

Affective Grounding in Human-Robot Interaction

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ABSTRACT

Participating in interaction requires not only coordination on content and process, as previously proposed, but also on affect. The term *affective grounding* is introduced to refer to the coordination of affect in interaction with the purpose of building shared understanding about what behavior can be exhibited, and how behavior is interpreted emotionally and responded to. Affective Ground is achieved when interactants have reached shared understanding about how behavior should be interpreted emotionally. The paper contributes a review and critique of current perspectives on emotion in HRI. Further it outlines how research on emotion in HRI can benefit from taking an affective grounding perspective and outlines implications for the design of robots capable of participating in the coordination on affect in interaction.

Keywords

Affective grounding; emotion and emotion regulation, human robot interaction.

1. INTRODUCTION

Participating in social interaction requires the successful coordination of emotion. The kinds of emotions that are expressed by participants of an interaction over time and the ways in which they are responded shape immediate and distant outcomes of dyads, teams and larger groups. For example, the emotional interaction dynamics, the moment to moment dynamics of emotion expression and responding have been shown to be highly predictive of outcomes of married couples [39], negotiation pairs [22], engineering teams [47][48], and cancer support groups [35]. As robots increasingly participate in social interactions as direct collaborators, tools, or bystanders it is important not only to understand how robots shape the coordination of emotion in interactions but also how robots can be equipped with capabilities to actively participate in the coordination of emotion.

To date, work on emotion expression in human-robot interaction has followed the dominant paradigm of emotion as a signaling mechanism and emotion expressions are seen as signals that reveal processes and states that would otherwise be hidden. Research in HRI has focused on examining how this signaling

makes people think and feel about the robot itself, often with the goal of improving communication between the person and the robot (e.g. [5]). In other words, the role of emotions and emotional expression is generally seen as a way to make robots more understandable, likable, intuitive, and predictable (or “believable”) by using patterns that allow people to apply mental models and heuristics from interactions with people to infer a robot’s internal states and intentions (e.g. [10][9][36][66][73]).

While this perspective takes the idea of emotion as a social signal into account, I argue that the current signaling paradigm does not successfully capture the complexity of emotion as it unfolds in interactions because it conceptualizes emotions as a phenomenon that happens within and on-top of individuals. Instead I propose that in order to develop the understanding necessary for enabling robots to successfully participate in social interactions we need to view emotion and emotion regulation as something that takes shape in between interaction participants.

I introduce the term *affective grounding* to refer to the coordination of affect in interaction. Just as participants of interactions work together to ground the informational content of their messages (e.g. [17][16]), I propose that they need to likewise work together to build a shared understanding about the emotional meaning of each other’s behavior. Emotion expression and regulation in interaction is thus conceptualized as a dynamic process by which group members collaborate to shape which emotional behaviors are exhibited, how they are interpreted and how they are responded to.

This new affective grounding perspective extends current HRI research agendas and to some degree current affective computing research in three ways. First, with the notion of affective grounding this paper contributes a perspective on emotion for HRI that conceptualizes emotion and emotion regulation as joint activities. As such it extends established literature on emotion regulation (both intra and inter-personal e.g. [40][41][70][72][95]) by positing that emotion can be seen as a form of conversation, the dynamics and flow of which are shaped through the collaborative engagement (i.e. emotion regulation) of the participants and that is to some degree independent of the participants’ inner states or experiences. Second, an affective grounding perspective extends how we might study emotion in human robot interaction by focusing less on abilities to correctly identify expressions but to understand how people read emotional meaning into the behavior of robots. Third, as an interaction paradigm, an affective grounding perspective moves the focus from designing expressions for robots to make them “emotional” towards the understanding that emotion is part of any human-robot interaction and that expressions do not determine how people make sense of a robot’s behavior emotionally.

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HRI '17, March 06 - 09, 2017, Vienna, Austria

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ACM 978-1-4503-4336-7/17/03...\$15.00

DOI: <http://dx.doi.org/10.1145/2909824.3020224>

2. The current signaling paradigm of emotion expression in HRI and its limitations

Current approaches to emotion expression in HRI can be argued to largely fall within a signaling paradigm. According to this paradigm, emotion expressions are seen as signals that reveal processes and states that would otherwise be hidden. This signaling perspective on emotion is grounded in basic emotion theories (e.g. [26][3]), which assume the existence of a set of “basic” emotions (typically anger, sadness, fear, surprise, disgust, happiness) that are innate, each with distinct biological bases and mechanisms, and universal across cultures.

The signaling approach has its roots in Ekman’s 1984 [26] proposal of a one-to-one coupling between emotions and facial expressions and the idea that a person’s inner state could be reliably inferred from facial expressions. This idea of the one-to-one coupling between inner states and expressions, and the availability of detailed descriptions of facial expressions through the Facial Action Coding System [29] likely contributed to the wide adoption of this perspective among HRI researchers and the affective computing community more broadly. For example, among the eight papers that Thomaz, Hoffman and Cakmak [87] identified as computational approaches to emotion expression in HRI, seven papers rely on Ekman’s six basic emotions or a subset thereof ([36][63][53][4][84][20][96]) and one paper relies on an extended set of basic emotions ([1]). The same set of basic emotions is even applied across several approaches to emotion expressions through features other than the face. For example, [56][13][57][64] all implemented basic emotions or subsets through body movements.

While classic basic emotion theories conceptualize emotion as a purely intra-personal phenomenon, the signaling perspective combines perspectives on emotions as purely intrapersonal phenomena with perspectives that acknowledge that emotions fulfill social functions. Yet the signaling perspective has relied on a narrow understanding of expressions that has centered on the physical embodiment characteristics of an expression.

2.1 Limitations of the signaling approach

The signaling perspective on emotion expression has allowed roboticists to build systems that can form emotional expressions that can be correctly labeled by people and that produce more pleasant and intuitive human-robot interactions. However, the focus on basic expressions brings with it certain limitations that are stifling efforts in HRI to build systems that are better at participating in and contributing to successful interactions. First, the signaling paradigm assumes congruence between processes that are actually distinct, second it ignores that emotional expressions are not a reliable indicator of a person’s inner state, third, it ignores that the same expression can carry multiple and even emotionally opposed meanings, and finally it ignores that robots do not need to be equipped with special emotional expression capabilities to be perceived as emotionally expressive.

2.1.1 Assumption of congruence between distinct processes

The signaling approach assumes congruence between three phenomena that are actually distinct (see Figure 1): (1) Physical configuration and movement patterns (i.e. emotional expressions that people can identify as such), (2) subjective experiences, inner states and feelings, and (3) social meaning (i.e. how the expression is interpreted by participants of an interaction). However, a person’s expression of a smile during an interaction and people’s ability to label the expression as a smile neither

necessarily means that the person is actually happy, nor does it necessarily mean that an observer interprets the smile as communicating warmth and happiness. As Hochschild’s [43] work has shown, people can produce emotional expressions such as smiles driven by social demands while not feeling happy at all and even robots have been shown to provide a context for social smiling [55]. Also, research by Hoque and others [45] demonstrated the flexibility in interpretation of emotional behavior when whosing that a simple smile can be interpreted in a multitude of ways. I will unpack the limitations associated with this assumption of congruency further in the following sections.

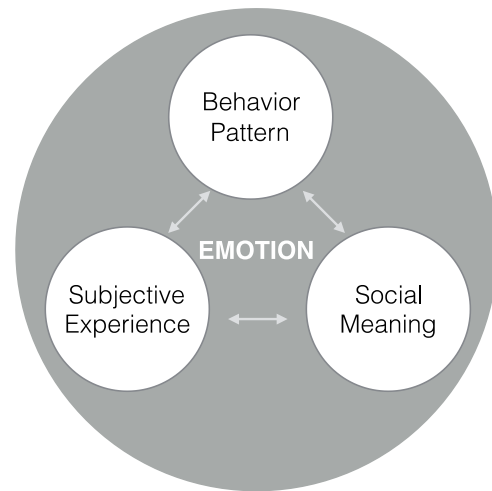


Figure 1: The dominant signaling paradigm assumes congruency between three distinct emotional phenomena that are actually largely independent of each other: The subjective experience of emotion, the behavior pattern that people label as expressing particular emotions, and the social meaning that people ascribe to behavior.

2.1.2 Emotional expressions are not a reliable indicator of a person’s inner state

One limitation of the signaling approach is that it relies on the idea of congruency between expressions and inner states or that emotional expressions provide a reliable source of information about a person’s inner state. However, it is often not known that Ekman later abandoned his own idea of a one-to-one coupling between emotions and expressions when evidence was accumulating that some emotions don’t have distinct facial expressions (e.g. awe, guilt, shame) and that some emotions share the same expressions [77][28][74]. Other studies (e.g. [30]) have confirmed that emotion expressions do not offer a reliable source of information to infer a person’s inner state, and reversely that emotion expressions can rarely be predicted based on a person’s inner state, thus calling the basic premise of the signaling paradigm into question.

To illustrate this point further, consider the picture in Figure 2 on the left. Studies have shown that an expression presented in the picture can be reliably classified as a smile across cultures [27]. However, the correct classification of a facial muscle configuration, movement, or other complex body movement does not mean that the person is actually happy. This idea that our capability to reliably classify emotional expressions is distinct from a person’s feelings is even more apparent when looking at

the smiley image in Figure 2. The image can be clearly labeled as a smile but the smiley certainly does not feel happy.



Figure 2: People can reliably label images like the ones shown above as depicting happiness. However, the correct classification of a facial muscle configuration, movement, or other complex body movement does not mean that the entity depicted is actually happy. This disconnect between people's ability to label expressions and actual inner states is particularly apparent for the smiley image on the right.

2.1.3 Emotional expressions carry multiple meanings

Another key limitation of the signaling approach is that it relies on the idea of congruency between expressions and their emotional interpretation. However, in interactions no one-to-one relationship exists between expression and interpretation.

The very same body configuration or movement (i.e. a smile or smirk) can carry a wide array of meanings dependent on the context the interaction takes place in, the long term or immediate history of interactants, and the directionality of expressions. Dependent on the configuration of interactants the same expression can simultaneously carry multiple emotional meanings.

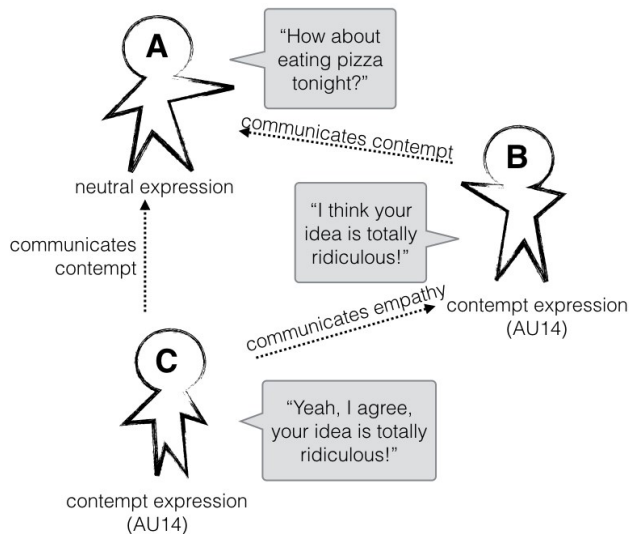


Figure 3: An exchange between three people (A, B, and C) demonstrates that the same contempt expression can be interpreted as contemptuous or empathetic at the same time, dependent on who interprets the behavior.

To illustrate this point further consider the situation depicted in Figure 3 in which person A suggests “How about eating pizza tonight” and is responded to by B who makes a smirk (categorized as Action Unit/AU 14 in the Facial Action Coding System) and says “I think your idea is totally ridiculous!”. Shortly after, C also

smirks and shouts “I agree, that idea is totally ridiculous!” With the same behavioral characteristics, from A’s perspective, both B’s and C’s behaviors communicate contempt. From B’s perspective, however, C’s behavior communicates empathy as it is interpreted as supportive of and validating B’s position.

The example above shows that the very same expression can be interpreted in two very different ways dependent on who observes the expression: contempt and empathy. One negative and hostile, one positive and warm and this emotional interpretation is independent of participant A’s and C’s ability to correctly label B’s expression as a contempt expression.

2.1.4 There need not be an expression to communicate an emotion.

A final key limitation of the signaling approach is that it assumes that emotional expressions are required for emotion to be communicated.

In their paper about a novel approach to crowdsourcing an AI for a social robot that jointly solves tasks with human participants, Breazeal and colleagues observed a series of instances in which the robot was seen as condescending even though the robot’s AI did not model emotion at all. In one such instant a participant asked the robot “Would you like me to put this item into the bucket?” upon which the robot turned around and drove away, leaving a somewhat flustered participant behind [11],p.104 (see figure 4).

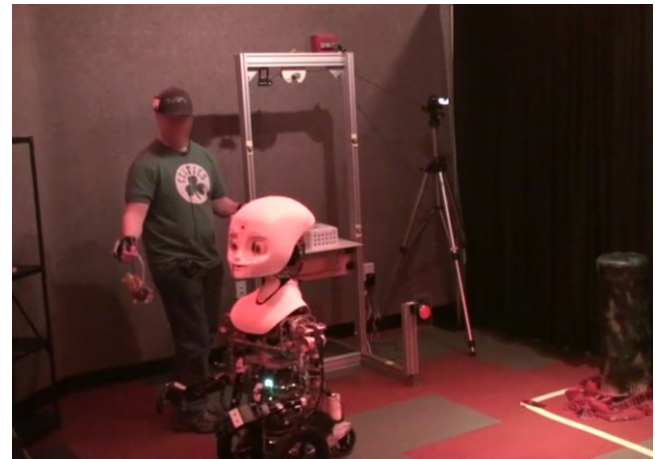


Figure 4: Interaction instance from [11] in which a participant addresses a robot with a polite question upon which the robot just turns around and drives away. While the robot’s AI did not model affect and was not making specific facial or bodily expressions of emotion, the robot’s behavior was perceived as ignorant.

According to the signaling paradigm there was no emotion. Neither did the robot display an emotional expression nor was the robot in any emotional internal state since emotion was not modeled as part of the robot’s AI. Yet, the robot’s behavior communicated condescension and lack of respect or interest towards the participant.

This exchange illustrates that the emotional interpretation of behavior is not determined by the behavior itself but by its positioning in the sequential organization of an interaction. It is jointly shaped by the participants of an interaction through the way in which a behavior is responded to. For example, a robot’s behavior of turning away does not carry emotional meaning in itself, but if the behavior occurs while someone is attempting to

interact with the robot, that same movement can be interpreted as disrespectful and offensive [25].

In sum, the predominant signaling perspective limits our abilities to not only understand how robots shape interactions but also how we design better systems to participate in interactions because the signaling perspective limits the focus of analysis on emotional expressions as it assumes that emotion resides in expressions, and in particular a specific set of six basic expressions. In order to understand emotion in interaction and in order to build systems that are able to shape the emotional dynamics of interactions, I argue that we need to take a new perspective on affect, and shift the focus from what is expressed towards how it is interpreted, and towards how emotional meaning is constructed out of an ongoing flow of interaction. In other words to understand and shape emotions in interactions it is less important to be able to label emotions correctly based on their physical features. Rather it is important to understand how people interpret others' behavior emotionally, how that interpretation is collaboratively established between interactants, and how behavior patterns can be produced that will communicate the intended emotional meaning to others. .

3. AFFECTIVE GROUNDING

I propose that participating in interaction not only requires coordination on content and process, as previously proposed [16], but also on affect. I use the term *affective grounding* to refer to the coordination of affect in interaction with the purpose of building shared understanding about what behavior can be exhibited, and how behavior is interpreted emotionally and responded to. Affective Ground is thus achieved when interactants have reached shared understanding about how behavior should be interpreted emotionally. Affective grounding conceptualizes emotion and emotion regulation in interaction as a collaborative activity, a phenomenon that occurs *between* interactants rather than *on top* (e.g. through facial expressions) or *within* them.

To illustrate the idea that affect is coordinated alongside content and process, consider the following example from Clark and Brennan's ([16], p.223) highly influential work on grounding:

- (1) Alan: Now, - um, do you and your husband have a j- car
- (2) Barbara: - have a car?
- (3) Alan: Yeah
- (4) Barbara: No -

From an information processing perspective [17], these messages are organized in terms of a presentation phase (1) and an acceptance phase (2-4). Barbara's utterance "have a car?" provides evidence that the content of the message has not been understood.

From an affective grounding perspective, this same sequence of utterances can also be viewed as instances of emotion and emotion regulatory moves. Alan's question "Now, - um, do you and your husband have a j- car" also expresses interest towards Barbara and sets up an emotionally relevant moment. Barbara's response, "have a car?" thus also provides emotional feedback that she is engaged in the interaction. A possible non-response from Barbara could not only mean that the question was not heard but, as I will explain in the next paragraph, even more likely would have been interpreted as disinterest and lack of respect.

This idea, that a question and answer pair can be viewed as an emotion and emotion regulatory exchange, is highlighted in Driver and Gottman's [25] research on couples. In their studies of how couples regulate emotions during everyday conversations,

such as those that occur during dinner, Driver and Gottman were unable to analyze emotional interaction dynamics with traditional measures that focus on emotional expressions. Occurrences of behavior that could be classified by established emotion categorization schemes (e.g. SPAFF [19] or FACS [29]) turned out to be too scarce to provide meaningful data. Instead, Driver and Gottman found that emotion and emotion regulation was organized through bid and response pairs. A bid is defined as an attempt to interact with one another [25]. Bids can be statements (e.g., "look at that!"), questions, or even nonverbal behaviors. Once a bid is made, the subsequent responsive behavior or even the absence of responsive behavior becomes emotionally relevant. Bid and response form what Sacks and colleagues [78][80] called an adjacency pair: The emotional interpretation of the behavior following the bid is contingent upon the bid.

Responses to bid can be categorized into three basic types (see [90] and [44]), each carrying a different emotional meaning (see also table 1): *Turning towards* are responses that show positive engagement with the bid. Barbara's utterance, "have a car?" is an example of a turning towards response that signals listening and engagement but a simple nod would also count. *Turning away* are responses that show no engagement with the bid. An example of a turning away response would be if Barbara had not shown any responsive behavior after Allan's bid, such as not even looking or nodding at him, a response which is likely interpreted as disinterest or lack of respect. *Turning against* are responses that are actively negative or hostile, such as a belligerent "What kind of a ridiculous question is that!"

The idea of bid-response pairs highlights a perspective on affect that is independent of a person's inner states and feelings and instead as something that can be found within peoples' interactions with each other. Just as an answer needs a question to be interpretable as such, a moment of silence needs a bid to be interpretable as a turning away response from an affective perspective.

Table 1: Behavior type classification based on the relational impact an observed expression has on the observer. Behavior type classification based on [90] and [44].

| Behavior Type | Description |
|-----------------|---|
| Turning towards | "Turning towards" captures behavior that is interpreted as orienting the expresser towards the observer. Behavior that is interpreted to signal interest, excitement, validation, and empathy but also sadness and direct anger can orient people towards each other and decrease social distance. |
| Turning away | "Turning away" captures behavior that is interpreted as orienting the expresser away from the observer. Typical behaviors are "avoiding the interaction partner, suppressing thoughts about the situation, refusing to take action, and adopting a passive stance (p. 59)" [90] or behaviors that Coan and Gottman [19] categorized as defensive, or stonewalling and increase social distance. |
| Turning against | "Turning against" captures behavior that is interpreted as orienting the expresser against the observer. Behavior that is typically interpreted in this way includes what Coan and Gottman described as expressions of contempt, belligerence, criticism, or disgust [19] |

3.1 Back-channel responses and repair

Two specific behaviors that have been argued to play a crucial role in the coordination of process and content [16] also play an important role in the coordination on affect: back-channel responses and repair.

Back-channels response like “mhm,” for example, or nods and other forms of verbal and nonverbal acknowledgments have been argued to indicate positive evidence of understanding [16]. However the very same behaviors have been found to also signal emotional attunement toward the speaker [68][19]. As highlighted in the previous examples on bids and responses, acknowledgments can carry emotional meaning by signaling engagement and interest. Research has shown that the emotional interpretation of back-channel responses extends to robots. For example, in a study for which participants collaborated with multiple robots in solving a complex task, Jung and colleagues [49], demonstrated that robots can employ non-verbal back-channel responses to signal engagement and interest.

Similarly, the notion of “repair” not only refers to fixing misunderstandings of message content (as described in [17]) but also efforts to dampen, limit, or even eliminate the negative impact that an expression has had on the emotional progression of an interaction. For example, strong negative, rude or hostile behaviors tend to trigger negative reactions in others, sometimes initiating a downward spiral of increasing negativity [2][61][60]. To prevent a downward spiral, the impact of the initiating behavior has to be repaired through strategies such as choosing not to reciprocate a perceived violation or for the original violator to offer an apology [2]. There is also initial evidence that robots can engage in affective repair. A study that examined the collaborative efforts of three people to jointly solve a complex task with a robot found evidence that a robot’s repair of a confederate’s hostile remark successfully shaped interaction participants’ perceptions of the interaction [50].

3.2 What implications does an affective grounding perspective have for the study of emotion in HRI?

Current analyses of emotion in human-robot interaction that follow the signaling paradigm are constrained by an analytical lens that focuses on a pre-specified set of typically six basic emotion expressions. Taking an affective grounding perspective on emotion in HRI extends current approaches to study emotional expression in human-robot interaction as it shifts the analytic focus from a phenomenon that occurs within or on top of interactants towards a phenomenon that unfolds between interactants over time as part of a joint activity. Figure 5 offers a framework to study the joint coordination of affect in human robot interaction through three key aspects: Emotion – the interpretation of behavior as emotionally relevant; Feedback – signs of trouble and confirmation about how ones own behavior gets interpreted by others; and Emotion Regulation – attempts to re-adjust the emotional meaning of behavior through repair and other regulatory moves.

The notion of emotion and regulation as joint activities extends established literature on emotion and emotion regulation by adding a dynamic interactional perspective. The majority of the literature on emotion regulation has conceptualized emotion regulation as a purely intra-personal process (see [40][41] for reviews of that work). More recent work on inter-personal emotion regulation (e.g. [70][72][95]) has acknowledged

interpersonal processes to play a crucial role in how people regulate how they themselves or others feel, but this literature still conceptualizes intra-personal feelings and experiences as the object or focus of that regulation. Instead, an Affective Grounding perspective posits that emotion can be seen as a form of conversation, the dynamics and flow of which are shaped through the collaborative engagement (i.e. emotion regulation) of the participants and that is to some degree independent of the participants’ inner states or experiences.

Research in the area of affective computing has begun to take interpersonal aspects into account when building emotion and emotion regulatory models for robots to improve human-robot interaction (e.g. [97]) in particular in learning (e.g. [42]) and caregiving contexts (e.g. [62]). However, this work in affective computing and HRI is consistent with the perspectives on inter-personal emotion, that focus on how people use inter-personal interactions with others to regulate intra-personal emotional experiences, states, or feelings (e.g. [70][72][95]). This paper attempts to highlight a perspective that conceptualizes emotion and emotion regulation as phenomena that unfold between people, rather than within (experience/state), or on top (emotional expression) of them and that is co-constructed by participants of an interaction over time. As such this paper also extends previous critical accounts of affective computing research that have challenged the underlying notion of emotions as objective, externally measurable units (e.g. [6][59]), towards emotion as an interactional phenomenon that can be described, studied and designed for irrespective of interactants’ internal processes or states.

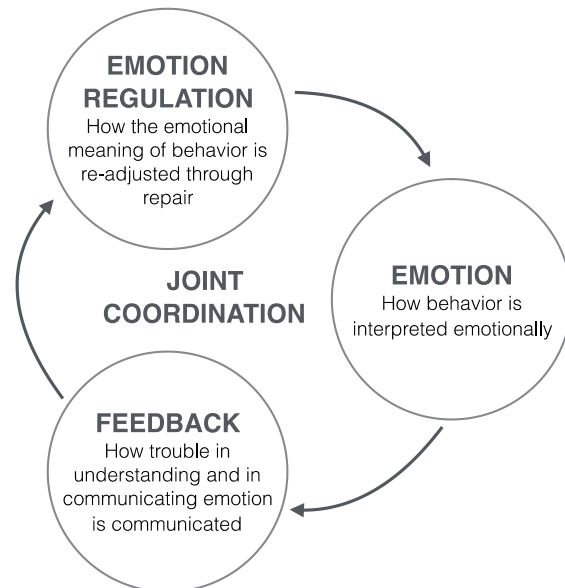


Figure 5: Framework highlighting key elements of an affective grounding perspective on emotion. The key idea here is that emotion and emotion regulation are not only internal processes but that can be seen as interpersonal processes that are jointly coordinated by participants of an interaction.

3.2.1 Studying emotion and emotion regulation as joint activity

Rather than starting an analysis of emotion in human-robot interaction with a predetermined set of fixed expression, an affective grounding perspective offers a lens on emotion in

interaction that focuses on the question of how people orient towards emotional aspects of interactions and how emotionally relevant situations might emerge and should be responded to in interactions with robots. As argued by Goodwin and Goodwin [38]:1 “the relevant unit for the analysis of emotion is not the individual, or the semantic system of a language, but instead the sequential organization of action.”

Conversation analytic approaches provide an analytic lens on emotion and emotion regulation as a joint activity and have shown successfully how the sequential organization of interactions provides the context for the emotional interpretation of behavior (see [75] for an overview). According to [75] the idea that participants of an interaction carefully coordinate “their visible emotional state in accordance with the demands (or the ongoing definition) of the situation [75]:333” can be traced back to Goffman’s essay “Fun in Games [37].” For example, Jefferson, Sacks and Schegloff [46] showed that “laughter is a methodically produced activity—it is carefully coordinated with other ongoing conversational activities, such as talk or the laughter of other participants” ([75], p.334). This finding is also consistent with research in psychology by Kraut & Johnston [58], who found that people in a bowling alley upon a successful strike smiled more when facing their friends than when facing the pins. Even robots have been shown to provide a context for social smiling [55]. Further, Couper-Kuhlen [21] shows how a statement of “oh” that is expressed with a specific prosody pattern is understood as a disappointment response only when expressed in a disappointment relevant moment but the same utterance expressed in the same way takes on other meanings when placed otherwise in conversation. Research by Wilkinson and Kitzinger [92] showed how surprise is produced as an interactionally achieved performance. Finally, Perakyla & Ruusuvuori [69] demonstrate how emotion regulation in interaction can be examined from a conversation analytic perspective. This research offers a perspective on emotion expression and regulation as “outward emotive performances” [82] that are independent of internal states and instead dependent on the social dynamics of an interaction.

Studying emotion and emotion regulation as joint activity opens a space to ask a host of new questions about the role of emotion in human-robot interaction:

How do emotionally relevant situations come about in interactions with robots?

Are there differences in how we interpret a person’s behavior as emotional in comparison with that of a robot?

How does the perception of a robot’s behavior as emotional shape the subsequent flow of an interaction?

How do people repair emotionally taxing situations when interacting with robots?

3.2.2 Extending how to categorize expressions of emotion

Focusing on emotion and emotion regulation as a jointly coordinated activity emphasizes the role emotions play in regulating how participants of an interaction relate to each other. This interpersonal focus calls into question the usefulness of the valence and arousal model as the appropriate paradigm for categorizing emotions.

The valence and arousal model has been the dominant approach to organizing emotions in HRI. This model dates back to 1978 when Russell proposed that emotional experiences can be organized by their degrees of pleasure and displeasure as well as inactivation

and activation [76]. Focusing on valence and arousal emphasizes experiential and intra-personal dimensions of emotion and ignores the interpersonal and social functions of emotion. Yet the valence arousal dimensions are the dominant framework in studying emotions expressed by robots. In part its attractiveness lies in a multitude of measures that have been developed and also in that it can be easily applied to expressive modalities other than the face. For example, both Karg and colleagues [52] as well as Sharma and colleagues [83] relied on a valence scale to measure how participants inferred a robot’s inner state based on expressive movement. Focusing only on assessing users’ inferences of a robot’s internal state leaves important questions about what emotional meaning the behavior communicates towards others unanswered.

Emotional expressions have been shown to shape people’s relational orientation towards each other in distinct ways (e.g. [54][65][89][90]). For example, an expression of joy draws others in, and an expression of hostility pushes others away. Therefore expressions can be categorized not only along a valence and arousal dimension but alternatively also along an interpersonal orientation dimension with affiliative behaviors on one end of the continuum and distancing behaviors on the other. Affiliative behaviors are those that turn people towards each other ([44]; see also [90]) and reduce interpersonal distance. Affiliative behaviors include expressions of interest, affection, humor or excitement but also more subtle, often non-verbal, signs of listening such as back-channeling through nods or “mhm” vocalizations that signal attention and engagement towards a speaker. Affiliative behaviors strengthen the relations within a group thus establishing and maintaining cooperative and harmonious interactions with other group members [32]. Distancing behaviors are those that turn people away from and even against each other ([44]; see also [90]) and increase interpersonal distance. Distancing behaviors include behaviors such as frustration, passive aggressive behavior, domineering, contempt, or belligerence. Distancing behaviors can be exhibited non-verbally for example through contemptuous eye-roll or smirk, but also through a sarcastic voice tone [19]. Distancing behaviors harm successful cooperation and harmonious interaction [32].

The difference between valence-arousal based and orientation based perspectives on affect becomes clearer when looking at behaviors that are negative from a valence perspective but positive from an affiliative-distancing perspective. Sadness, for example, while negative from a valence perspective (e.g. [76][91]), is positive from an observer perspective as it has been found to turn people towards each other, serving an affiliative function when it is interpreted as a cry for help (e.g. [18]).

Since the relational dimension of emotion is highly consequential for the progression and outcome of interactions it is important to extend our understanding of emotion in human robot interaction by including systematic analyses of how a robot’s behavior orients observers of the behavior towards the robot.

3.3 What implications does an affective grounding perspective have for the development of affective capabilities in robots?

According to an extensive literature review by Thomaz, Hoffman and Cakmak [87], current computational approaches to emotion in HRI have focused on three areas:

1. Approaches to model intra-personal affective processes, for example, to drive the elicitation of expressions or to regulate attention.
2. Approaches to express emotions that can be reliably identified by humans even when expressed across various modalities.
3. Approaches for the automated detection of emotions in human interaction partners.

For robots to participate in social interactions with humans the ability to coordinate on affect is required. Building shared understanding about what behavior can be exhibited, and how behavior should be emotionally interpreted and responded to requires capabilities beyond the ones outlined above.

An important design implication of an affective grounding perspective is that it encourages designers to think of any robot as emotional even if it has no affective AI or physical architecture for “emotion expression”. As such this paper reiterates Damm et al.’s [23] assertion that “in HRI one cannot be not emotional” and points designers of human robot interactions to focus on the question of *how* a robot is made “emotional” rather than *whether* it is emotional. Understanding any robot as inherently *affective* also has implications for how “emotional” or “emotionally expressive” robots should be evaluated in HRI. Current studies, that evaluate novel affective HRI systems, often compare affective with non-affective robots (e.g. [88]) in their evaluations. Observed differences are typically attributed to the presence or absence of affect rather than to a deliberate design of affective responding which misses opportunities to understand how people orient emotionally to the “un emotional” robot. In other words, HRI researchers should consider to stop thinking of the baseline condition that a novel “affective” robot is compared to as non-affective. Instead the baseline or control condition should also be understood as affective or non-deliberately affective.

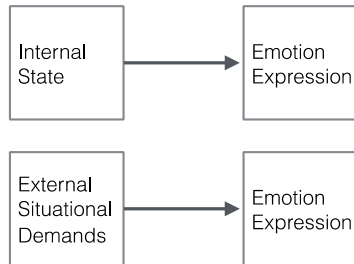


Figure 6: Extending the dominant approach that sees a robot’s internal state as the key determinant of an expression towards an approach that also includes external situational demands as key determinants of a robot’s emotional expressions.

While this paper cannot provide a technical roadmap to achieving affective grounding capabilities for robots, a few starting points can be given. Most importantly, an affective grounding approach implies a shift from the current dominant approach that sees a robot’s internal emotional state as the most important determinant of a robot’s emotional expressions (e.g. robot made a mistake which leads to a negative affective state, and an expression of disappointment) towards an approach that includes social situational demands as important determinants of a robot’s emotional expressions (e.g. a person’s display of disappointment makes an empathic expression by a robot relevant, see figure 6). Thus, the trigger for a robot’s appropriate emotional expression is not only an internal emotional state but a social situation that calls for an emotional expression. For example, Selting [82] showed

that people have to display emotional involvement at certain specific moments while listening irrespective of their internal emotional state. Therefore robots need to learn to express emotions (e.g. show interest and engagement in the listening example) when they are socially appropriate and demanded irrespective of a robot’s internal state.

Table 2: Simplified Turning System

| Code | Description | Example |
|----------------------------------|---|--|
| <i>Bids</i> | | |
| Silent | Nonverbal action that the other participant can notice and acknowledge. | Pointing at an object. Handing over an object. Initiating a hand-shake or high-five. |
| Comment | Comment containing information exchange. | “That’s a nice picture over there!” |
| Question | Question of general interest or information | “Do you want help with this?” |
| Re-bid | Repeat the same bid or similar bid after the previous one has been turned away. | |
| <i>Turning Towards Responses</i> | | |
| Passive | It is clear that the bid has been received, but minimal effort is taken to reply. | Looks up briefly then looks away. One syllable responses. |
| Low Energy | Answers the bid only. | Short one-word answers and brief action. |
| Attentive | Welcomes the bid. Effort is made to respond. | A asks B for help (bid). B replies with a pleasant “sure!” and pours the milk. |
| Enthusiastic | High energy and eye contact. Effortful response. | Similar as attentive but with more enthusiasm and more signs of engagement. |
| <i>Turning Away Responses</i> | | |
| Preoccupied | Receiver of bid is engaged in an activity and doesn’t respond. | Looking out the window. Watching a screen. |
| Interrupt | Receiver of bid begins a new bid without acknowledging that the other participant has made a bid. | A: “Do you want me to put the ...?” B: “Grab the blue big cup there.” |
| Disregard | Complete lack of response to the bid. | A makes a bid and B just walks away to do something else. |
| <i>Turning Against Responses</i> | | |
| Against | Receiver of bid responds in a negative or even hostile (with contempt, criticism, domineering, belligerence or defensiveness) way | A makes a bid and B responds: “I don’t give a damn!” |

An crucial next step could therefore be to enable robots to become sensitive to emotionally relevant moments. That is, the sequential organization of an interaction should be taken into account as a key contextual factor in determining how a situation should be interpreted emotionally and what emotional responses need to be produced in response. While not focusing on affect, Kaindl and colleagues [51] have proposed a discourse model for HRI that draws on Sacks et al.'s [78] notion of adjacency-pairs and takes the temporal organization of discourse into account. Similarly Rich's [71] work on connection events and Chu et al.'s [15] work on detecting contingency point to opportunities to adapt these inference techniques to model affect in interaction and design new ways for robots to respond emotionally to demands of interactional situations.

A possible starting point could be to build on these techniques in enabling robots to recognize bids for attention that set up subsequent moments as emotionally relevant. Table 2 presents a modified version of the Turning System that was developed by Driver and Gottman [25] and that categorizes types of bid-response pairs according to their affective qualities. For example, if a person engages a robot in by making a comment about the robot's behavior and the robot does not respond at all, the interaction can be described as a comment-bid-disregard-response pair and the robot will likely be perceived as disrespectful. Alternatively, a robot that responds to such a situation with gaze and a nod (passive or low energy response) is likely perceived as attentive. The effectiveness of gaze and a nod as a one-fits-all response to a potential bid has been demonstrated by Jung and colleagues [49] in a study in which robots responded with such a behavior to any audible utterance a participant made during a joint problem solving task.

4. CONCLUSION

When people interact their behavior conveys affect alongside informational content. Because the affective dimension of messages is often unclear and open to multiple interpretations, participants of interactions whether human or robot must work to achieve affective grounding, or a mutual understanding of how behavior ought to be interpreted and responded to emotionally. Building common ground about affect is important because behavior that is interpreted in unintended ways can cause harm with potentially serious consequences for participants of an interaction, especially if the damage caused by that behavior is not repaired effectively.

For robots to participate in social interaction, they require the ability to participate in this coordination on affect because robots shape the emotional dynamics of interactions in ways that are not fully understood as they can directly induce emotions in others (e.g. [8][93]), but also indirectly by affecting related social processes such as attention (e.g. [67]), and in often unintended ways (e.g. [31]). Despite a few studies that have explored the role of emotions in teamwork scenarios in which a robot collaborated directly with a human (e.g. [12][81]), not much is known about how robots affect the emotional dynamics of interactions that include them.

This paper introduced the idea of affective grounding and with that it hopefully opens new possibilities for how we can not only study emotion in human robot interaction but also build new ways for robots to engage emotionally with people. The idea that participating in interaction requires the coordination of emotion extends how we study and build emotional capabilities for robots beyond basic emotion approaches and towards approaches that view emotion and emotion regulation as joint activities.

5. ACKNOWLEDGMENTS

This paper elaborated on ideas that Susan Fussell and I developed with Ge Gao for an NSF proposal. I am grateful to Susan Fussell and Ge Gao for the invaluable discussions that led to the ideas presented here. I further want to thank Kerstin Fischer for her time and suggestions that helped me improve this paper and for the invaluable comments and suggestions I received from 6 anonymous reviewers. This material is based upon work supported by the National Science Foundation under Grant No. IIS-1421929. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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