato de ser humilde.

45 Soy una persona productiva, que siempre termina su trabajo.

46 Rara vez estoy triste o deprimido.

47 A veces reboso felicidad.

48 Experimento una gran variedad de emociones o sentimientos.

49 Creo que la mayoría de la gente con la que trato es honrada y fidedigna.

50 En ocasiones primero actúo y luego pienso.

51 A veces hago las cosas impulsivamente y luego me arrepiento.

52 Me gusta estar donde está la acción.

53 Con frecuencia pruebo comidas nuevas o de otros países.

54 Puedo ser sarcástico y mordaz si es necesario.

55 Hay tantas pequeñas cosas que hacer que a veces lo que hago es no atender a ninguna.

56 Es difícil que yo pierda los estribos.

57 No me gusta mucho charlar con la gente.

58 Rara vez experimento emociones fuertes.

59 Los mendigos no me inspiran simpatía.

60 Muchas veces no preparo de antemano lo que tengo que hacer.

RODEE UNA DE LAS RESPUESTAS

¿HA RESPONDIDO A TODAS LAS FRASES? SÍ NO

¿HA ANOTADO SUS RESPUESTAS EN LOS LUGARES INDICADOS? SÍ NO

¿HA RESPONDIDO FIEL Y SINCERAMENTE A LAS FRASES? SÍ NO

FIN DE LA PRUEBA

RODEE CON UN CÍRCULO LA ALTERNATIVA (A a E) QUE CORRESPONDA MEJOR A SU MANERA DE SER

A En total desacuerdo	B En desacuerdo	C Neutral	D De acuerdo	E Totalmente de acuerdo

1 A B C D E	2 A B C D E	3 A B C D E	4 A B C D E	5 A B C D E
6 A B C D E	7 A B C D E	8 A B C D E	9 A B C D E	10 A B C D E
11 A B C D E	12 A B C D E	13 A B C D E	14 A B C D E	15 A B C D E
16 A B C D E	17 A B C D E	18 A B C D E	19 A B C D E	20 A B C D E
21 A B C D E	22 A B C D E	23 A B C D E	24 A B C D E	25 A B C D E
26 A B C D E	27 A B C D E	28 A B C D E	29 A B C D E	30 A B C D E
31 A B C D E	32 A B C D E	33 A B C D E	34 A B C D E	35 A B C D E
36 A B C D E	37 A B C D E	38 A B C D E	39 A B C D E	40 A B C D E
41 A B C D E	42 A B C D E	43 A B C D E	44 A B C D E	45 A B C D E
46 A B C D E	47 A B C D E	48 A B C D E	49 A B C D E	50 A B C D E
51 A B C D E	52 A B C D E	53 A B C D E	54 A B C D E	55 A B C D E
56 A B C D E	57 A B C D E	58 A B C D E	59 A B C D E	60 A B C D E

MUY IMPORTANTE
NO ANOTE NADA EN ESTE RECTÁNGULO

NEO-FFI

¿Ha respondido a todas las frases? SÍ NO
El cuestionario no es válido si la respuesta es NO SÍ NO
El cuestionario no es válido si la respuesta es NO SÍ NO

En cada columna (N, E, O, A y C) sume los puntos señalados por el sujeto.
Traslade esas puntuaciones directas al perfil de la izquierda (según el baremo a utilizar: Total, Varones o Mujeres) para obtener las puntuaciones T y elaborar el gráfico.

1	0	1	2	3	4	2	0	1	2	3	4	3	0	1	2	3	4	4	0	1	2	3	4	5	4	3	2	1	0
6	4	3	2	1	0	7	0	1	2	3	4	8	4	3	2	1	0	9	4	3	2	1	0	10	0	1	2	3	4
11	0	1	2	3	4	12	0	1	2	3	4	13	0	1	2	3	4	14	4	3	2	1	0	15	0	1	2	3	4
16	0	1	2	3	4	17	4	3	2	1	0	18	0	1	2	3	4	19	4	3	2	1	0	20	0	1	2	3	4
21	0	1	2	3	4	22	0	1	2	3	4	23	4	3	2	1	0	24	0	1	2	3	4	25	0	1	2	3	4
26	0	1	2	3	4	27	4	3	2	1	0	28	0	1	2	3	4	29	0	1	2	3	4	30	0	1	2	3	4
31	0	1	2	3	4	32	0	1	2	3	4	33	0	1	2	3	4	34	4	3	2	1	0	35	0	1	2	3	4
36	0	1	2	3	4	37	4	3	2	1	0	38	4	3	2	1	0	39	0	1	2	3	4	40	0	1	2	3	4
41	4	3	2	1	0	42	4	3	2	1	0	43	4	3	2	1	0	44	0	1	2	3	4	45	0	1	2	3	4
46	4	3	2	1	0	47	0	1	2	3	4	48	0	1	2	3	4	49	0	1	2	3	4	50	4	3	2	1	0
51	0	1	2	3	4	52	0	1	2	3	4	53	0	1	2	3	4	54	4	3	2	1	0	55	4	3	2	1	0
56	4	3	2	1	0	57	4	3	2	1	0	58	4	3	2	1	0	59	4	3	2	1	0	60	4	3	2	1	0
N						E						O						A						C					

AI.2.2 – PANAS

Escala de Afectividad (PANAS) de Clark y Watson en Adultos Mayores

Instrucciones: A continuación se presentan palabras que describen diferentes sentimientos y/o emociones. Indique en qué medida usted generalmente, se siente así utilizando la siguiente escala.

1	2	3	4	5
Nada	Muy poco	Algo	Bastante	Mucho

Por ejemplo: **2**(Muy poco) ***Triste*** **4**(Bastante) ***Molesto***

----------	Interesado	----------	Irritado*
----------	Dispuesto	----------	Tenso*
----------	Animado	----------	Avergonzado*
----------	Disgustado/enfadado*	----------	Inspirado
----------	Enérgico	----------	Nervioso*
----------	Culpable*	----------	Decidido
----------	Temeroso*	----------	Atento
----------	Enojado*	----------	Intranquilo*
----------	Entusiasmado	----------	Activo
----------	Orgulloso	----------	Asustado*

Nota. Los reactivos con * responden a la escala de Afecto Negativo, el resto a la escala de Afecto Positivo.

AI.2.3 – Aptitudes and Beliefs Test

CUADRO 6. *Versión española del* Attitudes and beliefs test (adaptado de Burgess, 1990)

ESCALA DE ACTITUDES Y CREENCIAS

Sexo _____ Edad _____ Ocupación _____ Fecha: _____

Carrera _____ Año de carrera: Primero ____

Segundo ____

Tercero ____

Cuarto _____

Quinto _____

Lugar donde vivió los 10 primeros años: Pueblo _____ Ciudad: _____

Madre - Lugar donde vivió los 10 primeros años: Pueblo _____ Ciudad: _____ Edad: ____

Padre - Lugar donde vivió los 10 primeros años: Pueblo _____ Ciudad: _____ Edad: ____

Este inventario presenta distintas actitudes o creencias que la gente mantiene a veces. Lee cada frase atentamente y anota el grado de acuerdo o desacuerdo con la misma.

En cada frase, responde colocando un círculo alrededor del número que mejor describa cómo piensas. Asegúrate de escoger solamente una respuesta para cada frase. Debido a que cada persona es diferente, no hay respuestas correctas o incorrectas a estas frases.

Para saber si una determinada actitud es típica de tu forma de ver las cosas, ten presente cómo eres la mayor parte del tiempo.

Puesto que nos interesan tus reacciones inmediatas o espontáneas, no es necesario que le des muchas vueltas a una frase. Anota tu respuesta rápidamente y pasa a la siguiente pregunta. Aunque aparentemente parece que hay muchas preguntas, la mayoría son breves y tardarás poco en responderlas.

Fíjate en el ejemplo que sigue. Para mostrar el grado en que una frase describe tu actitud, rodea con un círculo un número del 1 (muy en desacuerdo) al 5 (muy de acuerdo). Una respuesta del 2 al 4 indicaría que estás algo de acuerdo o algo en desacuerdo; una respuesta de 3 indicaría que no estás de acuerdo ni tampoco en desacuerdo.

	Estoy muy en desacuerdo				Esto muy de acuerdo
Ejemplo: Me gusta conocer gente.....	1	2	3	4	5

Completa el ejemplo y asegúrate de que entiendes la tarea

Gracias por tu participación y cooperación

¿EN QUÉ GRADO ESTÁ DE ACUERDO CON ESTAS AFIRMACIONES?	MUY EN DESACUERDO	MODERADAMENTE EN DESACUERDO	NEUTRAL	MODERADAMENTE DE ACUERDO	MUY DE ACUERDO
1. Quiero caerle bien a algunas personas	1	2	3	4	5
2. A veces es desagradable cuando no hago las cosas bien	1	2	3	4	5
3. En ocasiones, cuando estoy tenso/a, me es imposible funcionar adecuadamente	1	2	3	4	5
4. Algunas veces, cuando no le caigo bien a la gente, pienso que soy una mala persona	1	2	3	4	5
5. Quiero hacer bien algunas cosas	1	2	3	4	5
6. A veces es desagradable cuando estoy tenso/a	1	2	3	4	5
7. Algunas veces, cuando no le agrado a la gente, me resulta imposible funcionar adecuadamente	1	2	3	4	5
8. En ocasiones, cuando hago las cosas mal, pienso que soy un fracaso	1	2	3	4	5
9. De vez en cuando quiero estar relajado/a	1	2	3	4	5
10. A veces es desagradable cuando no le agrado a la gente	1	2	3	4	5
11. Algunas veces, cuando no lo hago bien, me es imposible funcionar adecuadamente	1	2	3	4	5
12. En ocasiones, cuando estoy tenso/a, pienso que siempre estaré de esa manera	1	2	3	4	5
13. Necesito caerle bien a algunas personas	1	2	3	4	5
14. A veces es terrible cuando no hago las cosas bien	1	2	3	4	5
15. En ocasiones, cuando estoy tenso/a, me resulta imposible funcionar adecuadamente	1	2	3	4	5
16. Pienso que no soy una mala persona incluso si no le caigo bien a algunas personas	1	2	3	4	5
17. Necesito hacer algunas cosas bien	1	2	3	4	5
18. En ocasiones es terrible cuando estoy tenso/a	1	2	3	4	5
19. Algunas veces, cuando no le caigo bien a la gente, me es difícil funcionar adecuadamente	1	2	3	4	5
20. Pienso que no soy un fracaso incluso si hago mal algunas cosas	1	2	3	4	5
21. De vez en cuando necesito estar relajado/a	1	2	3	4	5
22. A veces es terrible cuando no le caigo bien a la gente	1	2	3	4	5
23. En ocasiones, cuando no lo hago bien, me es difícil funcionar adecuadamente	1	2	3	4	5

¿EN QUÉ GRADO ESTÁ DE ACUERDO CON ESTAS AFIRMACIONES?	MUY EN DESACUERDO	MODERADAMENTE EN DESACUERDO	NEUTRAL	MODERADAMENTE DE ACUERDO	MUY DE ACUERDO
24. Pienso que no siempre estaré tenso/a, incluso si a veces no me encuentro relajado/a	1	2	3	4	5
25. Es esencial que le agrade a algunas personas	1	2	3	4	5
26. Algunas veces, cuando no hago las cosas bien, me siento perturbado/a	1	2	3	4	5
27. En ocasiones es frustrante cuando estoy tenso/a	1	2	3	4	5
28. Sólo porque no les agrade a algunas personas no significa que sea una mala persona	1	2	3	4	5
29. Es esencial que haga bien algunas cosas	1	2	3	4	5
30. Algunas veces, cuando estoy tenso/a, me perturbo	1	2	3	4	5
31. A veces es frustrante cuando no le caigo bien a la gente	1	2	3	4	5
32. Sólo porque hago algunas cosas mal, no significa que sea un fracaso	1	2	3	4	5
33. De vez en cuando es esencial estar relajado/a	1	2	3	4	5
34. Algunas veces cuando no le agrado a la gente me siento perturbado/a	1	2	3	4	5
35. En ocasiones es frustrante cuando no hago las cosas bien	1	2	3	4	5
36. Sólo porque estoy tenso/a algunas veces, no significa que siempre estaré así	1	2	3	4	5
37. Es importante que le agrade a algunas personas	1	2	3	4	5
38. A veces, cuando no hago las cosas bien, me siento decepcionado/a	1	2	3	4	5
39. Algunas veces es insoportable cuando estoy tenso/a	1	2	3	4	5
40. Si no les agrado a algunas personas eso significa que soy una mala persona	1	2	3	4	5
41. Es importante que haga bien algunas cosas	1	2	3	4	5
42. En ocasiones, cuando estoy tenso, me siento decepcionado/a	1	2	3	4	5
43. A veces es insoportable cuando no le caigo bien a la gente	1	2	3	4	5
44. Si hago algunas cosas mal eso significa que soy un fracaso	1	2	3	4	5
45. De vez en cuando es importante estar relajado/a	1	2	3	4	5
46. En ocasiones, cuando no le gusto a la gente, me siento decepcionado/a	1	2	3	4	5
47. A veces es insoportable cuando no hago las cosas bien	1	2	3	4	5
48. Nunca voy a conseguir estar relajado/a	1	2	3	4	5

AI.2.4 – Assessment of results questionnaire

Evaluación de una simulación

Estimado colaborador, esta es la última de las ayudas que le pedimos desde este grupo investigador.

En este caso, le adjuntamos una simulación que ha sido realizado especialmente para usted, de acuerdo a las respuestas obtenidas en sus respuestas anteriores.

Con este documento tenemos el objetivo de conocer su opinión personal sobre los pensamientos/sentimientos (texto en naranja) y comunicación no verbal (texto en azul) que se muestran en la simulación. Es importante que su análisis se circunscriba sólo a lo escrito en naranja y azul, no siendo relevante su opinión sobre el diálogo concreto.

La simulación muestra un ejemplo de conversación ante una situación como la descrita en el escenario: ***Diagnóstico de Cáncer***.

El escenario se presenta en forma de diálogo entre el paciente -en este caso, tiene que imaginar que es usted- y el médico que comunica la mala noticia. Como dijimos arriba, no es relevante para nuestra investigación lo que se dice verbalmente en el diálogo, por eso **sólo queremos saber si la información que aparece en naranja (lo que piensa/siente la persona de la simulación) y la información que aparece en azul (la comunicación no verbal) cree que encaja con la usted hipotéticamente tendría ante una situación similar a la que se expone**. Comprobará que el paciente pasa por varios estados sucesivos, esa cadena y evolución de estadios del paciente es también nuestro objeto de estudio

Puede reflejar su valoración general sobre la simulación en una escala que encontrará en la página 3. **Le pedimos que complete el cuestionario en este mismo documento y lo devuelva cumplimentado al mismo correo desde el que se lo enviamos.**

Será importante cualquier comentario libre en el apartado "justifique su elección" que nos ayude a entender mejor su valoración.

Le agradecemos de antemano su colaboración, pues su opinión será de gran ayuda para nuestra investigación.

Caso de uso: Diagnóstico de Cáncer

Usted, acudió al médico por tener problemas de hipertensión e hiperlipidemia. Una ecografía del abdomen muestra varias lesiones en el hígado sugestivas de metástasis. Tras realizarle una biopsia, el médico debe comunicarle el resultado de la misma, y usted acude a consulta. Recuerde en el dialogo, usted tiene el rol del paciente.

Diálogo *(en naranja lo que piensa/siente, en azul la comunicación no verbal)*

Doctor - Buenos días
Paciente - Buenos días

- Se siente emocionado, algo nervioso
- Se muestra neutral

Doctor - Lamento decirle que tengo malas noticias
Paciente - Doctor, tiene que decirme lo que tengo

- Piensas es que esto podría afectar mucho a tu familia
- Siente ira
- Se muestra nervioso, ahora mismo quisieras no estar allí

Doctor - Lo siento mucho… aunque me gustaría tener mejores noticias, la realidad es que la biopsia muestra claramente que el tumor es cancerígeno
Paciente - ¡Cáncer! Pero por qué… ¿es muy grave?

- Piensas que no quieres ser una molestia para tu familia
- Siente ira y depresión
- Se muestra triste, estás a la defensiva y quieres irte de allí

Doctor - Lo siento, realmente es muy agresivo
Paciente - ¡Oh Dios mío! ¿Pero hay algún remedio… aunque no sea fácil?

- Piensa que es una catástrofe
- Siente depresión
- Se muestra triste, estás a la defensiva

Doctor - Si, hay posibilidad de tratamiento. El oncólogo la va a citar lo antes posible para explicarle el plan a seguir en estos casos
Paciente – ¡Esto no me puede estar pasando a mí!

- Piensa que no puede flaquear, que tiene que ser fuerte y capaz, le digan lo que le digan
- Siente ansiedad
- Se muestra tenso, estresado…sencillamente, le gustaría irse de allí

Cuestionario: Diagnóstico de cáncer

Acorde a las características del escenario presentado, en qué medida cree que la simulación se ajusta a su realidad en una situación como la expuesta. Marque lo que corresponda con una cruz en la caja que refleje su opinión:

	Nada	Poco	Bastante	Mucho	Justifique su elección
Lo que piensa y siente el paciente, ¿se ajustaría a su realidad?					
Las expresiones no verbales del paciente ¿se ajustarían a su realidad?					

¡GRACIAS DE NUEVO POR SU COLABORACIÓN!

ANNEX II: ECA-BASED APPLICATION

AII.0 - Annex Introduction

In this annex, the proposed ECA-based application is presented. An overview of the application as weell as its possible uses are explained.

AII.1 – ECA-based application overview

In the ECA-based application the chat-based interface of the Presentation layer is substituted by an ECA (Embodied Conversational Agent) interface. The ECA interface has been implemented in Unity 3D and the Application layer communicates with the ECA interface through sockets.

The ECA-based application has three main components: Graphic User Interface (GUI), Mapping Manager and ABC-EBDI Engine. In Fig. AII.1 a high level view of the architecture is presented.

The GUI (Graphic User Interface) is composed of three panels (see Fig AII.2): Dialog flow, Agent information and the Simulation panel. The Dialog flow panel shows the text output related to the dialog between the doctor and the agent during the simulation. The Agent information panel shows the information related to what the agent thinks, what the agent feels and how the agent behaves in each step of the dialog. At the end of the panel, a start and change view botton can be found. The start botton launches the simulation, initializing the socket connection to the ABC-EBDI Engine and loading the predefined user inputs stored in a json file. If the connection is successfully established with the ABC-EBDI Engine, user inputs are sequentially send to the Chat Panel. After each user input a response provided by the ABC-EBDI Engine is obtained. The change view botton is used to change the camara perspective, from a body view to a face view. The Simulation panel shows the Embodied Conversational Agent (ECA).

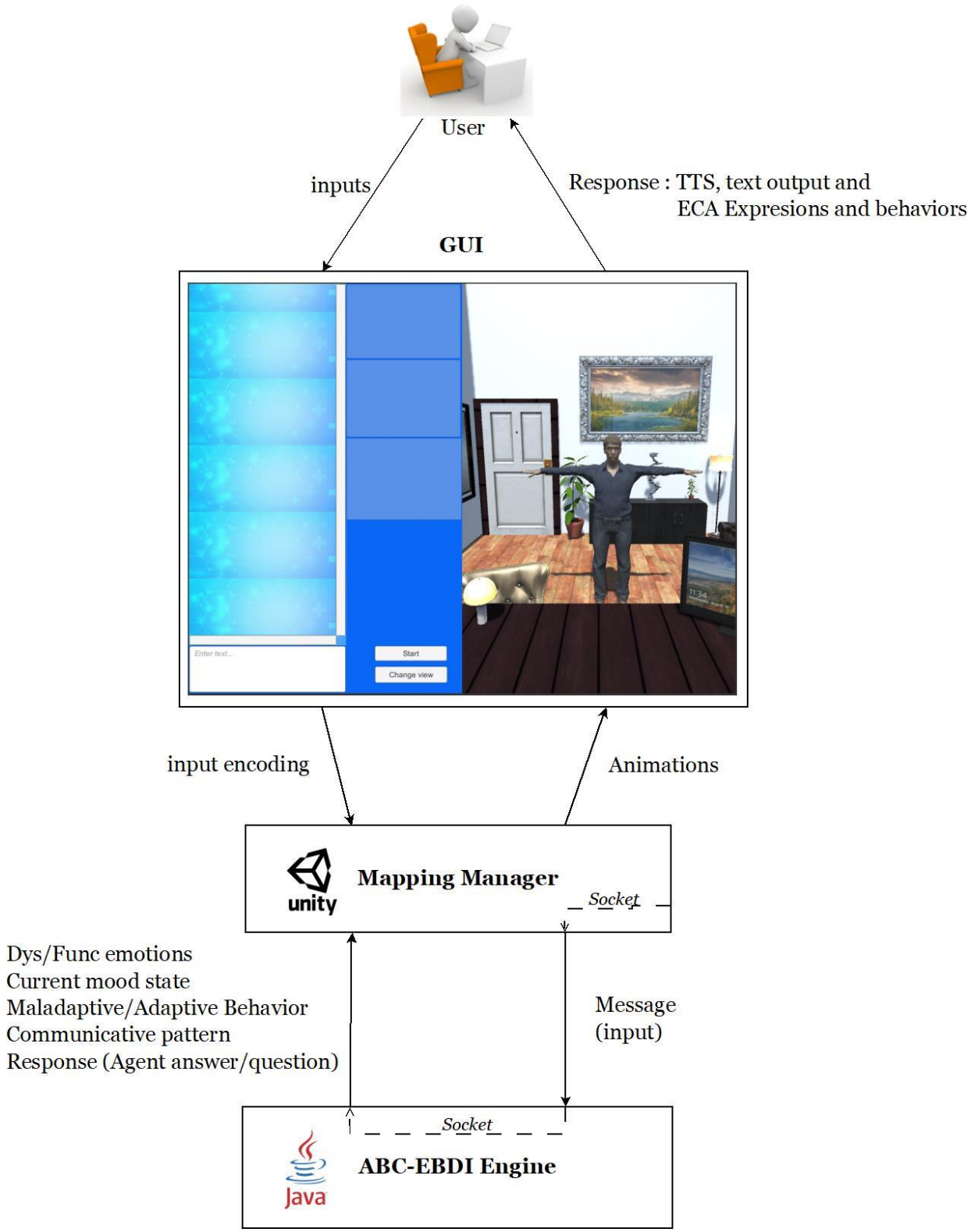


Fig. AII.1. High level view of the ECA-based application.

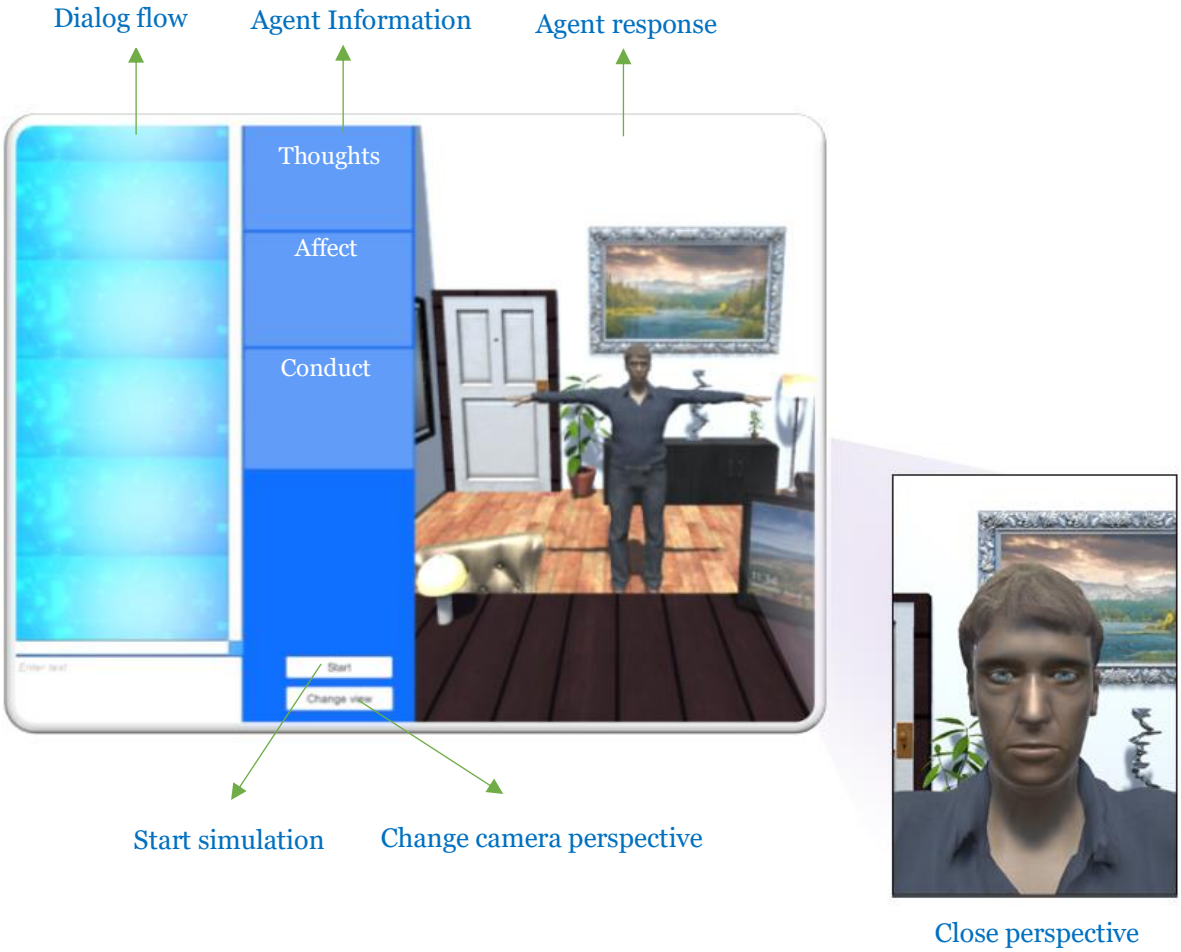


Fig AII.2. GUI component. On the left, the Dialog flow output. In the middle, the Agent information output related the cognitive-affective state of the agent during the simulation. On the right, the agent response is shown.

The application is under construction. In this first stage, only the agent's response including the simulation of verbal and non verbal outputs are shown. To implement verbal output Text-To-Speech (TTS) and a lips-syncronization libraries (Oculus Libsync) are used. Regarding non verbal output, a 3D model endowed with body gestures, facial expressions and body gestures has been created (Yubero, 2016). The animations modeled can be grouped into three categories: facial expressions, body gestures and body movements. Facial expression category contains eleven animations corresponding to the dysfunctional/functional emotions. Body expression category contains thirty body gestures composed by a neutral posture and twenty-nine gestures according to the twenty-three mood states and the five communicative Satir's patterns.

Finally, body movement category includes eight general movements such walk, walk crestfallen, sit disagreement, walk straight, walk to the right , walk to the left, walk in circles, turn right and turn left.

In Fig. AII.3 and Fig. AII.4, the emotional facial expresions and the Satir's body gestures are shown.

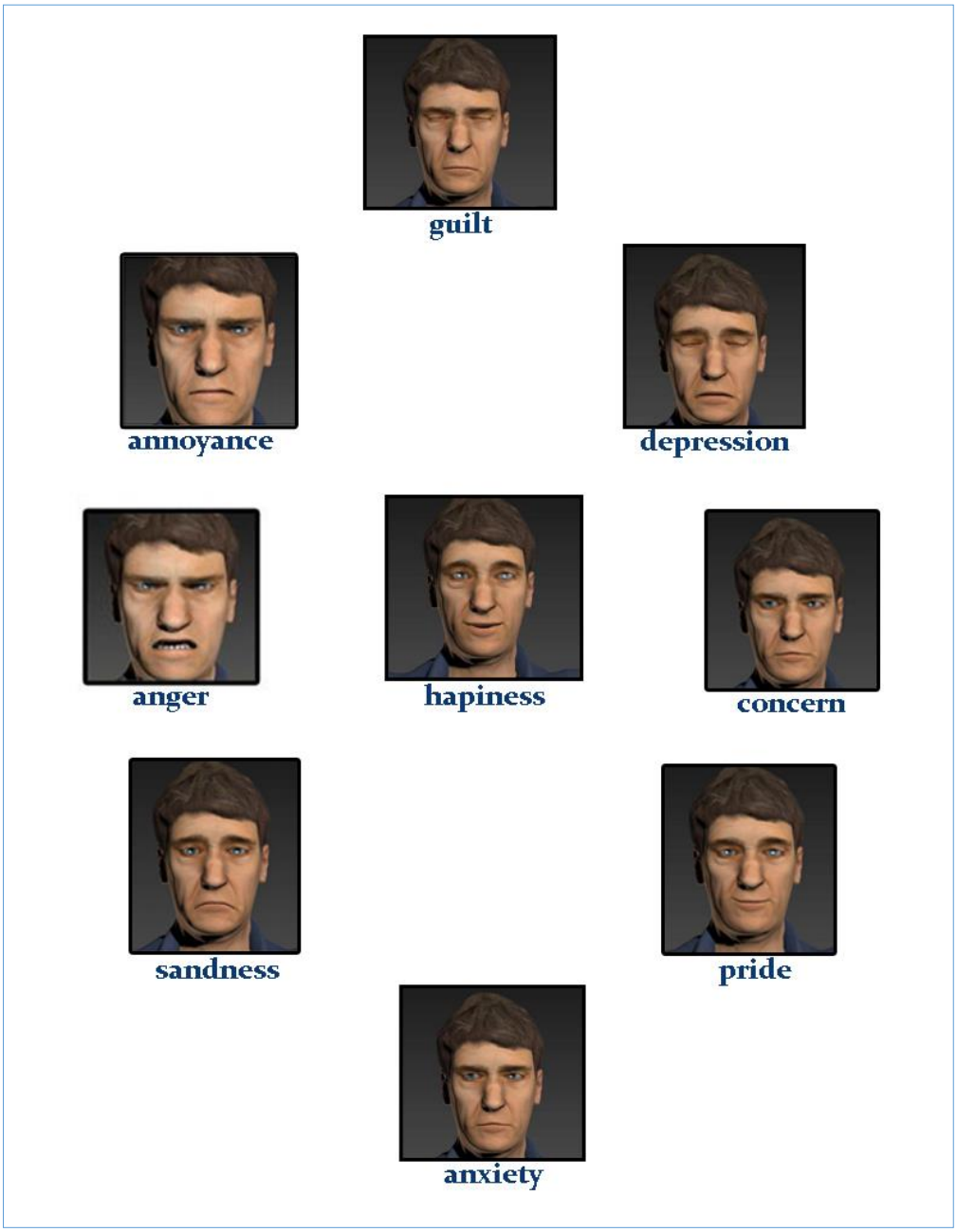


Fig. AII.3. Nine facial expressions related to dyfunctional (anxiety, anger) and functional (concern, sadness and annoyance) emotions.

Fig. AII.4. Five body gestures acoording to Satir's patterns.

The Mapping Manager is in charge of mapping the ECA's outputs with the cognitive-affective output of the ABC-EBDI engine. In each step of the dialog the response managed by the Mapping Manager has to be consistent with the agent's internal mental state in terms of facial expressions, body gestures and intonation. Besides, all verbal and non-verbal outputs have to be synchronized. To render the appropiated facial expresion, voice and body expressions and movements, the value of emotions, mood and Satir's patterns are combined to produce a credible animation. Emotions elicited during the simulation condition facial expressions

and voice intonation. Mood and communicative patterns modulate body gestures. Each animation has a blend and speed value with a default value of 5 and 1, respectively. In this version, the speed value is fixed and does not change over animations. On the other hand, the blend value related to facial and body expressions are set according to the arousal (high/low energy) value related to emotions and moods provided by the ABC-EBDI Engine output (see Fig. 4.10, Chapter 4). To do so, the absolute value of the arousal value is re-scaled into the [1;10] range. In the case of body expressions related to communicative patterns, the blend value is the default value(5). In Table AII.1, the mapping between facial expression animations and emotional outputs is presented. In Table AII.2, the mapping between body expression animations and communicative pattern outputs is presented. Finally, in Table AII.3, the mapping between body expression animations and mood state outputs is presented.

Tabla AII.1.

Mapping between facial expression animations and emotional outputs.

ABC-EBDI emotional output	Facial expression animation
None	neutral
Anger	emotive_anger
Anxiety	anxiety
Guilt	confirmed_fears
Depression	emotive_sadness
Annoyance	annoyance
Concern	emotive_fear
Sadness	sadness_cry
Remorse	emotive_fears
Pride	placer
Gratitude	emotive_satisfaction
happiness	emotive_happiness

Tabla AII.2.

Mapping between body expressions animations and communicative patterns output.

ABC-EBDI communicative output	Body expression animation
Leveling	neutral
Placating	look_away
Superreasonable	body_nod
Irrelevant	bored
Blaming	point

Table AII.3.

Mapping between body expression animations and ABC-EBDI mood state outputs.

ABC-EBDI mood state output	Body expression animation
happy	excited_happy
excited	
dependent	
exuberant	happy_hand
alert	neutral_state
elated	
relaxed	
docile	
contented	
serene	
hostile	hostile_state
upset	
nervous	heavy_breathing
distress	
anxious	
tense	tense
sad	sad_state
gloomy	fall_down
disdainful	prepotent_gesture
bored	bored
lethargic	
fatigued	look_away
calmed	body_nod

To start with the ECA-based application execution, some configurations have to be set. In particulary it is necessary:

1- To configure the ABC-EBDI Engine according to use case that is going to be simulated:

   a. To configure the dialog flow in the IBM Watson Assistant.

   b. To configure the agent beliefs base, desires, initial mood state and personality.

2- To configure socket connection values (ip address and port) in ABC-EBDI Engine and in the ECA interface.

3- To start the ABC-EBDI Engine.

4- To start the ECA interface.

5- To start simulation.

Once the simulation is started user inputs are sent to the ABC-EBDI engine, and the responses obtained are shown in the interface as shown in Fig. AII.1. In Fig. AII.5, the simulation flow is presented. For the moment, just predefined user inputs are processed.

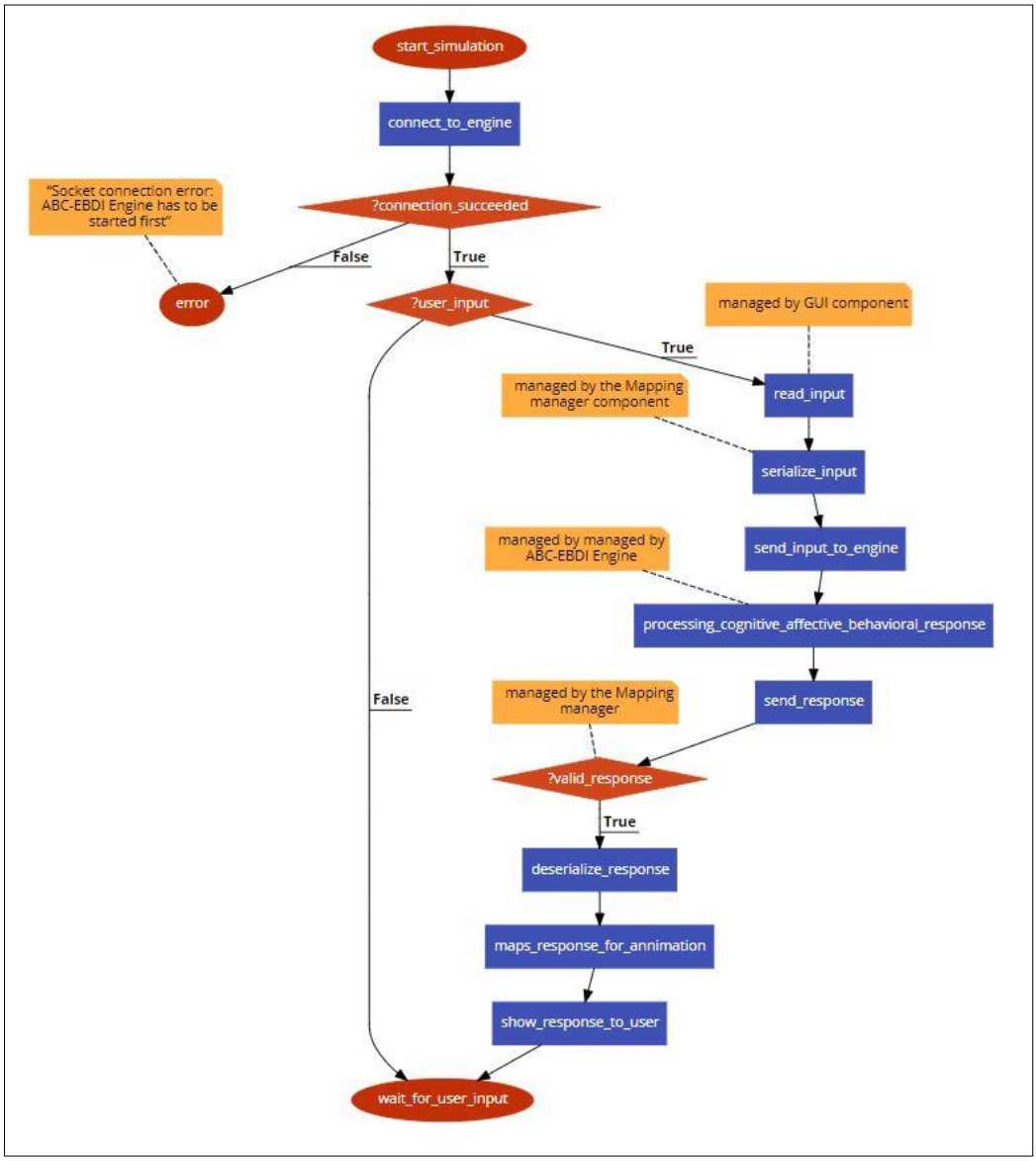


Fig. AII.5. ECA-based application flow diagram.

Once the ECA-based application is operative the idea is to use it to train healthcare students in the bad news communication scope as it is commented in the next subsection.

AII.2 - ECA-based application uses

Communicating bad news to patients is recognized as one of the most stressful activities any healthcare professional must perform. Several studies have found that poor communication of an adverse diagnosis can have negative consequences not only for the patient but also for family members (Loaiza and Arroyave, 2009), and even for the health professional, so that, it can hinder communication with the patient and impair the course of treatment to be followed (Abbaszadeh et al., 2014), (Prado et al., 2013). However, most healthcare professionals do not receive any formal training on how to break bad news and skillfully conduct crucial conversations with patients and families (Defining Bad News, n.d.).

This kind of bad news communication scenarios can be useful for Nurses, Dietitians, Social Workers, Spiritual Care, Physiotherapists, Occupational Therapists and Pharmacists. But it is more common in medical scenarios such as diagnosis, survival, limitations, error, death, among others. In this regard, the research about bad news communication has resulted in several protocols that make the process of communicating bad news feasible, giving the health professional the opportunity to minimize the emotional impact of the bad news on the patient and family members. The SPIKES (Baile et al., 2000), the ABCDE (VandeKieft, 2001), the BREAKS (Narayanan et al., 2010), the SHARE (Tang et al., 2014) and the PACIENTE (Pereira et al., 2017), protocols stand out. These protocols define the steps to be followed by the health professional when communicating bad news. Within these steps there is a very important issue that all the protocols consider: how the professional must respond to the behavioral reactions (verbal and non-verbal) and emotions of the patient. At this point, the protocols highlight that patients accompany their immediate emotional responses to an adverse diagnosis with expressions such as shock, incredulity, insolation, and pain. The emotions are a mixture of various negative emotions such as fear, anger, frustration, distress, fear, sadness, which can go from one to the other or be experienced ambivalently (Kennifer et al., 2009). From our point of view the ABC-EBDI Engine is very well suited to simulate the several emotional and behavioral reactions of patients in those scenarios. Several medical scenarios could be simulated in the ECA-based application such as diagnossis, death news,

chronic life altering illness (i.e., chronic heart failure, cirrhosis). To do so, IBM Watson Assitant should be endowed with the appropiated dialogs and a varied beliefs set should be created.

In addition, these protocols also highlight the importance of the professional welcoming the patient's emotions and behaving empathically with him/her. This implies, that the professional identifies the patient's emotions and verbally express that he/she is aware of them, which is a difficult process to carry out (Bascuñán R., 2013). Precisely, identifiying patient's emotions will be the main objective of the profesional-ECA interaction. Moreover, we think that the ECA-based application could have an aditional module to assess the user (healthcare professional) interaction. In this regard, one of the protocols mentioned above, particulary, the SPAIKES protocol could be used to carry out the assessment.

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