No Sense of Distance: Improving Cross-Cultural Communication with Context-Linked Software Tools

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ABSTRACT

Many studies have established the difficulties inherent in both cross-cultural and distance communication. Distance work interferes with close collaboration and trust. Physical distance and lack of time zone overlap can exacerbate cross-cultural misunderstandings. Nevertheless, international collaboration over distance is becoming increasingly common in many fields. Scientific collaborations, in particular, are becoming larger and more international in scope. There has been much research in the area of understanding cultural differences, but not as much in how technology might bridge such communication gaps in international scientific collaboration. In an effort to begin to form guidelines for such technology development, we undertook an empirical study of how computer-mediated communication tools facilitated cross-cultural communication over distance and led to greater team effectiveness in an international astrophysics collaboration.

Categories and Subject Descriptors

H5.3. [**Information interfaces and presentation**]: Group and organization interfaces–Computer-supported cooperative work.

General Terms

Human Factors.

Keywords

Computer-mediated communication, cross-cultural collaboration, scientific collaboration.

1. INTRODUCTION

As the world becomes increasingly networked and globalized, the need to conduct collaborative work across geographic and culture boundaries increases correspondingly. Numerous studies [8, 16] have elucidated the challenges of cross-cultural collaboration [9] as well as distance work [17], especially when performing complex technical or scientific work. At the same time, budgetary constraints often preclude frequent in-person meetings or individual cross-cultural training. Lightweight computer-mediated communication (CMC) tools could potentially ameliorate some of these communication difficulties, such as the tendency to assume the worst [22] of your partner in remote communication, but only if they take into account cultural differences that may exist in international groups.

We conducted a long-term ethnographic study and chat log analysis of an international astrophysics collaboration (with members primarily located in France and the United States) in operation during 2004-2008. The scientists performed their astrophysical observations and analysis with the aid of a set of CMC technologies including what have been called "context-linked" tools [19], where both task information (immediately pertinent to the job at hand) and context information (background processes and events in the environment) are directly included in the shared communication space.

We developed our study within the framework of Hofstede's cultural dimensions [9-11], and specifically studied areas where the two subject countries (France and the United States) had recognized cultural differences. We identified sections in the chat logs that demonstrated these cultural differences, and then observed how the software tools used by the collaboration fostered the bridging of these differences in cultural styles over time. We then conducted interviews of collaboration members to evaluate how the context-linked software tools facilitated this process of increased cultural understanding.

Scientists on the team report that over the period of the experiment (2004-2008), incidents of cross-cultural misunderstandings decreased significantly over time, team cohesion increased, the rate of data collection increased by a factor of four, and the rate of human error decreased by an order of magnitude. They attribute much of this improvement in team performance to the development of the context-linked software tools. The scientific effort successfully collected the largest homogeneous supernova data set to date, and produced many significant astrophysics publications.

The contribution of this paper lies in the case study of context-linked software tools bridging cultural differences. Previous work has described the development of the software tools in detail [2, 19]; this paper presents the study of how team members used the tools to span cultural gaps in the context of Hofstede's cultural dimensions. Although there have been many critiques of Hofstede's work, including his use of a sample of primarily IBM employees, the age of his data (over 30 years ago) and his assumption of cultural homogeneity [12, 14, 15], there are few frameworks available to use to study cultural differences. We believe Hofstede's work is still useful as a lens through which to view and discuss cross-cultural collaboration. Clearly, it is a difficult and elusive subject; we do not

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presume that we have found the definitive solution to the problem of enabling cross-cultural groups to transcend their differences. However, we believe the case study is illuminating and that the work can make a contribution to the development of guidelines for the design of CMC tools for distributed cross-cultural groups.

2. CROSS-CULTURAL SCIENTIFIC COLLABORATION

The Nearby Supernova Factory (SNfactory) [1] is an international astrophysics collaboration studying supernovae (exploding stars) (Figure 1) 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. During each observing night, the telescope is typically operated by a geographically separated group of two to six people. 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 in person, and about half are not native English speakers.

Figure 1. Hubble Space Telescope image of supernova SN1994D in galaxy NGC4526, observed 1994.

The astronomers' task of observing the heavens with a large, multi-million dollar telescope from a remote observing station is challenging and involves working under time pressure. Scientists must operate as a team to monitor a large and complex set of operational data while maneuvering the telescope within constraints; the violation of these constraints could lead to loss of data or even damage to the telescope. Close coordination on telescope observation tasks is critical.

Due to the expense of telescope time, nights are often fully scheduled with an array of astronomical objects, which must be observed in a particular order in a tightly scheduled timetable for maximum scientific benefit. Further, the phase of the moon, upper air turbulence, fog, and changing cloud conditions throughout the night can cause unpredictable variations in the schedule, as certain objects may be no longer visible at their appointed time slots.

Team members must be able to analyze and evaluate a large amount of data and rapidly make cognitively demanding calculations, while at the same time being fully aware of changing weather conditions, the approach of daylight and other safety issues. These challenging conditions create stress and compound the difficulties of cross-cultural communication, especially if team members are using a language that is not their native tongue.

Due to the difficulty of the overall science task, multiple software tools were developed to ease the process and increase scientific output. Collaboration scientists use chat (augmented by a virtual assistant) and VNC (virtual network computing) as their primary means of communication during remote telescope observation (referred to as the "shift" due to the fact that collaboration members sign up for specific time slots) (Figure 2).

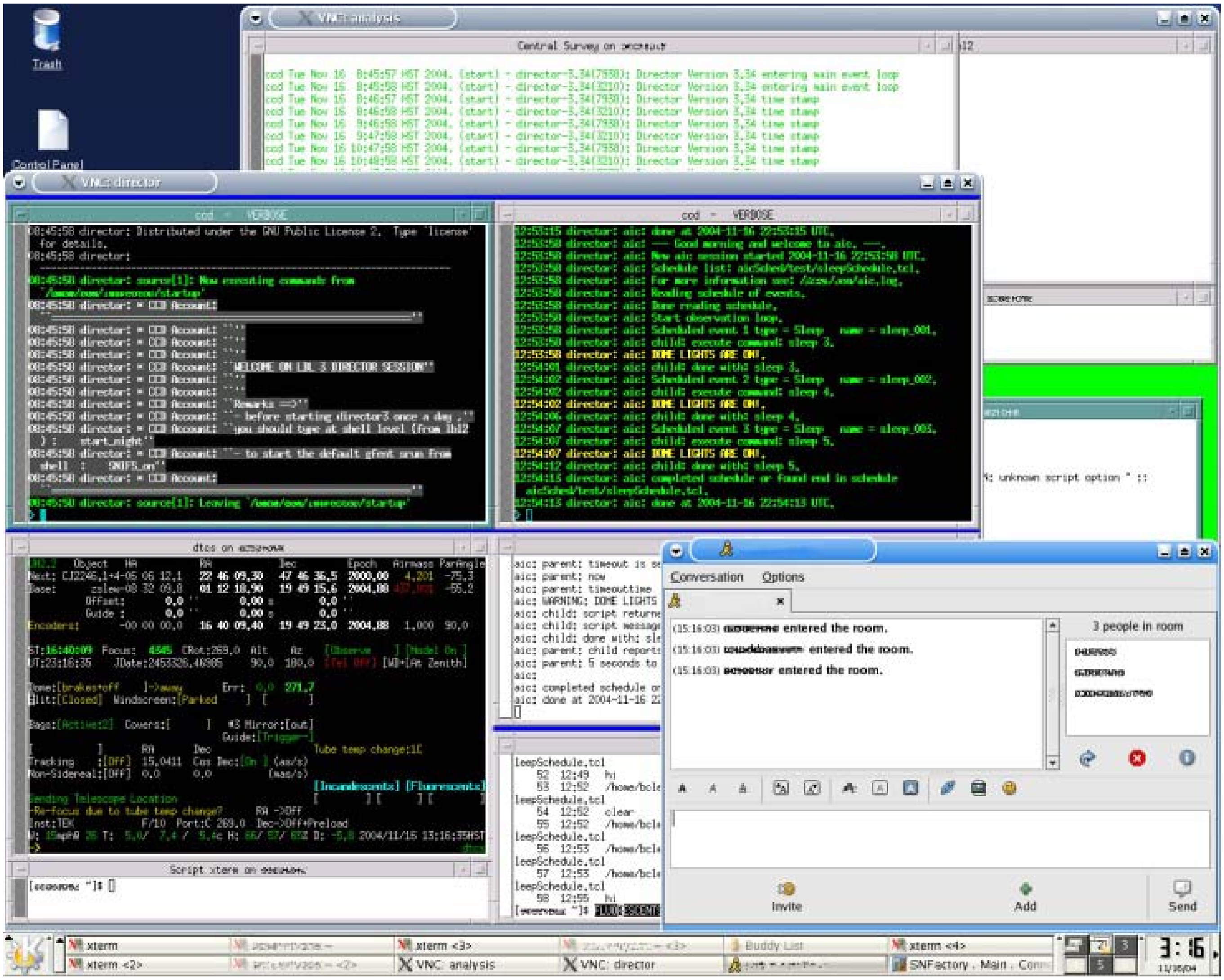
Multiple studies of scientific collaborations have shown that chat can be used as a grounding and orienting tool and can facilitate asynchronous communication [3-7].

3. SCIENCE BACKGROUND

One of the grand challenges in astrophysics today is the effort to comprehend the mysterious "dark energy," which accounts for three-quarters of the matter/energy budget of the universe. The existence of dark energy may well require the development of new theories of physics and cosmology. Dark energy acts to accelerate the expansion of the universe (as opposed to gravity, which acts to decelerate the expansion). Our current understanding of dark energy comes primarily from the study of supernovae [18, 21].

The SNfactory [1] is an astrophysics experiment designed to discover and measure Type Ia supernovae in greater number and detail than has ever been done before. These supernovae are stellar explosions that have a consistent maximum brightness, allowing them to be used as "standard candles" to measure distances to other galaxies and to trace the rate of expansion of the universe and how dark energy affects the structure of the cosmos. The SNfactory receives 50-80 GB of image data per night, which must be processed within 12-24 hours to find potential supernova candidates immediately and obtain maximum scientific benefit from the study of these rare and short-lived stellar events.

Promising supernova candidates are sent for confirmation and spectrophotometric follow-up by SNIFS (the SuperNova Integral Field Spectrograph) [13] on the University of Hawaii 2.2m telescope on the summit of Mauna Kea (Figure 3). Candidates are imaged through a 15 x 15 microlens array on SNIFS, the spectral data are processed at the summit, and then saved to a remote database.



Central Survey on [redacted]

```
cod Tue Nov 16  8:45:57 HST 2004. (start) - director-3.34(7938): Director Version 3.34 entering main event loop
cod Tue Nov 16  8:45:58 HST 2004. (start) - director-3.34(3210): Director Version 3.34 entering main event loop
cod Tue Nov 16  8:46:57 HST 2004. (start) - director-3.34(7938): Director Version 3.34 time stamp
cod Tue Nov 16  8:46:58 HST 2004. (start) - director-3.34(3210): Director Version 3.34 time stamp
cod Tue Nov 16  9:46:58 HST 2004. (start) - director-3.34(7938): Director Version 3.34 time stamp
cod Tue Nov 16  9:47:58 HST 2004. (start) - director-3.34(3210): Director Version 3.34 time stamp
cod Tue Nov 16 10:47:58 HST 2004. (start) - director-3.34(7938): Director Version 3.34 time stamp
cod Tue Nov 16 10:48:58 HST 2004. (start) - director-3.34(3210): Director Version 3.34 time stamp
```

cod - VERBOSE

```
08:45:58 director: Distributed under the GNU Public License 2.  Type 'license'
  for details.
08:45:58 director:
  ------------------------------------------------------------------------------
08:45:58 director: source[1]: Now executing commands from
  '[redacted]/startup'
08:45:58 director: * CCD Account:
  ``______________________________________________________''
08:45:58 director: * CCD Account: ``''
08:45:58 director: * CCD Account: ``''
08:45:58 director: * CCD Account: ``''
08:45:58 director: * CCD Account: ``WELCOME ON LBL 3 DIRECTOR SESSION''
08:45:58 director: * CCD Account: ``''
08:45:58 director: * CCD Account: ``''
08:45:58 director: * CCD Account: ``Remarks ==>''
08:45:58 director: * CCD Account: ``- before starting director3 once a day ,''
08:45:58 director: * CCD Account: ``you should type at shell level (from lbl2
  ) :     start_night''
08:45:58 director: * CCD Account: ``- to start the default gfont snus from
  shell  :    SNIFS_on''
08:45:58 director: * CCD Account:
  ``______________________________________________________''
08:45:58 director: source[1]: Leaving '[redacted]/startup'
>
```

cod - VERBOSE

```
12:53:15 director: aic: done at 2004-11-16 22:53:15 UTC.
12:53:58 director: aic: --- Good morning and welcome to aic. ---.
12:53:58 director: aic: New aic session started 2004-11-16 22:53:58 UTC.
12:53:58 director: aic: Schedule list: aicSched/test/sleepSchedule.tcl.
12:53:58 director: aic: For more information see: /[redacted]/aic.log.
12:53:58 director: aic: Reading schedule of events.
12:53:58 director: aic: Done reading schedule.
12:53:58 director: aic: Start observation loop.
12:53:58 director: aic: Scheduled event 1 type = Sleep   name = sleep_001.
12:53:58 director: aic: child: execute command: sleep 3.
12:53:58 director: aic: DOME LIGHTS ARE ON!.
12:54:01 director: aic: child: done with: sleep 3.
12:54:02 director: aic: Scheduled event 2 type = Sleep   name = sleep_002.
12:54:02 director: aic: child: execute command: sleep 4.
12:54:02 director: aic: DOME LIGHTS ARE ON!.
12:54:06 director: aic: child: done with: sleep 4.
12:54:07 director: aic: Scheduled event 3 type = Sleep   name = sleep_003.
12:54:07 director: aic: child: execute command: sleep 5.
12:54:07 director: aic: DOME LIGHTS ARE ON!.
12:54:12 director: aic: child: done with: sleep 5.
12:54:13 director: aic: completed schedule or found end in schedule
  aicSched/test/sleepSchedule.tcl.
12:54:13 director: aic: done at 2004-11-16 22:54:13 UTC.
>
```

```
4: unknown script option " ::
```

dtcs on [redacted]

```
UH2.2     Object    HA              RA           Dec          Epoch     Airmass  ParAngle
Next: CJ2246.1+4-05 06 12.1    22 46 09.30   47 46 36.5   2000.00    4.201    -75.3
Base:       zslew-08 32 00.0    01 12 18.90   19 49 15.6   2004.88             -55.2
         Offset:         0.0 ''        0.00 s        0.0 ''
         Guide :         0.0 ''        0.00 s        0.0 ''
Encoders:          -00 00 00.0    16 40 09.40   19 49 23.0   2004.88    1.000    90.0

ST:16:40:09  Focus:  4545  CRot:269.0  Alt    Az    [Observe    ] [Model On ]
UT:23:16:35    JDate:2453326.46985      90.0  180.0  [Tel Off] [WD+[At Zenith]

Dome:[brakes+off    ]->away        Err:  0.0  271.7
Slit:[Closed]  Windscreen:[Parked      ] [        ]

Bags:[Active:2]   Covers:[      ]   #3 Mirror:[out]
                                    Guide:[Trigger-]
[          ]       RA        Dec                    Tube temp change:1C
Tracking    :[Off]  15.0411  Cos Dec:[On ] (as/s)
Non-Sidereal:[Off]  0.0       0.0          (mas/s)
                                                   [Incandescents] [Fluorescents]
Sending Telescope Location                         [          ] [      ] [      ]
-Re-focus due to tube temp change?       RA ->Off
Inst:TEK            F/10  Port:C 269.0  Dec->Off+Preload
W: 15mph@ 35 T:  5.0/  7.4 /  5.4c H: 66/ 57/ 69% D: -5.8 2004/11/16 13:16:35HST
->
```

Script xterm on [redacted]

```
[[redacted] ~]$ 
```

```
aic: parent: timeout is se
aic: parent: now
aic: parent: timeouttime
aic: WARNING: DOME LIGHTS
aic: child: script returne
aic: child: script message
aic: child: done with: sle
aic: parent: child reporti
aic: parent: 5 seconds to
aic:
aic: completed schedule or
aic: done at 2004-11-16 22
```

```
leepSchedule.tcl
    52  12:49   hi
    53  12:52   /home/bcle
leepSchedule.tcl
    54  12:52   clear
    55  12:52   /home/bcle
leepSchedule.tcl
    56  12:53   /home/bcle
leepSchedule.tcl
    57  12:53   /home/bcle
leepSchedule.tcl
    58  12:55   hi
[[redacted] ~]$ FLUORESCENTS
```

(15:16:03) [redacted] entered the room.

(15:16:03) [redacted] entered the room.

(15:16:03) [redacted] entered the room.

3 people in room

[redacted]

[redacted]

[redacted]

Figure 2. VNC telescope control window with chat client

Figure 3. University of Hawaii 2.2m telescope on the summit of Mauna Kea

4. CULTURAL DIMENSIONS

Cross-cultural research conducted by Geert Hofstede over a period of thirty years and across over sixty countries yielded a theory of cultural relativism that includes five key dimensions that categorize the differences between cultures [9-11]. In this paper, we focus on two of these dimensions, where Hofstede finds the greatest differential between France and the United States: *power distance* and *uncertainty avoidance*. We also emphasize Hofstede's results in university and academic institutions as most relevant to the scientific collaboration studied here, consisting primarily of professors, senior scientists, junior scientists, and students.

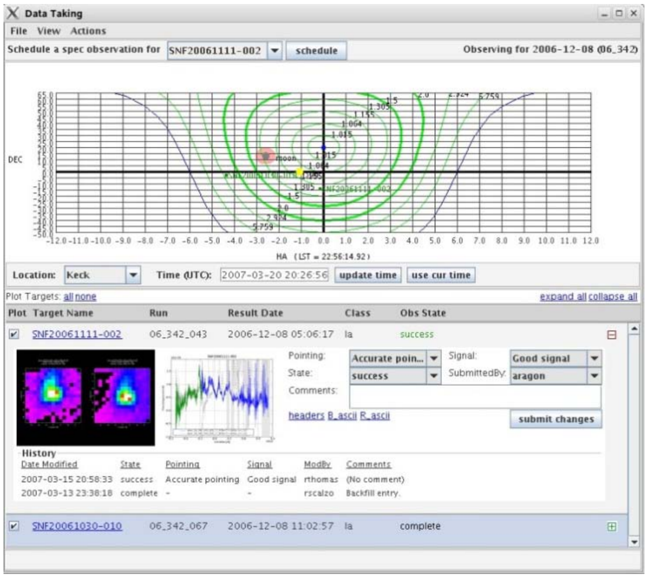
Hofstede defines *power distance* as the degree to which less powerful members of societies or organizations tend to accept that power is distributed unequally. In cultures showing high power distance, subordinates, or those lower in the hierarchy, expect to be told what to do. For example, students will speak up only when invited to; they expect the instructor to initiate communication and will not tend to publicly criticize those above them in the hierarchy. In a low power distance academic culture, instructors expect to be treated as equals by students; students are supposed to take the initiative to ask questions when they do not understand something. Hofstede found that France has a relatively high power distance of 68 (out of 100), while the United States scores lower at 40 [11].

Uncertainty avoidance, as defined by Hofstede, refers to the tendency of individuals to feel uncomfortable in unstructured situations. Uncertainty-avoiding cultures tend toward strict rules, safety measures, and the belief that there is an ultimate truth. Individuals tend to express more emotion and anxiety in work situations. Individuals from uncertainty-accepting cultures, on the other hand, tend to profess more tolerance of different opinions and open-ended situations, and have less room to express emotions in their work environment. Along this axis, France scores 86 while the United States scores only 46 [11].

5. SOFTWARE TOOLS

We discuss two software tools developed for the SNfactory collaboration. "Bert" is a virtual assistant or chatbot that operates within the group chat room and provides event notification (e.g. time of sunrise, exposure completion), answers questions about telescope and system status, and enables text messaging of team members. Sunfall Data Taking is a web-based visual analytics interface designed specifically for collaborative telescope observation and supernova data collection and analysis (Figure 4).

Bert was developed to assist the astronomers to maintain awareness of the approach of sunrise and perform time-critical science tasks. Bert has two main functions: announcing relevant events, such as completed exposures or the number of minutes until sunrise, and responding to user queries for information. It has been in operational use since 2005. Bert's interface was built through a process of cross-cultural user-centered design. For example, originally the French shifters acted offended when Bert did not respond when they greeted him or when they entered the chat, so Bert's interface was modified to respond and to greet each person by name as they entered. Other modifications in Bert's interface were made over time, based on scientist feedback [19].



Schedule a spec observation for SNF20061111-002

Observing for 2006-12-08 (06_342)

Location: Keck

Time (UTC): 2007-03-20 20:26:56

Plot	Target Name	Run	Result Date	Class	Obs State
☑	SNF20061111-002	06_342_043	2006-12-08 05:06:17	Ia	success
☑	SNF20061030-010	06_342_067	2006-12-08 11:02:57	Ia	complete

Pointing: Accurate poin...

Signal: Good signal

State: success

SubmittedBy: aragon

Comments:

History

Date Modified	State	Pointing	Signal	ModBy	Comments
2007-03-15 20:58:33	success	Accurate pointing	Good signal	rthomas	(No comment)
2007-03-13 23:38:18	complete	-	-	rscalzo	Backfill entry.

Figure 4. Sunfall Data Taking window. The observer can retrieve supernova data, take notes on the success or failure of each observation, telescope status and weather conditions, and reschedule observations if necessary.

Both Bert and Sunfall Data Taking include in the shared communication space both task information pertinent to the immediate job, and context information such as background processes or events. This software has been described as *context-linked* [19]. We found evidence that presence of these tools in the shared communication space facilitated interaction and the development of common ground among the scientists.

6. CASE STUDY

6.1 Methodology

The SNfactory collaboration consists of about 30 astrophysicists in the United States and France. Although group membership is somewhat fluid as members join and leave the collaboration, typically the membership has been evenly distributed between the US and France, with approximately equal numbers of each nationality holding the positions of senior scientists (scientists with permanent research positions), junior scientists (postdoctoral fellows and other scientists with temporary or term-limited positions), and graduate students. Typically about 35% of the participants are senior scientists, 50% are junior scientists, and 15% are graduate students. The collaboration is usually around 10% female.

The collaboration agreement was signed in 2001, when the group began building the dedicated spectrograph for the project. Operations began in 2004.

The authors were active participants in the SNfactory collaboration from 2005-2008, developing software specific to the scientists' needs, and attending both formal collaboration meetings and informal get-togethers. Study methods included participant observation, semi-structured interviews, and chat log analysis.

Shifting is a collaborative and distributed task, which is facilitated by the use of chat. Since 2004, the logs of these chats have been archived, with sparse records of chats prior to 2004. The archive contains over half a million lines of bilingual (English and French) dialog. Since 2004, over 60 participants from both US and French universities have participated in this chat, including junior and senior scientists, engineers, and telescope operators. Starting in 2005, the authors were participants in the chat. The analysis of this chat archive, including coding of a portion of this archive, is part of an ongoing study of the use of chat in scientific collaboration (analysis of this coding not included in this paper).

For this paper, we focused mainly on evidence of technological mediation of cross-cultural differences or miscommunications along the dimensions of power distance and uncertainty avoidance. Since the archive is so large, we targeted our analysis by focusing on 15 scientists, categorized by status (senior, junior, or student), and nationality (US or France) (Table 1). We randomly selected dates when particular scientists were scheduled to shift, approximately five dates each (with overlap). Because a major software effort occurred in 2007, we also examined nearly all the chat logs that occurred between April 2007 and December 2007.

Table 1. Categorization of nationalities and statuses for 15 scientists studied for this paper.

	France	**US**
Senior scientists	3	2
Junior scientists	4	4
Graduate students	1	1

In addition to chat log analysis, our research includes data collected using ethnographic techniques of participant observation and interviews.

We conducted over 100 hours of in-person and dozens of email interviews with a total of 26 scientists, 16 from the United States, and 10 from France. Two of the interviewees were female. For this particular paper, we focused on interviews of the 15 scientists described above. We also performed followup interviews with four of the target scientists to confirm and elaborate on findings from our chat analysis and ethnographic data. Two of these scientists were from the US and two from France.

We collected over 500,000 lines of bilingual (English and French) chat spanning nearly five years of collaboration. For this paper, we focused mainly on evidence of technological mediation of cross-cultural differences or miscommunications along the dimensions of power distance and uncertainty avoidance.

6.2 Findings

We found indications both in the chat logs and in interviews that the context-linked software tools were bridging cultural differences. The tools were lightweight and easy to use, and they were immediately and continuously available to all collaboration members. The ubiquitous presence of the software within the shared communication space lowered barriers to acceptance and facilitated frequent informal communication.

In our interviews, scientists reported that over the period studied (2004-2008), incidents of cross-cultural misunderstandings decreased significantly, team cohesion increased, the rate of data collection increased by a factor of four (from an average of four targets successfully observed per night to 15-20), and the rate of human error decreased by an order of magnitude.

Because this was a field study and not a controlled experiment, we cannot definitively state that the context-linked software tools were responsible for the improvements in any of these metrics. However, in interviews, the scientists unanimously stated that the tools were of significant benefit to them, and that they believed that the software facilitated their work, lowered their stress levels, and improved cross-cultural understanding.

6.2.1 Power Distance

At the beginning of the experiment, novice French members of the collaboration remotely operating the telescope sometimes did not understand the next steps in the very complex nightly observation process. One stated in an interview that they did not usually ask questions on the shift, expecting to be told what to do by the experts. This is typical of a high power distance society. On the other hand, the US scientists (low power distance) expected they would ask questions if they didn't know what to do. This led to some early misunderstandings between the two groups when telescope observation was not conducted correctly and data was lost.

The implementation of Bert, the virtual assistant in the telescope chat room, led to greater understanding between the cultures in at least two ways. First, Bert lowered barriers to question asking. An automated assistant of negligible status did not require users to overcome reluctance to question authority. Bert’s interface was designed to foster frequent and lightweight information gathering. Although there are few pre-Bert chat logs, so a direct comparison is difficult, scientists stated in interviews that the amount of chat communication increased after Bert’s implementation because they responded to Bert’s announcements in the chat in addition to human comments. As a result, even novices began to ask operational questions with more frequency. This, in turn, according to project scientists, led to a lower rate of human error during the shift, estimated by one scientist as a decrease of an order of magnitude in the rate of human error over four years of telescope operation (as measured by the number of failed stellar observations over time).

Secondly, Bert logged all instant messages (both automated and human) in the chat room with a timestamp and participant identification. This not only captured instrument and software status, but also human reaction to excursions from normal procedures and gave an indication of the operator’s state of mind at the time of deviation or system error. As a result, by reviewing the logs, scientists could gain insight into chat participants’ assessment of system status. One scientist stated in an interview that “experts did not at first realize the steep learning curve that non-experts and beginner shifters had to contend with.” This awareness then led to improved training methodology and increased discussion among the collaboration as to best operational practices.

The senior scientists in the US at first expected that the shifters would at least the next day send emails explaining their problems. However, the shifters very rarely did this. As a result, some of the American scientists felt the shifters weren't investigating enough, e.g. checking acquisition images, before concluding that effects such as clouds were responsible for bad images. As time went on, and it became a regular procedure for senior US scientists to read the chat during difficult nights and send training email the next day, shifters learned how to better handle similar situations. In other words, the behavior of both groups moved slightly closer to each other along the power distance axis.

In a 2009 interview with an American scientist, he stated that he once thought that some of the French scientists “didn’t care” about the success of the experiment; but that as he read the chat logs, he realized this was an erroneous perception. He characterized the current working of the collaboration as “very smooth” and attributed much of it to improved software tools that enabled abundant casual communication among collaboration members as well as more streamlined automation of telescope operation.

6.2.2 Uncertainty Avoidance

One of the attributes of the uncertainty avoidance index is "feeling stress or nervousness at work." A repeated concern of French scientists operating the telescope was the “stress” they felt during the remote shift. An example from the chat was the comment, “comme c'est mon premier shift 100% tout seul je commencais à drolement stresser.” [“since it’s my first shift 100% alone, I really began to stress.”] Analysis of the logs revealed that no American scientists mentioned stress during the chat, while the French used a form of the word “stress” in English or French over a dozen times. (Table 2).

Table 2. Use of the word “stress” in either English or French in the chat logs, 2004-08, broken down by nationality.

US	France
0	13

The Sunfall Data Taking (DT) interface was designed to facilitate telescope operation situational awareness and ease of scientific data access and entry. In interviews, French scientists specifically mentioned the program’s calming effects:

“Having a visual view of the schedule / candidates in this sky image has been extremely useful. Also, and this is one of my main remarks, taking data is hard [on] your nerves ... and when you are nervous ...you make lots of mistake[s] / bad choice[s]”

“[T]o be honest, the end of night / sunrise is not a stress at all today as it was in the past.”

“In 2007 we had really good efficiency; users [made] minimal mistakes ... and on this point [DT] helped a lot by ‘cooling down’ the shifter.”

“To be brief DT changed my life...”

6.2.3 Bilingual Communication

The official language of the collaboration was English, but whenever the French were alone in the chat, they used French amongst themselves. As soon as an American entered, they immediately switched to English.

Several scientists remarked in interviews that bilingual communication was eased due to the availability of chat. One scientist mentioned “chat users are very tolerant of a lot of odd phrases,” and described “the development of shifter patois” involving literal translations from French to English, such as “take the hand” for “take control of the telescope.”

7. DISCUSSION AND FUTURE WORK

We presented a case study of the deployment of context-linked software tools in an international astrophysics collaboration, and described examples where these tools facilitated cross-cultural communication in the framework of Hofstede’s cultural dimensions. According to interviews with scientists, these software tools were credited with increasing team communication, leading to improved team morale, reduced rates of human error, and eventually scientific collaboration success (as measured by an increase in astrophysics journal publications).

One scientist stated that due to the frequent remote collaboration over chat and VNC, that he felt that there was “no sense of distance” in the SNfactory. When the collaboration was initially just using monthly videoconferences and no instant messaging, he felt that he didn’t know the other collaboration members personally. But once they started using chat, Bert, Data Taking, and other software tools, it seemed that “everything collapsed,” and that “everybody was basically just next door.” For example, it was through the use of chat that he learned that another scientist’s wife was expecting a baby that night.

We believe that this initial evidence may provide design guidance for collaborative software for multi-cultural teams. Lightweight, context-linked tools with low barriers to entry, being easy to use and incorporated in the shared communication space, appeared to have the specific effect of overcoming cross-cultural communication obstacles.

In reading the extensive bilingual chat logs, we found many intriguing conversations that point to potential cultural differences and ability of custom software tools to overcome such cultural barriers. We plan to evaluate the full corpus of half a million lines of chat logs in further detail, including the employment of natural language processing to categorize conversations and detect further correlations between software deployment and user behavior.

8. ACKNOWLEDGMENTS

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