A Tale of Two Online Communities: Fostering Collaboration and Creativity in Scientists and Children

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ABSTRACT
There has been much recent interest in the development of tools to foster remote collaboration and shared creative work. An open question is: what are the guidelines for this process? What are the key socio-technical preconditions required for a geographically distributed group to collaborate effectively on creative work, and are they different from the conditions of a decade or two ago? In an attempt to answer these questions, we conducted empirical studies of two seemingly very different online communities, both requiring effective collaboration and creative work: an international collaboration of astrophysicists studying supernovae to learn more about the expansion rate of the universe, and a group of children, ages 8-15, from different parts of the world, creating and sharing animated stories and video games on the Scratch online community developed at MIT. Both groups produced creative technical work jointly and were considered successful in their communities. Data included the analysis of thousands of lines from chat and comment logs over a period of several months, and interviews with community members. We discovered some surprising commonalities and some intriguing possibilities, and suggest guidelines for successful creative collaborations. Specifically, systems that support social creativity must facilitate sharing and play, and their design must consider the effects of repurposing, augmentation and behavior adaptation.

Author Keywords
Collective creativity, social creativity, computer-supported cooperative work, computer-mediated communication.

ACM Classification Keywords
H5.3. Information interfaces and presentation (e.g., HCI): Group and organization interfaces.

General Terms
Human Factors

INTRODUCTION
Creativity is no longer the exclusive domain of the solitary artist or scientist [16, 26]. In recent years, significant creative work in many widely disparate domains (including science, engineering, art, media, business, and education) is emerging from large and small groups of individuals working together, either in person or over a distance via the use of social media or computer-mediated communication (CMC) [9, 11, 14-16, 25, 26, 42]. With the advent of new lightweight online communication modalities, such collaborative and social creativity [16, 36, 49] is becoming more accessible than ever before. At the same time, understanding how technology can facilitate the process of collaborative creativity is still in its infancy. Corporations, scientists, and educators, among others, are all seeking to develop tools to foster effective collaboration at a distance.

Previous studies have demonstrated that distance matters for collaboration success [2, 21, 29, 40], and that collocated workers in most cases outperform distributed workers. However, technology is changing so rapidly, and more importantly, users' facility with such technologies is varying so significantly over time, that it is difficult to keep up. Allen's oft-cited study [2] that engineers' communication frequency decreases with distance was conducted over 30 years ago, when use of technology was radically different from today. The conditions under which controlled studies of human use of technology are conducted may be drastically transformed within a space of only a few years.

Consider, for example, the adoption of email. Studies from only a decade ago discuss the technology readiness of groups in terms of whether or not they correspond via email. Today, the use of email is practically a given, and indeed, can even be seen as a bit stodgy in comparison with Web 2.0 technologies, texting, and instant messaging. Studies from two or three decades ago have to contend with significantly different levels of knowledge and facility with the use of a keyboard, for example, than would be true today.

There is a generational shift taking place within the United States and around the world, where young people are growing up around computers, cell phones, and other communication technologies. They are developing a mode of text-based communication that is as natural to them as spoken language is to older adults [23, 24].

A growing number of everyday people are increasingly shifting to a "produsage" mode of participation when engaged with media [8] in what scholars call the "participatory culture" [25]. The relevance of this shift goes beyond media and is estimated [25] that it will reach other

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areas of human activity such as science and civic participation. Early examples of this are NASA's Clickworkers efforts [5, 27] and more recently the active use of social media in the 2008 US election [32].

What are the effects that these changes will have on the conditions for successful remote collaboration? Is it possible for text-based tools to effectively support distributed collaboration on non-routine, creative work? Questions such as these led us to conduct empirical studies of two relatively youthful online collaborations engaged in challenging technical and creative work. The authors of this paper collectively participated both as software developers and as active participants in the two online communities studied. As members of these groups, we were struck by some of the novel practices and modalities of text-based CMC that organically developed within these two very different communities.

Creativity is often thought of as a trait exclusive to artists and primarily an individual activity. However, social creativity is at the core of science inquiry [13] and the kind of creativity young people and amateurs engage in nowadays through the use of participatory technologies [17]. Resnick's [42] creative spiral includes sharing as part of the creative process. Our observations suggest that the other elements of the spiral (imagine, create, play and reflect) are also augmented by the social interactions in a community of creators. The astronomers and the amateur programmers we followed exchanged messages in each of these stages. For example, the kids imagined together and brainstormed on the projects they were going to make, created them together, and ultimately were all part of the playing with their and others' creations. Similarly, we witnessed the scientists throwing out imaginative ideas and making playful suggestions as they worked together on scientific publications and technical tools. We found that lightweight CMC tools facilitated many elements of the creative spiral in both communities.

The core contributions of this paper are 1) the long-term empirical study of two previously unstudied communities, both of whom made heavy use of text-based CMC to generate collaborative creative work, and 2) the discovery of commonalities among the two apparently disparate groups that may have implications for the development of collaborative tools in a future where professional scientific and artistic exploration will perhaps co-exist along with that of amateurs. Since many previous studies have demonstrated that it is difficult to perform creative work in distributed settings [16, 40], our case studies showing the success of lightweight tools in supporting such distributed creative work represent a novel contribution to this area.

DESCRIPTION OF THE TWO COMMUNITIES

The Nearby Supernova Factory

The Nearby Supernova Factory (SNfactory) [1] is an international astrophysics collaboration studying supernovae (exploding stars) in order to learn more about the expansion rate of the universe. The collaboration consists of about 30 members; about half of the scientists work at several different locations in the U.S. and the other half in three research institutes and universities in France. Collaboration members develop software to aid the collection and analysis of supernova data, remotely operate a telescope in Hawaii, and collaborate on scientific research and publications. The scientists are in different time zones from each other (France, California, the U.S. East Coast) and from the telescope itself (Hawaii). Some of the team members have never met each other and come from differing cultures with dissimilar assumptions, and some are not native English speakers.

Collaboration scientists use chat (augmented by a virtual assistant [41]) and VNC (virtual network computing) as their primary means of communication during telescope observation (Figure 1). For most of the period of this study, many of the junior scientists, while programming, scanning supernova images, making scientific calculations, or performing other daily office work, also communicated via a chat room they nicknamed the "hive brain." This communication occurred among both collocated and remote members of the group.

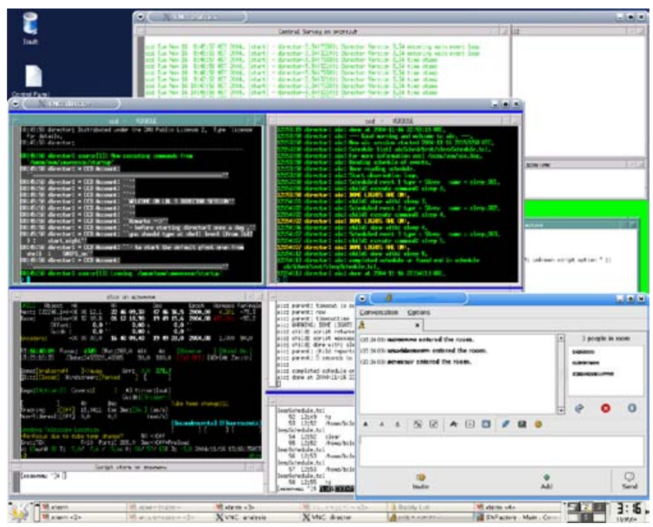

Figure 1. VNC telescope control window with chat client

Scratch

Scratch [31] is a programming language developed by the Lifelong Kindergarten Group at the MIT Media Lab to foster the elements of Resnick's [42] creative spiral. It enables children to create programmable media such as games, interactive stories, animations, music and art. The Scratch Online Community (scratch.mit.edu) [35] (Figure 2) was designed along these lines to be a source of inspirational ideas, to provide an audience for children's creations and to foster collaboration among its members.

Users range primarily from 8 to 17 years old, with peak age of 12. Members not only contribute programming projects, but also participate via commenting, tagging, bookmarking, joining galleries and taking part in discussion forums. The diversity of projects that have been shared on this YouTube-like website ranges from episodic narratives to role-playing games to scientific simulations to newscasts.

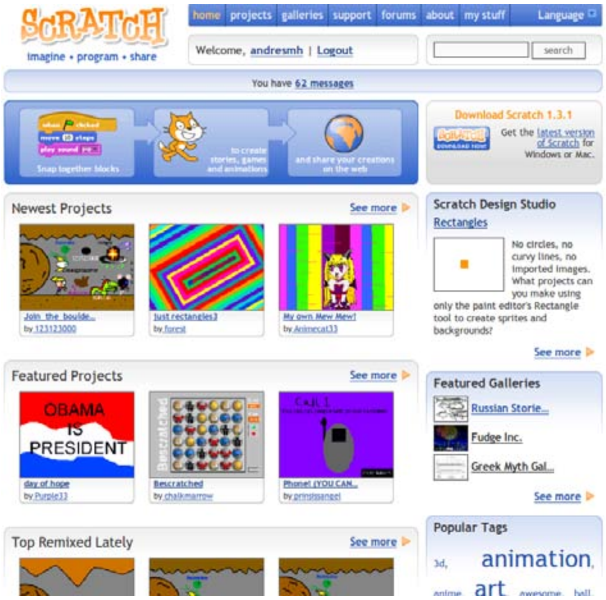

Figure 2. Scratch online community website, scratch.mit.edu

The design of the Scratch website was inspired by recent Web 2.0 trends and published usability studies [38] on youth online preferences as well as earlier work on situated learning [30]. Two key features of the community website:

- Encourage and support creative appropriation (remixing). The platform makes it easy for people to reuse other people's work and let users know when and how this happens.
- Social but with a focus on creative content. While providing the basic features of a social networking site, befriending others is not the goal of the site. Instead, it encourages the development of creative endeavors.

Green Bear Group

Since scratch.mit.edu went online in May 2007, a number of "companies" have been formed spontaneously on the Scratch web site by the children themselves, with the main goal of creating projects collaboratively. We chose to study one such company that has been relatively successful in terms of producing several finished video games which were "published" to a gallery on the Scratch web site. The company, referred to here as "Green Bear Group" (GBG), had been in existence for three months as of the end of the study (Sept. 2008). Three children, ages 8, 13, and 15, were the "founders" of the company, and it has had a membership ranging from 12 to 18 children over the period studied. The active participants in Green Bear Group have, for the most part, never met one another, live in different time zones, and do not even know each other's real names.

The 8-year-old "owns" the GBG gallery and the founders collectively make decisions on company membership. The members then vote on which games to develop. Each member has a specific skill, such as art, music, programming, or storytelling, which they contribute to the game by downloading an unfinished version, editing the program, and re-uploading a new version. This process is called "re-mixing" and is iterative. Each finished GBG game has had on average 17 remixes.

Why Study Two Such Different Groups

It has been shown to be highly informative for learners to discover that two very dissimilar objects are actually similar (this often yields more useful knowledge than the comparison of similar objects) [6]. We believe the study of the similarities between the two disparate groups discussed in this paper is thus worthwhile to researchers attempting to discover the characteristics of successful computer-mediated collaborative creative work.

Both of the groups studied here have significant barriers to effective communication and collaboration: the lack of common cultural ground, time zone differences, and in the case of the Scratch company GBG, have none of the socio-emotional context that one might expect would be a prerequisite for collaborative work. However, both groups have been successful in the collaborative development of software and the production of creative technical work (as measured by the number and content of science publications from the astrophysicists and completed video games from the children on Scratch). In this paper, we speculate on some of the reasons for this success, and suggest guidelines for geographically distributed groups using CMC for creative work.

GROUP COMMUNICATION AND DISTANCE WORK

Beginning in the 1950s, Goffman [18, 19] described how people establish "frames" and "fronts" to present their identities in face-to-face encounters. Innis [22] suggested that a society's methods of communication profoundly shaped that society. Meyrowitz applied these ideas to electronic media [33] in 1985, and theorized that new methods of electronic communication such as television led to changing methods of establishing identity and contributed to societal change of that period. More recent studies have related these ideas to CMC [24, 34].

Studies of often low-bandwidth new media use (such as mobile phones, texting, and instant messaging or IM) among young people have shown that people are establishing "fronts" and personal identities through a variety of new media technologies [23, 24]. These studies have demonstrated that youth are using text-based communication to establish emotional bonds. There has been much interest in youth culture, but not as much on how youth are producing creative technical work using text-based new media to collaborate.

Distance Work

In an extensive survey of group work, published in 2000, Olson and Olson [40] describe difficulties with remote collaboration and develop a list of factors contributing to success or failure of such projects. These four conditions are common ground, coupling of work, collaboration readiness, and collaboration technology readiness. Olson and Olson state that many remote collaborations fail if one or more of these conditions are not fulfilled. Studies of radically collocated teams (sharing a single large office) and the success experienced by such teams have suggested that a virtual recreation of such environments may be a solution to solving problems within distributed teams.

One of the advantages of radical collocation is the awareness of others' availability for interaction. Several studies have suggested that video and audio components are needed to successfully support this level of awareness [37, 40, 46, 50], recreating the visual and audio cues that would be transmitted in face-to-face communications.

Collocation also facilitates informal communication, which is brief, unplanned, and frequent in nature. Informal communication helps to support execution of work-related tasks, free exchange of creative ideas, coordination of group activities, and team building. Studies have shown that reductions of informal communication can slow down work [20, 21]. In distributed teams, previous studies have shown that such informal communication is less frequent [50].

However, a study by Churchill [10] showed that lightweight communication tools, such as chat and text-based MUDs (Multi-User Dungeons), facilitate this type of awareness, and in fact may have advantages over audio and video solutions, such as allowing for both synchronous and asynchronous communications. Text-based CMC is also ubiquitous and easy to use. This study showed that participants felt sufficiently co-present using very simple representations. Churchill suggests that the richness of face-to-face interactions is not always a requirement for communication and collaboration.

Thus, we believe that long-term studies of distributed groups producing creative work while making heavy use of chat are warranted. The children and teenagers writing programs on Scratch may very well be tomorrow's artists, scientists and software designers, and the postdoctoral researchers of today will be tomorrow's senior scientists and collaboration leaders. The study of how they use technology for creative collaboration will be relevant in the future.

METHODOLOGY

Study methods consisted of participant observation, semi-structured interviews, and log analysis. We studied three months' worth of archives of two active chat rooms used by the SNfactory during daily operations, and three months of archived comments from the Green Bear Group gallery on Scratch. Most interviews were conducted via email or online; for the Scratch group, an online survey was distributed. Two of the active participants in GBG were physically observed at their computers as they interacted with the Scratch web site, and in-person interviews were conducted with them. Additionally, paper authors were active participants in the two communities during the respective three-month periods.

We developed a faceted, hierarchical taxonomy in order to describe the nature of the content in these three chat rooms (Table 1). To develop this taxonomy, we read through three months' worth of both SNfactory chat logs (about 35,000 lines) and Scratch comments (1470 lines) and used grounded theory methodologies [48] to determine the common content patterns within the chat logs. (For convenience, we will refer to all the archived content in both SNfactory and Scratch as "chat logs", although the Scratch comments are not, strictly speaking, "chat".) For the SNfactory analysis, we then selected at random 22 days worth of chat logs with lengths representative of the corpus (i.e. we eliminated daily chat logs that were exceptionally short, indicating either a problem in log capture or truncated periods of observation) and classified 8000 lines of chat logs using this taxonomy. Since the GBG chat log was shorter, we coded the entire log of 1470 lines. If a message contained elements of more than one category, it was coded with the tag representing the majority of the text.

Paper authors familiar with SNfactory and Scratch, respectively, performed the coding of the logs from each domain. There were two coders for the SNfactory data and two for the Scratch data. A random sample of approximately 200 lines of SNfactory chat was coded by two people who then discussed the discrepancies (originally less than 10% in the major categories) and came to consensus on the proper categories for each line. Each one then proceeded to code the other logs individually. A similar procedure was used for the Scratch logs, but with 50 lines (8% discrepancy).

Description of the Taxonomy

Grounded theory techniques [48] were used to create the taxonomy. During the open coding phase, we uncovered many of the subcategories, such as conversations related to programming and general socializing. The axial and selective coding phases led to the organization of these subcategories into three primary categories: contextual, task, and socio-emotional. Studies suggest that contextual, task and process, and socio-emotional information are important for establishing situation awareness, defined as "the gathering, incorporation, and utilization of environmental information", in scientific collaborations [46]. Both the SNfactory scientists and the children on Scratch regularly exchanged all three types of information within their respective chats.

Context information pertains to issues related to the work and environment context. These comments involve, for example, scheduling the work, asking about a person's state (especially important in the remote case), or discussing the politics of the group.

Task information relates directly to the job that needs to get done, whether it is science, programming, or game content and design, depending upon domain. We also noted a fair amount of discussions about collaboration and technical questions and answers, so wanted to capture those in separate subcategories.

Socio-emotional discussions consist of socializing and personal discussions not necessarily related to work. These could include greetings, personal opinions, technical puns and jokes, praise and criticism, and thanks to other collaboration members.

SNfactory

We studied the archives of two active chat rooms used by the SNfactory during daily operations. The first chat room (referred to here as the postdoc chat) is used during normal business hours, and the chat participants primarily consisted of postdoctoral researchers (postdocs) and graduate students

Tag	Category	Examples
C	**Context**	**issues related to work, but not directly task-related, e.g. organization or scheduling**
C:S	Scheduling/ process/ politics	arranging when to meet, how to organize work, group politics
C:T	Technology	e.g. system administration, hardware
C:Q	Questions & Answers	questions about context issues
C:SE	Socio-Emotional	socializing specifically to give context about remote environment, e.g. it's cold here, I'm eating lunch now
T	**Task**	**related directly to the job that needs to get done**
T:W	Work	Science (Scratch analogy is game content and design), writing code, technical operations
T:C	Collaborative Decision Making	discussions about how to get the work done
T:Q	Technical Q&A	asking for technical help
SE	**Socio-Emotional**	**socializing, personal discussions**
SE:S	Socializing	greetings, personal discussions
SE:W	Work-Related	social comments about the work (not specifically technical)
SE:T	Technical	technical jokes and puns

Table 1. Coding taxonomy with three major categories: Context, Task, and Socio-Emotional

working at the SNfactory. Over the course of two years (Sept 2005 - Sept 2007), two of the authors actively participated in the postdoc chat room. During this two-year period, 21 people participated in the chat.

The second chat room (referred to here as the summit chat) is used during telescope observation at Mauna Kea. Members of the collaboration are assigned to remotely operate the telescope and other related processes, and the responsibility is shared by senior scientists, postdocs, and graduate students. We participated in the summit chat room over a three-month period (Apr 2007 - Jun 2007).

Both chat rooms were set up by the younger, more junior scientists (postdocs). The postdoc chat was used almost exclusively by the junior scientists, while senior scientists participated regularly in the summit chat.

We then interviewed three scientists who participated in both chat rooms. During the course of two years, we actively participated in both formal and ad hoc group meetings, both in person and online.

Scratch

We analyzed 1470 comments posted on the Green Bear Group gallery on the Scratch website. Over a period of three months, we observed two of the members at their computers participating in GBG creative work. We created a 30-question online survey, including questions about methods of collaboration, group work, and socio-emotional issues, and a link was sent to all GBG members. 15 members responded to the survey.

LOG ANALYSIS RESULTS

We present the results from the log analysis first, and then discuss them in detail in later sections. The overall distribution of the top-level categories – Context (C), Task (T), and Socio-Emotional (SE) – was as follows. For the SNfactory chats, 45% of the comments concerned Task, 32% Socio-Emotional, and 23% Context. (We group the content of the two chats here for brevity, but break the data down by chat in subsequent sections.) In Scratch, 19% of the comments concerned Task, 49% Socio-Emotional, and 32% Context. We compared these values to the chat analysis results Olson et al. [39] obtained in their seminal study of the scientific collaboratory UARC during the 90s (Figure 3).

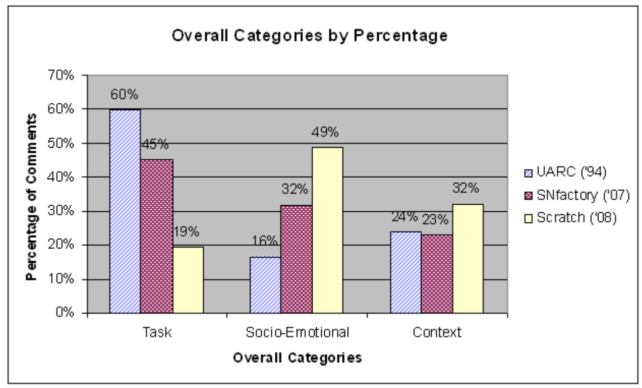

Figure 3. Coding of chat logs from three collaborations

One must be cautious and not read too much into the apparent trends in these results. Olson et al. used a different coding scheme, and we have made only a rough translation into our taxonomy. However, we believe it may be significant that the amount of socio-emotional chat is much larger in the more contemporary collaborating groups.

The breakdown of individual subcategories is given in (Figure 4). Note that the most popular subcategory for the children is SE:Socializing at 28%; this is the second-most popular subcategory for the scientists at 16% (after Task:Work at 23%).

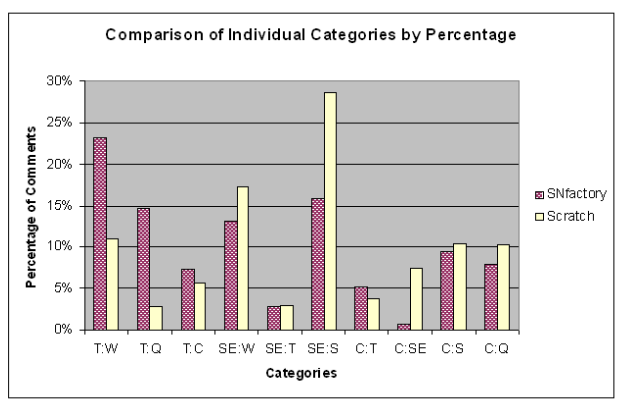

Figure 4. Subcategory breakdown: SNfactory and Scratch chat

In-person communication in groups tends to be dominated by a few active speakers, followed by a much larger group of infrequent contributors [39] (in other words, the comment frequency distribution approximates Zipf's Law, with larger groups showing a longer tail to the right). Previous studies [47] have suggested that online communication may show different patterns from face-to-face communication, and may equalize communication levels. Olson et al. [39], however, found that not to be true for UARC scientists. Our results (Figure 5) confirmed Olson's results: the Zipf's Law distribution holds for both the scientists and the children.

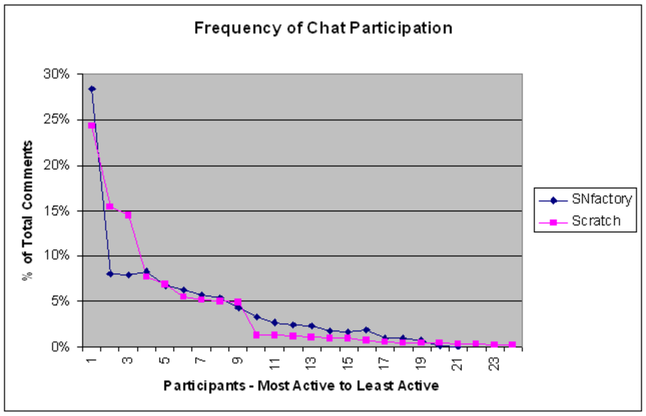

Figure 5. Frequency of chat participation

SNFACTORY CASE STUDY

Postdoc Chat

Background on the postdoc work environment

During the time of our study, the majority (although not all) of the postdoctoral and graduate student members of the SNfactory at LBNL worked in a single room, referred to as the postdoc room. The postdoc room housed between 4 - 5 scientists, each working in a small cubicle. Although from any given cubicle one could not see all other people in other cubicles, the walking distance between any two cubicles was short, and scientists could easily speak to each other across the room, although they preferred to isolate themselves with headphones for privacy. It was common practice among the postdocs and graduate students to log into the postdoc chat room during work hours. At times, one or more postdocs would log into the chat room remotely, either because they were working from home or at a conference in another city. The majority of these scientists had been working together for at least a year, and the scientists regularly ate lunch together. The level of technological readiness among the postdoc group was high, with most members using chat and IM outside of work. The postdocs worked on several highly interdependent tasks during the time of our study. They were building software needed for their day to day operations, and discussion about the design, implementation, and science behind this software were part of their daily tasks.

The postdoc chat content

Face-to-face communication for collaborative problem solving was common practice. However, a large fraction of the communication among these postdocs did not take place in person. Despite the fact that they were physically working in the same room, a significant amount of their communication took place over chat. On average, approximately 500 lines of chat were generated within the group chat per day. Most of the postdocs deliberately isolated themselves from others in the postdoc room by wearing headphones, drowning out noise with music.

Based on our sample set, we found that roughly 50% of the postdoc chat consisted of task-related conversations. Task-related question and answering made up 19% of the total, with common topics including asking for programming or task help. A common daily task for the scientists was *scanning*, where scientists compared images of the sky on different nights to try to determine whether a bright spot had appeared in recent images (a potential supernova). The image comparisons would at times produce ambiguous results, and it was common practice for the scanner to seek the advice of anyone actively participating in the postdoc chat. Roughly 9% of the chat involved collaborative decision making efforts, e.g. determining the best configuration for servers at the summit.

33% of the lines in the postdoc chat covered socio-emotional topics, including general complaints about work and also praise, such as thanking people for help with problem solving.

Context discussions comprised 16% of the total. The participants in the postdoc chat had very high common ground, since they were working in the same location, often on very similar tasks, so the majority of these context discussions related to scheduling, such as determining the time for a meeting.

Summit Chat

The summit chat is the primary communication medium among scientists during telescope observation. Collaborators in both France and the U.S. are among the participants in the summit chat. A night is divided into 4 shifts, typically with U.S. scientists working (remotely, at home) during the beginning and end of the night and French scientists working in the middle of the night (daytime for them), with some overlap between shifts. The scientists operating the telescope are called "shifters." Each night, a schedule of targets to observe in the sky is created, and since telescope time is both limited and expensive, it is the goal of the shift to complete the schedule. Scientists operate the telescope on VNCs, usually with one active operator and one or more people observing the VNCs in read-only mode. If no problems occur, a shift can be routine and even boring for the shifter. However, weather and technical problems often arise, sometimes resulting in the need to make critical decisions in as little as 45 seconds [41].

Many of the French and U.S. scientists have worked together for years and have met face-to-face, during annual collaboration meetings. In addition, the two groups meet monthly for videoconference meetings.

The summit chat content

39% of the chat content is related to task conversations, with 24% of the chat discussing the direct process at hand, running the software to operate the telescope and log the results of these observations. Another 10% consists of questions and answers. Shifting requires a great deal of training, so chat participants often asked each other questions in order to learn how to respond to emergent situations and how to interpret results. Additionally, whenever problems arose during the night, the shifters often found themselves in ambiguous situations and looked to other chat participants for clarification and guidance. Another 5% of the conversations involve the chat participants collectively making decisions, usually related to whether there is enough time to observe another target, and if so, what target should be observed. It should be noted that these types of highly interdependent tasks were often performed by French and U.S. scientists collaboratively, not just by the French with each other or U.S. scientists with each other. In fact, one piece of software that was often used by French novices during a difficult shift is a paging mechanism that allows the shifter to request help from experts in the U.S. During such times, the U.S. expert entered the chat room and worked with chat participants to troubleshoot problems.

31% of the summit chat consists of the exchange of context information, and 12% contains questions and answers. Because scientists enter and leave the chat throughout the night, one very common context task is to check how the night is going (whether there are problems with weather or other technical problems) by querying people in the chat. In addition, since the software to run the telescope is a single resource, much coordination is involved to avoid collisions. Despite the fact that context information makes up almost a third of the chat conversations, chat participants usually have very high common ground in regards to performing work such as troubleshooting and collaborative decision making. This is because much task, context, and environmental information is presented within shared communication and workspaces, serving as grounding tools. Additionally, we found that over time, as the scientists discovered they needed more context information, they augmented existing tools, repurposed others, and changed their behavior in using the technology. This is similar to behavior we observed in Scratch users, and will be discussed further in a later section.

30% of the summit chat is related to socio-emotional content, and about half of that is work-related and half purely social. Common work-related SE conversations included expressions of excitement about interesting results observed at the telescope, or alternatively, frustration when problems arose. The shift can be routine when no problems arise, and during these times, much socializing can occur in the chat. One scientist remarked that you could tell how well the shift is going based on the amount of "play" conversations taking place in the chat. This is a commonality with the Scratch users, where we observed a very high level of "play" and socializing, excitement and positive feedback about each other's work, and at the same time successful development of collaborative projects (as measured by "published" work). It also indicates how elements of Resnick's [42] creative spiral (imagine, create, play, share, reflect) emerged spontaneously in the scientists' collaboration, facilitated by lightweight CMC.

SCRATCH CASE STUDY

In contrast to the level of SE chat by the scientists, the children on GBG had much higher percentages of SE discussion, nearly 50%. Socializing (SE:S) accounted for 29% and socializing about work (SE:W) accounted for 17%. Typical comments in these categories included: "good morning/afternoon/whatever time it is around the world," "you are an awesome writer," "stop putting your great ideas down," "what instruments do you play," "I hope you like it," "lol," and many forms of smileys. There was a long exchange of comments on what a typical day was like for each of the children. Many of the SE comments involved praise or positive feedback for other members.

Given that the participants are children and the fact that Scratch is a hobby for the majority of them, it is perhaps not surprising that nearly 50% of their conversation is categorized as socio-emotional. However, one must not ignore the fact that communication within this group is almost exclusively online, and that the participants for the most part do not know one another. GBG, like SNfactory, is an international collaboration. Although the majority of the children live in the United States, two of the members are from England, one lives in India, and another in Poland. The members of GBG use chat to develop a common social ground, e.g. "I had a lot of good dreams last night" or "Where did you go on your vacation?" We believe that the high socio-emotional content is critical in forming the relationships and trust that are required for successful collaborative work. This is borne out by a statement in an interview, expressing comfort with sharing creative work: "I would trust [another member] because I've known her for over a year and she's really nice."

Task-related comments comprised 19% of the total. Examples included: "Hey! I found a dancing brown bear gif! will dat help," "I added V.2 of [the new game] and also i made an advertisement," "I will start programming and [another member] will make it scroll," "yes, multiple skeletons would be annoying," and "I don't think we need a game over menu, do we?" However, due to the nature of the Scratch online community, much of the task-related information was contained within the projects themselves, and we believe this partially contributes to the low percentage of task-related comments. A typical exchange might include a pointer to a new project uploaded, which all the other children will then view and make short comments (usually containing positive feedback), followed by one person volunteering to take on the next phase of the project (e.g. improving the programming or story line, or adding art or music). Because much of the content has been exchanged in a project (again establishing common ground), the text commentary can be much briefer. The projects serve the same purpose for GBG as the VNC does for the scientists -- a rich common ground upon which to base communication.

After three months, GBG had completed 6 games. The company has one main gallery where all projects (including prototypes) are shared along with discussions that help the team organize themselves. GBG has a separate gallery to display only their completed games and another one devoted to the display of the 14 versions that it took to complete one of their early games.

Context-related comments make up 32% of the total, a slightly higher ratio than in the scientist group. Again, we believe this relates to the need to establish common ground among a purely remote collaboration. Context comments include: "Can I join [the company]?" "It says I have messages here because someone is replying to my comments, but I can't see where!" "I'm on, is anyone on?"

The last comment points to a unique use of the Scratch website. Typically, a child will post a comment, then constantly refresh the screen to see new posts from others. Essentially, the children have repurposed the comment functionality as a chat function. (This is why, in an earlier section, we referred to Scratch comments as "chat.") Through this repurposing, they develop greater presence and situation awareness. We observed similar adaptations of technology in the SNfactory as well. Users adapt both their behavior and their use of the technology to meet their communication needs over time. This is the kind of behavior that is difficult to observe in a short-term controlled study.

Another key issue for collaboration on Scratch is motivation. Why do the children work so hard to produce their video games? Survey results may point to an answer. Responses to the question, "What motivates you to work on group projects?" include "I can't let the group down," "Others are counting on me," and "people like our group's projects." People want to "do their part" and contribute. It is interesting that this anonymous group with no extrinsic motivation to collaborate feels such a strong sense of duty. Perhaps it is the extent of socio-emotional contact, even though text-based, that leads to these ties to the community.

An interview with one of the GBG members appears to confirm this. When asked about the high levels of "non-work-related" comments, she stated, "It's easier to work with someone when you know them, and it's hard to get to know each other without injecting personality and emotion into your comments. Also, saying 'good job!' motivates people to contribute good features to the games."

Another very strong motivator is social status within the community. This has been documented in other studies of online communities [28]. When children are asked why they joined the company, many answers mention "fame," "credit" or "reputation." In an intriguing parallel, for the scientists we studied, reputation is the prime motivator. As one stated, "there's certainly no money in it!"

In a related interview discussion with a GBG founder, she stated, "People want to join our company because it's successful." She then went on to note that they could be selective: "We can pick the best programmers." When asked how the group selected members, she said, "We've found that people with better spelling contribute more." This is an interesting analogue of what Goffman called a "front" in his work on the presentation of self [19]. Instead of clothes or bodily adornments, it is the individual style of text-based comments that creates a first impression online.

The GBG member also mentioned some benefits of text-based CMC over face-to-face communication. "You can be part of a group with lots of different kinds of people. The girl-boy barriers, age barriers, anything based on appearance -- you don't have those." Even the asynchronous nature of the Scratch comments across many time zones has been turned to an advantage: "Since conversations are stretched out over time, all the active members get a chance to participate." This parallels some of the advantages the astrophysicists cited for asynchronous chat communication.

It is interesting to note that rules have emerged in GBG as a result of organizational needs. For example, members need to keep active in order to maintain their membership as explained on the gallery description: "Members who aren't active and don't have a reason (sick, vacation, etc.) are not in the company any more, but if they come back they are automatically let back in because they were members before. If they disappear without an excuse many times, then they are no longer members, and their spot will be given to someone else." We also observed the spontaneous growth of self-organizing structure in the SNfactory, where rules developed to hand off telescope control and shift organization.

The need for documentation has also emerged, leading to some members creating an interactive "magazine" created in Scratch itself that narrates the events surrounding the company's activity. This correlates with the development of an SNfactory wiki (not mandated by management) collecting accumulated group knowledge such as recipes for troubleshooting telescope problems.

DISCUSSION

Our empirical observations suggest that designers of computer-supported social environments for creative collaboration should focus on building to allow repurposing, augmentation and behavior adaptation.

Dourish et al. [12] noted that over the long term, people adapt to CMC, often in surprising ways. During our long-term observations of the SNfactory and Scratch communities, we noticed changes over time in the way people used communication technologies, such as *repurposing* (e.g. Scratch users refreshing the comment screens to increase their interactivity), *augmentation* (e.g. development of new software tools within the SNfactory chat), and *behavior adaptation* (e.g. spontaneous generation of rules and structures within both communities).

While observing two of the children using Scratch, we noted at least four examples of change over the three-month period: an increased rate of refreshing the screen, a decrease in hesitancy to post comments and projects, an increase in typing speed, and a wider range of less formal commentary.

As an example of how both collaborations demonstrated repurposing, augmentation, and behavior adaptation, we consider the development of common ground. The Olson study suggests that in cross-cultural collaborations, it can be difficult to establish common ground. There is some evidence in the SNfactory chat archives to suggest this is true. For example, colloquial terms often need clarification. However, we feel one reason for the collaboration's success in performing tightly coupled work was their augmentation of the chat client by the development of grounding tools, such as a context-linked virtual assistant and software that fosters situation awareness [3, 41]. The end result was that a person could shift from anywhere in the world. People from different parts of the world could have the same amount of context about the state at the summit. In other words, the collaboration developed its own or adapted tools to build common ground.

The GBG group had negligible external common ground, as the participants were from different regions and countries and didn't know one another outside Scratch. However, the Scratch online community itself was developed to provide common ground to its members; the rich content of the projects, along with terminology, organic common structures, and a set of ground rules for behavior that evolved over time, provides common ground and engenders trust and bonding among its members, facilitating cooperative and creative work. Again, the users themselves developed or adapted technology to meet their needs for common ground.

We see this type of social common ground as playing a key role in the success of computer-mediated social creativity. In both Scratch and SNfactory, we see a significant portion of the chats being used for socio-emotional conversation, and these types of conversations help to build relationships among collaborators.

We mentioned earlier the trust that developed among long-term Scratch collaborators. Rocco [44] performed a short-term, controlled study in 1998 that showed significantly higher levels of trust were generated when participants communicated by voice rather than chat. However, more recent studies [7, 43, 51] have suggested this may not always be true. Interviews with GBG participants confirm that significant levels of trust have developed.

Both groups repurposed and augmented text-based CMC to include means of developing emotional bonds among group members, as evidenced by the high levels of socio-emotional chat content and confirmed by participant observation and interviews. Additionally, group members found advantages in characteristics of chat (such as asynchrony) that normally would be considered disadvantages.

CONCLUSIONS

We conducted a long-term, empirical study of two different communities engaged in creative work and communicating primarily via text-based CMC. Studies of such collaborations are important because many of the problems facing us today are of such complexity that a single human mind cannot encompass them [16]. Creative solutions increasingly require the interaction of many different individuals each bringing their own ideas and expertise to the problem. These individuals may be separated geographically, over time, or by level of expertise. These differences can be bridged through the use of CMC. Studies such as this one can begin to provide guidance to designers of the next generation of computer-supported social environments for creative collaboration.

We learned that one of the key elements for designers of systems to foster social creativity is a low barrier to entry. Lightweight tools that can be accessed by anyone on any platform facilitate the kind of easy, open sharing and communication that is a key component of creative collaboration. Such tools must also encourage large amounts of socio-emotional communication and play. By analyzing the chat logs of both communities, we noted the importance of socio-emotional communication to successful creative work.

Additionally, we noted repurposing and augmentation of communication technologies in both communities, and observed long-term behavior adaptation in the use of such technologies, suggesting that designers take these effects into account.

However, the contributions of this work lie not only in the observation of commonalities between the two communities, but also in the case studies themselves. For as technology changes the fundamental character of human communication, the nature of collaborative activity and the methods required to study it are also undergoing profound changes [4, 45]. Techniques such as the longitudinal case study are acquiring increasing prominence [45] in this changing world.

For as we discuss technology to facilitate creativity, we must also foster creativity in the technology designers themselves. One of the most time-honored methods of nurturing creativity is storytelling. Case studies are a form of the "teaching story," a very ancient form of human interaction that is often more memorable than abstractions or categorizations. In the presentation of this comparative study, we hope to extend the ways designers think about computer-supported social environments for collaborative creative work of all types.

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