Modeling the Enactive Emotion Theory: Methodological Considerations

Martina Truschzinski [1] and **Maike Klein** [2]

Abstract. In emotion research, there is an increasing gap between emotion theory and emotion modeling. Many emotion theories exist but most emotion models depend on emotion theories that may not describe emotions adequately. We suggest that this gap can be bridged by a close interdisciplinary collaboration which unites the strenghts of the disciplines involved and that at the same time ensures the general comprehensibility of the modeled emotion theory. This may be achieved by a dynamical systems approach to emotion. In this paper, we take up the possible computational modeling of Giovanna Colombetti's enactive emotion theory which explains emotion in dynamical terms, because (1) it overcomes emotion theoretical problems other emotion theories face, (2) it is philosophically and technically plausible, and (3) it can fulfill our demand of a close interdisciplinary grounding.

1 INTRODUCTION

Emotions and their modeling have been studied over years in several disciplines and in interdisciplinary projects [34, 28, 44, 41, 16]. Psychologists investigate how emotions influence our performance [38, 42, 55], well-being [11] and decision-making [58, 37]. Computer scientists and roboticists investigate human emotional expressions [8], emotional neuronal networks [29] and emotional appraisal [39, 32] in order to build the perfect companion [18] or software that supports humans during work, free time and at home [9, 57, 12, 5]. Emotion research, however, faces some problems. One of those affects the relation of emotion theory and emotion modeling.

In this respect, the use of the notions "model" and "theory" and their relation need some clarification. We understand a theory as frame-giving, it integrates philosophical insights, for instance clear and sound definitions, and scientific findings and should be logically consistent. It is abstract and concrete at the same time: abstract because it is not (yet) applied, it refers to general laws and considerations, and concrete because of its clear definitions and explanations that may be put into words. In contrast to a theory, a model is an application of a theory to a part of reality that serves a certain purpose. A model is more specific than a theory, it stays within the methodological framework derived from the theory and within the given methods of the discipline the model is designed in. Therefore, a model is in a certain manner more limited than a theory. In this paper, we mention psychological and computational models. Psychological models are designed to test whether a concept provided in a theory is empirically plausible. For this purpose, psychologists mostly use linear and sometimes also dynamical models. These models transfer "loose" theories into measurable concepts. In this way, they depict a part of reality. A psychological model is at the same time more abstract and more concrete than a theory: more abstract because some specifications are taken away from the theory, a method is applied to depict a part of reality, and more concrete because within this abstraction, the investigated relation can be described. Computational models are the further application of measurable concepts into computational concepts, so to say, numbers and mathematical functions. It is at the same time more abstract and more concrete than a theory or a psychological model: more abstract because some specifications are taken away from the theory (and the psychological model), its input and output are numbers and functions, and more concrete because the model makes the theory applicable in practical settings. It is important to note that there ideally is an exchange between theory and model: both should be open for possible impacts (e. g. due to new findings) of the other.

There is, however, a gap between emotion theory and emotion modeling: There are many emotion theories while most emotion models [33, 3] are constructed on the basis of emotion theories (e. g. Basic Emotion Theory [17] and Appraisal Theory [45]) that do not seem to describe emotions in living systems adequately, that seem to take away aspects of an emotion that are a part of the phenomenon. One main problem of Basic Emotion Theory lies in the explanation of higher emotions such as jealousy. As Colombetti discusses, this is done by either blending Basic Emotions or by claiming that higher emotions are of a different kind than basic ones. As a consequence, they need a different description. Appraisal Theory faces the problem that bodily signals accompany the emotion but are separated from the cognitive component. Thus, the theory does not consider the body adequately [10].

It seems that over years the gap between emotional theories and computational modeling increased despite of the fact that research in these disciplines provides new insights in emotions of humans and their modeling. One reason is, of course, that we have no exact definition of emotion. There exist several discussions about what emotions, feelings, and other affective phenomena are and how we could classify and establish a border between them [15]. Another reason is that different disciplines use different methods to describe and produce their results and each discipline has an own standard by which results are accepted [6, 26, 31]. This leads to criticism on both sides: on the one hand, psychologists criticize computer scientists for modeling only older and 'easier' theories without any validation in the real world [21]. On the other hand, computer scientists criticize that psychologists do not take note of the insight they gained [6, 7]. Close interdisciplinary work that is needed to overcome the gap seems to be difficult [43].

[1] Institute of Automation, Chemnitz University of Technology, Germany, email: mtru@hrz.tu-chemnitz.de
[2] Institute of Philosophy, University of Stuttgart, Germany, email: maike.klein@philo.uni-stuttgart.de

In this paper, we present Giovanna Colombetti's enactive emotion theory as a candidate for an emotional model because it could overcome the gap between emotion theory and computational emotion modeling: First, it provides an account of emotions which does not have problems faced by other emotion theories of living systems. Second, it is interdisciplinary in three ways: The theory already combines several disciplines, its modeling requires close interdisciplinary work, and it can be understood by each discipline involved because of its grounding in dynamical systems theory, which directly connects the philosophical theory to computer science, engineering, and natural sciences.

2 WHY IS COLOMBETTI'S ENACTIVE EMOTION THEORY PROMISING FOR EMOTIONS IN ARTIFICIAL SYSTEMS?

2.1 Philosophical considerations

Based on the enactive approach [52, 56], Colombetti's emotion theory does not explain emotions in cognitivist terms. Within the enactive approach, a living being is understood on one hand biologically as a living system and on the other hand phenomenologically as a subject of experience. In sum, a cognitive agent is a dynamic and embodied individual that brings forth its world through the interplay of brain, body and world. This interplay enables cognition that is thus rather something that we do than something that happens internally [52, 10]. We believe that the advantages of this theory are at least twofold, compared to other emotion theories [40, 47, 48]: First, through its non-cognitive theoretical framework described above, it accentuates the context as part of the affective process. Second, it appears to be rather concrete because it describes emotions in dynamical systems vocabulary. This should facilitate modeling it while being at the same time philosophically plausible. This integral perspective is interesting, as cognitivist approaches to emotion modeling did not lead to a breakthrough up until now. Colombetti explains emotions as embodied and context-related phenomena. In her theory, an emotion can take place as a more complex process within the basic affective attitude every living being possesses (she calls this basic affective stance "primordial affectivity"; this is comparable to "proto-affect" [39]). Emotions are of the same kind as cognition. The cognitive and affective activity is called "sense-making", which is the enactivist term for the basic activity of each organism to actively be in its environment, extracting personally important parts out of it [53]. Even very basic life forms practice sense-making.

In other words: The system that is always situated in a world creates itself a meaningful environment. It is able to make sense of its world, in an affective way. This means that it is able to get away from harmful things and to strive to things which help to maintain its integrity, for example, food. Moreover, because of the interplay of the system components in sense-making, cognition and emotion arise. Primordial affectivity, the default affective stance that belongs to every living being, is already given in the simplest life forms, as long as they possess a certain form of autonomy. Within primordial affectivity, further affective phenomena can occur. But: Only more complex systems may have further forms of affectivity, namely feelings, moods and emotions. Those are restricted to conscious beings, and within the framework of the enactive approach, consciousness arises only in systems that have a certain level of complexity.

As Colombetti's theory describes affective phenomena of living systems, further considerations of how to transfer some of her used concepts and notions to artificial systems, e. g. autonomy, cognition, and sense-making [19, 53] are necessary in order to create a computational model of her emotion theory. Although this cannot be part of this paper, we would like to mention that for instance a possible synthetic notion of life is discussed in philosophy, robotics and synthetic biology [13].

Colombetti [10] describes emotions as "dynamical patterns" that can temporarily enlarge primordial affectivity. "Emotional episodes are best conceptualized as dynamical patterns, namely, as self-organizing configurations of the organism or emotion forms. These patterns are flexible and loosely assembled, can be culture specific and even individual specific, but may also occur reliably across cultures" (p. 82). This suggests that Colombetti's account is sufficiently flexible to integrate any emotion function, no matter whether it is already known or may be discovered in the future. We have to keep in mind that emotions in natural and artificial systems may have different functions.

2.2 Computational considerations

Colombetti's emotion theory can be modeled mathematically, as it is based upon dynamical systems theory, which is an area of mathematics. In the run-up to modeling this emotion theory, further work has to be done in order to bring out its grounding in dynamical systems theory more clearly. Dynamical systems are established in natural sciences and engineering disciplines, they are described as a rule for time evolution on a state space [1]. In his work, Lewis [30] described such a dynamical system for emotion, which is able to bridge the gap between emotion theory and neurobiology because nonlinear dynamical systems operate through reciprocal, recursive, and multiple causal processes. He claims "that process models have the potential for more realistic explanations; but the linear sequencing of appraisal events, and the general disinclination to see emotions as componential, leaves no place for emotional effects on the formation of whole appraisals" (p. 16). Moreover, several evidences from across the branches of emotion theory indicate that many cognitive processes influence emotions and emotions influence many cognitive processes, which suggest complex, causal relations that go in both directions.

The fact that these dynamical systems are not only applied in neurobiology but as well in electrical engineering [22] and in computer science [4] suggests that they may have a key function in bridging the gap between emotional theory and computational modeling of emotions.

Moreover, we suggest that dynamical systems theory could help to bridge the gap between computer science and psychology if we assume it as the common "language" or theoretical background of the disciplines involved. There is some existing research that considers a dynamical perspective for psychological emotion research [46, 35], where new approaches can draw upon. In terms of process modeling, a model is described by an input, an output and a transfer function which describes the dynamic change that a given input provokes in the output [23]. In psychological experiments, we have independent variables, dependent variables and a regression or variance analysis. In most psychological experiments, linear models are used but this seems not to be adequate [30]. If we describe the independent variables in terms of dynamical systems theory as inputs with step or impulse functions and the dependent variables as system states in the output, we have a full range of possibilities to analyze underlying dynamic functions and principles from linear to nonlinear or from direct to indirect or from non-recursive to recursive [23].

An example are our preliminary results for modeling workload [54], this approach can also be used in other contexts, like for example modeling emotions. As described in the paper, we conducted an experiment within an simulation where participants were asked to solve an air controller task. Within this task we logged several events that may influence the workload of our participants, e.g whether a couple of aeroplanes appeared or disappeared when participants changed the routes of displayed aeroplanes or when a collision between aeroplanes happened. Within this setting the logged events are our independent variables and could also be described as step responses (see [54]). During the experiment we recorded the pupil dilation, following Beatty and Lucero-Wagoner (2000) who reported that task-evoked pupillary responses could be used as a measurement of processing load or in our context workload [24, 2]. Thus in our experiment the recorded pupil dilation as the measurement of workload is our dependent variable. In our systems theory approach, we found dynamical patterns in our modeling data set that described in mathematical functions the increase of workload during our logged events. Based on this, we built an dynamical system that was able to make predictions about the workload of participants in our validation data set (obviously these participants were excluded from the modeling part).

Indeed, modeling workload may not be equal to modeling emotions but bodily expressions of the internal emotional process, like in our approach the pupillary response, could be found in the face [17, 49], in the body [25, 14] and in other physiological measurements like EDA [20, 27] and EEG [49, 14]. These signals could give researchers in both disciplines, psychology and computer science, access to the current emotional state. Moreover, since the signals could continuously be recorded, it could give them the ability to analyze the dynamic behavior of the induced emotion(s) over time. For computer scientist this could create a large database to build their models on real data including the individual starting points and individual differences in feeling and expressing emotions during the conducted experiments.

Based on this data, we may have found a general dynamical pattern as a mathematically description how humans react to emotional events. To take into account other emotion theories and that our emotion is not only based on our bodily reaction but as well in the interpretation of our situation we would suggest that this measurements can be used in combination with more subjective measurements like questionnaires that access the mood and emotional state of humans (e.g. [51, 36, 50]). The combination of both measurements could enable researchers to map higher emotions or emotional constructs to emotional, bodily expressed dynamical patterns that could be analyzed over time and could be used to build dynamical systems of emotions. We think that emotion models based on the combination of dynamical systems and other subjective measurements like questionnaires that are used as an adjustment between bodily expression and cognitive interpretation could provide further insights in the phenomena of emotions. A dynamical model which takes into account that we are embodied living individuals could be implemented based on the real data we collect during the experiments.

With her enactive emotion theory, Colombetti integrates dynamical systems theory into the phenomenon of emotion in its entirety, which due to its enactive nature includes as well the phenomenality of emotions. Thus, by modeling her theory, an emotion may be modeled as an integral, embodied phenomenon. It is to note that, as stated above, the exact grounding of her theory in dynamical systems theory is still to be done.

2.3 Considerations from emotion research as an interdisciplinary endeavour

Colombettis theory can overcome the gap between emotional theories and computational modeling because of at least three reasons: First, as mentioned above, it seems to meet philosophical and technical demands while providing a description of emotion that does justice to the phenomenon. Thus, it overcomes problems faced by other emotion theories. Second, as a theory that reunites findings of different disciplines such as mathematics, biology, psychology, and philosophy, it provides a basis for interdisciplinary work. Third, modeling Colombettian emotions requires interdisciplinary work.

3 IDEAS FOR AN INTERDISZIPLINARY PROJECT ON COLOMBETTI'S EMOTION THEORY

In this paper, we will stress point 2.3, the considerations from emotion research as an interdisciplinary endeavor. We do not aim at providing a computational model at this stage of our research. Instead, we aim to prepare the ground for this. We will argue that in order to achieve a common goal, it is not enough to work on the same subject in different disciplines. Rather, a close collaboration between the disciplines which is process-oriented through continuous exchange and interaction is required. This includes that the goal-relevant tasks have to be distributed according to the competences of every involved discipline. At the same time, every involved discipline has to make a move towards the others and their respective practices. This is what we mean by ”close interdisciplinary collaboration”. For instance, modeling Colombettian emotions in an interdisciplinary project involving philosophy, psychology, and computer science could be structured as follows:

3.1 The philosopher's tasks

Philosophy provides the conceptual and theoretical basis of the object of investigation. In the case of modeling emotions in artificial systems, this includes elaborating a reasonable and well-founded working definition and a theoretical framework of emotions. This has to take into account existing emotion theories and it has to meet philosophical and technical requirements. We suggest that Colombetti's emotion theory could accomplish this. During the process of the interdisciplinary project, the philosopher's task would be to ensure consistency as well as to tune and to update the working definition of emotions on the basis of the results the computer scientists and psychologists obtained. He or she should constantly consider the following questions: ”What is an emotion?”, ”Is the phenomenon tested or modeled (still) an emotion (and in what way)?”, and ”What should be added or removed in order to classify this phenomenon as an emotion?”.

3.2 The psychologist's tasks

In order to empirically investigate emotions, psychologists choose a working definition and test whether it is valid or not. In case of our interdisciplinary project on emotions and emotion modeling, we suggest that the philosophically provided definition is used, as it has already been well thought-out not only within one discipline but with the goal to provide a working definition that actively considers the requirements of the disciplines involved. Generally, experimental testing requires to subtract all disturbing influencing factors from the test setting to define how hypothetical factors are relevant to explain variance differences. This leads to the result that experiments are only able to describe a part of the whole phenomenon. Moreover, psychological experiments are mostly validated as points in time and not as processes, thus the analyses of the relationship are only valid for the measured range of values. This is shown as an assumed linearity leads to infinite increasing or decreasing of variables. Humans, however, have limited capacities in e. g. working memory, attention, and feeling emotions. Thus, variables that increase towards infinity are implausible.

3.3 The computer scientist's tasks

At this point, computer scientists can complete the endeavor to capture the processuality of emotions. They use the factors involved in emotions that result from psychological experiments (which are ideally expressible by functions) to build models that describe (parts of) emotions as processes. From these processes, psychologists can extract new hypotheses for further experiments.

Thus, the complete dynamical system of an emotion can be described through a close interdisciplinary collaboration and exchange. In order to ensure a consistent model which can be easily understood by the involved disciplines, the mathematical vocabulary should be standardized for example by using the dynamical system theory approach in psychological measurements. This implies that the measured points or states (ideally as many as possible) psychologists record during their experiment are not only used to postulate a significant effect or influence, but also to find the underlying dynamical function. In a first step, system identification methods could help to find a mathematical model derived from the measurements [23]. Afterwards the identified model could be implemented and analyzed. The important impact of such a dynamical system model is that it does not only describe the given data set (points of the measurements), but that it can also extrapolate and predict new data points or hypotheses which could be used in further experiments.

4 CONCLUSION

As we have discussed in this paper, developing computational models of emotions is an interdisciplinary endeavor that has to be clearly structured. It needs to take into account the respective scientific practices of the disciplines involved in order to achieve the common goal. As an example for a future interdisciplinary project in emotion research, we discussed the possible transferral of Colombetti's enactive emotion theory into a computational model. This is promising for at least two reasons: First, dynamical systems theory is the grounding of Colombetti's emotion theory for living systems that overcomes problems faced by other emotion theories. Thus, it can bridge the gap between emotion theory and emotion modeling. Second, it can be applied by computer scientists to model emotions as processes. For this, they require measurable parameters and relevant factors of emotions, discovered by psychological experiments. This close interdisciplinary collaboration of philosophy, psychology and computer science based on dynamical systems provides the possibility to find a definition, a theoretical framework, and a model of emotions that contain the relevant insights of each discipline involved. Furthermore, because Colombetti's philosophical emotion theory is already based on dynamical systems theory, all involved disciplines can understand the resulting model in its integrity. Moreover, new findings can be easily integrated in every involved discipline because they all use the same conceptual vocabulary of dynamical systems.

To put this paper in a larger context, we conclude by emphasizing that working on the transferral of Colombetti's enactive theory of emotion has positive impacts for emotion research and emotion modeling. Generally, it helps to better grasp and define the entire phenomenon of emotions. On one hand, this has impacts on the study of artificial systems: We can develop better artificial systems that dispose of emotional aspects while keeping in mind that the overall goal is to build the perfect companion that is able to (1) understand human emotions, (2) to estimate and react adequately to human emotions, and (3) make use of the functions that emotions dispose of (e. g. better decision making, motivational factors). On the other hand, due to the developing of a computational model of Colombetti's emotion theory, we can equally gain new insights about emotions in living systems.

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