Emotion: Theoretical Investigations and Implications for Artificial Social Aggregates

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Abstract. One of the most pressing issues in the social sciences and in distributed artificial intelligence research is the micro-macro link that is the question of how individual action and social structure are interrelated. Besides others disciplines, sociological research has identified emotion as being a possible key component in this link. Unfortunately, sociological theories in question remain relatively basic, and do not refer to emotion research from other disciplines. We show that emotion theories and models from cognitive science, psychology, neuroscience, and computer science constitute a valuable, if not mandatory foundation for sociological issues in emotion research. We therefore present an integrated view on emotion. The goal is to relate specific micro-macro aspects of emotion theory with general sociological theories of societal structuration. This issue is briefly discussed in the context of an exemplifying multi-agent architecture.

1 Introduction

This paper analyses the interrelation of emotion and social structures in natural and artificial social aggregates. One of the key problems, both in distributed artificial intelligence and in the social sciences is the micro-macro link, i.e. how individual action is related to social structures and vice versa [71]. In this article, we argue that emotion plays a major role in this linkage. It is hypothesized that emotion is capable of "absorbing" structured physical and mental environments and of "impinging" them on an individual's information processing architecture. Over and above that, subjects continually recreate these structures by means of emotionally biased behavior of diverse kinds.

We will briefly outline functional basics of emotion in individuals and also focus the *link between* two or more socially interacting subjects and how social order is supposed to emerge from these interactions. To do this, we draw upon a wide range of research results from various disciplines such as psychology, neuroscience, sociology, and computer science.

Computer science as the only mentioned discipline not directly concerned with research on natural emotions is considered both, an enabler and profiteer of our investigations. Computer science can enable research in this field by providing techni-

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ques to model, depict, and simulate complex systems, processes, and interdependencies while probably profiting in many ways from new insights into the social dimensions of emotion which are ideally presented in a formal, agent-based model [12, p. IX].

The article is structured as follows: In the second section we present notions and methodologies and specify the goals we pursue. Then we briefly summarize the latest developments in research on emotions regarding the disciplines in question. The fourth section illustrates our approach to integrate emotion theories from diverse disciplines, focusing on the social world as one cause and consequence of emotion. In the fifth section we make suggestions on how our theoretical findings could be combined with aspects of Pierre Bourdieu's and Norbert Elias's social theories which have already been modeled by means of agent-oriented Petri nets. Finally, we draw conclusions and give an outlook on future work.

2 Means and Methods

This section describes our research goals, the methodological approach we pursue, and defines important terms.

2.1 Goals and Methodology

Our research goal is threefold:

1. To gain new insights into the *social* causes and consequences of human emotion by combining research results from those disciplines concerned with analyses on the micro-level (e.g. neuroscience, psychology) with results and *open questions* found within the social sciences, traditionally concerned with questions of social aggregation (macro-level analysis) [60].
2. In computer science – especially in the fields of human-computer interaction (HCI) and DAI – there is an increasing need for theories of emotion that explicitly account for large scale social dimensions and that can easily be related to existing approaches. Therefore, we strive for a theory that (a) explains the social structural components of emotion as well as their dynamics, and (b) is formulated in a way that makes it useful for computational models.
3. It is not a new insight that computer science and the social sciences could mutually benefit from broader foundations for agent- and multi-agent system-concepts [26]. Malsch [54] has coined this endeavor "socionics". In this respect, cooperation of computer science and sociology could support the construction and analysis of large scale (social) systems – but emotion in a sociological interpretation has not yet been covered in an appropriate way. This is probably due Weber's [81] and Parsons' [64] conceptualizations of action: "Under the aegis of this conceptualization, emotion was regarded as not only irrational but pre-modern: such views became sociological conventions" [3, p. 16].

Future software systems will on the one hand involve many human participants and on the other hand they will (probably) be designed following the MAS-paradigm. Questions with respect to the interaction of these human and artificial actors are numerous. In this context, emotions being generated, shaped, and transformed in / by

these systems and emotions generating, shaping, and transforming these systems need to be investigated. For these questions we provide a theoretical background as well as basic requirements for an emotion-based MAS-architecture.

Why, one may ask from a social scientist's point of view, co-operate with computer science? Where are the benefits for social theory? When conducting emotion research in an interdisciplinary way, combining micro- and macro-level analyses, we consider an actor-centered approach to be the most suitable. Benefits then result from three observations:

1. Because neuroscientific and psychological emotion research is strongly actor-centered, and
2. sociological emotion research dealing with macro causes and effects is also largely actor-centered [33,43,78]. Moreover, there is considerable consensus in sociology that macro-phenomena can in some cases be traced down to micro-acts and instances [15,45].
3. Because in computer science *agents* are an increasingly popular and promising concept. Conceptually they can be understood as a technological counterpart to human actors. To fulfill the pretensions of autonomy, intelligence, mobility, sociability or even emotionality, aspects of the human or animal cognitive system are interpreted as a model for agents' formal reasoning and behavior generation (decision-making, plan-generation, action-selection) [82].

Thus, agents and multi-agent systems are ideally suited to simulate and possibly validate theories that employ the actor as a central concept. Furthermore, due to methodological and theoretical heterogeneity in the distinct disciplines which conduct research on emotion, a conceptual framework is needed that is capable of incorporating and interfacing different theories and concepts. Computational, agent-based models and modeling languages are designed to describe and depict complex systems of various kinds in formal, operational semantics. In this respect, a plea for more profound and formal models in the social sciences, especially in sociology, has been made by [77]. In our opinion, the concept of an emotion system is of such complexity and analysis thereof can fundamentally profit from formal, computational models.

Considering emotion theory, our method is a qualitative-heuristic analysis according to [44]. It is not our intention to build a completely new theory of emotion. Instead, we present first steps towards an integrative view on the diverse and broad theoretical perspectives. Qualitative-heuristic analysis is a means to discover "blind spots" in a specific theory. Although much work is currently done [30,32,41], it is our conviction that most "blind spots" in emotion theory today still can be found at higher levels of social aggregation. Many questions concerning social aggregates could be answered by interfacing and extending existing theories.

2.2 Notions

Much work in computer and cognitive science has been done examining emotion in isolated entities and in (dyadic) social interactions (see the next section for an overview). However, little research has been carried out scrutinizing emotion in the context of larger social aggregates and comprising the role of social structural implications.

Social aggregates (or units, if one likes) like groups, teams, communities, societies or organizations, are considered to be forms of social interaction which are mutually, repeatedly, and orderly carried out by a specific, although possibly dynamic number of individuals. Social aggregates are not necessarily required to be coherent in time and space – they may exist independently of physical presence or time disparities. Natural social aggregates are made up by the interactions of (human) actors, whereas artificial social aggregates require artificial agents (e.g. BDI-agents [31]) to interact with each other (e.g. acting on behalf of one and the same user/client or sharing a common goal).

Social aggregates have specific qualities of diverse kinds such as norms, rules, laws, rites, institutions, etc. For any individual within a social aggregate it is important to have either implicit or explicit knowledge about these qualities to be able to act in relation to these qualities. They may constrain or enlarge actors' options for action and facilitate interactions among actors. These qualities are not objects of the physical world, rather they are "mental objects" of individuals within a social aggregate, and they are internalized by learning or socialization [17,45]. Depending on how actors act in relation to these qualities, the structure of a social aggregate remains more or less stable. Also, joint actions, coalitions, and co-operations require participating actors to act in congruence with norms or rules.

In view of emotion, we are foremost interested in their functional components and will neglect phenomenological, physiological, and related issues here. It is of primary interest, how emotion influences (neuro)cognition and vice versa, and – what is specific to our approach – how this relation affects and is affected by societal conditions. We perform a functional-conceptual analysis in order to resolve questions mentioned above and refer to [39, p. 203] for more detail in this respect. Therefore, specific emotions such as fear, anger, sadness, joy or the like are not accounted for, neither are "social" emotions distinguished from "non-social" emotions.

We define emotion as a state or process that mediates, influences, and is influenced by social, perceptual, physiological, and higher cognitive capabilities of an entity. They are "functional, organized responses to environmental demands that prepare and motivate the person to cope with the adaptational implications of those demands" [74, p. 36]. In human actors, emotion consciously or unconsciously facilitates information processing, verbal and non-verbal communication, social behavior, action selection, decision-making, etc. Emotions have phylogenetic and ontogenetic components, of which the latter are of primary interest here. That means we will analyze components which are alterable during an individual's lifetime (runtime), e.g. by socialization, adaptation and learning.

Choosing this definition and understanding of emotion should not be (in view of computer scientific models) considered superficial – instead it facilitates simulation by omitting possible questions of subjective experience or embodiment.

Although computers may probably never *subjectively experience* emotion (at least in the near future and in a phenomenological sense), it is no question that computers can have "special states that correspond functionally to emotions in organisms" [61].

Having thus clarified our goals we proceed illustrating theoretical and computer-scientific research on emotion to make our goals clear more precisely and to show the urgent need for such an approach.

3 Emotion in Human Actors and Artificial Agents

This section resumes trends and results in theoretic, empiric as well as in computer scientific emotion research. Although, clear-cut distinctions between the different disciplines cannot always be made, we subsume disciplines according to our research goals under "sociology" and "cognitive sciences". With this distinction the focus is either on macro- or micro-level analyses. "Cognitive science" encompasses disciplines such as cognitive and social neuroscience, and cognitive psychology, whereas "sociology" focuses sociological and social psychological research.

3.1 Sociology

The recently established field of sociological emotion research has – in our opinion – not yet fully realized the importance of emotion for social life and social phenomena. Although elaborated and original work exists (e.g. [42,78]), the majority of sociological research tends to neglect important findings from psychology and/or neuroscience despite the fact that there are many valuable connections made with social issues in these lines of research. The sociology of emotion has a long time struggled with intradisciplinary rows between so called positivist and social constructionist positions [43]. By now, it seems that radical constructionist positions [72] have been abandoned and the moderate positivist position is widely accepted.

Most important contributions from sociology (also regarding problems in psychology and artificial intelligence) emerge from areas dealing with *inter-* rather than intrapersonal aspects of emotion, an issue that has somewhat been neglected in psychology [13, p. 212]. Inseparable from this are aggregational (macro) causes and consequences of emotion, a topic sociologists have made valuable contributions to. Kemper for example argues that emotions result from social relationships which are in turn characterized by social status and power [43, p. 344]. Social structures, i.e. vertical stratifications on the macro-level, are made up by the distribution of the social resources status and power amongst individuals. Thus, social structure and emotion influence each other reciprocally.

Collins [16] on the other hand, illustrates that the exchange of "emotional energy" in social interactions facilitates societal structure generation. According to Collins, individuals have an inherent drive to keep up a certain level of "emotional energy" and therefore steadily seek interactions that provide a gain of emotional energy and avoid those that cause a loss.

Although these are valuable contributions toward understanding the relation between individual behavior and social structures, almost all approaches from sociology lack concrete evidence, specifications, and testable models. Collins's [16] concept of "emotional energy" for example is hardly defined at all and remains very vague throughout his explanations.

One step toward more precise and specific models is made by the newly emerging sub-discipline neurosociology that combines neurological evidence obtained by (functional) magnetic resonance imaging (MRI/fMRI) or other techniques with sociological theories of interaction and structuration [25]. Unfortunately, most works presented in that volume lack cognitive foundations, so that an important part of the emotion process is once again not accounted for.

Therefore, to thoroughly understand the social causes and consequences of emotion, an integrative perspective is needed that comprises and interrelates the social, cognitive, and neurological dimensions of emotion.

3.2 Cognitive Sciences

Without a doubt, the most comprehensive research on emotion has come from psychology, with a strong emphasis on cognitive and social psychological theories, whereas the predominant perspective has been intraindividual [55, p. 202]. The results of the diverse works are too extensive even to be summarized here, instead we will focus and very briefly introduce *central topics* and *conceptual models* on which considerable consensus has been achieved.

One of the most prominent and central issues in psychology is the cognition-emotion interrelation that is lead by questions on how emotions influence thoughts and how thoughts influence emotions. There is unchallenged evidence that emotional states decisively affect human cognitive performance, such as problem solving, learning, memory formation, attention, judgment, decision-making, etc. [6,14,24,38].

Despite these results derived from experimental psychology that mainly scrutinize the effects of feelings on cognition, there are elaborated theoretical approaches to emotion that shed light on the question how cognition generates and regulates emotion. Departing from the discussion between [50] and [83] on the question, if cognition is at all involved in emotion generation, there now seems to be wider agreement on *appraisal theory* as one conceptual approach [63]. Basically, appraisal theorists assume that cognitive evaluation of external stimuli generates a subjective meaning on which emotions are based.

The "primacy of affect" [83] within this concept can e.g. be explained by refined information processing theories, such as Leventhal and Scherer's [52] perceptual processing theory that divides perceptual processing into hard-wired sensory-motor, internalized schematic, and inferential conceptual processing as a basis of appraisal.

However, evidence from cognitive neuroscience suggests that emotions *can indeed* occur without any (higher) cognitive involvement [51]. Furthermore, as stressed by other researchers, emotional reactions and their consequences for cognition and overt behavior are often (socially) conditioned and unconscious [18]. Attention to the unconscious has been largely disregarded in sociological (emotion)theory since Max Weber's [81] definition of social action as *intentional* behavior. Although, many prominent works describe mechanisms of structuration whilst tacitly assuming the existence and effectiveness of unconscious determinants of social action (e.g. [28]). The significance of unconscious activity of the emotion system lies within those substantial influences of emotion on cognitive activity which are not accessible by conscious deliberation and do not enter awareness. These mechanisms give conditioning and socialization a whole new meaning because as long as actors are not aware of them, they can hardly be intentionally altered or regulated. Thus, they emphasize the significance of the functional components of emotion over those of subjective feelings.

3.3 Computational Models

Computational models of emotion seek to capture and synthesize functional and expressive components of emotion in the first place; subjective feelings are far beyond what is currently achievable, discussed or even desirable.

The emerging field of "affective computing" is defined by [66] as "computing that relates to, arises from or deliberately influences emotions". In broad terms, the field can be subdivided into efforts to capture and model emotional user states, to synthesize emotions in AI systems for optimized reasoning or decision-making capabilities or to build emotionally expressive systems for richer interactions. Many of the up to date approaches prefer agent oriented systems design, either to make use of methodological advantages or to realize better implementation of emotion theories.

Researchers in the area of affective computing consider emotions to be a crucial part of overall intelligent behavior or as [56, p. 163] stated: "The question is not whether intelligent machines can have emotions, but whether machines can be intelligent without any emotions". Therefore, in order to build systems that are capable of exhibiting intelligent behavior, computational models of emotion are needed which fit into currently used techniques from the field of artificial intelligence.

By now, research conducted on the various aspects of affective computing is focused on cognitive and recently also on social components of emotion, whereas the social dimension is analyzed mainly in view of dyadic agent-human or agent-agent interactions. There are efforts to increase performance and efficiency by means of emotional heuristics [70,80], to improve interactions [5,40,65] or to analyze the role of emotion in artificial minds [73].

Still largely detached from affective computing and related AI-techniques is a continued trend towards distributed AI (DAI) systems. DAI systems rely on the assumption that intelligence is not primarily a matter of isolated entities but rather a question of socially interacting entities [19,2]. Besides the intelligence debate, there are endeavors to transfer the qualities of primate (including human) or animal societies, i.e. natural social aggregates, to computational systems. These qualities are robustness, failure-tolerance, adaptivity and autopoiesis [12]. In this respect, multi-agent systems, i.e. artificial social aggregates, are currently the most promising methodology [22].

To achieve the above mentioned qualities of natural social aggregates, research is actually focused on social phenomena such as coordination, cohesion, cooperation, trust, commitment, and the like. Only recently and very partially, emotions have been considered to be an important part of these phenomena and of global system behavior [1,11,29,75]. However, important findings from sociology dealing specifically with social structural aspects – which are of great interest here – have been largely neglected so far.

We think that there is an enormous potential for computational, especially distributed (and possibly affective) systems, in marrying the neurological, cognitive, and social (sociological) components of emotion; a position that will be illustrated in more detail in the following section.

4 An Integrative Approach

This section describes our integrated approach to analyze the social components of emotion and how they can be found in each of the disciplines addressed above. We first illustrate the influential forces of sociality in different domains and then depict in detail how they are interrelated.

4.1 Sociality as a Common Issue

What has been disregarded in many theories of emotion so far is the fact, that the social worlds individuals are located in are more than a mere collection/aggregation of social agents inhabiting this world. Social systems have specific qualities that emerge from interactions taking place within this system – but these qualities and their causes often cannot be traced back to an individual agent. Nevertheless, these qualities are a major source of influence on any agent's biological, cognitive, and emotion system – in other words: on the determinants of an individual's overall behavior, be it overt (external) or covert (internal). These qualities do not only affect, as it has been assumed for a long time, an individual's "social conventional" actions acquired by learning and priming, but more profoundly also the very basis of an individual's information processing architecture.

We will show in which way we consider emotion to be one key component in the micro-macro link, that is how emotions are directly influenced by social phenomena and via intermediate neural and cognitive pathways, and how emotions and their neural and cognitive underpinnings work concerted to maintain or alter social structural qualities.

As we have briefly illustrated in the preceding section, the various approaches each shed light on specific components of human emotions, such as emotion and social structures, emotion and neural correlates, emotion-cognition relations, and the synthesizing of emotions. Since we aim at finding a stable link between macro-aggregates and micro-acts, we first have to examine if and in which way that, what is widely accepted to be "social", possibly affects the components of an individual's information processing architecture relevant for the emotions.

Second, we have to analyze to what extent social processes and structures influence that what operates on this information processing architecture, namely cognitive activity and mental representations.

Third, it is of interest how these internal mechanisms become involved in communication and social interaction, how they are expressed, interpreted, and judged, and how they become (through bodily or verbal manifestation) part of a social environment.

4.2 Social Neuroscience

As briefly illustrated before, findings from neuroscience suggest that "rational" decision-making based on "pure reason" or "formal logic" is – at least in cognitive tasks serving socially oriented purposes or personal future outcomes – hardly achievable [18, p. 170-3]. To explain the possibility of successful and quick decision-

making in such tasks, Damasio introduces the somatic-marker hypothesis. Somatic-markers can be thought of as a biasing device that (unconsciously) assists human deliberation in reducing alternative options by emotionally marking appropriate (positive) and inappropriate (negative) options.

Damasio goes on to explain that somatic-markers are not predefined or hard-wired in the emotional system, rather they are acquired during (early) socialization and education by "connecting specific classes of stimuli with specific classes of somatic state" [18, p. 177]. Thus, defective or highly erroneous human decision-making in socially oriented tasks, such as in certain types of sociopathy, are at least partly traceable back to maladjusted social development, unless pathological conditions are indicated.

Thus, somatic-markers are a neural and therefore hardly correctable or avoidable means by which behavioral regularities in a social environment, particularly during primary socialization (parents, peers, and friends), can be impinged upon an individual's information processing system. By provoking specific emotional reactions to specific classes of stimuli (real or imagined), a certain form of behavior tendency, also of "non-emotional" character, is promoted. These behavior and decision-making tendencies, we presume, roughly resemble characteristics of prevailing socially shared cognitions and common emotional reactions in the social environment, i.e. the social aggregate, an individual is socialized in. We certainly do not deny individual differences in emotional reactions – emotion to a great extent is what makes us "individual". We also firmly acknowledge subjective interpretations of the social world, which precede any establishment of somatic-markers. But, as we will argue in the following section, initial and supposedly subjective interpretations are also biased by social forces.

Furthermore, there is evidence from the social neurosciences that the very basis of cognitive and emotional activity, the physiological structure and development of certain brain regions (individual's information processing architectures), is affected by social environmental conditions (see [10] for an overview). As [9,27] have argued, socio-cultural factors play an important role in how the brain organizes and selects incoming information, e.g. from the sensory cortices. That means, brains are transducers, they "[..] *change* environmental information (to which the organism could not otherwise respond) into physiological processes that can be received and processed into something humanly meaningful" [25, p. 159, italics original]. Tredway and associates state, that "critical to the formation of a well developed limbic system are *healthy affective* interactions, especially during infancy and early years" [76, p. 110, italics added].

Without further investigation of the latter issue here, we conclude that social aggregational qualities (the social environment) impinge specific modes of biological development, of information processing and (emotional) behavior upon individuals. As long as these forms of behavior are of no pathological kind, we assume that they serve to maintain the structures of social aggregates that originally built them.

The results from neuroscientific investigation set in relation to research efforts in the sociology of emotion (see above) suggest a picture of micro-macro linkage that is fundamentally based on the neural underpinnings of emotion. What has been examined and described by sociological emotion researchers such as [16,42] as well as by sociologists like Elias [21] or Bourdieu [7] could find its more "evidential" foundations in the affective and social neurosciences. We will refer to this possibility in more detail in the following sections.

4.3 Social Cognition

As we have sketched above, there is an unquestioned interrelation between emotion and cognition, and because of their tight connection, both seem only to be conceptually and possibly anatomically, but not functionally separable. In the process of behavior, there is no zero-level emotion or cognition state, unless in some pathological cases. Thus, behavior is neither solely cognition-driven nor solely emotion-driven.

The preceding section has shown in how far social environments may shape emotional responses regardless of *actual* higher cognitive activity operating on working memory. This section examines in which way cognitive activity that is relevant for emotion processes depends on social environmental conditions. In doing this, we refer to the models mentioned before, namely cognitive activity in the appraisal process and in different modes of information processing. Central to this endeavor are the concepts of social cognition and distributed cognition [23].

Besides the aspects of externalization and temporal distribution of cognition, the social distribution of cognition seems to be most relevant for the emotions [62, p. 82]. Socially distributed cognition describes the distribution of cognitive activity (on a specific task) among different individuals. This is either to achieve goals that could not otherwise be accomplished individually (complex or large task-domain, insufficient knowledge) and requires cooperation and coordination, or to overcome deficiencies of individual cognition, such as biases in social judgments [8].

In order to synchronize cognitive activity on a specific task, individuals probably have to adapt their cognitive style to the requirements of their peer-group. Especially from a developmental perspective and since "many, perhaps most, human activities involve socially distributed cognition" [62, p. 83], one can assume that the prevailing or most successful cognitive style within a specific social aggregate is presumably adopted by other individuals up to a certain degree.

Social cognition, on the other hand, is cognitive activity that selects, interprets, and uses social information to make judgments and decisions about the social world. Central concepts are *schemas* and *scripts*. Schemas are a collection of related beliefs individuals use to organize their knowledge about the social world. Upon perception of a certain class of stimuli, one categorizes other persons (stereotypes) or the roles they perform to fit a known schema. Actions and further inferences are often based on a schema rather than on what is actually perceived, i.e. on raw data [4]. Scripts are schemas about events and situations and involve action and behavior strategies.

Although scripts and schemas help to behave according to norms and rules or to act and decide quickly, they are a major source of erroneous behavior (in situations and encounters deviating from standard every-day situations), since possibly valuable information is filtered and not accounted for. Schemas and scripts are based upon past experiences; they are socially learned and internalized. That means individuals belonging to the same social aggregate are likely to acquire similar scripts and schemas and corresponding reactions.

Thus, when appraising social situations that have triggered scripts or schemas to become active, the appraisal process – from which emotions arise – is based on schematic processing. It operates on schemas instead of on "unbiased", raw data [52]. In such situations, it is likely that the resulting emotions do not reflect an individual's response to the actual "objective" person or situation, but rather the triggered schemas. This way, the amount to which social cognition is schematic and possibly

erroneous may also affect emotional reactions and thus provoke "schematic emotions" [67].

Therefore, social cognition and socially distributed cognition lead to certain (classes of) emotions that do not reflect an "objective" appraisal of a person or situation, but instead the schemas of persons and the scripts of events an individual maintains. Because in social aggregates there is a high probability that many people share similar representations of scripts and schemas, also emotional reactions may bear features of these regularities. This way, social aggregates induce a certain amount of relatively homogenous emotional reactions to classes of acts, events, and objects.

What we have said in view of sociological models of emotion at the end of the preceding section also holds for the relation between social cognition and emotion. Though, we assume that the neurological dimension is more profound and stable, since the alteration of once established somatic-markers is hardly feasible. On the other hand, cognitive schemas, scripts, and consequent appraisals based thereon can be acquired and with greater effort also be altered throughout the lifespan. Therefore, they can serve as a means to adapt to fundamentally different social environments. Again, we will refer in more detail to the interrelation between sociological and cognitive theories in the following sections.

4.4 Social Control through Expression, Feedback, and Regulation

A component of the emotions we have not yet considered, although it is of utmost importance for the approach proposed here, is the communicative function of emotions. Until now, we have only dealt with cognitive and neural (that means internal) aspects of individuals' emotions and their consequences for social structures. But one of the most striking features of emotion is their communicative, i.e. *inter*individual function. We assume that the expression, communication, and regulation (coping) of emotion act as a crucial social control operator.

There is strong and consistent evidence that the expression of certain emotions such as anger, fear, enjoyment, sadness, and disgust – often called basic emotions – is distinctive and universal among the human species [20]. The expression of other emotions – sometimes called social emotions – such as shame, grief or embarrassment, does not seem to be universal among the human species, although patterns of expression are highly consistent in a cultural setting. However culture-specific expression of these emotions may have evolved, as long as individuals remain in the cultural setting they were socialized in, they can be almost certain to interpret emotion expressions in the appropriate way. Thus, emotions are a powerful communication device that signals to other individuals the emotional state an individual is in. Perceived emotion expressions allow with great certainty to infer a specific state of mind and the probable consequences for individual behavior, course of interaction, and group behavior.

Sociological and social psychological research conducted in the field of emotion expression has revealed several strategies actors use to deal with their emotions and emotions expressions. Hochschild [36] for example found out that *feeling rules* (or display rules), i.e. social norms, stipulate what an individual is supposed to feel in a specific interaction situation, and what emotions to display. Showing the appropriate emotions, that means the socially expected emotions in specific interaction situations,

is mandatory for an individual in order to be socially accepted. Emotion work, or coping, is volitional cognitive effort to regulate and modulate both, the emotion actually felt and the facial and bodily display of an emotion, regardless whether the emotion on display is really felt or not.

The voluntary or involuntary display of an emotion is subject to social judgment by other individuals who perceive this emotion expression. Depending on what feeling rules are considered valid in a situation, an expression is judged to be either adequate or inadequate. Emotion expressions found to be inadequate signal that the individual expressing (and also probably experiencing) this emotion does not conform (mentally and behaviorally) to what is socially expected. Sanctions may be the consequence [21].

One possible sanctioning mechanism is, again, emotion. By showing anger for example, individuals can signal that they consider behavior to be deviant and not standard conforming. The result may be shame or embarrassment felt by the deviant individual. These emotions are supposed to encourage an individual to adapt its preceding behavior (emotion) by means of emotion work in order to be socially accepted.

The mechanisms illustrated show how emotions serve a reciprocal social control function: on the one hand as a norm-enforcement operator and sanctioning mechanism, on the other hand as an indicator that an individual's assessment and appraisal of a situation is not congruous with that of other individuals. By means of (emotional) sanctions and feedback an individual is then enforced to comply or to terminate an interaction. Social norms and feeling rules, being qualities of a social aggregate, therefore promote behavior regulation via emotions in order to maintain the qualities of a social aggregate.

This emotional control function acts on top of the mechanisms described before. The main difference compared to these mechanisms presumably is the degree to which emotional control is exerted and experienced consciously. Because of the interactive and immediate nature of this form of control, arousal is usually high and actors are aware of their (not necessarily volitional) emotional reactions.

The function of social control has already been described by [21], although in connection with his general social theory and not in view of an explicit sociological theory of emotion [68].

5 Emotion and the SAM Architecture

This section illustrates how the social components of emotion described in our integrative approach can be theoretically and conceptually applied to the multi-agent system architecture SAM (Socionic[1] Agent Model) [46]. We first give a very brief overview of the architectural modeling approach and then relate theoretical findings to the social theories that serve as a basis for the architecture.

[1] See [54] for an introduction to Socionics.

5.1 The Micro-Macro Link and the SAM Architecture

The SAM architecture is modeled by means of Petri nets using the "Renew" tool that allows direct implementation and execution of the model [49]. Here, reference nets (see [48] for a complete definition) – which are based on the "nets within nets"-paradigm as defined by [79] – are used to depict interdependencies between macro- and micro-level in hierarchical layers. We will focus on the three main social layers of the model that have been derived by an analysis of Bourdieu's [7] and Elias's [21] social theories: social structures, social processes, and actors. Originally, the intention was to use social theories to implement mechanisms of social control and habitual (i.e. organizational) behavior in order to analyze the interrelation between large-scale (macro-level) behavior of a multi-agent system and actions of individual agents (micro-level).

The ASKO (Behavior in Social Contexts) research group has modeled different aspects of these interrelations on an abstract conceptual level by describing social states, processes and acts [53]. Further investigations have shown that the sociological theories under examination provide an elaborated and extensive picture of large-scale processes. What is missing is how these features are represented inside individual actors. As long as one is concerned with modeling social structures, processes, acts and their interdependencies, this view is sufficient, but when it comes to modeling actual behavior generation or decision-making of individual agents, several problems arise.

Without a doubt, many valuable agent architectures already incorporate AI-based cognitive activities like planning, action-selection, emotion generation, etc. but unfortunately without making dedicated connections to macro-level phenomena [26]. Analysis of Elias's and Bourdieu's social theories has shown that several mechanisms they describe by which action and social structures are interlinked seem to have an "internal" functional counterpart in emotion. With our integrated approach to emotion presented above, the theories in question could be extended and given emotional foundations which also encompass cognitive and neural aspects. Results of the integration can be used to extend (and therefore probably to enhance) the multi-agent architecture and possibly also the sociological theories in a way that leads to an integration of emotional concepts and factors.

5.2 Habitus and Emotion

Central to the work of Bourdieu is the habitus-field theory with which he addresses the micro-macro link problem [7]. According to Bourdieu, the relationship between habitus and the logic of practice is crucial to understand micro-macro dynamics. The habitus is a cultural and social habitat that becomes internalized in the form of dispositions to act and behave, to think, reason, perceive, and even to feel in a certain way. The habitus can be seen as a set of socially determined bodily and mental dispositions that lack representational content and therefore seldom come to conscious awareness. If this should indeed be the case (e.g. through a field change or a personal crisis), it is important to note that not the habitus *itself* is atomized into a set of mental representations such as beliefs, desires, or intentions, but rather an individual forms beliefs *about* the habitus (and this belief-formation is again based on habitual reasoning).

Where does the habitus come from, then? It can be seen as the incorporation and internalization of the *logic of practice*. The logic of practice is a property of the *social field* within which all human action takes place. Basically, social fields are arenas for the struggle for resources and characterized by vertical stratification. Social fields operate by various mechanisms and rules which, taken together, form the logic of practice. The logic of practice defines the "borders" of a social field by issuing explicit and specific rules.

Individuals who have incorporated the logic of practice of a specific field provide practical acceptance of the practical logic of this specific field and thereby reproduce this very logic via the habitus. This way, a social field controls the behavior of its individuals. Thus, the habitus stabilizes its field, i.e. the field that originally produced the habitus [47].

This far Bourdieu's habitus-field theory has been modeled within the ASKO project [34]. As can be seen from the brief summary, the micro-macro dynamics described by the model resemble the micro-macro dynamics illustrated in our integrated approach to emotion. In view of general habitual behavior primarily the cognitive and neural components of emotion that we described seem to be relevant, whereas in view of the logic of practice and the social field, the regulation and control of emotion through norms and feedback deserve special attention.

We assume that the integrated approach to emotion presented here can serve as a neurocognitive foundation for some aspects of the habitus-field theory. Since the habitus is a phenomenon unconsciously guiding human behavior, we refer to our explanations of Damasio's somatic-marker hypothesis and the role of schemas, scripts, and schematic information processing. By interlinking both, general social theories and interdisciplinary research on emotion, a better understanding of micro-macro dynamics is achievable. The advantage is that this understanding is based on experimental and empirical evidence, rather than on theorizing alone.

5.3 Social Control and Emotion

One central aspect of Elias's [21] grand theory is the exertion of social control through norms and emotions. Tightly interlinked with social control and emotions is the reproduction and maintenance of social norms. According to Elias, any coherent social group (social aggregate) is characterized by struggles for status, power, prestige, social success, and appreciation. This rivalry leads to anxiety about the possible loss of one of these social resources. Elias assumes that this form of anxiety is inherent to the human species and goes back to attachment behavior in mother-infant relationships. Anxiety drives individuals in a social aggregate to constantly monitor other individuals' behavior in order to estimate one's own position in the social order relative to those of others. Knowledge of the positions of other individuals gives rise to efforts to maintain or even improve one's own position.

Crucial for an actor's position in the social order is willingness to comply with the norms of a social aggregate. Deviant behavior will be sanctioned by other individuals in various ways. On the one hand, the loss of social resources such as status, appreciation, and prestige may be the consequence. This may lead to negative emotions such as fear, anger or sadness. On the other hand, other individuals will also show negative emotions to express their discomfort with the deviant individual. Both, loss of resources and the expression of negative emotion may again have emotional

consequences for the deviant individual: shame and embarrassment are the main emotions by which – according to Elias – social control is exerted.

Control then results in social bondage, i.e. "mental" bonds are created that tie an individual to the setting and configuration of a specific social aggregate. Fear of loosing group sympathy and support may transform the social bondage into a self-bondage, i.e. a volitional behavior regulation to be in accordance with prevailing social norms. This way, norms are exerted and exertion leads to the reproduction of a social norm [47,69].

Hinck and associates [35] have modeled this process of norm reproduction by means of high-level Petri nets. Further efforts towards modeling and incorporation of social norms and emotion in interface agents have been done by [57,59]. That work clearly shows the necessity to consider social norms for emotional expressive, socially intelligent agents in human-agent interactions. There, feeling rules are specified and related to an application, and requirements for agent- and user-modeling are outlined [58]. Staller and Petta [75] also have introduced emotions to the computational study of social norms, but from a slightly different perspective.

What has not been done yet is to further examine the role of emotions *per se* as a general indicator for deviant (internal or external) behavior. In the approach mentioned above, deviance is defined as overt behavior that clearly violates specific norms valid in a social aggregate. But when one relates Elias's theoretical findings to our integrated approach, it becomes obvious that the mere and possibly subtle display of an emotion in an interaction situation may indicate that an individual's assessment of a situation in general is not congruous with that of other individuals. This means, that for an actor to realize that another individual has assessed a situation differently from common social expectance, it is probably sufficient to perceive and interpret that individual's emotion expression at a certain time – obvious deviant external and norm-violating behavior is not necessary [37].

We assume that, according to appraisal theoretic approaches, emotions reflect an individual's perception and judgment of a social situation. In coherent groups, as explained, individuals constantly monitor each other's behavior to ensure norm compliance and to prepare eventual sanctions. Emotions are an early indicator that overt deviant actions might be carried out that could disrupt group coherence. They therefore allow interception and regulation at a stage where consequent and probably malicious actions have not yet been carried out.

Therefore, expression, perception, and judgment of emotions act as a control structure *on top* of neurocognitive components and their relation with the structure of a social aggregate. Emotional feedback, sanctions, feeling rules, and social norms make explicit and consciously available what has been impinged upon individuals in infancy and socialization. Social norms being one of the most important components of a social aggregate are tightly interlinked with emotions and are also reproduced via emotions. We thus conclude that the display of emotions and the feedback they provoke are also a vital component of the micro-macro link.

6 Conclusion and Outlook

We have presented an integrative approach to emotion that specifically aims at explaining the role of emotion in the micro-macro link. The micro-macro link is an

unresolved key issue in the social sciences as well as in DAI research and addresses the problem of the relationship between individual action and social structure. Basically, the question is how regulation of individual behavior is achieved in a way that leads to social structural configurations allowing for phenomena such as cooperation, coherence or coordination, to name just some.

There are prominent theories in the social sciences that explicitly address this problem and which have been (partly) adopted by the DAI community (e.g. [28]). Even so it remains largely unsolved. With our approach to emotion that wedges the neural and cognitive underpinnings of the emotion process with sociological theories of emotion and general social theory, we contribute to an understanding of the micro-macro link that is most valuable for computer science since it draws on concepts that have been on the AI research agenda for quite a time.

Cognitive architectures and lately also emotional agents based on neurocognitive theories of emotion are drawing more and more attention. The work done in these areas and the problems of large-scale distributed multi-agent systems could have a stimulating effect on each other that has not been examined thoroughly. The problem still is that today there is neither a *theory* of emotion in sociology nor in the cognitive sciences that incorporates the diverse micro- and macro aspects and that could be used to design improved computational systems. Progress is made rapidly, as illustrated above, but mostly without consideration of the macro causes and consequences of emotion which are so important for DAI systems.

The core notion of our approach is that mental representations which are subject of cognitive activity and neural mechanisms and structures that enable as well as channel different modes of information processing in the brain are influenced by specific qualities of a social aggregate an individual is situated in. Priming, socialization, and social learning in various stages of the lifespan impinge the regularities found in a social aggregate, e.g. interaction chains, emotional reactions, judgments, stereotypes, norms, and rules, upon development dependent parts of the emotion process.

Characteristics and qualities of a social aggregate are emotionally represented in the way an individual's information processing architecture operates. Operation in this "biased" mode then works to maintain the structures and features that originally designed this mode of operation. There is no operation whatsoever free from social influence! Thus, social structures reproduce themselves via emotions and their foundational, (socially) formed and established neural and cognitive processes.

To specify the link between these mechanisms and dedicated grand theories in sociology, we have chosen Bourdieu and Elias as examples, since they have already described the micro-macro linkage with an emotional connotation. They obviously knew about the importance of the emotions but did not elaborate their role. In the ASKO project, parts of Bourdieu's habitus-field theory and Elias's social theory have been modeled. Here we improved the purely sociological interpretation and used emotion theories to relate psychological and neuroscientific work in such a way to these theories, that the micro-macro link gets a new and challenging perspective which might be adopted in the area of agent-oriented software engineering.

Further work has to be done to model the integrated approach to emotion in order to fit the existing models. But also for researchers using other methodologies, it is important to have a handy theory of emotion that can be used for any agent-oriented approach. The work presented here should be seen as a first step in this direction.

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