Affective Computing

Ph.D. Comprehensive Exam

Mohammad Shayganfar - mshayganfar@wpi.edu
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1 Introduction to Affective Computing

In this section, I discuss the concept of artificial emotions. I briefly review the influential cognitive theories which describe emotions. These theories provide cognitive structure of emotions and some of them describe the underlying evaluative processes of emotion eliciting mechanisms. This is important in my work because I am interested to investigate how emotions are involved in collaboration and how the dynamics of a collaboration structure impact the underlying processes of emotion.

Studies show that the decision making of humans is not always logical [25], and in fact, not only is pure logic not enough to model human intelligence, but it also shows failures when applied in artificial intelligence systems [17]. Emotions impact fundamental parts of cognition including perception, memory, attention and reasoning [10]. This impact is caused by the information emotions carry about the environment and event values. The influence of emotions depends on an individual's focus of attention. For instance, a positive affect can cause a positive attitude towards an object if the individual's focus is on the object, whereas the same positive affect can be interpreted as a positive feedback towards one's partner during the course of a collaboration. As another example, a positive feedback can promote certain cognitive processes, or it can inhibit other cognitive processes according to the conditions in the environment [11]. In both cases, emotions play a regulatory role for cognitive processes [24]. Some of the effects flow from underlying shifts in the way people perceive and think under the influence of emotion.

2 Computational Theories of Emotion/Affect

There are different types of computational theories of emotion. These theories differ in type of relationships between their components and whether a particular component play a cricual role in an individual emotion. For instance, the basic component of an emotion can be the behavioral tendencies,

cognitive elements, or somatic processes. Emotion theories can also differ based on their representationial distinction.

2.1 Appraisal Theory

The emotional experience is the experience of a particular situation [20]. Appraisal theory describes the cognitive process by which an individual evaluates the situation in the environment with respect to the individual's well-being and triggers emotions to control internal changes and external actions.

2.1.1 Componential approach

This approach emphasizes the distinct components of emotions, and is often called the *componential* appraoch [38]. The "components" referred to in this approach are the components of the cognitive appraisal process. These are referred to as *appraisal variables*, and include *novelty, valence, goal relevance, goal congruence*, and *coping abilities* (further on, in this section, some of the appraisal variables used in computational models are introduced) [54, 57]. A stimulus, whether real or imagined, is analyzed in terms of its meaning and consequences for the agent, to determine the affective reaction. The analysis involves assigning specific values to the appraisal variables. Once the appraisal variable values are determined by the organisms evaluative processes, the resulting vector is mapped onto a particular emotion, within the n-dimensional space defined by the n appraisal variables. The semantic primitives for representing emotions within this model are thus these individual appraisal variables. Figure 1 shows the relationship of the individual appraisal dimensions to the broader categories of evaluations taking place during appraisal (Relevance, Implications, etc.).

2.1.2 Appraisal Process

According to this theory, appraisals are separable antecedents of emotion, that is, the individual first evaluates the environment and then feels an appropriate emotion [57]. The appraisal procedure begins with the evaluation process of the environment according to the internalized goals and is based on systematic assessment of several elements [56]. The outcome of this process triggers the appropriate emotions. In many versions of the appraisal theory, appraisals also trigger cognitive responses often called *coping strategies*. In fact, the coping mechanism manages the individual's action with respect to the individual's emotional state and the existing internal and/or

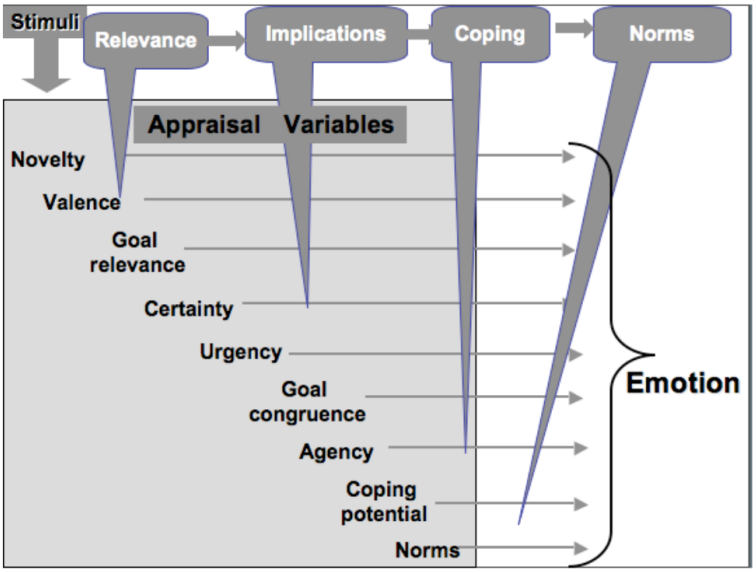

Figure 1: Schematic View of the Componential Theory of Emotion [30].

external demands [19]. The large majority of computational models of emotions are based on this theory. An individual can also use knowledge about the emotional reactions of others to make inferences about them. According to the appraisal patterns, different emotions can be experienced and expressed. Since expression of emotions reflects one's intentions through the appraisal process, the *reverse appraisal* mechanism helps one to infer other's mental states based on their expressions. [15, 27].

Appraisal process is typically viewed as the cause of emotion and the cognitive and behavioral changes associated with emotion. For instance, which particular pattern of the appraisal variables (i.e., individual judgements) would elicit certain emotion or an emotional expressions.

- List and brief description of appriasal variables.
- List and brief description of coping mechanisms.

2.1.3 OCC as an Example of Cognitive Appraisal

OCC model, similar to Lazarus' [35] and Scherer's [54] cognitive views, considers emotions to arise from affective or valenced reactions subsequent to

the appraisal of a stimulus as being beneficial or harmful to ones concern [43]. The model categorizes emotions based on their underlying appraisal patterns. These patterns are fundamental criteria a person employs for evaluating the situation. They involve the persons focus of attention, their concern, and their appraisal preceding an affective reaction. Figure 2 shows main building blocks of OCC model.

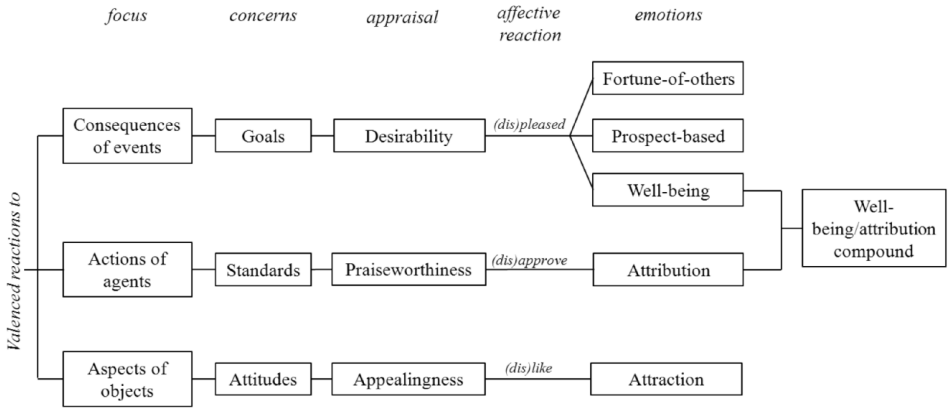

Figure 2: A simple visualization of OCC model [43].

As shown in Figure 2, a person could alternatively have three types of focuses. These types of focuses are consequence of events, actions of agents, and aspects of objects. The person evaluates the significance of causes behind these three types of focuses based on her personal concern. As a result, an affective reaction will be elicited resulting in an emotion. Various combinations of the elements depicted in Figure 2 create specific patterns demonstrating six main groups of emotions in which all emotion types in a group share the same cognitive pattern. Emotion groups are *fortune-of-others, prospect-based, well-being, attribution, well-being/attribution- compound*, and *attraction*. The OCC model introduces 22 emotion types. These emotions are introduced each as a representative of a family of similar emotions with various intensities (since relying on a list of discrete emotions that is understood by everyone equally is impossible due to people's language barriers and various interpretations of the actual words). For instance, happyness can be referred to by other emotion terms such as joy, cheerful, glad, delighted while they all share the same eliciting conditions. Thus the emotion types used in the model (e.g., relief, love, pride, and shame) are meant to represent an emotional experience rather than a lexical taxonomy.

Fo instance, as shown in Figure 2, the appraisal criterion for consequences of events is their *desirability* (see Section 2.1) for achieving ones goals. This generates the affective reaction of being *pleased* in possitive cases, or *displeased* in negative ones. Figure 3 shows the resulting emotion groups in OCC model such as *fortune-of-others* (e.g., gloating, pity), *prospect- based* (e.g., satisfaction, relief), and *well-being* (e.g., joy, distress) [43]. The appraisal of the praiseworthiness of the actions of an agent against one's personal standards, as well as the appealing aspects of objects happens in the same way as shown in Figure 2.

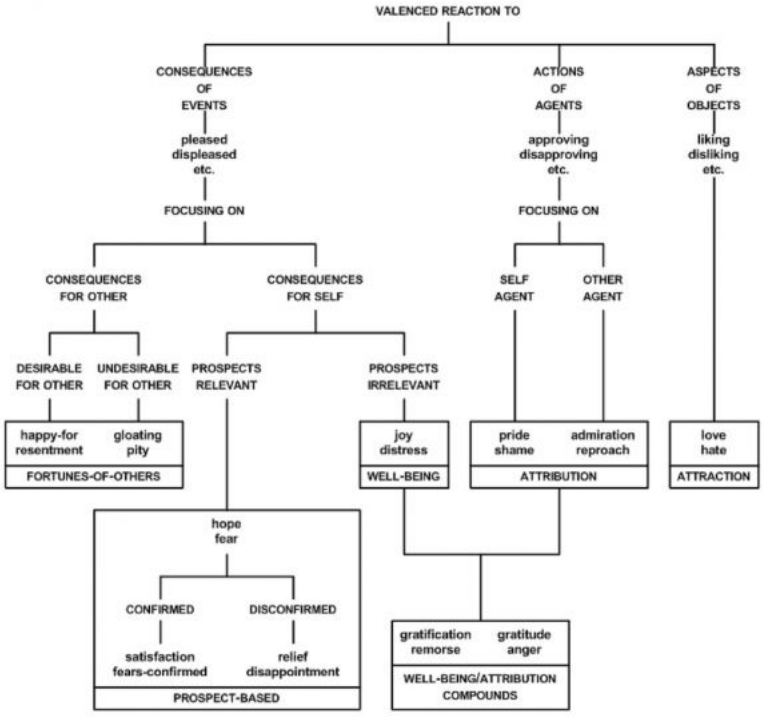

Figure 3: OCC taxonomy of emotion triggers and emotions [43].

Finally, the OCC model introduces some global variables of emotions intensity to distinguish all types of emotions that a person could experience when encountering events, agents or objects. These variables are as follows:

1. Sense of reality (representing the degree to which the event, agent or object in focus appear real to the person),

2. Proximity variable (representing the psychological proximity of event, agent or object),

3. Unexpectedness (representing how unexpectedly one is taken by surprise, either positive or negative),

4. Arousal (representing how arousing an event, agent or object is).

2.2 Dimensional Theories

The components and dimensions of emotions were the subject of much speculation since the 19th century. Dimensional models of emotion attempt to conceptualize human emotions by defining where they lie in two or three dimensions. Dimensional theories of emotion argue that emotion should be conceptualized, as points in a continuous (typically two or three) dimensional space rather than looking at them as discrete entities (see Section 2.3.1) [8] [41] [52] [61].

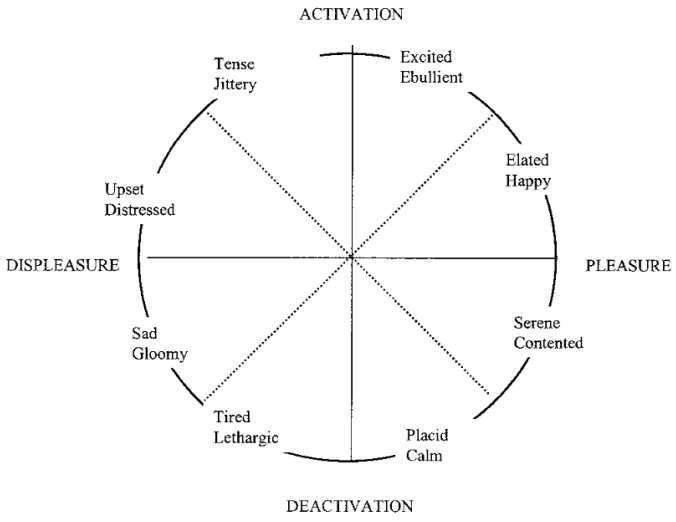

Figure 4: Core affect [52].

Two dimensions that are commonly proposed to describe emotions are valence and physiological arousal [2] [35] [51]. Models based on dimensional theories contrast theories of basic emotion, which propose that different

emotions arise from separate neural systems [50]. Many dimensional theories argue that discrete emotion categories (e.g., sadness, fear and anger) have no "reality" in that there are no specific brain regions or functions that correspond to specific emotions [4]. Dimensional theories do not emphasize the term emotion.

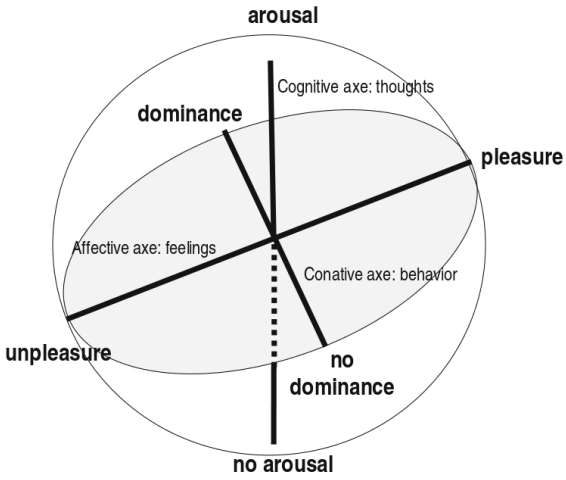

Figure 5: Three dimensional model of pleasure, arousal and dominance as tripartite view of experience [3].

One of the two-dimensional models that are most prominent is Russell's circumplex model [51]. Russell suggested that affective states are all related to each other systematically through what is called core affect [51, 52] (see Figure 4) and emotions are best described as a change in core affect which, in turn, is describable as a point in a space between two bipolar dimensions. One dimension is *valence* or how good or bad are objects and events for a being ranging from pleasant to unpleasant. The other dimension is *arousal*, ranging from calm to excited. Russell put a number of affective states around a circular space between those two dimensions (see Figure 4) which is also known as *circumplex*, representing the variety of core affects [51, 52]. Since sometimes two-dimensional space cannot easily differentiate among emotions that share the same values of arousal and valence, e.g., anger and fear (both characterized by high arousal and negative valence), some of the dimensional models incorporate valence and arousal as well as *intensity*, or *dominance* or stance dimensions. Many computational dimensional models build on the three dimensional PAD model of Mehrabian and Russell [41] where these dimensions correspond to pleasure (a measure of

valence), arousal (indicating the level of affective activation) and dominance (a measure of power or control). Figure 5 shows these three dimensions.

2.3 Other Approaches

2.3.1 Discrete approaches

Discrete theories emphasize a small set of discrete and fundamental emotions. The underlying assumption of this approach is that these emotions are mediated by associated neural circuitry, with hardwired component [18]. Different emotions are then characterized by stable patterns of triggers, behavioral expression, and associated distinct subjective experiences. The emotions addressed by these theories are typically called the *basic* emotions. Emotions including happiness, sadness, fear, anger, surprise, and disgust are often considered to comprise the most prototypical basic emotions [18]. The theory of basic emotions holds that there is a set of emotions shared by all humans that evolved to deal with ancestral life challenges [18]. For instance, disgust evolved to deal with the challenge of avoiding noxious stimuli, and fear evolved to deal with the challenge of avoiding dangers. Because of the emphasis on discrete categories of states, this approach is also termed the *categorical* approach [44]. Much of the supporting evidence offered for the theory comes from experiments that show how certain facial expressions are universally associated with specific basic emotions, regardless of the observer's cultural background. This universality has a production side and a recognition side. On the production side, a particular emotional state is said to elicit a facial expression comprised of a fixed set of facial muscles. On the recognition side, observers are able to infer the emotional state of the person who expresses an emotion, due to the direct correspondence between emotional states and the facial expressions they cause.

2.3.2 Anatomic Approaches

2.3.3 rational Approaches

2.3.4 Communicative Approaches

3 Relation to Psychology and Sociology

- Refer to functions of emotions (Page 48 in proposal).

Figure 6: Basic emotions and corresponding expressions.

3.1 Emotion in Social Context

Emotions are involved in developing social context. Humans are social and most of the causations and constitutions of their emotions are social. Brian Parkinson in [45] argues that many of the causes of emotions are interpersonal and communicative rather than internal and reactive phenomena. There are different social aspects of emotions influenced by various factors such as social context and social relationship type. For instance, a dominant-submissive social relationship can cause and contain different emotions with different intensities compared to a reciprocal or a friendship social relationship type. As another example, an emotion can be interpreted in a certain way when an individual is situated in an environment with other people who are expressing a particular emotion.

There are numerous ways that emotions can be social [60]. There is a consensus on the fact that social events and entities surrounding the indi-

vidual play an essential role in the generation of emotion. There are several ways in which other people elicit emotional responses in us. One is that we feel the emotions of those around us. Also, we have emotions about actions of those people around us. Another is we have emotions about the things that happen to other people. Yet another is our concern about our relationship with others that elicits emotion in us. The groups to which we belong can also elicit our emotions. Moreover, we can feel emotion about the success and failure of our own group or of other groups. In addition, groups or individuals may make salient cultural concerns or societal expectations that can elicit our emotions.

Beside the fact that social context can cause eliciting emotions in individuals, social context provides information about what emotion should be expressed, by whom, and in what situations. For instance, people are well aware of the inappropriateness of expressing too much emotion to acquaintances [60]. However, the social knowledge of emotion expression is only partially delivered in an explicit fashion. There are studies on the regulatory role of society and social relationships on emotions, showing that people's emotions become socialized in implicit and unconscious ways. From this perspective, social context can control and direct our attention toward certain types of events and away from others.

3.2 Social Meaning of Events

Humans are emotional and social beings. Their emotions and the social context in which they are involved have mutual impacts on each other. But, what if humans can share their emotions with others just as they share their thoughts, resources and their environment. Sharing an emotion with others may alter the experience of an event. For instance, according to the nature of the relationship between the individuals, the expression of emotions can either restrain them from further interactions or improve their relationship. Furthermore, individuals sharing emotions might possess a shared understanding of their environment. Socially shared and regulated emotions also provide social meanings to the events happening in the environment [63]. For instance, people are likely to make social inferences based on the presence or absence of particular emotions in their social environment. Moreover, emotions can provide a basis for judgment depending on the individual's relationships with others. In other words, emotions can associate or disassociate an individual, therefore, they can change or maintain the individual's social relationships [60].

3.3 Social Motivator

Emotions can also play the role of a motivator in a social context. There is a subset of social emotions delineated as role-taking emotions in [58]. Shott provides two categories of *reflexive* (e.g. shame or pride) and *empathic* (e.g., empathy or pity) role-taking emotions. The reflexive emotions can motivate the individual's self-control which depends on the anticipated reactions of others to the individual's behaviors. For instance, guilt might lead the individual to behave altruistically to restore a positive social stance for that individual. Empathic or vicarious emotions are based on an individual mentally placing himself in other's situation to understand how the other feels in that situation. These emotions motivate prosocial behaviors to maintain an individual's internal well-being [59].

3.4 Communicating Emotions

Humans need to communicate their emotions within the social context for different reasons. In [22] Goffman argues that human behaviors around others are performative which is often intended to convey information to others. When human's actions are visible in the social context, they behave differently in the presence of the others [65]. The social life of an individual is comprised of the individual's internal cognitive competencies and his interactions in the society. Lazarus says, if society is a fabric, then emotion is its color [36]. Although emotions undeniably have personal aspects, they are usually experienced in a social context and acquire their significance in relation to this context [39].

A successful and effective emotional communication necessitates ongoing reciprocal adjustments between interactants that can happen by interpreting each other's behaviors [39]. It not only requires proper interpretation of the other's expressions, but also correct assessment of the extent to which others can read an individual's expressions. In emotional communication, individuals are constantly exchanging messages about their mental states, and modifying each other's emotional responses as they occur. Individuals perceive other's emotional states through verbal and nonverbal responses during the interaction by processing relevant messages. Communication dynamics represent the temporal relationship between these communicative messages. The verbal and nonverbal messages from one participant are better interpreted inside the correct context including the history and the ongoing messages from the other individuals. Interpersonal dynamics (also known as micro-dynamics in sociology) represent this influence of relation-

ships between individuals [42].

3.5 Social Functions

Humans are able to communnicate their emotions in a social context. The social functions of emotions are the reason behind why humans try to communicate their emotions. In this section, I briefly discuss these social functions of emotions since they are directly related to my work. Ekman in [18] asserts that the primary function of emotions is to mobilize the organism to deal with important interpersonal encounters. Darwin in [13] argues the significance of social communicative functions of emotions. Emotions describe interpersonal dynamics in a way that they can constitute individuals' relationships [45, 60]. One aspect of expressing and communicating emotion in a social context is to express one's social motives and intentions [29]. Another aspect of communicating emotions is to reveal the underlying mental states of an individual [46]. In other words, emotions constitute two different functionalities of expressing communicative signals associated with one's social motives and intentions as well as expressing one's internal states and how one feels about something. In [34] Van Kleef has discussed the idea of inferential processes with which individuals can infer information about others' feelings, relational orientations and behavioral intentions based on their emotional expressions. He also argues that emotional expressions can impact social interactions by eliciting others' affective responses.

Functional accounts vary according to the kind of system being analyzed. Therefore, functional approaches to the emotions should vary by level of analysis. Social functions of emotions can be analyzed in *individual, dyadic, group* and *cultural* levels. My focus in this research is on social functions in dyadic interaction (more specifically collaboration); I also consider these functions at the individual's level especially when interpreting the other collaborator's behaviors. Studies in all these levels share a few assumptions about social accounts of emotions. They assume a) individuals are social by nature and pursue solutions to survival problems in social relationships, b) individuals apply their emotions to coordinate their social interactions and relationships to address these survival problems, c) emotions are processes mediating the individuals' relations to their dynamic environment [32]. In dyadic interactions, studies focus on how emotions impact the interactions of individuals in meaningful relationships. In [32] Keltner and Haidt discuss that in a dyadic setting, researchers mostly focus on communication of emotion (e.g. Scherer [55], DePaulo [16]), properties (e.g. emotion contingency, emotion synchrony) of dyadic emotions (e.g. Levenson & Gottman

[37]), discourse (e.g. Bretherton [7]), and attachments (e.g. Hazan & Shaver [28]).

3.6 Dyadic Interaction

As mentioned earlier, the social context is an important factor influencing one's emotions. A dyadic interaction is one type of a setting in a social context. Dyadic interaction tasks allow us to study emotion in a social setting [12]. Dyadic interaction tasks make it possible to examine how individuals experience and express emotions during social interactions and how emotions shape and are shaped by the reciprocal interactions between individuals. In addition, eliciting and monitoring emotional processes yields useful information about the role emotion plays in interpersonal relationships. Compared with other emotion-eliciting events, events in a dyadic interaction can better help us study an ongoing emotional relationship between two individuals in addition to their internal emotional and cognitive processes. Dyadic interaction tasks are ideal for studying a range of emotional responses because of the fairly unstructured conversations between the individuals. Thus, dyadic interaction tasks will generate a wide range of emotions in comparison with the controlled emotion-eliciting events.

4 Similarities and Differences

Different theoretical perspectives should not be viewed as competing for a single ground truth. They should be seen as distinct perspectives, each arising from a particular research area (e.g., biological vs. social psychology), focusing on different sets of affective phenomena, considering distinct levels of resolution and fundamental components (e.g., emotions vs. appraisal variables as the distinct primitives). These different perspectives also provide different degrees of support for the distinct processes of emotion, e.g., the componential theories provide extensive details about cognitive appraisals [30].

4.1 Dimensional Vs. Discrete

Dimensional theory's main criticism of basic emotions theory is based on the observation that affective phenomena appear to be both qualitatively and quantitatively diverse. Russell in [52] argues the labels such as "fear", "anger", "happiness" do not capture this diversity. For instance, one might

say: a) a person being chased by an assailant brandishing a knife, b) a person who retreats from an insect moving across the floor, and c) a person who is concerned they will never find a career that is fulfilling are all in a state of fear. On the basic emotions account, an emotional episode involves fixed patterns of neurophysiological and facial expression changes in response to an eliciting stimulus that are distinct between emotions, but are the same within the same emotional category [18]. If this were the case, one would expect that the three individuals described above would respond to their eliciting stimuli in the same way, yet the similarity of behavioral responses between these three cases seem unlikely. Dimensional theorists, in contrast, would argue that the individuals in the above three cases are applying the concept of fear to experience, despite the fact that each individual has a unique core affect. While basic emotion theorists would hold that since all three individuals are experiencing fear, they would perform the same behavioral responses to the stimuli, dimensional theorists would argue this is not the case, as each individual bears a core affective state that is distinguished from the other two. For instance, the individual's arousal in response to an armed assailant should be higher than the individual in response to an insect, as the former case poses a threat to their life. As a result, the individual in the first case would likely make every effort to escape from the assailant, including trying to negotiate and plead with the assailant, while the individual in the second case would be relatively less dedicated to escaping the insect. In sum, dimensional theory is compatible with the differences in the behavioral responses to eliciting stimuli, while basic emotions theory only allows for a single fixed behavior of responses to a given emotion. Furthermore, dimensional theories can represent instances of basic emotions (see Figure 7), for example, fear elicited by a snake (green rectangle), in terms of variation along affective dimensions, i.e., arousal and valence.

Also, basic emotion theory fails to account for affect that lacks object-directedness [52]. In basic emotions approach, an emotion is supposed to have an intentional object it is directed towards (e.g., being angry at someone, or being sad for someone). The dimensional theory argues that it may not necessarily be aimed at a particular object. For instance, an individual can experience a certain type of emotion (e.g., anger) without knowing of anything in particular that has offended them. Dimensional models of emotion are therefore capable of accounting for a wider range of affective phenomena than basic emotions theory.

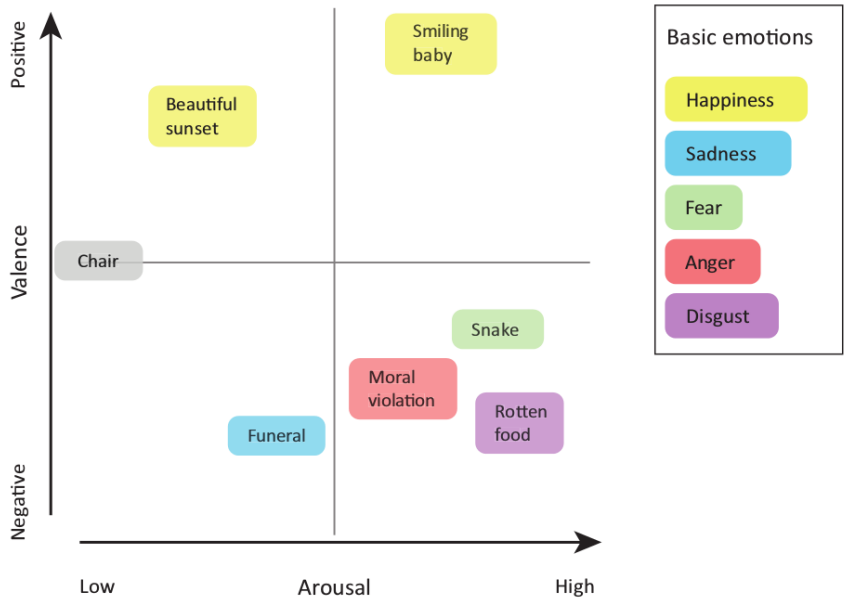

Figure 7: Representing basic emotions within a dimensional framework [26].

4.2 Appraisal Vs. Dimensional

- Dimensional theories might suffer to adequately distinguish emotions because of the existance of the limited dimensions.

- Rewrite this part [It is worth noting that there is a relationship between the dimensions of core affect and appraisal dimensions the pleasure dimension roughly maps onto appraisal dimensions that characterize the valence of an appraisal-eliciting event (e.g., intrinsic pleasantness or goal congruence), dominance roughly map onto the appraisal dimension of coping potential, and arousal a measure of intensity. However, they have quite different meaning: appraisal is a relational construct characterizing the relationship between some specific object/event and the individuals beliefs desires and intentions and several appraisals may be simultaneously active; core affect is a non-relational construct summarizing a unique overall state of the individual.]

- Rewrite this part [Dimensional theories emphasize different components of emotion than appraisal theories and link these components quite differently. Dimensional theories foreground the structural and temporal dynamics of core affect and often do not address affects antecedents in detail. Most significantly, dimensional theorists question the tight causal linkage

between appraisal and emotion that is central to appraisal accounts. Dimensional theorists conceive of core affect as a non-intentional state, meaning the affect is not about some object (as in I am angry at him). In such theories, many factors may contribute to a change in core affect including symbolic intentional judgments (e.g., appraisal) but also sub-symbolic factors such as hormones and drugs (Schachter and Singer, 1962), but most importantly, the link between any preceding intentional meaning and emotion is broken (as it is not represented within core affect) and must be recovered after the fact, sometimes incorrectly (Clore and Plamer, 2009, Clore et al., 1994). For example, Russell argues for the following sequence of emotional components: some external event occurs (e.g., a bear walks out of the forest), it is perceived in terms of its affective quality; this perception results in a dramatic change in core affect; this change is attributed to some object (e.g., the bear); and only then is the object cognitively appraised in terms of its goal relevance, causal antecedents and future prospects (see also, Zajonc, 1980).]

- Rewrite this part [The major similarity between the models presented earlier is that they all consider emotions to descend from valenced reactions to stimuli or situations. Moreover, they acknowledge the role of arousal in determining emotional reactions in one way or another. Russell (1980) and Desmet (2002) consider arousal as one of the two key dimensions of emotions which could be used to discriminate emotional states to some extent. On the other hand, OCC model recognizes arousal as a necessary condition for emotions which rather gives rise to valence to generate an emotion. The former also accounts for it as a determinant of emotions intensity, distinguishing among various emotions of a particular type (for instance between fearful, petrified, and scared). Scherer (2005) argued that arousal dimension in valence-arousal models is relatively fuzzy in definition as it could refer to both the physiological arousal as well as the perceived activation in the situation. He speculated that arousal gives little information about the underlying appraisal of the elicited emotion and proposed to replace it with coping potential which is an appraisal dimension referring to ones perceived control in the situation. Furthermore, dimensional approach pursued in circumplex of core affect is based on joint featuresof emotional reactions (Scherer, 2005) while OCC is based on patterns of antecedent of emotions (Ortony, Clore, and Collins, 1988). This is the fundamental difference between OCC and the circumplex approach of Russell and Desmet. In comparison, OCC model employs causation, attribution and eliciting conditions in order to distinguish emotions while the eliciting conditions or attribution are not directly accessible from dimensional approach. This is likely to be

a consideration when choosing an emotion model in product design. A dimensional model might fall short in establishing why certain emotions are elicited. However, when the objective is to identify the generated emotions and their level of pleasantness and intensity, circumplex model brings about a perfect opportunity.]

See Figure 8

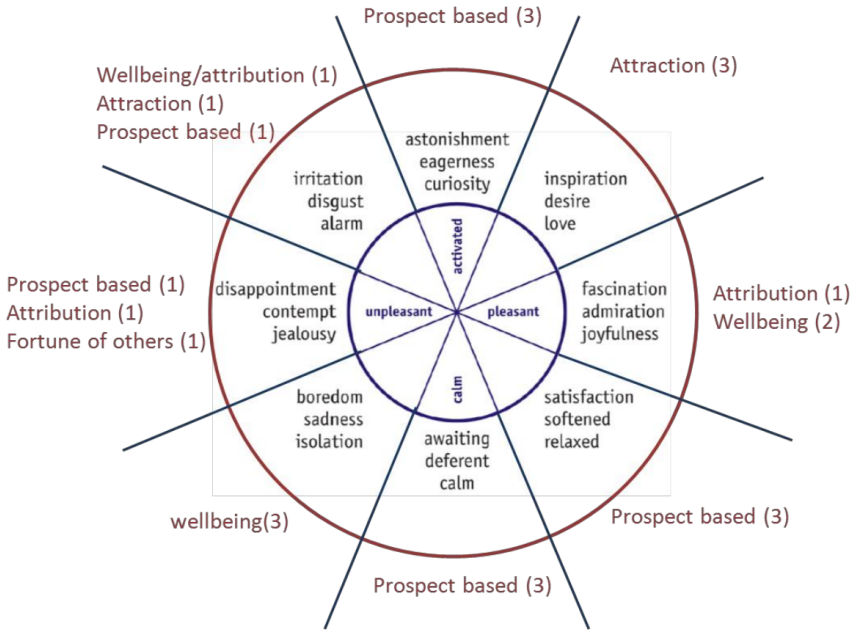

Figure 8: A rough projection of emotion groups of OCC on the circumplex of affect [3].

- Rewrite this part [The number of emotions in a section of Desmets circumplex that fall into an emotion group of OCC are shownin parentheses. For instance all three emotions on the top section (highly excited-neutrally valenced emotions) fall into prospect based emotion group, hence number (3) is indicated.]

5 Applications in Autonomous Agents and Robots

There are several examples in artificial intelligence and robotics of applying the appraisal theory as the basis of a computational model for emotions [1, 33, 40]. In [53] authors describe a system approach to appraisal processes

based on Scherer's work on appraisal and the Component Process Model (CPM) [54]. They show how the temporal unfolding of emotions can be experimentally tested. In this thesis, I use the cognitive appraisal theory of emotion provided by Gratch and Marsella in [23]. They lay out a general domain-independent computational model of appraisal and coping. I use this appraisal approach, in general, as an evaluation mechanism for the internal and external events to assist the cognition and collaboration processes in my theory.

- Rewrite this [Computational dimensional models are most often used for animated character behavior generation, perhaps because it translates emotion into a small number of continuous dimensions that can be readily mapped to continuous features of behavior such as the spatial extent of a gesture. For example, PAD models describe all behavior in terms of only three dimensions whereas modelers using appraisal models must either associate behaviors with a larger number of appraisal dimensions (see Scherer and Ellgring, 2007, Smith and Scott, 1997) or map appraisals into a small number of discrete, though perhaps intensity-varying, expressions (Elliott, 1992). For a similar reason, dimensional models also frequently used as a good representational framework for systems that attempt to recognize human emotional behavior and there is some evidence that they may better discriminate user affective states than approaches that rely on discrete labels (Barrett, 2006).]

5.1 Sociability

Social skills have been mostly neglected in artificial intelligence and robotics. However, there is a broad discussion in natural and social sciences, e.g. psychology and primatology [5, 6, 31, 62, 64], about the role of social factors in the development of intelligence [14] (see Sections **??** to **??**). Robots in the real world, e.g. domestic robots or collaborative robots, require extensive understanding of aspects of humans' behaviors within their environment as well as the ability to communicate and collaborate with them. Emotions, as coordinated responses to detected or inferred relational meanings of the environment (based on appraisal theory), can provide understanding of the social environment, and the capability of communicating internal mental states and maintaining collaborations with human partners. In fact, the emotion processes momentarily respond to the unfolding affordances and constraints offered by the dynamic context of a social interaction [47]. Appraisal can provide the assessment of goal relevance and goal congruence with focus on self or other, the event, or the object in a social context [48].

In short, the agent will be capable of appraising the social environment in order to maintain effective social interaction.

5.2 Decision Making

Decision-Making is an important and complicated process for any robot or virtual agent. This process becomes more complicated when the agent needs to make a decision considering its own private goal, the collaboration's shared goal and the human collaborator's interests. I will provide more details about the following concepts in Chapter **??**.

There are examples of rational and social agents designed based on the decision theory and emotional states [21]. Agents must take a form of action after making a decision. Zhu and Thagard argue how emotions significantly affect the action generation procedure as well as action execution and control [66]. The decision-making procedure, as the basis of an agent's behaviors and actions, is a crucial process for an agent in a social environment. Decision-making is a process that unfolds over time and should be explored in more detail. According to [49], the temporal structure of the decision-making process contains three component processes:

1. Choosing among options initially involves the process of *assessing* the available options. One's affective state and appraisal evaluation of one's internal state as well as the surrounding environment helps in the assessment of all available options. For example, based on the scenario in section **??**, Robot's emotion instance is fear because of an existing block in the plan and its evaluation of Astronaut's emotion as anger (for the same reason). The assessment of available options will be based on minimizing the distance to the shared goal and Astronaut's satisfaction. For instance, if Robot faces a non-critical task, it will give higher value to Astronaut's demanding task which will cause the postponement of its own.

2. This process is followed by the *selection* of an option based on the value that has been assigned to the option. This process is also augmented by affective evaluation of the world, including self, other(s) and the environment. For instance, in our scenario (see section **??**), following the assessment of available options, Robot will focus on Astronaut's preferred task. Also, Robot creates and annotates meta information of the current state of the collaboration with affective evaluations.

3. Finally, the outcome associated with the selected action is *evaluated*

and *incorporated* into existing knowledge for subsequent decisions which implicitly and explicitly help the belief and appraisal emotion systems to operate coherently over time. For instance, if something goes wrong the Robot gives a negative affective attribution to the outcome of the selected action or even a certain path to that action to be used in future assessments.

People's experience of events leak into their beliefs and ultimately decisions. One aspect of these type of experiences is conscious or unconscious annotations by different emotions. For instance, one will never forget working with a friend due to the pleasant feeling of experiencing the outcome. On the other hand, a person will always remember a particular experience in life because of an utterly negative emotion that was felt at the time [49].

Emotions appear to influence the value and weight computation of available alternatives, and these computations are dynamically adjusted based on the environment and the individual's internal states [9]. This way agents can operate and take actions based on preferences. In other words, emotional states of individuals are linked to their decision-making processes, assuming that emotions affect the way gains or losses are transformed to weights and values of the alternative beliefs, actions, tasks, and, in general, plans [49]. The outcome of an action is also profoundly bound to the decision making process as a final and an important stage. The experience of an outcome and in particular, the differences between the expected and observed outcome provides an opportunity to improve one's beliefs about consequences (value) of the available alternatives and adopt a better decision policy in the future [9, 49].

6 Conclusion

References

[1] Carole Adam and Emiliano Lorini. A BDI emotional reasoning engine for an artificial companion. In *Workshop on Agents and multi-agent Systems for AAL and e-HEALTH (PAAMS)*, volume 430, pages 66–78. Springer, 2014.

[2] Magda B. Arnold. *Emotion and personality.* Cassell Co., 1961.

[3] Iris Bakker, Theo van der Voordt, Peter Vink, and Jan de Boon. Pleasure, arousal, dominance: Mehrabian and russell revisited. *Current Psychology*, 33(3):405–421, 2014.

[4] Lisa Feldman Barrett. Are emotions natural kinds? *Perspectives on Psychological Science*, 1(1):28–58, 2006.

[5] Malikeh Beheshtifar and Fateme Roasaei. Emotional intelligence: a review and appraisal. *The Journal of Public Management*, 28(2):197–203, 2012.

[6] Travis R. Bradberry and Lac D. Su. Ability-versus skill-based assessment of emotional intelligence. *Psicothema*, 18(Suppl):59–66, 2006.

[7] Inge Bretherton, Janet Fritz, Carolyn Zahn-Waxler, and Doreen Ridgeway. Learning to talk about emotions: A functionalist perspective. *Child Development*, 57(3):529–548, 1986.

[8] Charles S. Carver. Affect and the functional bases of behavior: On the dimensional structure of affective experience. *Personality and Social Psychology Review*, 5(4):345–356, 2001.

[9] Jean charles Pomerol. Artificial intelligence and human decision making. *European Journal of Operational Research*, 99:3–25, 1997.

[10] Gerald L. Clore and Jeffrey R. Huntsinger. How emotions inform judgment and regulate thought. *Trends in Cognitive Sciences*, 11(9):393–399, 2007.

[11] Gerald L. Clore and Janet Palmer. Affective guidance of intelligent agents: How emotion controls cognition. *Cognitive System Research*, 10(1):21–30, 2009.

[12] James A. Coan and John J.B. Allen. *Handbook of Emotion Elicitation and Assessment*. Oxford University Press, USA, 2007.

[13] Charles Darwin. *The expression of the emotions in man and animals*. New York; D. Appleton and Co., 1916.

[14] Kerstin Dautenhahn. Getting to know each other - artificial social intelligence for autonomous robots. *Robotics and Autonomous Systems*, 16:333–356, 1995.

[15] Celso M. de Melo, Jonathan Gratch, Peter Carnevale, and Stephen J. Read. Reverse appraisal: The importance of appraisals for the effect of emotion displays on people's decision-making in social dilemma. In *Proceedings of the 34th Annual Meeting of the Cognitive Science Society (CogSci)*, 2012.

[16] Bella M. DePaulo. Nonverbal behavior and self-presentation. *Psychological Bulletin*, 111(2):203–243, 1992.

[17] Hubert L. Dreyfus. *What Computers Still Can'T Do: A Critique of Artificial Reason*. MIT Press, 1992.

[18] Paul Ekman. An argument for basic emotions. *Cognition & Emotion*, 6(3-4):169–200, 1992.

[19] Susan Folkman and Judith T. Moskowitz. Coping: Pitfalls and promise. *Annual Review of Psychology*, 55:745–774, 2004.

[20] Nico H. Frijda. *The Emotions*. Cambridge University Press, 1986.

[21] Piotr J. Gmytrasiewicz and Christine L. Lisetti. Emotions and personality in agent design and modeling. In John-Jules Ch. Meyer and Milind Tambe, editors, *ATAL*, volume 2333 of *Lecture Notes in Computer Science*, pages 21–31. Springer, 2001.

[22] Erving Goffman. *The Presentation of Self in Everyday Life*. Anchor, 1959.

[23] Jonathan Gratch and Stacy C.Marsella. A domain-independent framework for modeling emotion. *Cognitive Systems Research*, 5(4):269–306, 2004.

[24] James J. Gross, Gal Sheppes, and Heather L. Urry. Emotion generation and emotion regulation: A distinction we should make (carefully). *Cognition and Emotion*, 25(5):765–781, 2011.

[25] S. Grossberg and W. E. Gutowski. Neural dynamics of decision making under risk: Affective balance and cognitive-emotional interactions. *Psychological Review*, 94(3):300–318, 1987.

[26] Stephan Hamann. Mapping discrete and dimensional emotions onto the brain: controversies and consensus. *Trends in Cognitive Sciences*, 16(9):458–466, 2012.

[27] Shlomo Hareli and Ursula Hess. What emotional reactions can tell us about the nature of others: An appraisal perspective on person perception. *Cognition & Emotion*, 24(1):128–140, 2009.

[28] Cindy Hazan and Phillip Shaver. Romantic love conceptualized as an attachment process. *Personality & Social Psychology*, 52(3):511–524, 1987.

[29] Ursula Hess and Pascal Thibault. Darwin and emotion expression. *American Psychologist*, 64(2):120–128, 2009.

[30] Eva Hudlicka. Guidelines for designing computational models of emotions. *International Journal of Synthetic Emotions*, 2(1):85–102, 2011.

[31] Daniel P. Keating. A search for social intelligence. *Journal of Educational psychology*, 70:218–223, 1978.

[32] Dacher Keltner and Jonathan Haidt. Social functions of emotions at four levels of analysis. *Cognition and Emotion*, 13(5):505–521, 1999.

[33] Hyoung-Rock Kim and Dong-Soo Kwon. Computational model of emotion generation for human-robot interaction based on the cognitive appraisal theory. *Journal of Intelligent and Robotic Systems*, 60(2):263–283, 2010.

[34] Gerben A. Van Kleef. How emotions regulate social life: The emotions as social information (EASI) model. *Current Directions in Psychological Science*, 18(3):184–188, 2009.

[35] Richard S. Lazarus, J. R. Averill, and E. M. Opton. Toward a cognitive theory of emotions. In *Feelings and Emotions*, pages 207–232. New York: Academic Press, New York, 1970.

[36] Richard Stanley Lazarus. *Emotion and Adaptation*. OXFORD University Press, 1991.

[37] Robert W. Levenson and John M. Gottman. Martial interaction: Physiological linkage and affective exchnage. *Personality and Social Psychology*, 45(3):587–597, 1983.

[38] Howard Leventhal and Klaus Scherer. The relationship of emotion to cognition. *Cognition and Emotion*, 1:3–28, 1987.

[39] Claudia Marinetti, Penny Moore, Pablo Lucas, and Brian Parkinson. Emotions in social interactions: Unfolding emotional experience. In *Emotion-Oriented Systems, Cognitive Technologies*, pages 31–46. Springer Berlin Heidelberg, 2011.

[40] Stacy C. Marsella and Jonathan Gratch. EMA: A process model of appraisal dynamics. *Cognitive Systems Research*, 10(1):70–90, March 2009.

[41] Albert Mehrabian and James A. Russell. *An approach to environmental psychology*. The MIT Press, 1974.

[42] Louis Philippe Morency. Computational study of human communication dynamic. In *Proceedings of the 2011 Joint ACM Workshop on Human Gesture and Behavior Understanding*, pages 13–18. ACM, 2011.

[43] Andrew Ortony, Gerald L. Clore, and Allan Collins. *The Cognitive Structure of Emotions*. Cambridge University Press, 1988.

[44] Jaak Panskepp. *Affective Neuroscience: The Foundations of Human and Animal Emotions*. NY:Oxford University Press, 1998.

[45] Brian Parkinson. Emotions are social. *British Journal of Psychology*, 87(4):663–683, 1996.

[46] Brian Parkinson. Do facial movements express emotions or communicate motives? *Personality and Social Psychology Review*, 9(4):278–311, 2005.

[47] Brian Parkinson. What holds emotions together? meaning and response coordination. *Cognitive System Research*, 10(1):31–47, 2009.

[48] W. Gerrod Parrott. Appraisal, emotion words, and the social nature of self-conscious emotions. *Psychological Inquiry*, 15(2):136–138, 2004.

[49] Martin P. Paulus and Angela J. Yu. Emotion and decision-making: affect-driven belief systems in anxiety and depression. *Trends in cognitive sciences*, 16(9):476–483, 2012.

[50] JONATHAN POSNER, JAMES A. RUSSELL, and BRADLEY S. PETERSON. The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathology. *Development and Psychopathology*, null(3):715–734, 2005.

[51] James A. Russell. A circumplex model of affect. *Journal of Personality and Social Psychology*, 39(6):1161–1178, 1980.

[52] James A. Russell. Core affect and the psychological construction of emotion. *Psychological Review*, 110(1):145–172, 2003.

[53] David Sander, Didier Grandjean, and Klaus R. Scherer. A systems approach to appraisal mechanisms in emotion. *Neural Networks*, 18(4):317–352, 2005.

[54] Klaus R. Scherer. On the nature and function of emotion: A component process approach. In Klaus R. Scherer and Paul Ekman, editors, *Approaches To Emotion*, pages 293–317. Lawrence Erlbaum, Hillsdale, NJ, 1984.

[55] Klaus R. Scherer. Vocal affect expression: A review and a model for future research. *Psychological Bulletin*, 99(2):143–165, 1986.

[56] Klaus R. Scherer. On the sequential nature of appraisal processes: Indirect evidence from a recognition task. *Cognition & Emotion*, 13(6):763–793, 1999.

[57] Klaus R. Scherer, Angela Schorr, and Tom Johnstone. *Appraisal Processes in Emotion: Theory, Methods, Research.* Oxford University Press, 2001.

[58] Susan Shott. Emotion and social life: A symbolic interactionist analysis. *The American Journal of Sociology*, 84(6):1317–1334, 1979.

[59] Peggy A. Thoits. The sociology of emotion. *Anuual Review of Sociology*, 15:317–342, 1989.

[60] Larissa Z. Tiedens and Colin Wayne Leach. *The Social Life of Emotions (Studies in Emotion and Social Interaction).* Cambridge University Press, 2004.

[61] David Watson and Auke Tellegen. Toward a consensual structure of mood. *Psychological Bulletin*, 98(2):219–235, 1985.

[62] Mark N. Wexler. Emotional intelligence: a review and appraisal. *The Journal of Public Management*, 30(2):1–8, 2000.

[63] Allison K. Wisecup, Dawn T. Robinson, and Lynn Smith-Lovin. *The Sociology of Emotions.* SAGE Publications, Inc., 2007.

[64] Robert P. Worden. Primate social intelligence. *Cognitive Science*, 20(4):579–616, 1996.

[65] Robert B. Zajonc. Social facilitation. *Science*, 149(3681):269–274, 1965.

[66] Jing Zhu and Paul Thagard. Emotion and action. *Journal of Philosophical Psychology*, 15(1):19–36, 2002.