Is Representational Guidance Culturally Relative?

Ravi Vatrapu, Center for Applied ICT (CAICT), Copenhagen Business School, vatrapu@cbs.dk
Daniel Suthers, Dept. of Information and Computer Sciences, University of Hawai'i, suthers@hawaii.edu

Abstract: The basic hypothesis of this research project is that since the perception and appropriation of affordances vary across cultural dimensions, representational guidance may be culturally relative. An experimental study was conducted to evaluate this hypothesis. The study design consisted of three independent groups of dyads from similar or different cultures (American-American, American-Chinese, and Chinese-Chinese) doing collaborative problem-solving in a knowledge-mapping learning environment. Participants interacted through an asynchronous computer interface providing multiple tools for interaction (diagrammatic workspace, embedded notes, threaded discussion). Based on empirical findings documenting cross-cultural variations in communication and cognition, several research hypotheses were advanced. Statistical results show that members of different cultures appropriated the resources of the interface differently in their interaction, and formed differential relations with and impressions of each other. However, analyses of the individually written essays show no statistically significant differences in learning outcomes. Implications for CSCL are discussed.

Introduction

The central premise of the representational guidance line of work is articulated by Suthers (2001b) as:

> The major hypothesis of this work is that variation in features of representational tools used by learners working in small groups can have a significant effect on the learners' knowledge-building discourse and on learning outcomes. The claim is not merely that learners will talk about features of the software tool being used. Rather, with proper design of representational tools, this effect will be observable in terms of learners' talk about and use of subject matter concepts and skills.

The above hypothesis follows from two lines of reasoning. The first line of reasoning focuses on properties of representational notations (as realized in representational tools and artifacts) that can bias users of the notations to take certain actions over others (Suthers, 2001b). A given notation *constrains* what can logically be expressed, and information that is expressed will be differentially available depending on what the notation makes *salient* relative to a given user. These notational dimensions are not intrinsically social. The second line of reasoning identifies how the constraints and salience of notations amplify certain social interactions. As listed by Suthers and Hundhausen (2003), (1) the potential acts available in a notational system lead to *potential negotiations* between participants concerning how to act; (2) salient elements of a representation provide *referential resources* supporting further interaction about the ideas associated with those elements; and (3) mutual awareness of participants' orientation towards representations supports *implicit awareness* of each others' activity. Suthers and colleagues have experimentally demonstrated representational guidance effects in a variety of external representational learning environments, and under face-to-face and synchronous and quasi-asynchronous computer-mediated interactional conditions with dyads (Suthers & Hundhausen, 2003; Suthers, Hundhausen, & Girardeau, 2003; Suthers, Vatrapu, Medina, Joseph, & Dwyer, 2008).

There are reasons to believe that representational guidance is relative to the cultural properties of the user. Four distinct lines of empirical research have demonstrated that:

1. *Culture influences social behavior* (House, Hanges, Javidan, Dorfman, & Gupta, 2004).
2. *Culture influences communication* (Hall, 1977).
3. *Culture influences cognitive processes* (Dimaggio, 1997; Nisbett & Norenzayan, 2002; Ross, 2004).
4. *Culture influences interacting with computers* (summarized in Vatrapu & Suthers, 2007).

The research project reported here builds upon the body of empirical work listed above and investigates the cultural relativity of representational guidance. The collaborative learning paradigm is grounded in social constructivist epistemology, with some researchers in Computer Supported Collaborative Learning (CSCL) adhering to a radically dialogical epistemology of intersubjective learning (see Suthers, 2006, for a discussion of different epistemologies in CSCL). CSCL emphasizes social interaction and in the era of globalization, social interaction could often be intercultural. Research into social aspects of Human Computer Interaction (HCI) has shown that even computer-literate users tend to use social rules and display social behavior in their interactions with computers (Reeves & Nass, 1996). Social behavior is strongly grounded in culture as every person carries within himself/herself patterns of thinking, feeling and potential acting. To learn new patterns of thinking, feeling and acting one has to unlearn and/or adapt old patterns, a more difficult task than acquiring them in the first place (Vatrapu & Suthers, 2007). This research's particular concern is to empirically investigate the extent to which culture influences how participants in intra- and inter- cultural

computer supported collaborative learning environments (a) appropriate affordances, (b) perceive themselves and their collaborative others, and (b) subsequently perform on individual learning outcomes assessments. This research is not merely about Human Computer Interaction (HCI)—i.e., interacting with technology—it is also about technological intersubjectivity (TI)—i.e., interacting with people. In this paper, we focus on the appropriation of affordances and individual learning outcome measures. For results related to TI, please refer to (Vatrapu, 2007, 2008; Vatrapu & Suthers, 2009).

Methods

We designed an experimental study that introduced a variation in the cultural background of individuals (by selecting participants from a nation-state based ethnically stratified random sampling frame) but kept invariant the technological interface, collaboration task, and interactional setting. The experimental study investigated how pairs of participants from similar or different cultures (American-American, American-Chinese, and Chinese-Chinese) appropriated affordances in a quasi-asynchronous computer supported collaborative environment with external representations in order to collaboratively solve a public health problem.

Experimental Design

The experimental study design consisted of three independent groups of dyads from similar and different cultures (American, Chinese) doing collaborative problem solving in a knowledge mapping learning environment (described below). The three experimental conditions were the Chinese-Chinese *intra*-cultural condition, the American-American, *intra*-cultural condition and the Chinese-American *inter*-cultural condition.

In all three experimental conditions the dyads were given the same experimental task (described below). All the dyads interacted in the same software environment after reading the same instructions, software tutorial and demonstration. Construct validity was addressed by using existing instruments with high validity and reliability (Bhawuk & Brislin, 1992; Harper, Slaughter, & Norman, 2006; House et al., 2004; Schwartz et al., 2001; Suinn, Ahuna, & Khoo, 1992).

Materials

Software

The software environment used in this study was originally constructed in support of a research program on how representational affordances influence and are appropriated by collaborating dyads (Suthers et al., 2008). We chose to use a configuration of this environment that offered a diversity of resources for interaction, so that there would be sufficient degrees of freedom to allow cultural influences to be manifest. Figure 1 displays a captioned screenshot of the environment used in the experimental study. It has an *information viewer* in which materials relevant to the problem are displayed. This information viewer functions as a simple web browser, but the presentation of materials is constrained as discussed in the next section. The environment has a shared workspace or *information organizer* in which participants can share, organize, and discuss information they gather from the problem materials as well as their own interpretations and other ideas. The *discussion tool* below the information viewer enables participants to discuss their ideas in a threaded discussion format.

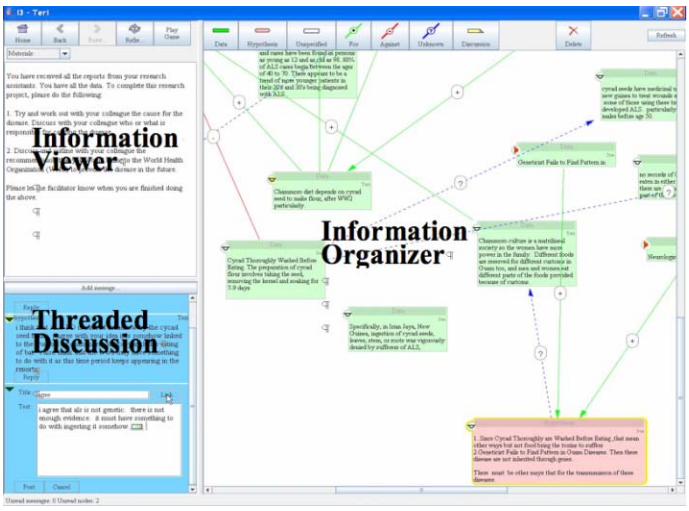

Figure 1: Screenshot from an experimental session

The information organizer includes tools derived from Belvedere (Toth, Suthers, & Lesgold, 2002) for constructing knowledge objects under a simple typology relevant to the experimental task of identifying the cause of a phenomenon (e.g., a disease), including data (green rectangles, for empirical information) and hypotheses (pink rectangles, for postulated causes or other ideas). There are also *linking* tools for constructing consistency ("for") and inconsistency ("against") relations between other objects, visualized as green links labeled "+" and red links labeled "-" respectively. "Unspecified" objects and "unknown" links provide for flexibility. Finally, an *embedded note* object supports a simple linear (unthreaded) discussion that appears similar to a chat tool; except that a note is interactionally asynchronous and one can embed multiple notes in the knowledge map and link them like any other object. In the threaded discussion section of the environment (see

Figure 1) participants can embed references to knowledge map objects in the threaded discussion messages by selecting the relevant graph object(s) while composing the message. The references show up as small icons in the message. When the reader selects the icon, the corresponding object in the knowledge map is highlighted, indicating the intended referent.

Awareness of Artifacts and Activity

The software supports mutual awareness of participants' *artifacts*. All knowledge map nodes and threaded discussion messages show the name of the creator. The mutual awareness features of *artifacts* and of *activity* are as follows: "ego" refers to the participant using the screen at hand and "interlocutor" to the study partner. The screen name selected by each participant appears on the title bar of ego's application window and on knowledge map nodes and message created by ego. Artifacts created by the interlocutor are marked with a solid red triangle in the top right corner until they are opened by ego. Artifacts created by ego are marked with a yellow circle until they are read by the interlocutor. Further, the number of unread nodes and unread messages are displayed at the bottom of the window. Thus, each ego participant is provided with cues identifying new artifacts from the study partner as well as which artifacts are not yet read by their partner.

Protocol for Workspace Updates

To simulate asynchronous online interactions, the actions of each participant in the shared workspace were not displayed immediately in the other participant's workspace. As a person worked, the actions of that person were sent to the other participant's client application, but were queued rather than displayed. Participants were given a new report (discussion forthcoming) after playing the game of Tetris™. Tetris™ was chosen as it presents a different sensory-motor perceptual task than the primary experimental task of reasoning about conflicting evidence (described below), and simulates taking a break from study (Suthers et al., 2008). After the game of Tetris™, all of the currently queued actions on that client were displayed. The delayed updating protocol simulates one aspect of the experience of asynchronous computer supported collaboration: a participant sees what one's partner has done upon returning to a workspace after a period of time. It excludes the possibility of synchronous conversation in which one participant posts a message in the workspace and receives an immediate reply.

Alternates for Action

The software environment provides multiple alternatives for action. Participants have multiple ways of sharing the information presented to them (threaded discussion, embedded notes, and knowledge-map). Participants can discuss the task at hand or any other topic of interest using the threaded discussion tool to the bottom-left of the knowledge map or the embedded notes tool within the knowledge-map. Participants can also use the knowledge-map objects to interact. Participants can refer to artifacts by deictic referencing (this, that, etc…) or use the cross-referencing feature of the threaded discussion. Participants can externalize the perceived relations between their concepts by creating evidential relation links between objects in the knowledge-map, by spatial arrangement such as proximity and clustering, or by mentioning these relations in discussion. The research strategy was to provide participants with a feature rich collaborative environment with multiple alternates for action. By incorporating systematic variation in the assignment of participants to the collaborative dyad based on their cultural background and gender, the experimental design strategy was to observe and evaluate systemic differences in how participants used the tools and resources of the technology (appropriation of affordances).

Topics

The study required participants to identify the cause of a disease on the island of Guam. This disease has been under investigation for over 60 years, in part because it shares symptoms with Alzheimer's and Parkinson's diseases. Only recently have investigators converged on both a plausible disease agent (a neurotoxic amino acid in the seed of the Cycad tree) and the vector for introduction of that agent into people (native Guamians' consumption of fruit bats that eat the seed). Over the years numerous hypotheses have been proposed and a diversity of evidence of varying types and quality explored. The unlikelihood of prior exposure to the problem, multiple plausible hypotheses, contradicting information, ambiguous data and high interpretation make this a good experimental study task for eliciting cultural differences in approaches to complex problems. All experimental study materials were in English. All participants began with a mission statement that provided the problem description and task information. Four mission statements corresponding to the four participant assignment configurations (Chinese vs. American x P1 vs. P2) were administered accordingly. Evidence was distributed across participants in a "hidden profile" (Stasser & Stewart, 1992) design that required participants to share evidence in order to expose the weakness of some proposed causes (e.g., genetics, minerals in the drinking water) as well as to construct the more complex explanation involving bats and cycad seeds (see Vatrapu, 2007, 2008). Identification of this hypothesis involves making connections across reports given to the two participants over time and considering and rejecting other explanations. The study task and task materials

are designed to highlight social division of cognitive labor. The experimental study encouraged participants to interact with each other by including the following reinforcing task instruction on each report (set of 4 articles): "*Please share and discuss this information with you colleague. Please play the game to receive the next report from your research assistant.*"

Research Hypotheses

This section discusses several research hypotheses generated from culture theory and empirical findings in cross-cultural psychology.

Research Hypothesis 1 (RH1): Chinese participants will appropriate affordances to reference regions of the knowledge maps and groups of knowledge map objects; American participants on the other hand will appropriate affordances to refer to individual objects. Experimental studies of the manipulation of "focal" objects in perceptual fields have found that East-Asian participants attended more to the perceptual field as a whole (Nisbett & Norenzayan, 2002). American participants attended more to the "focal" objects. In a knowledge map environment, Chinese participants might pay attention to a group of interrelated knowledge map objects whereas American learners might pay more attention to individual objects and evidential relational links. The cultural difference in attention might vary the ways in which referencing and deixis are carried out in collaborative discourse.

Research Hypothesis 2 (RH2): Chinese participants will create a greater number of evidential relation links in the knowledge map compared to American participants. East-Asian participants in experimental studies perceive relationships between objects more than American participants in the same experiments (Nisbett & Norenzayan, 2002). We predicted that compared to the Americans, Chinese participants will perceive more relationships between the information in knowledge map and instructional materials leading to the creation of a greater number of evidential relation links in the knowledge map.

Research Hypothesis 3 (RH3): American participants will create more threaded discussion messages compared to Chinese participants. This hypothesis was derived from the cultural difference of low-context vs. high-context communication (Hall, 1977) between American participants and Chinese participants and the cultural differences in attention and perception (Nisbett & Norenzayan, 2002). According to Edward Hall (1977), high-context cultures (e.g., Chinese) privilege social motivation in communication and low-context cultures (e.g., American) prefer rational attributes in communication. In collaborative problem solving environments, the communicative context style of the participants can influence how they engage in active discussion, elaboration and reflection. The low-context communication style of American participants might be more conducive to threaded discussion than embedded discussion.

Research Hypothesis 4 (RH4): Chinese participants will create more embedded discussion notes compared to American participants. This hypothesis was also made from the cultural difference of low-context vs. high-context communication (Hall, 1977) discussed above. Chinese participants might perceive and appropriate affordances for embedded discussion as it is in the same informational, communicational, and interactional space as the collaborative knowledge-map.

Research Hypothesis 5 (RH5): More American participants will explicitly discuss information sharing strategies and techniques than Chinese participants. Interactions in socio-technical environments are a dynamic interplay between ecological information as embodied in artifacts and individual actions grounded in cultural schemas. In low-context cultures, members might be more inclined to influence others to act by explicitly pointing out pertinent information sharing, reporting, and archiving strategies and techniques.

Research Hypothesis 6 (RH6). More American participants will explicitly discuss knowledge map organization strategies and techniques than Chinese participants. This prediction was made based on both the communication style differences (Hall, 1977) and knowledge organization differences between a reliance on categories of objects and events vs. relationships between objects (Nisbett & Norenzayan, 2002).

Participants

Participant recruitment drew from the graduate student population at the University of Hawai'i. Participant stipends were US$75.

There is a tendency in cross-cultural computer mediated communication research to use cultural models bounded by modern nation-states. Nation-state boundaries are not tantamount to culture, but nationality-based sampling frames are a methodologically convenient way to categorize participants provided that cultural differences are assessed on validated instruments. To address the possible mismatch of nation-state boundaries and cultural identity, previously validated instruments were used for assessing cultural differences (as a "manipulation check"). The Portrait Values Questionnaire (PVQ) (Schwartz et al., 2001) was used to assess cultural values at the individual level. The GLOBE instrument (House et al., 2004) was used to assess cultural dimensions at the group level. Participants were randomly assigned to either the intra- or the inter- cultural profiles and the same or different gender profiles. Excluding 6 pilot studies, a total of 33 experimental sessions involving 66 pairs of participants were conducted. Data from 3 experimental sessions was discarded due to

issues of a missing screen recording, a software crash and a disqualification. There were 10 pairs of participants for each of the three treatment groups: Chinese-Chinese intracultural; American-American intracultural, and American-Chinese intercultural groups. All the three conditions were gender-balanced as prior research has shown that gender can substantially influence social interaction (Tannen, 1996). Each treatment group included 3 female-female, 3 male-male and 4 female-male dyads.

Instruments

The different instruments used for the measurement of the constructs are listed below.

Demographic Questionnaire

A demographic questionnaire (see Vatrapu, 2007, pp. 275-276) collected participants' prior knowledge about the study problem, familiarity with each other, with online learning environments, with usability evaluation studies as well as data about age, gender, ethnic background, duration of stay in the USA, and duration of stay in the state of Hawai'i. All participants were requested to make a self-report of their cumulative grade point average (CGPA). Participants signed a release form for obtaining official records of their CGPA and graduate record examination (GRE). Chinese participants authorized release of their test of English as a foreign language (TOEFL) scores (see Vatrapu, 2007, p. 277).

Self-Perception: Portrait Value Questionnaire (PVQ)

The 40-item version of the PVQ instrument (see Vatrapu, 2007, pp. 277-279) recommended for intercultural contexts (Schwartz, S. H, personal communication) was administered. The PVQ scale measured cultural values at the individual level. Cronbach's "alpha measures of internal consistency range from .37 to .79 for the PVQ (median, .55)" (Schwartz et al., 2001, p. 532). Gender specific versions of the self perception PVQ scale were administered.

GLOBE Cultural Dimensions Instrument

The GLOBE instrument (House et al., 2004) was used to measure cultural values at the group level (see Vatrapu, 2007, pp. 280-293). Section 1 and Section 3 of the original GLOBE instrument were administered. Section 1 of the GLOBE instrument measures a responder's perceptions of their society ("Section 1 — The way things are in your society"). Section 3 of the GLOBE instrument measures a responder's preferences for their society ("Section 3 — The way things generally should be in your society"). According to the "Guidelines for the Use of GLOBE Culture and Leadership Scales", "the construct validity of the culture scales was confirmed by examining the correlations between the GLOBE scales with independent sources (e.g., Hofstede's culture dimensions, Schwartz's value scales, World Values Survey, and unobtrusive measures)" (House et al., 2004).

Individual Essays

Participants were required to write individual essays following the collaborative science problem solving exercise. Essay writing instructions were identical for all participants. The instructions asked the participants to state the hypotheses they considered. They were also asked whether and how their hypotheses and conclusions differed from those of their study partners.

Peer-Perception: Portrait Value Questionnaire (PVQ]

The second immediate post-test was the administration of the Portrait Value Questionnaire (PVQ) (Schwartz et al., 2001) instrument with a reversal of the direction of assessment (see Vatrapu, 2007, pp. 304-306). This time instead of assessing themselves, participants assessed their partners.

Acculturation: SL-ASIA Questionnaire

The experimental study recruited Chinese graduate students at a university in the USA. Acculturation occurs when members of one culture live in another culture. Acculturation becomes another variable in cross-cultural research. This can be controlled by measuring the acculturation level of the participants belonging to the minority immigrant culture (Triandis, Kashima, Shimada, & Villareal, 1986). This research project used the Suinn-Lew Asian Self Identity Acculturation (SL- ASIA) scale (Suinn et al., 1992) to measure the acculturation levels of the Chinese participants (see Vatrapu, 2007, pp. 307-311). Suinn et al. (1992) reported an internal-consistency estimate of .91 for the SL-ASIA instrument.

Intercultural Sensitivity: Intercultural Sensitivity Instrument

Intercultural sensitivity is a vital skill for intercultural collaborations (Bhawuk & Brislin, 1992). The intercultural sensitivity instrument (ICSI) (Bhawuk & Brislin, 1992) was used to measure the American participants' self-assessment of intercultural sensitivity (see Vatrapu, 2007, pp. 312-315). Bhawuk and Brislin (1992) report that "the ICSI was validated in conjunction with intercultural experts at the East-West Center with

an international sample (n=93)" (p. 423). "China" substituted for "Japan" in the original ICSI instrument for this experiment. Pilot testing showed that Part 3 of ICSI was irrelevant to the experimental task and hence not used.

User Satisfaction: QUIS Questionnaire

The QUIS 7.0 questionnaire (Harper et al., 2006) was administered to collect the participants subjective perceptions and preferences of the learning environment (see Vatrapu, 2007, pp. 316-321). The QUIS has high reliability (Cronbach's alpha = 0.95 and high construct validity (alpha = 0.86) (Harper et al., 2006). The QUIS instrument also measured participants' subjective satisfaction with the instructions and the software tutorial besides various subjective user satisfaction measures.

Procedure

Approval for use of human subjects was sought and granted, and informed consent was obtained from all participants for both the pilot studies and the experimental studies. Two students participated in each session. Experimental sessions lasted about 3.5 hours on average. After signing the informed consent forms, participants completed a demographic questionnaire. They were then given a CGPA/GRE/TOEFL score release form, the Self-Perception PVQ (Schwartz et al., 2001) and the GLOBE instrument (House et al., 2004). Participants were next trained to use the software. After the software demonstration, the two participants were led back to their respective workstations in two different rooms to begin work on the study task. Participants had up to 90 minutes to work on the information available for this problem. The update protocol described in (Suthers et al., 2008) was used to synchronize the workspaces of the two participants. At the conclusion of the investigative session, each participant had up to 30 minutes to write an individual essay. The essay focused on the hypotheses that were considered, the evidence for and against these hypotheses, and the conclusion reached. The software environment remained available to each participant during the essay writing, but the participants were requested not to engage in any further communication. After each participant had finished writing the individual essay, the other-perception PVQ instrument (Schwartz et al., 2001), and the QUIS instrument (Harper et al., 2006) were administered. The SL-ASIA instrument (Suinn et al., 1992) was administered to assess acculturation of Chinese participants. The ICSI instrument (Bhawuk & Brislin, 1992) was administered to assess inter-cultural sensitivity of American participants. This concluded the experiment.

Results

The data generated were then analyzed at four levels of *culture* (comparing American to Chinese participants), *gender* (comparing Female to Male), *dyadic culture* (comparing American-American, American-Chinese and Chines-Chinese dyads) and *dyadic gender* (comparing (Male-Male, Male-Female and Female-Female dyads). Unless otherwise stated, no significant differences were found for gender and dyadic gender levels.

Demographics

There was no significant difference in age at any of the four levels of analysis. As expected, American participants spent significantly more time in the USA than the Chinese participants. On the other hand, the time spent by the participants in Hawaii with respect to culture and gender was not statistically significant. This was done as control for context effects. There were no significant differences at any of the four levels of analysis for prior experience with experimental studies, prior knowledge about the experimental task, and partner familiarity. Further, results for the Learning section of the QUIS instrument showed no significant difference on the ease of learning the software usability measure at any of the four levels of analysis. Results for the Tutorial section of the QUIS instrument showed no significant difference for participants' subjective evaluation of the software demo and experimental instructions at any of the four levels of analysis. Therefore, experimenter bias and "demand characteristics" can be confidently ruled out as confounding factors.

Culture Measures

As mentioned earlier, Portrait Values Questionnaire (PVQ) (Schwartz et al., 2001) was used to measure culture at the individual level. The GLOBE instrument (House et al., 2004) was used to measure culture at the group level. Similarly, significant differences resulted on both sections of the GLOBE instrument as well as the PVQ instrument. Significant differences observed on the GLOBE instrument correlated with those observed on the PVQ instrument. None of the Chinese participants had high acculturation scores and none of the American participants scored lower on intercultural sensitivity. In summary, even though a nation state based stratified random sampling frame was employed; systemic variation between the two participant groups was documented and not stereotypically assumed.

Hypotheses Testing

For RH1, video analysis of the screen recordings of participant sessions was done to obtain counts of *referencing* objects or regions of the knowledge map. For RH2, RH3, and RH4 counts for *evidential relation*

links, threaded discussion messages and *embedded discussion notes* were obtained from the software logs of participant sessions. For RH5 and RH6 participants' logs were coded for discussion of information sharing and knowledge-map organization strategies. An example of information sharing strategy is "*I think we should chunk related information (e.g., diet, culture, genetics) to make it easier to fit the 'pieces' together and connect them to hypotheses*." An example of a knowledge-map organization strategy is "*Lets use the top left to add new ideas / data that has not been connected to anything*." Table 1 presents a summary of the null hypothesis significance testing results: overall, significant differences were observed for 5 of the 6 theoretical predictions. Table 2 below presents a summary of the results between the three intra- and inter- cultural dyadic groups: overall, significant differences were observed on 4 of the 6 dependent measures.

Table 1: Summary of Hypotheses Testing Results for the Two Cultural Groups

	American Mean (SD)	**Chinese Mean (SD)**	**Test-Statistic (p-value)**
RH1	None: 19 Unit:2 Composite:9 Region:0	None: 21 Unit:3 Composite:3 Region:3	χ^2 (3,60)=6.30, p=0.09†
RH2	22.17(12.44)	15.87(7.50)	F(1,56)=5.542, p=0.022*
RH3	10.13(5.18)	6.37(4.59)	F(1,56)=8.878, p=0.004**
RH4	3.37(4.05)	5.13(6.08)	F(1,56)=1.727, p=0.19
RH5	No: 9 Yes:21	No:19 Yes:11	χ^2 (1,60)=6.70, p=0.0097**
RH6	No: 14 Yes:16	No:24 Yes:6	χ^2 (1,60)=7.18, p=0.0074**

† p<0.10, * p<0.05, ** p<0.01

Table 2: Summary of Hypotheses Testing Results for the Three Dyadic Cultural Groups

	American-American Mean (SD)	**American-Chinese Mean (SD)**	**Chinese-Chinese Mean (SD)**	**Test-Statistic (p-value)**
RH1	None:15, Region:0, Unit:1, Composite:4	None:10, Region:2, Unit:2, Composite:6	None:15, Region:1, Unit:2, Composite:2	χ^2 (6,60)=5.65, p=0.46
RH2	21.05(10.95)	20.95(12.13)	15.05(7.83)	F(2,57)=2.16, p=0.13
RH3	9.05(5.35)	10.85(5.06)	4.85(3.18)	F(2,57)=8.84, p<0.0001**, partial η^2=0.24
RH4	4.35(4.43)	1.95(3.73)	6.45(6.23)	F(2,57)=4.157, p=0.02*, partial η^2=0.13
RH5	No:4 Yes:16	No: 10 Yes:10	No: 14 Yes:6	χ^2 (2,60)=10.18, p=0.006**
RH6	No:8 Yes:12	No:13 Yes:7	No:17 Yes:3	χ^2 (2,60)=8.76, p=0.013*

* p<0.05, ** p<0.01

Individual Learning Outcomes: Analysis of Individually Written Essays

Each participant wrote an individual essay at the end of their dyadic collaboration. The software environment was available for the participants during the essay writing process. For the individual learning outcomes analysis of the essays, two coders analyzed the essays for (1) number of hypotheses mentioned by each participant, (2) participant's perception of study partner's divergence on hypotheses, (3) overall agreement between the two participants on final conclusion, and (4) Latent Semantic Analysis (LSA) of pair agreement of the individually written essays of the two participants. The two coders analyzed essays from six sessions (2 sessions were selected from each of the three experimental conditions: American-American, Chinese-American, and Chinese-Chinese). Intercoder reliability measures were estimated on these initial coding (6 coded sessions = 20% of 30 total sessions), discrepancies were corrected, and the second coder then coded the rest of the sessions.

Individual Essays: Number of Hypotheses Mentioned by Each Participant

The first item in the essay writing instructions asked participants to describe the hypotheses they considered. For this analysis each coder, counted the number of hypotheses mentioned in the essays. Since this was a simple count of the number of hypotheses explicitly mentioned in each essay, both the coders agreed on the number of hypotheses mentioned. No significant results were observed at the level of culture or at the dyadic cultural level.

Individual Essays: Participant's Perception of Study Partner's Divergence on Hypotheses

The second item in the essay writing instructions asked participants to describe how their hypotheses differed from those of their study partners. To analyze these subjective perceptions, a coding scheme of 5 categories of

divergence was created (1=very different, 2=different, 3=slightly different, 4=similar, 5=very similar) for assessing participants' comparisons to their study partners' hypotheses. The interrater reliability for this analysis was high (*Kappa statistic* =0.87, *2-tailed p* <0.0001). A Kruskal-Wallis test of perception participant's perception of study partner's divergence on hypotheses was not significant with respect to culture or dyadic culture.

Individual Essays: Overall Agreement between the Two Participants

The third item of the essay writing instructions asked participants to state their conclusions and assess how they came to agreement or disagreement with their study partners. A coding scheme of 4 categories of agreement was created (1=no agreement, 2=partial agreement, 3=substantial agreement, 4=complete agreement) for assessing participants' statements about agreement/disagreement with their study partner on the final conclusion. The interrater reliability for this analysis was moderate (*Kappa statistic* =0.63*, 2-tailed p*=0.0001). A Kruskal-Wallis test of overall agreement was not significant with respect to culture or dyadic culture.

Individual Essays: Latent Semantic Analysis of Pair Agreement

Latent semantic analysis (Landauer, Foltz, & Laham, 1998) was done on the two individually written essays of a collaborative learning session. Specifically, pair-wise comparison each of the two essays of the 30 experimental sessions was conducted within the topic space of CSCL with 300 factors. Thus, we obtained 30 pair-wise agreement values for the 60 essays. A one-way analysis of variance of the LSA pair-wise agreement values with respect to dyadic culture (American-American, American-Chinese, Chinese-Chinese) was not significant.

Discussion

Any medium of interaction will provide a set of potentials for action, but it is up to the actors to decide which potentials are taken up, and for what purposes. Furthermore, the meaning of actions in a technology medium is negotiated interactionally—implicitly and/or explicitly. The results for RH1-RH3 provide initial support of the claim that representational guidance is culturally relative. The results on RH5 and RH6 show this negotiation is also influenced by cultural communication contexts of the actors. Results for *research hypothesis 1* suggest that cultural considerations should inform the design and implementation of referencing functionality in socio-technical environments. Indexical expressions (Garfinkel, 1967) and embedding artifacts in discussion both vary across cultures. For *research hypothesis 2*, the observed effect was exactly opposite to the theoretical prediction; American participants appropriated more affordances for evidential relation linking of knowledge map objects. One interpretation of the result is that if Chinese participants consistently perceive relationships between objects then there is little benefit to represent those relations externally and incur interactional labor costs. On the other hand, if the American participants attend to individual objects then they need to appropriate representational affordances to "reify" evidential relations as external representations. In other words, persistent perception of relationships might be necessary and sufficient for interactional purposes. However, there is no direct empirical evidence to support this interpretation. Further empirical studies might confirm or reject this interpretation. *Hypotheses 3 and 4* concerning threaded vs. embedded discussions has mixed results. These results suggest that the relative advantages of linked versus embedded discussion (Suthers, 2001a) might also be culturally relative. Significant findings on *hypotheses 5 and 6,* about explicit discussion of information sharing and knowledge-map organization strategies, respectively, have important consequences for collaborative applications. If task performance depends on information sharing that is to be accomplished primarily through social interaction then this study's results, like those of (Setlock, Quinones, & Fussell, 2007), suggest that interaction designers should incorporate prompting protocols or scripts for participants from high-context communication style cultures.

Despite differences between the two cultural groups on (a) how they used the tools and resources of the learning environment and (b) how they related to each other during and after their collaborative learning interactions, individual learning outcomes analysis of the essays indicated no significant differences. Put differently, interactional process differences during the collaborative problem solving session on how participants (a) used the tools and resources of the learning environments, and (b) related to and formed impressions of each other (Vatrapu, 2007, 2008; Vatrapu & Suthers, 2009) are not accompanied by learning outcome product differences in the individually written essays. Recall that the software design included multiple alternates for individual action and interaction. Participants interacted through an asynchronous computer interface providing multiple tools for interaction (diagrammatic workspace, embedded notes, threaded discussion). One interpretation of the individual learning outcomes results is that participants utilized the "alternates for action" incorporated into the learning environment effectively and appropriately from their own cultural standpoints, so they learned equally well. For example, Anglo-American participants created more evidential relation links, made more individual contributions, and were more likely to explicitly discuss information sharing and knowledge organization strategies than their Chinese counterparts. However, as mentioned earlier there are no individual learning outcome differences on the essays. Information sharing is

necessary for joint problem solving in an asynchronous learning environment but it might be insufficient to account for learning outcomes (Suthers, Medina, Vatrapu, & Dwyer, 2007). The results of the experimental study hint at the existence of multiple interactional pathways to learning outcomes in intra- and inter- cultural computer supported collaborative learning. However, more systematic empirical work is needed to (a) establish the existence of and (b) evaluate the efficacy of multiple cultural interactional pathways.

Implications for Design

The empirical evidence from this study indicates that the informational focus of natural language communication and real world interaction of Anglo-American participants (low-context communication style) carries over to the online interactions. Both technology designers and instructional designers can incorporate this understanding into their practice. Chinese participants' preference of embedded discussion compared to threaded discussion has implications for practitioners of online courses and asynchronous learning networks that still predominantly use threaded discussion boards. It could be the case that the socio-technical affordances of current hierarchical tree structured threaded discussion boards vary systemically across cultural dimensions. Although the cognitive embeddedness of discourse and knowledge-building have been theorized and empirically evaluated (Suthers et al., 2008), social engagement and cultural embeddedness aspects of these design implementations have remained unexamined so far. Instructors and designers of online courses need to consider incorporating relatively more embedded forms of discussion than the threaded discussion boards. They need to consider ways of facilitating the varying degrees of social and cognitive embeddedness in a multi-cultural online classroom setting by using scripts and scaffolding. The results of this empirical study also suggest that instructional and organizational technology practitioners and designers need to recognize and facilitate both the individual and collective modes of contributions. Given that both seminal networked learning research (Hiltz, 1994) and current online learning best practices prescriptions (Moore, 2006) emphasize student collaboration, and since these aspects vary across cultures in traditional classroom settings (Hofstede, 1986) as well as online learning settings (Edmundson, 2007), mono-cultural design assumptions that do not incorporate diverse "alternates for action" might not achieve the best results in terms of student learning processes, outcomes and satisfaction.

Future work

In order to exhaustively study the potential effects of culture on the appropriation of potentials for action and the negotiation of the meaning of those actions, one needs to analyze individual actions in the context of their interactional sequences (Jordan & Henderson, 1995). Proposed future work includes microanalysis of this experimental study's data set. Combining the computational architecture of the mind, representational guidance, and Gibson's theory of affordances (Gibson, 1979; Wells, 1998, 2002), this micro-genetic analysis program will investigate how *cultural code, ecological data* and *interactional structure* intertwine to account for social interaction as appropriation of socio-technical affordances and the emergence of technological intersubjectivity.

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