Beyond the Individual: The Dynamic Features of Distributed Affect

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ABSTRACT
Affect has been identified as an important component of the communication practices of distributed teams. Our emerging theory of *distributed affect* moves beyond the individual as the primary unit of analysis, focusing instead on affect as a dynamic group process. Drawing upon a data set of over four years of chat logs from a distributed scientific collaboration relying on text-based communication to coordinate their work, we expand upon the framework of distributed affect and characterize the concept through five features: *transference, resonance, pervasiveness, persistence*, and *representation*. These features provide a set of descriptive components for interactions between people and their environment, their tools, and their present and historical references as part of a dynamical system of affect. We examine specific events in the group's history which highlight the dynamic way affect is operating in this context, and how it influences factors such as creative problem solving. The framework we describe offers a unique analytic lens for the study of computer-supported group work, and a useful tool for framing questions about the continued study of affect in collaborative teams.

Keywords
Distributed affect; distributed groups; computer-mediated communication; collaborative creativity.

1. INTRODUCTION
Affect underlies and informs all human interaction, and is central to group functioning. Acknowledgment and understanding of its role in driving group creativity [6] and productive working [4], particularly under pressure, is often lacking or denied [51] especially in technological and scientific areas [40]. This paper offers a framework for a deeper understanding of affect's impact, focusing on distributed groups that are communicating predominantly through text chat.

Although the mechanisms of distributed cognition [34, 49, 50] have been extensively studied in distributed teams, less work has been done on the operation of affect beyond the individual. To address this gap, we examine how affect is dynamically distributed when people collaborate, specifically through text-based media, drawing on an extensive data set of chat logs derived over four years from the Nearby Supernova Factory (SNfactory), an international astrophysics collaboration between French and American scientists [3]. We build upon two sets of related research on affect in groups using text-based communication: Aragon and Williams' work [6] where the term distributed affect is used without detail; and works by Scott et al. [47] and Brooks et al. [10] identifying and codifying a taxonomy of affect in chat logs. These demonstrations that affective processes are visible in groups' text-based communication in decision-making [42] establish the need to describe in more detail how affect operates within the processes of distributed groups.

Our research builds upon previous work on cognition, postulating that Hutchins' [34, 49, 50] and Arrow et al.'s [7] respective approaches to group cognitive dynamics apply equally to affect, and that an affective ecosystem of dynamics between group members and their environment can be observed in our chat data set. We describe these interactions in detail in the Results Section below.

The question underlying this research is: "What is distributed affect, and how does it work?" In this paper, we identify five distinct features of distributed affect that, we posit, provide the mechanism for understanding its operation within a group context: *transference, resonance, pervasiveness, persistence,* and *representation*. We describe the five features and provide examples of each based on key affective events in the data set. This effort builds upon previous work in affect and emotion, distributed cognition and dynamical systems to explicate each of the features of distributed affect.

We utilize computer-mediated discourse analysis (CMDA) [32] as our primary means of qualitative analysis to study affective responses to unforeseen events occurring in our data set, mapping affective interactions over the four years of the collaboration. CMDA is a linguistics-based content analysis method specifically formulated for computer-mediated communication (CMC), and its different levels of language can be used to examine expressions of affect as we have operationalized them. The features are then examined in context to demonstrate their usefulness in accounting for the dynamic affective interaction of the group members as they go about their work. Through this analysis, we position our framework as an effective tool for posing and answering research questions about the operation and importance of affect in distributed teams and the unique ways that the communication of affect occurs in text-based media.

1.1 Definitions
We define affect as a state distinct from cognition [45], and as a person's 'capacity to affect and be affected' by other people [5]. Although this is a broad definition, we agree with Brennan [9] and Smith-Lovin [48], who describe it as a "physiological shift

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accompanying a judgment," while acknowledging that its definition is both more complicated and nuanced. The wide range of affective phenomena that we are accounting for is further informed by Ekkekakis' definition of affect as a "broader concept than mood and emotion" which provides the experiential substrate upon which moods and emotions are woven [17].

The events analyzed from the chat logs are predominantly tackled by the astrophysicists through creativity and problem-solving, searching for an operation to transfer the given (problematical) state of the system to a goal state [18]. We follow Mayer [38] to define creativity as: (1) novel, (2) useful with a valued outcome, and (3) a time-based process.

We use 'distributed' in two senses: for teams who span different time zones, countries, languages and cultures [16]; and for the attributes of those distributed teams, including distributed cognition [34, 49, 50] and distributed affect [6].

2. BACKGROUND AND RELATED WORK

The three main areas of literature pertaining to this paper are: a) the substance of human interactions (affect and emotion, distributed cognition and dynamical systems), b) one particular type of interaction, text-based communication, and c) previous work on distributed affect.

2.1 Affect and Emotion

The study of affect has moved beyond psychology into multiple disciplines, including geography [5], literary studies [46], feminist studies [9], and HCI [39]. Recent thinking posits affect as more than a "non-rational phenomenon" [5] emphasizing the importance of understanding the dynamics of affective life, and affect's physiological aspects. Seeing affect as plural, rather than singular, Anderson suggests that affects are interwoven through all aspects of life, "organized and patterned as part of diverse socio-spatial formations" [5]. Moore and Isen's [39] work on positive and negative affect and Watson et al.'s PANAS (Positive And Negative Affect Schedule) [53] also proposes that people are affected by or affect others, and that the affect is shared. Paralleling this, Hatfield, et al. [30, 31] examine 'emotional contagion': how affect and emotion are transmitted between people. They describe a *multiply determined* family of psychophysiological, behavioral, and social phenomena that is also *multilevel* where "the precipitating stimuli arise from one individual, act upon (i.e. are perceived and interpreted by) one or more other individuals, and yield corresponding or complementary emotions […] in these individuals" [30, 31]. These concepts of emotional contagion have further been applied within computer-mediated communication by Hancock et al. [29], finding relationships between affect and the production of words, terms, and message rates. However, they did not account for more dynamical relationships over time, which we have found to be a crucial component of our findings. Additionally, both Barsade and George [8, 22] acknowledge that "group emotions" do exist and have an effect on group dynamics but also that the process by which these effects occur is not well understood, a question our research directly addresses. The laboratory studies carried out by Barsade showed strong evidence of emotional contagion in groups, but he specifically calls for future research to focus on a longitudinal study in an ongoing working team, which is precisely what we set out to do.

Gottman et al.'s [25] methodologies for analyzing affect in recorded exchanges by married couples have been applied to organizational domains by Jung and Leifer [36] to understand interaction dynamics and the performance of engineering design teams. These complex readings of affect and emotion inform our extended framework of distributed affect and its dynamical quality as evidenced across the SNfactory data set (details to be provided in the Dynamical Systems subsection below).

2.2 Distributed Cognition

Hutchins' concept of distributed cognition [34], "extends the reach of what is considered *cognitive* beyond the individual to encompass interactions between people and with resources and materials in the environment" [33] and where "interaction [is] a source of novel structure" [35]. Cognitive processes thus extend beyond the individual to other members of a social group, involving coordination between people and their environmental context, and are capable of being distributed temporally so the outcomes of earlier events impact later events [33]. Recent work in the study of cognition acknowledges the importance of distributed cognition, contrasting the 'extended' with the 'brainbound' mind [13], and proposing a "potent, slow, pattern-based learning [enabling us] to learn to deal with highly complex situations in a remarkably nuanced and efficient manner" [13].

Aragon and Williams [6] note that Hutchins does not explicitly call out possible affective states driving the collaborative problem-solving demonstrated by the distributed navigation system he references [34], despite the high levels of stress involved in the operation that might have been thought, inevitably, to have played a part. Furthermore, Clark's discussions of the extended mind [13, 14] focus on cognition but not affect. However, the growing body of literature on affect and emotion previously referenced demonstrates the importance of affective states in group interaction, laying the groundwork for this paper.

2.3 Dynamical Systems

McGrath et al. [37] argue that complexity, adaptation, and dynamic cross-level interaction are essential characteristics of groups, referencing both Abraham's [1] work in dynamical systems theory in the context of psychology, and complexity and chaos theory [43]. A dynamical systems approach has been used in previous research to analyze communication patterns and affect. Arrow et al. [7], studying the dynamics of concocted groups (i.e. built purposively), observe "the coordination network of an operating group connects members, tasks, and tools – both the tangible resources of hardware and money and the intangible resources of knowledge and procedures – into a functional whole." We have observed these principles of dynamical systems at play in distributed group problem-solving and creativity, and this has informed our framing of distributed affect, particularly in relation to groups as "inherently dynamic systems, operating via processes that unfold over time [and] are dependent both on the group's past history and on its anticipated future" [37]; and what Arrow et al. [7] call *affective* and *cognitive integration*.

2.4 Text-Based Communication

Chat is a central computer-based collaborative tool, used by teams for general communication, and extensively for problem-solving when there are events to be dealt with (i.e. things going wrong, or things going right). Events catalyze affect, positive as well as negative, which is expressed in the chat through content (what is said) and expression (how it is said) [6]. In face-to-face communication, affect is frequently communicated through unconscious, spontaneous, non-verbal expressions such as body language, speech rhythm, and intonation. In contrast, text-based communication, with fewer expressly non-verbal channels available, requires more explicit, deliberate expression of affect, although some evidence exists of spontaneous non-verbal cues

still playing a role in the interpretation of affect in text-based communication. For example, Gill et al. [21] found that the length of a message had an impact on how well participants agreed on any particular affect being expressed in a blog post, particularly where the affect expressed had low agreement among interpreters.

While the communication of affect was previously believed to occur purely through spontaneous non-verbal cues such as message length, the results of research on text-based chat communication suggest otherwise. Hancock et al. [29] reported that *spontaneous* non-verbal cues (such as message frequency) were not responsible for the spread of emotions between text-based chat partners. Rather, in an earlier study, Hancock, Landrigan and Silver [28] found that the use of intentional verbal and nonverbal cues such as disagreement and punctuation were accurate predictors for how a chat partner could correctly discern their partner's affective state. Similarly, Guillory et al. [26] found that people intentionally use verbal and nonverbal cues to communicate affect in text-based chat, and Walther and D'Addario's [52] study of the intentional use of emoticons found that a smiley face amplified a positive message while a negative message became more strongly interpreted as negative with a frown face.

These studies suggest that the expression of affect in text-based communication may be a more cognitive, deliberate, and explicit act than in face-to-face communication, and as such, represents a rich account of the intentional expression of affective states of the participants where evidence of distributed affect can be empirically observed.

2.5 Distributed Affect

Aragon and Williams [6] propose the concept of distributed affect as part of a dynamical systems theory addressing how affect helps maintain and accelerate creativity across a distributed group through the creation of what they term creative resonance. They propose a distributed dynamical system that describes how "[t]he affect within the system makes the connections between ideas and between people stickier" and how when local dynamics [7] are tuned to develop socio-emotional links with other group members "there is a greater possibility of distributed affect creating the [creative] resonance that drives and grows ideation." They suggest "the information to be transferred must include the two strands of cognition and affect. Thus we have not only distributed cognition but also distributed affect."

3. METHODS

We arrived at the extended framework of distributed affect and a description of its interactions in the context of our data through mixed methods [46], using multiple sources of data and in two distinct phases discussed in the following sections. Although Aragon and Williams name distributed affect and provide evidence for its existence in text-based communication and its contribution to group creativity, the exact nature of distributed affect as a comprehensive theory remains – as they suggested – to be described, hence our first research question:

RQ1: What are the features of distributed affect?

Our underpinning methodology in phase one in the service of RQ1 is constructivist grounded theory whose structure, while requiring a rigorous 'fit' with the data [41], permits initial concepts and findings ('exploratory conceptual and theoretical development') [19] to emerge early in the process and to mature iteratively through the constant comparative method [24] over the course of the study. The grounded approach allows the use of data of 'whatever type' [23] from multiple sources [11]. In the first phase of the research we analyzed data into categories as they were collected and tested findings as they emerged. Our multiple sources of data included the chat logs themselves, as we immersed ourselves deeply in the copious amounts of text, researched and constructed a taxonomy of affect within the logs and scrutinized early work on distributed affect; our continual reflections and discussions, captured in notes and memos; and the pertinent literature and our reading of it in this emerging context, again noted and memo-ed. Constructivist grounded theory [11], in contrast to grounded theory [24], encourages wide reading at all stages of the research. This identification of the features does not in-and-of-itself describe the mechanisms by which DA operates which is addressed in our second research question:

RQ2: How do these proposed features interact with one another and how does this interaction contribute to group dynamics such as the collaborative problem solving that the group displays?

In the second phase of the study we used computer-mediated discourse analysis (CMDA) as a rigorous means of examining the chat logs for evidence of how the features are operationalized and enacted in the data set (RQ2). We employed Weiss and Cropanzano's Affective Events Theory (AET) [54] to identify events where affect levels would likely be high. Where we identified the features in action, we then described them, using the constant comparative method, until we were satisfied that each category (i.e. each feature) was saturated. These methods are discussed in further detail in the following sections.

3.1 Our Data

The dataset analyzed for this paper is a text-based chat log corpus from the SNfactory group with approximately 485,000 messages sent over a period of four years. The group used text chat (AOL Instant Messenger) as their primary means of synchronous communication to jointly make scientific and operational decisions about the telescope they were remotely and collaboratively operating [6]. The group consisted of about 30 core members who were physically located at various sites in the U.S. and France, none of which were at the telescope site on Mauna Kea, Hawaii, U.S. The typical number of people engaging in the chat on any given night is 4-6, although this number varies from 2-10. Given the nightly and cyclical nature of the scientists' work, the chat is organized into 24-hour periods that we refer to as separate "logs" in this paper. The logs were coded for affect using a taxonomy of 42 distinct codes that were arrived at through an adapted grounded theory approach as part of our earlier research in this area [47]. This taxonomy included substantive codes that were not mutually exclusive, as well as valence and intensity labels. Using this technique, nearly 67,000 (approximately 14%) lines of the corpus were manually coded using each chat message as a discrete element, and it is these coded logs that form the central focus of our analysis.

We recognize the necessary interpretive nature inherent in this type of qualitative coding. In this research we remained mindful of Glaser's [1992] principle of distance in conceptualizing the data while at the same time "embrac[ing] and discuss[ing] the idiosyncrasies of unique ethnographic encounters" [44] as reflective researchers. Our goal in applying these codes was to capture the affective expressions that could be empirically observed in the text, rather than any attempt to infer the internal state of the speaker. To assess reliability of the coding, Cohen's kappa was calculated over all messages coded by two or more people [47], achieving an overall kappa value of 0.647, with per-code kappas ranging from about 0.4 to 0.8.

Our previous work coding the data and the writing of digests and field notes described in Section 3.3 formed a substantial part of the first phase of our study, the exploratory conceptual and theoretical development [19] of distributed affect and the emergence of its features.

3.2 Sampling the Corpus

The telescope and its specialized software are the integral shared instruments of the SNfactory and a main focus of their communication. Problems that arise, especially equipment and software failures, can adversely impact crucial data gathering opportunities. Immediate solutions to these problems as they arise are a high priority for the group and these events lead to frequent instances of problem-solving communication in the chat logs. For example, the scientists explicitly focus on debugging the telescope in 59 chat logs, and they collaborated to solve more complex errors in 23 chat logs. The SNfactory's computer infrastructure is also a potential target for hackers. A possible unauthorized access to the SNfactory instruments and collected data required the scientists to assess the problem and repair any possible damage speedily.

For our examination of the emergent properties of distributed affect we adopted a purposive sampling approach, in which we identified events recorded in the logs that held a high possibility of affect, owing to their out-of-the-ordinary nature. Weiss and Cropanzano's Affective Events Theory (AET) highlights the role of workplace events as proximal causes for affective reactions [54], promoting affective cycles among group members. We therefore focused on three kinds of events that produced both negative and positive affective states: discovery of a security threat, shared system bugs, and shared tool failure, selected through an iterative process that identified recurring problem solving events in the dataset involving the interaction of several SNfactory members. We combined keyword and affect code searches over the chat logs to select data to analyze more closely. This method was repeated with different keywords to generate a list of logs containing potential events to analyze further. These three event types reveal the highly-layered and complex role that distributed affect plays in the dynamics of the group as they use collaborative problem solving to resolve these critical issues.

3.3 Writing Digests of the Chat Logs

Charmaz describes memos as an opportunity to become "actively engaged" in the data, grounding your emerging analysis [12]. We abstracted relevant information from the full conversational records in the selected chat logs by writing "digests," drawing on and expanding on the traditional memoing techniques of the constant comparative method.

Treating the chat log as a high-fidelity record of what transpired during any given shift, we "replayed" the events and wrote "field notes" in the form of episodic time stamped summaries taken directly from the logs. We also included reader comments, which are semi-analytic asides that provide the opportunity to note interpretive insights. Based on these field notes, we produced memos of several paragraphs that included causal claims about what is captured in the summary. In contrast to the field notes, these write-ups took an analytical perspective on the phenomena of affect and events. These digests performed two functions: as high-level summaries that enabled us to identify phenomena of interest in the emergent phase, and as entry points into the chat logs as our study moved into its analysis phase. During the course of coding the data and writing the digests, five features of distributed affect emerged: *transference, resonance, pervasiveness, persistence,* and *representation.* We describe these features in further detail in Section 4.

3.4 Computer-Mediated Discourse Analysis

CMDA applies "methods adapted from language-focused disciplines such as linguistics, communication, and rhetoric to the analysis of computer-mediated communication…[and has] at its core the analysis of logs of verbal interaction" [32] and thus takes advantage of the unique qualities of online discourse that occur in our chat logs. Of key importance to our analysis is that CMDA is specifically formulated to apply to the examination of five levels of language in CMC. These levels were particularly relevant in scrutinizing the chat logs for evidence of each of the emergent features of distributed affect. Each of these levels is described below (ranging from smallest to largest unit of analysis) [32] including a brief discussion of how they specifically correspond to our dataset. These levels of language played an integral role in how we went about operationalizing the features of distributed affect in Section 5.1.

1. Structure: Structural phenomena include the use of special typography or orthography, novel word formations, and sentence structure. This level can be found in our own dataset in the use of emoticons, intentionally deformed spellings and punctuation, and in the use of all caps.

2. Meaning: This level includes the meaning of words and utterances. Our data allow for us to make judgments about technical terms, foreign language use, and utterances that are specific to the technical work being carried out which go beyond usages found in normal conversation.

3. Interaction: The interactional level includes turn-taking, topic development, and other means of negotiating interactive exchanges. Turn taking is clearly demonstrated in the ordering of the messages in the log, and topic development is of importance to us in identifying shifts in the tone of a conversation as well as the focus of participants in addressing their work.

4. Social Behavior: The social level includes linguistic expressions of play, conflict, power, and group membership over multiple exchanges. Given the large number of ever-shifting participants in any given log, there are a variety of social dynamics that we examine in our data. It is also at this level that we would expect to have the most salient discussion of the affect codes which have been applied to a message.

5. Participation Patterns: These patterns are measured by frequency and length of messages posted and responses received in threads or other extended discourse samples. Our logs include information about the speaker and the time a message was sent (timestamp). This allowed us to measure the frequency of participation for each participant in a given log and leverage this information as an additional indicator of other levels.

We operationalized each of the features into well-defined concepts that can be directly observed in the logs in accordance with the five levels of language. Using a phenomenon-based sampling technique [32] a qualitative analysis was carried out, informed by relevant discourse phenomena as outlined in the CMDA approach, the previously applied substantive affect codes from the taxonomy, as well as the specific distributed affect features identified in the logs. The details of how these features were operationalized, as well as a presentation of our analysis and discussion of the features in context can be found in Section 5.1.

4. THE FIVE FEATURES

Throughout the first phase of our research, the framework of distributed affect evolved to describe in more detail a dynamical interplay between members of a distributed group. In this section we expand upon the mechanism whereby affect moves from being, in Aragon and Williams' [6] terms, an observation of affective states of individuals in a distributed group, to a dynamical property of that group's interaction with each other and with their context. We define and describe the five features of distributed affect as observed in the data as well as their relationship to existing theories below (RQ1). While the features themselves are a direct result of our examination of the data, this discussion of related literature is referenced to better situate our contribution within the context of other relevant work in this area and is representative of the sources we consulted as we were engaged in the grounded approach [11] we detailed in Section 3.

4.1 Transference

Transference: the passing and sharing of affect between members of the group.

Although transference of affective states is evidenced in work on emotional contagion [26], and we see additional evidence of this sharing and passing of affect in our own data, we focus on how affect is transferred to multiple participants at the same time. We examine this process at the level of the entire group, rather than in dyadic pairs, to account for the sharing of affective states that can become pervasive across the entire group.

Additionally, we posit that this transference of affect is one of the key mechanisms by which the other features are catalyzed and precipitated. We see examples in the data of transference of affect not only between human members of the group, but also transference of affective states to technical and conceptual artifacts which are related to the group's work and social lives.

4.2 Resonance

Resonance: the amplification and damping of affective states via positive and negative feedback loops.

Resonance describes how the affective states can build in positive or negative feedback loops between members of the group. This concept shares similarities with Aragon and Williams' [6] "creative resonance" in which ideas are amplified or damped according to affective and social aspects of group interactions within a system. We extend this understanding to include the production of new and additional affective states (e.g., how the damping or amplifying of one affective state, such as confusion, can precipitate that of another, such as surprise or apprehension).

4.3 Pervasiveness

Pervasiveness: the spread of one or more affective states throughout the group currently engaged in the chat.

Previous research in emotional contagion offers evidence of affect shared and spread among individual members of a group [8]. Pervasiveness, in our framework of distributed affect, is concerned with the dynamics of the group as a whole, including collaborative tools and interfaces.

4.4 Persistence

Persistence: a lasting, non-interruptive temporal duration of affective states in the group.

Persistence of distributed affect stands in contrast to the relatively short-lived and interruptive experiences typically associated with an individual emotion. While persistence as a term has been used in the psychology literature in reference to an emotional state felt or demonstrated over time [42], the unit of analysis has largely been that of the individual, not that of a more complex group system. Similarly, in text-based analysis of chat data, researchers have used persistence to refer to the likelihood that users might switch between emotional states as determined by a mean score of individual users [20]. Aragon and Williams [6] note the importance of temporal context in understanding creative resonance within the larger unit of analysis of a dynamic group.

4.5 Representation

Representation: Affect stored in a representational form within shared tools, events, memories, cultural artifacts, and historical artifacts.

This feature is similar to concepts of representational media in Hutchins' theory of distributed cognition [34]. For example, when scientists refer to "telescope stuck," this phrase holds context-dependent pre-existing negative affect among the group members who know the difficulty of having the telescope in this state.

5. ANALYSIS

We now build upon our presentation of the features to address RQ2, fleshing out the framework of distributed affect to address relevant factors, how and why they are related, and in which contexts the features apply. In order to empirically identify these features and highlight their interactions in the data, we utilized the previously discussed levels of language highlighted by the CMDA method (structure, meaning, interaction, social behavior, and participation patterns) as a means of operationalizing the features of distributed affect defined and described in the previous section. The levels of language served as a guide for surfacing and structuring the key elements that would best account for the unique ways that the features manifest themselves in this unique text-based medium [32]. The specifics of this step in the CMDA process are highlighted here to provide additional context for how these features were analyzed within the event-driven examples from our data.

Transference is operationalized when:

a) A speaker absorbs and reflects back a newly introduced expression of affect. For instance, transference can be observed as a change in the initial affective expression of a participant (e.g. substance, valence, intensity), as a result of exposure to the affective expression of another participant.

b) An artifact (which may be digital, cultural, or ideational) is imbued with an affective state by a member of the group.

Resonance is operationalized through:

a) Fluctuating intensity (increasing or decreasing) of the lexis including words, punctuation, capitalization, lengthening of vowel sounds, and emoticons; for example: "frustration…frustration!!!... FRUSTRAAATION!?!?".

b) Repetition of affective content and expressions occurring between participants over a given window of time, often resulting in amplification or damping of the other participants' affective expressions.

Pervasiveness is operationalized when:

a) A majority of the participating members of the group are expressing the same affect within a given window of time.

b) A new participant is exposed to the affective state of the group and also begins to express similar affect.

Persistence is operationalized through:

a) The sustained, repeated and pervasive expression of similar affect (e.g. substance, valence, intensity) by one or more members of the group over a given window of time.

Representation is operationalized when:

a) An ideational representation is invoked to express or produce an affective response in the group (e.g. saying "here we go again" when the telescope is stuck).

5.1 Interactions and Context of the Features

In this section we look at the five features in the context of the previously identified affect-laden event types based on AET as described in Section 3.2.: discovery of a security threat ("Hacked?"), shared system bugs ("No vacation from bugs!"), and shared tool failure ("Stuck again"). Each of these acute events calls forward distributed cognition in how the team members respond intellectually to the situation; here we examine how the group's *affect* is distributed. Through the examination of distributed affect's operationalized features, we demonstrate how they map to real-world interactions between members of the group in the chat logs (for the sake of privacy, pseudonyms have been used below). At times the features display an ordering, as transference and resonance can often occur as processes that precede and influence the pervasiveness and persistence of affect as expressed in the group. These features can also occur in overlapping ways with feedback loops, with one or more features building on each other as dynamical systems. In this section we examine how these features emerge and are interacting in the system, and are also contributing to some goal of the group, in three individual event types. Examining the behavior of the affect features and mapping their patterns over periods of time longer than a single event is part of future work on the corpus.

5.1.1 "Hacked?"

In this example of a highly affective event, we observe the features of transference, persistence, pervasiveness, and resonance at play.

The SNfactory scientists implicitly rely on their software and systems to aid them in their highly technical work, and any possible compromise of their integrity or reliability is seen as a potentially major threat to overcome and prevent. Because the SNfactory system is a high-profile operation, it is a prime target for compromise. The scientists had obvious concerns over this eventuality, and therefore we purposely sampled this type of event, observing a varied series of affective responses in the group as they worked towards a solution.

In the chat log prior to the evidence of the hacker arising, the affective state of the four members of the group currently participating in the chat is *pervasive*: everyone is focused on their work, making simple inquiries about ongoing tasks, and many of the preceding messages (~50) are coded as 'no affect'. We note that the majority of participants are expressing the same types of affect, specifically 'agreement' or 'no affect,' and that when a new member (Will) joins, he also begins to express similar affect; thus the pervasive mood in the group spreads to the new member. We have observed this pervasiveness of affect in the chat logs, and it also serves to set the stage for the oncoming event.

Phil first notices something may be awry when he notes "very funny history in account ccd" (3:58:28 am) meaning that he has found some unusual activity in one of the logs he is checking which indicates that there was a potentially unauthorized access to an adult website by an outside party that should not have occurred. This information triggers a flurry of questions and information-seeking activity as the group members work to understand the situation. The other three scientists meet this news with surprise and confusion, and we see a display of this affect when Roger replies with "whaaaaaaaaa" (4:00:13 am). The *transference* of this negative affect then occurs between all of the other participants in the chat except for one. Although a *pervasive* and *persistent* state of negative affect sets in for the others, Simon actually tries to combat this by damping the building of negative affect (*resonance*) by injecting humor into the situation. He inquires "what site ;p" (4:00:35 am), with the emoticon representing a winking face with the tongue sticking out indicating a light-hearted joke that he is curious which site was accessed. Although this joke is met initially with laughter (e.g. "hahahahaha") from one of the other scientists, the damping effect of this humor is short lived as the discussion quickly returns to a long series of technical and logistical back-and-forth attempting to get to the bottom of the issue.

Time	Name	Message	Affect
03:58:28AM	Phil:	very funny history in account ccd	amusement
03:59:03AM	Simon:	I find it empty	confusion
03:59:15AM	Phil:	which shell do you use?	interest
03:59:16AM	Will:	me too	agreement
03:59:20AM		csh	no affect
03:59:23AM	Phil:	ahhh	surprise
03:59:39AM		bash history had some curls to a porn site	surprise
04:00:00AM	Will:	bad!	disgust, surprise, anger
04:00:08AM	Simon:	hacked?	interest
04:00:13AM	Roger:	whaaaaaaaaaaa	surprise, confusion
04:00:17AM	Phil:	I hope not	apprehension
04:00:22AM	Will:	how old?	interest
04:00:29AM	Phil:	impossible to tell	no affect
04:00:35AM	Simon:	what site ;p	amusement
04:00:37AM	Phil:	it was before I logged in	no affect
04:00:45AM	Simon:	they all say that Phil	amusement
04:00:46AM	Phil:	hahahahaha	amusement

Table 1. Excerpt of chat log containing the SNfactory participants discovering possible evidence of a hack, as well as the corresponding affect codes.

We then enter a long stretch of dialogue that is coded with persistently negative valence affect codes (apprehension, confusion, annoyance), and these affective states are *pervasive* across the entire group attempting to solve the problem. Simon intermittently continues to try and damp this negative affect by making further humorous comments and lighthearted jokes that are often accompanied by an appropriate emoticon. Eventually it is indicated by Phil that "it may not be an intruder, just someone with a misguided cut-and paste" (4:23:53 am). This comment is followed up with several more jokes from Simon, and these seem to achieve their desired damping effect and finally break the *persistent* and *pervasive* negative mood of the group. We then see a shift towards all of the members of the group sending messages that were coded with 'amusement' and other positive valence affect codes, signaling a transition to a new state of positive *pervasiveness* which alleviates all of the tension from the preceding half an hour of chat, along with the sense of a resolution to their problem. At this point, Simon suggests that they return to finishing their current telescope scan before conditions for viewing are no longer suitable. The rest of the group agrees

that the potential hacker situation will need to be returned to later if it is deemed to be an actual threat, and thanks to Simon's continued damping of the negative affect resonating throughout the group, they are able to return to progress on their primary goal, thus resolving their immediate problem.

This example shows several of the features operating at once, feeding into one another (transference and resonance leading to a pervasive and persistent affective state) or serving to mitigate the effects of one or more features (Simon's humor working to defuse the situation and bring levity back to the group). At no point is any one person specifically setting the overall affective tone for the group, but rather the combined affective contributions and responses of all of the members trigger the group's global dynamic and problem solving. Through this dynamic the affective properties of the entire group assume a level of importance that moves beyond individual interactions highlighting the significance of the distributed nature of the mechanisms we see at the heart of the framework we develop.

5.1.2 "No vacation from bugs!"

This instance from the chat logs exhibits the features of resonance and its damping, and representation at play across the group as they work to solve a problem with a software bug.

Fixing software bugs absorbs SNfactory scientists' time and energy as they impact the group's ability to collect data and effectively monitor the telescope. In this particular event, Roger, one of the core contributors of software code in the group, gets increasingly frustrated and upset as he realizes that no one contacted him the previous evening regarding a system bug. When he is first introduced to the chat he asks playfully "any buggies?" to which one of the participants replies "big one" to which Roger replies two seconds later with "shit". Here we see how a bug in the software acts as a *representational* object, having developed negative affective attributes based on previous shared group experiences in finding and fixing them. There is no need to explain why a bug might be bad for their workflow, as the implications of a "big one" are pre-existing in the group. Roger's negative affect increases and starts to resonate as he goes from confusion about the bug throughout the next hour of the event to increased annoyance and frustration at having not been contacted earlier as he gains more information about it. We see the resonance of this negative affect exemplified by the use of elongated speech patterns such as "Baaaaaaaaaaaaad" (5:07:36), and within one single minute period the use of four frowning faces to indicate his state of displeasure. Roger's negative affect starts to resonate in other participants: Paul, for example, immediately after this strong resonance in Roger, expresses the same type of frowning face, and then in other participants who use these same elongated speech patterns as they work on their continued efforts at debugging "Grrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr" (6:01:14 pm).

Time	Name	Message	Affect
4:14:16 PM	Roger:	any buggies?	interest
4:14:20 PM	Rita:	big one	apprehension frustration
4:14:22 PM	Roger:	shit	apprehension frustration anger
4:18:42 PM	Rita:	this append twice on standard ...with more than 1 finding chart (first guess)	no affect
4:21:30 PM	Roger:	I am utterly confused	confusion annoyance
-		-	-
5:06:56 PM	Roger:	Someone not looking at image reconstructions?	interest annoyance
5:07:23 PM	Patrick	yes Rita ...saw them ...but didn't react ...	apprehension
5:07:36 PM	Roger:	Baaaaaaaaaaaaaaad Rita	annoyance anger
5:07:56 PM		Now life is much harder for online guys ... :(	annoyance frustration apprehension
5:08:02 PM		We have to try to debug in vacuum	annoyance frustration
5:08:14 PM		:(:(:(	sadness frustration
5:08:27 PM	Paul:	:(	sadness frustration
5:10:28 PM	Roger:	this is so annoying	frustration annoyance

Table 2. Excerpt of chat log containing the SNfactory participants working together to debug their software, as well as the corresponding affect codes.

Once Roger finds the source of the bug ("SHIT there it is") the negative affect is damped, and this damping is reinforced by Patrick, a French scientist, who initiates the shift to positive affect saying "relax … we got a standard today" to which Roger agrees "Yes, relazed (sic) now, because i know the bug!" (6:12:02 pm). Positive affect can now be seen resonating in the system as the members see the solution to their problem. We see the expressions of affect change with the expression of positive smiley emoticons among several group members showing persistence of this new affect state.

5.1.3 "Stuck again."

Here we observe the features of representation, transference and pervasiveness in the chat logs.

The most common of the type of events we sampled from our dataset is the telescope getting stuck. When this happens the scientists are no longer able to do their work, and face losing important and valuable opportunities for observation; so there is significant pressure to get the telescope working again. Because the scientists operating the telescope are doing so remotely and therefore do not have direct physical access to the telescope, if they are unable to resolve the problem themselves they have to contact another party physically located near the telescope to resolve the problem.

This particular telescope stuck event begins when Roger notes "hmmm…telescope is sticky" (2:43:29 am). This news is met with responses that are coded with annoyance, frustration, confusion, and even anger (all negative valence and high intensity) by the three primary participants in the chat at the time, and by a fourth member who joins later in the log as well. In this case, we see the negative affect not only being transferred between the group, but also being transferred to the telescope itself as a shared artifact which is becoming the focus of this negative affect. As well as transference, we see further evidence of the previously noted frequent occurrence of the telescope being invoked as a representation of negative affect specifically when it is stuck. Throughout this portion of the chat log, there are numerous examples of a reference made to the stuck telescope being followed by utterances coded for negative affect. For instance, after an initial attempt to use the available software-based resources to try and unstick the telescope, Will says "stuck

again" (2:59:43 am) and Roger, Will, and Morris all respond with messages that are coded as negative affect which is directed at the telescope.

Time	Name	Message	Affect
2:53:30 AM	Roger:	tele_unstick failed	no affect
2:53:36 AM		trying again	no affect
2:54:21 AM		looks like gonna fail again	anticipation
2:55:14 AM	Will:	I guess try sending it the other way?	supportive
2:55:39 AM	Roger:	gonna see if I can zslew back -- it tried the "one way then the other"	no affect
2:55:45 AM		but that failed	no affect
2:57:52 AM	Will:	what was the other instrument when you started?	interest
2:58:05 AM		maybe they changed instruments and didn't get the balance right	interest, supportive
2:58:56 AM	Roger:	didn't notice	no affect
2:59:10 AM		but I called summit and Ed was there when it was time for flats	no affect
2:59:15 AM		I see if he is still there...	no affect
2:59:33 AM		calling	no affect
2:59:43 PM	Will:	stuck again	annoyance
3:00:04 PM	Roger:	yes	agreement

Table 3. Excerpt of chat log containing the SNfactory participants coping with the telescope being stuck, as well as the corresponding affect codes.

Of particular interest in this example are also simultaneous occurrences of messages that were coded as positive, supportive affective expressions that immediately follow these small initial build-ups of negative affect. These bursts of supportive, positively coded messages are, we suggest, acting as negative feedback loops which serve to damp the resonance of the negative affect that pervades the group whenever the telescope being stuck is mentioned and as they work to solve this problem. This dynamic group process is, we posit, a way to maintain affective equilibrium during this highly stressful time, and thus prevent the situation from sliding into an unchecked stream of negativity and counter-productivity. This dynamical loop occurs repeatedly throughout this log as members join or leave the chat.

6. DISCUSSION

We have presented three narratives, from the many in the logs, that show the dynamic interplay of the five features of distributed affect evidenced in the corpus. These examples were identified based on the sampling techniques noted above, but are by no means exhaustive. Given the size of the corpus, and the guidelines of the CMDA process, we sampled by phenomenon once we had identified a suitable candidate log. This allowed us to show the features at work in several different contexts that are highly relevant to the group, as well as providing specific instances of how the features interact with one another.

Russ [45] has suggested that moderate amounts of negative affect can facilitate problem solving, whereas negative affect levels that are too high may stifle creativity, resulting in a curvilinear relationship. The features of our distributed affect model provide a means to describe these dynamic relationships as affect is spread or damped among members and tools in the group.

The analysis of the above examples shows how group members and representational artifacts act as agents providing affect feedback loops that can support problem solving across the entire group. These feedback processes mirror similar feedback loops researched by Arrow et al. [7] in a complex systems approach to understanding small group organizations. In the 'hacked' example above, Simon's playful quips are eventually able to damp the pervasive negative affect that grows during the discovery of the hack, and push the group back towards a state of equilibrium to continue telescope scans. In the 'bug' example, negative affect resonates at a growing frequency as group members work to find the source of a bug, yet the tension is released quickly when the bug is fixed and the problem is solved. In this case the software bug itself is acting as the representational agent that instigates and damps the pervasiveness of the affective state. Similarly, in the example of the telescope being stuck, the negative affect is damped by negative feedback loops as group members share supportive messages.

As can be seen from these illustrative examples, the global affective state of the group as it is described through the interactions of the five features frequently plays a critical role in maintaining and progressing the problem solving displayed by the group. Observed patterns in the logs further suggest that while the transference and resonance of affect may exist in bursty cycles based on the impact of outside contextual dynamics (e.g., the discovery of a bug or telescope failure), feedback loops of affect states including humor and support occur in more regular and persistent intervals to help the group more quickly return to a state of equilibrium when problem solving.

These examples also show how affective state is stored and propagated not only in the group members themselves, but also as stored representations and references in artifacts (e.g., the stuck telescope) based on past experiences of the group. There is strong evidence to suggest that not only must the unit of analysis shift beyond the individual when considering affect in this type of distributed, collaborative setting, but also that multiple features, interacting with one another in a dynamic system, must be accounted for. While our framework is formulated to capture this dynamic interplay, additional research is needed to provide a more thorough account of how artifacts are employed in this context, and the unique properties that distinguish them from the human actors in the system.

The kind of computer supported cooperative work we have examined here is increasingly taking place between distributed groups who have to rely on tools, such as online chat, that do not allow for the rich, multimodal forms of communication which accompany face-to-face interactions. As we have noted, while affect has been studied in research on computer-based collaborative systems, the focus is usually on the cognitive properties of the group [27, 50]. Our analysis demonstrates the importance of considering affect from a dynamical systems approach that operates at the level of the group rather than solely as a property of the individual, the crucial role that distributed affect plays in how these groups carry out their work, and how that affect is conveyed and propagated in the text-based medium. Our framework of distributed affect can serve as a theoretical lens to provide scaffolding and guidance for researchers wishing to examine the role of affect in their own similar data. At the core of this contribution are the five features and how we have defined and operationalized them within the specific textual phenomena that are of primary importance when analyzing the expression of affect in this context. These features, and subsequent examples

from our data, we hope provide a helpful tool for researchers wishing to be able to articulate questions about affect and emotion in their own investigations into collaborative groups in a much more robust and dynamic way than might otherwise be possible. We have provided a means for related research to move beyond the analysis of affect as a phenomenon that is necessarily tied to the individual, and instead have put forward a framework that can highlight the affective properties and dynamics at the group level.

7. LIMITATIONS AND FUTURE WORK

For this initial inquiry we chose to focus on salient events that act as catalysts for the communication of affect; our goal was to better describe these features of distributed affect and their interactions through an examination of relevant examples from the corpus of chat logs. There is undoubtedly still work to be done to continue to develop and fully describe the specific properties and interplay of the features in order to clarify their operation and identification as unique but interrelated aspects of the same overall framework, and to better situate them within the larger context of potential states of the group. As referenced earlier, it would be useful to examine the role that affect plays during "down" times as well. There may be equally important normative and meaningful instances of distributed affect, for example the important element of trust-building, which are taking place on a less dramatic level during times not accounted for through our method of sampling. Additionally, our research accounts for only a single chat data set. We intend to extend our study to other text data sets to further test the emerging theory of distributed affect and to examine our formulation against examples from other settings. While we posit that our current framework is well suited to collaborative chat, due to the unique properties of this form of communication, there may be additional features of distributed affect yet to be identified. We intend to expand our analysis to look for such mechanisms that may account for the distribution of affect in other forms of communication beyond text.

While we have focused on selected event types in this qualitative analysis described in Section 5.1, the five features also provide a means to examine longitudinal group patterns in future work and could be applied in a more quantitative manner to also examine patterns occurring over longer time scales than a single event. Additionally, we also propose a more discrete examination of creative outcomes related to the five features of DA. While previous work has argued for a more complex understanding of affect and creativity that moves beyond simply binning positive and negative affect [15] we would like to further address how the cyclical states of affect as captured by the features relate to specific areas of creativity such as the fluency, originality, and flexibility of ideas over time.

8. CONCLUSION

Our expanded framework of distributed affect has potential implications for distributed collaborations that utilize CMC and the design of the interfaces that enable it; furthermore, the distributed affect framework, as a theoretical lens, can provide scaffolding and guidance for researchers examining the role of affect in their own data. We believe that a rich account of the role that distributed affect plays in collaborative, distributed groups will provide valuable insights into addressing the socio-technical gap that has been identified as a key issue in research on computer-based collaborative systems [2].

The major contribution that our framework of distributed affect makes, however, is a means for examining affect as a dynamic and ongoing distributed phenomenon, existing – as distributed cognition does – beyond the unit of any one individual person. We posit that this dynamical socio-technical system describes the affective interactions between people and their environment, their tools, and their present and historical references. We offer the five features and how their interactions contributed to group dynamics in this paper as a first step in outlining the components and mechanisms of a theory of distributed affect.

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