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Group Affect in Complex Decision-Making: Theory and Formalisms from Psychology and Computer Science

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Abstract. Integrating affect in both individual and collective decision-making processes in order to solve real-world problems can be challenging. This research aims to: (1) investigate how group affect (moods, emotions, and feelings) can be integrated and formalized in the decision-making processes ; (2) develop current practices ; and (3) draw ideas for future perspectives and real-world applications. For this purpose, the role of affect in decision-making is investigated on the individual behavior level, emotional intelligence, and the collective behavior level. The used methodology consists of exploring and investigating the main characteristics developed in group affect in complex decision-making systems from psychology to computer science. From this, a common global structure is deduced: individual processes, group processes and emerging processes (bottom-up, top-down, and combination of bottom-up and top-down components). Following this, one psychological model and two computational models of group emotion and decision are analyzed, and discussed. Their different approaches to developing the main characteristics of a computational model integrating group affect in the decision-making process are highlighted. Finally, specific scenarios of real-world applications are presented in order to draw interesting and promising computational model perspectives.

Keywords: Complex systems; Affect (moods, emotions, feelings); Individual and collective decision-making; Psychology; Computer science

1 Introduction

Progress in cognitive science, psychology, and computer science allows us to deal with more and more complex systems and solve decision-making processes in dynamic, uncertain, and incomplete environments (information) with real-world applications [1]. Traditionally, decision-making was viewed as a rational process where reason calculates the best way to achieve the goal. However, human decisions and actions are much more influenced by intuition and emotional responses than it was previously thought [2¯5].

Throughout recorded human intellectual history, there has been active debate about the nature of the role of emotions or :passionsˇ in human behavior [6], with the dominant view being that passions are a negative force in human behavior [7]. By contrast, some of the latest research has been characterized by a new appreciation of the positive functions served by emotions [8]. An appreciation for the positive functions is not entirely new in behavioral science. Indeed, Darwin, in 1872, was one of the first to hypothesize the adaptive mechanisms through which emotion might guide human behavior [9]. More, emotions are not a luxury, they play a role in communicating meanings to others, and they may also play the cognitive guidance role [8]. In fact, emotions are another important motivation system for complex organisms. They seem to be centrally involved in determining the behavioral reaction to environmental (often social) and internal events of major signiEcance for the needs and goals of a creature [10], [11].

The affective role in decision-making is seen differently per research field. Traditionally, economists assumed people make rational choices, without emotions [12]. However, in behavioral economics there is a place for affect in decision-making. For example, in [13] it is described how the rational actor quickly consults his or her affective feelings to make a judgment or decision. Within neuroscience there is a perspective that felt emotions play an important role in decision-making. Damasioˇs Somatic Marker Hypothesis states that within a given context, each represented option induces (via an emotional response) a feeling which is used to mark that option [14], [15]. These markers are called somatic, because they are related to body-state structure and regulation, such as experiencing goosebumps or an increased heart rate. These markers influence of responding to stimuli in both conscious and unconscious manners. The hypothesis rejects decision making mechanisms only relying on conditioning or cognition alone.

At this stage, one cannot avoid the large and rich terminology used in the literature referring to affect. These definitions have led to controversies that have not reached consensus yet within the scientific community [16]. In order to try to be as much clear as possible, the hierarchical structure of affective processes developed in [16] will be used throughout this paper: (1) affect (long duration, primitive, dimensional: tone (valence) and intensity (arousal), and objective) ; (2) mood (dimensional: tone (valence) and intensity (arousal), medium duration, objective, and expectations) ; (3) emotion (categorical, very short duration, primary vs secondary, objective, and expressive) ; and (4) feeling (self awareness, subjective, and ::Iˇm Happyˇˇ).

This research aims to: (1) investigate how one can formalize and integrate group affect in the decision-making processes ; (2) develop current practices ; and (3) draw ideas for future real-world applications. This is done as follows. In Section 2, the role of affect in decision-making is developed. In Section 3, the main characteristics of group affect in complex decision-making systems are investigated from psychology and computer science perspectives and ideas for future real-world applications are discussed. This research is concluded in Section 4.

2 The Role of Affect in Decision-Making

2.1 Affective Impact on Individual Behavior Level

Contemporary decision-making research is characterized by an intense focus on the irrational part, related to affect in general [6], [17]. An interesting classiEcation of the roles that affect plays in decision making has been proposed in [18]. Affect is loosely deEned as experienced feelings about a stimulus, either integral or incidental. Four roles are identiEed. Firstly, affect plays a role as information, especially via the affect as information mechanism. These feelings, possibly misattributed to the stimulus, act as good-versus-bad information to guide choices, according to the affect heuristic proposed in [13]. Secondly, the role played by affect is as a spotlight, focusing the decision maker˘s attention on certain kinds of new information and making certain kinds of knowledge more accessible for further information processing. Thirdly, affect operates as a motivator, inZuencing approach-avoidance tendencies as well as efforts to process information [19]. Fourthly, affect serves as a common currency in judgments and decisions. Just as money does for goods, affect provides a common currency for experiences. In [18], it is claimed that affective reactions enable people to compare disparate events and complex arguments on a common underlying dimension.

On the other hand, personality psychologists agreed by the late 1990s that personality can be reduced to five orthogonal dimensions [20]. More, relations between dispositional affect and the five-factor model of personality seem to exist [21]. In the 2000s, considerable evidence accumulated against the five-factor model, in favor of a six-factor model, named HEXACO [22], [23]. Elsewhere, personality has been defined as temperament corresponding to psychological individuality aspects related to emotional expression. These are presumed to have a biological basis and correspond to personal attributes relevant to moral conduct, self-mastery, will-power, and integrity [24].

2.2 Affective Impact on Collective Behavior Level

There have been three major contexts within which researchers have studied the effects of affective states on intergroup perception and behavior. Two of the domains have to do with affect that is elicited by the group itself and the social situations within which the group is experienced. Research on chronic integral affect has examined the impact of enduring affective reactions to the social group on attitudes and behavior toward the group and its members. Research on episodic integral affect has examined the impact of affective reactions that are situationally created in intergroup settings, which may in principle be quite different from more chronic feelings about the group (as when one has a pleasant interaction with a member of an otherwise disliked group). The final domain involves affective states that arise for reasons having nothing to do with the intergroup context itself, but which are carried over from other events into an intergroup setting, see [25], [26]. In addition, there is broad consensus that shared positive feelings, like happiness and excitement, serve as a bonding function and promote social integration. There is significant ambiguity, however, regarding how shared negative feelings (e.g., anger or anxiety) influence social integration [27]. This ambiguity about the effects of group affect has been resolved. In particular for negative affect on social integration and group performance. In [27] it is proposed that shared negative feelings sometimes promote and sometimes inhibit, depending on the source of affect, the life span of the group, and social integration. Indeed, for groups, negative affect is most beneficial when localized in time and constructed in response to a specific external stimulus, whereas, over time, though, negative affect emanating from within a group may erode social integration [27].

Additionally, in [28] agent models are developed from social neuroscience concepts. It discusses how such neurological concepts can be used to obtain emergence of shared understanding and collective power of groups of agents, both in a cognitive and affective sense. A generic contagion model is then developed emphasizing the idea that irrationality also has strong social components which can influence the interactions on a group (collective) level, see also [29]. Further, in [30] the `WASABI_ affect simulation architecture is developed, which uses a three-dimensional emotion space called PAD (Pleasure-Arousal-Dominance). In this study, social robots generate and express their emotions in human-robot interaction.

3 Computational Models Integrating Group Affect in the Decision-Making Process

At higher levels of analysis, different processes by which group emotions (group affect) emerge have been defined from organizational science, sociology, and psychology [31]. These processes for group emotion emergence have been developed in [31] as: inclination, interaction (emotion contagion, sense-making), institutionalization (emotional norms, rituals and routines), and identification (group-based appraisals, emotional self-stereotyping). Further, in [32], [33], group affect is characterized in two basic ways: a :top-down˘ approach and a :bottom-up˘ approach. Additionally, a research topic of great interest in computer science is the method to control autonomous agents by integration of affect in the decision-making process during the motion of a group (humans, organisms, agents, robots). This could be viewed from the :unification of an entire group˘ (influent parameters have a significant influence on individual agent behaviors and consequently on the emergent agent group behavior) as well as from the :flexible behavior optimization˘ (optimization in sense of a criteria or a criterion, e.g., evacuation time: minimization of the evacuation time). Hereby: (1) the notion of group implies the notion of social ; (2) a number of autonomous agents existing in an environment are defined under group member conditions (space proximity, common interests, ǔ) ; (3) individual autonomous agents should make their decision-making about their motion.

Thus, in Section 3.1 and 3.2, important facets of the process for group emotion emergence are investigated, namely levels of analysis at which group emotions converge, processes by which they emerge, and their consequences. Hereby, focusing mainly on the process of emotion emergence from *interaction* under the basic ways: *bottom-up* and *top-down* approaches. This is done in order to explore, analyze, and suggest interesting and promising theoretical bases, concepts, and formalisms from psychology and computer science necessary for computational models, which integrate group affect in the decision-making process. Then, in Section 3.3, real-world applications for group affect in decision-making are discussed.

3.1 Main Theories and Formalisms from Psychology and Computer Science

In this subsection, the main characteristics of affect from psychology and computer science perspectives are explored in order to deduce a common global structure. Numerous different individual and group affective influences of great importance in the decision-making process have been developed, and the main characteristics are defined as follows:

1) Individual processes, individual level emotional experiences (emotions, moods, feelings, and emotional intelligence).

2) group processes, group level emotional effects (the emotional infection, the homogeneousness, circular action, and suggestibility).

3) Emerging processes (the ːsum of its partsˇ, bottom-up approach [32], [34].

4) Emerging processes (group affect viewed as ːa wholeˇ, top-down approach) [32], [34].

In addition, Bosse et al. modeled the broaden-and-build hypothesis in group emotion, [35] inspired from the research works of Frederickson [36]. This hypothesis is on the individual level at first point, but when modeling a group, you can get an amplifying emotion effect (or the opposite constraining). In fact, in most circumstances, positive affect enhances problem solving and decision-making, leading to cognitive processing that is not only flexible, innovative, and creative, but also thorough and efficient [37]. These cognitive effects of positive affect are considered in the context of effects on social interaction that show that positive affect leads to helping, generosity, and interpersonal understanding [37]. Moreover, the notion that social interaction between individuals is the fundamental process through which organizational phenomena emerge at collective levels is a pillar of organizational theory [38]. It comes as no surprise, then, that most research in organizational science (and in organizational behavior in particular), relies on the proposition that emotions emerge at higher levels of analysis as a result of the social interaction between people. There are two primary processes by which emotions become shared in the course of these interactions: emotion contagion and sense-making [31].

Thus, a summary of the main characteristics are shown in the first column of Table 1. From the common global structure drawn in Table 1, three computational models of group affect and decision-making will be analyzed in the next Section 3.2.

3.2 Comparison of Different Computational Models of Group Affect and Decision-Making

In this subsection, a psychological computational model of group affect and group decision-making is analyzed [39]. This will be contrasted against the analysis of two computational models of group affect and group decision, named IMPACT and ASCRIBE [40], [41], [42]. These models have been chosen from several models developed in the literature [43][44][45]. This choice has been guided from several similarity and difference reasons:

- they are all dealing with group affect in complex decision-making systems (dedicated to solve similar complex problems related to the decision-making integrating group affect),
- the different points of views and fields from which these three models are developed, from mass psychology and social neuroscience,
- they have some different approaches to modeling group decision-making and they have some overlap at the same time,
- they have been chosen to be studied, analyzed, and discussed in order to highlight their interesting approaches in their ways to answer to and develop the main characteristics (main theoretical bases, concepts, and formalisms) in building a computational model integrating group affect in the decision-making process.

3.2.1 Computational Model from Mass Psychology: Psychological Model

In [39], different group behaviors emerge under different group conditions, ranging from the emotion variation of individuals. Mass psychologists derive typical reasons (of the heightened emotional of violent behavior out of the degree of control by itself based on five factors) based on suggestion factor, imitation factor, infection factor, pressure of number, and frustration. More, the emotion have the characteristics of reducing with time evolution, having the possibility to be effected by the circumstance, and to be influenced back by its own behavior.

Then, the consideration of these characteristics leads to an emotional group with four important points: reducing as time passes (decay or downward spiral), mutual effects, circumstancial effects, and self-feedback effects.

Thus, the Psychological model, based on mass psychology developed in [39], has been expressed as a numerical psychological model through an emotional value E[t] of the agent (robot), consisting of two major parts, a part of self effects (self-suggestion, self-frustration) and a part of mutual effects (imitation, common sense, suggestion, and frustration), in Eq. (1):

$$E[t] = \exp(\omega_t(E[t-1] - E[t-2]))(\omega_{mut}E_{mut} + \omega_{sel}E_{sel}), \tag{1}$$

$$\text{with } \ll_{mut} + \ll_{sel} = 1,$$

where $\ll_t$ is a coefficient of reduction as time passes, $\ll_{sel}$ is a coefficient of self effects, and $\ll_{mut}$ is a coefficient of mutual effects.

Individual Processes. E_{sel} is an emotional value of the agent depending on the condition of himself, expressed in Eq. (2):

Table 1. Main characteristics in group affect in complex decision-making systems.

Main Characteristics in Group Affect in Complex Decision-Making Systems [32], [33], [34], [35], [37], [38]	**Computational Model from Mass Psychology: Psychological model** [39]	**Computational Models from Social Neuroscience: IMPACT and ASCRIBE models** [40], [41], [42]	**Discussions and Conclusions**
Individual Processes (emotions, moods, feelings, and emotional intelligence)	Behavior of Itself (Self Effects) Self-Suggestion Self-Frustration	Somatic Marking Cognitive responding Affective biasing Affective responding Cognitive biasing	Don˘t model mindless crowd Don˘t model automatic social contagion
Group Processes	Behavior of the Other (Mutual Effects) Imitation Common Sense Suggestion Frustration	Social group process Mirroring of Cognitive and Emotional States	Do model social contagion as: - dependent on relations between agents - as dependent on personality characteristics
Emerging Processes ¯ Bottom-Up approach Group Affect: from the :sum of its parts˘: Implicit and Explicit Processes from Group Interaction ; Emerging Group Behaviors under Different Group Conditions ; Affective Compositional Group Effects	Emotional Infection Homogeneousness Circular Action Suggestibility Infection Parameter (infection strength of imitation)	Emotional Contagion Social Contagion	Model affect in the workplace with: contextual factors, such as group lifespan, leadership style
Emerging Processes ¯ Top-Down approach Group Affect: viewed as :a whole˘ ; Group˘s Affective Context - affective tone, amplified, or constrained - ; Affective Context Group Effects on Social Interaction ; Broaden-and-Build Theory ; Positive and Negative Affect	Character Parameter (positive and negative characters) Common Sense		Leaders for larger scale emotion contagion [31] **Important Context Variables** Institutionalisation (emotional norms, rituals and routines) [31]

$$E_{sel} = \omega_{sel\text{-}sug}\, sel\_sug + \omega_{sel-fru}\, sel\_fru\,, \tag{2}$$

$$\text{with } \ll_{sel\text{-}sug} + \ll_{sel\text{-}fru} = 1,$$

where $\ll_{sel\text{-}sug}$ is a coefficient of self suggestion, $\ll_{sel\text{-}fru}$ is a coefficient of self frustration, sel_sug is a value of self suggestion and sel_fru is a value of self frustration (which are obtained from functions depending on cha and conditions of the other and himself). In fact, cha is a parameter character giving particular characters to robots (cha=+1 robots have positive character, and cha=-1 robots have negative character).

Group Processes. E_{mut} is an emotional value of the agent depending on the conditions of the others, expressed in Eq. (3):

$$E_{mut} = \omega_{imi}\, imi + \omega_{com}\, com + \omega_{sug}\, sug + \omega_{fru}\, fru\,, \tag{3}$$

$$\ll_{imi} + \ll_{com} + \ll_{sug} + \ll_{fru} = 1,$$

where $\ll_{imi}$ is a coefficient of imitation, $\ll_{com}$ is a coefficient of common sense, $\ll_{sug}$ is a coefficient of suggestion, $\ll_{fru}$ is a coefficient of frustration, imi is a value of imitation (obtained from a function depending on cha, inf, and conditions of the other and himself), com is a value of common sense (obtained from a function depending on cha, imi, and conditions of the other and himself), sug is a value of suggestion (obtained from a function depending on cha and conditions of the other and himself), and fru is a value of frustration (obtained from a function depending on cha and conditions of the other and himself). In fact, inf is an amount of infection defining infection strength of imitation.

Emerging Processes (Bottom-Up Approach): Affective Compositional Effects. The emerging processes in this model are the affective compositional effects of individual and group processes from group interaction. These are expressed through parameter inf: the infection parameter (infection strength of imitation).

Emerging Processes (Top-Down Approach): Affective Contexts Effects and Broaden-and-Build Theory. The emerging processes in this model are the affective context effects expressed through parameter cha: the character parameter (positive and negative characters).

Combination of Bottom-Up Components with Top-Down Components. The combination is calculated with Eq. (1) of the emotional value of each group member.

3.2.2 Computational Models from Social Neuroscience: IMPACT and ASCRIBE

Individual Processes. Multiple individual emotional processes are modeled in the ASCRIBE model [40]. Each agent has different states: beliefs, emotions and intentions. Each state can influence another state. Somatic marking as described by [14] is modeled as emotion levels influencing intentions. For example, an option can feel good and is therefore given a higher valuation. Further, affective biasing, affective responding and cognitive responding are modeled. This represents the changing of openness to certain information, beliefs of a certain situation (is there a real threat or is it a fake ?) influencing emotions and intended actions to be based on the situation beliefs. In IMPACT [41], [42], agents have multiple states, namely emotions (fear), beliefs, desires and intentions. From ASCRIBE it has adopted affective biasing, cognitive responding and somatic marking. It adds a new interaction effect of cognitive biasing (desires can increase or decrease the level of fear).

Group Processes. Emotional states, beliefs and intentions can be mirrored in ASCRIBE [40]. Each person in the model can affect another person (within a viewing range) with his beliefs, emotions and intentions. Based on personality and relational characteristics these states are being transferred between people. In IMPACT [41],

[42] emotional contagion is also modeled like in ASCRIBE. The fear and belief levels can be transferred between agents within an observation distance.

Emerging Processes (Bottom-Up Approach): Affective Compositional Effects. In IMPACT there is a bottom-up approach. Fear and beliefs can be mirrored, but they do not get amplified on the group level. Emotion in the group is more like a sum of its parts and can be redistributed within the group.

Combination of Bottom-Up Components with Top-Down Components. In ASCRIBE, the agent states are both modeled as being amplified in the group or absorbed in the group. It depends on the situation. ASCRIBE has chosen a top-down approach. The equations for social contagion effects contain a parameter ß with the range [0,1] that can simulate upwards and downward spirals. This simulates group affect whereby group affect is more than the sum of its parts. When ß is 0.5, upwards and downwards spirals have equal effect, making the model a bottom-up approach, whereby the emotions, beliefs and intentions are redistributed in the group.

3.3 Real-World Applications for Group Affect in Complex Decision-Making

When reporting crowd disasters or emergency evacuations, the media tends to use wordings as panic spreading through the crowd quite quickly. Recent academic research explains this view is wrong and that crowd members can act rationally and also non-selfish during these situations [46]. Crowds are not mindless crowds that all behave in the same way. When social contagion mechanisms are used for the spread of information or emotion, it is important that these mechanism do not model the spread as in a mindless crowd. Relations between people should be modeled that have an influence on the contagion effect. For example in- and out-groups could be modeled or other divisions of groups of people that are closer or farther related from each other. This is done in both IMPACT and ASCRIBE [40], [41], [42]. Another approach is to base emotional contagion on personalities. Hereby, the personality characteristics have influence on the susceptibility and spread of emotions and communications [43]. In ASCRIBE [40] the social contagion was dependent on both the relation between agents and two personality characteristics of the sender and receiver: susceptibility and expressiveness.

Another real life scenario is that of how affect influences the performance in the workplace. Hereby it is important that a distinction should be made between positive and negative group affect and contextual factors, such as group lifespan, the source of affect [27]. Another approach would be to look if the leadership style and development level of the employee match so that the employee is happy and can blossom [47].

4 Conclusion

The aim of this research was to: (1) investigate how one can formalize and integrate group affect in the decision-making processes ; (2) develop current practices ; and (3) draw real-world applications. In this paper, different mechanisms of individual and group affect were suggested for complex decision-making systems. The strength of this work lies in the comparison of theories and formalisms from different science perspectives, namely psychology, computer science, and (social) neuroscience. Based on the investigation of the main characteristics of group affect a common global structure was deduced: individual processes, group processes, emerging processes (bottom-up, top-down, and a combination of bottom-up and top-down). Based on this global structure, the different approaches to formalize group affect in three computational models were compared. For each characteristic, different concepts were formalized from both psychology and computer science perspectives. For instance, individual process formalisms for self-suggestion, self-frustration, and somatic marking were discussed. Finally, different real-world applications for group affect in complex decision-making scenarios were presented. Both social contagion in crowd interactions and at the workplace seem interesting areas for future development and research.

An interesting alternative, for future research is to investigate the emotional intelligence and affective learning more in order to integrate the group affect in complex decision-making systems [48]. On the other hand, it is very important to investigate the link between the personality factors and dispositional affect, a promising way for computational models integrating group affect in the decision-making process.

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