Explaining Culture: An Outline of a Theory of Socio-Technical Interactions

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ABSTRACT
This paper presents four criticisms of positivistic research in cross-cultural human-computer interactions. An outline of a theory of cultural influences in socio-technical systems is then presented. Based on the ecological approach to perception and action and the philosophical approach to intersubjectivity, the dual aspects of interaction in socio-technical systems- (a) *interacting with technologies* and (b) *interacting with social others using technologies* are respectively theorized as (a) *perception and appropriation of affordances* and (b) *structures and functions of intersubjetcivity*. Affordances are action-taking possibilities and meaning-making opportunities in a socio-technical system relative to actor competencies and system capabilities. Technological intersubjectivity refers to the production, projection and performance of identities and subjectivities in technology supported social relationships. The comparative informatics methodological framework is then presented followed by a brief description of the experimental evaluation of the theoretical framework. Implications for design of computer supported intercultural collaboration systems and a set of open research questions are discussed.

Author Keywords
comparative informatics, computer supported intercultural collaboration (CSIC), culture, socio-technical interactions, Perception and appropriation of affordances, structures and functions of technological intersubjectivity

ACM Classification Keywords
H.1.2 User/Machine Systems: *Human Information Processing*; H.5.3 Group and Organization Interfaces: *Theory and models, Asynchronous interaction, Collaborative computing, Evaluation/methodology.*

General Terms
Design, Experimentation, Human Factors, Theory

INTRODUCTION

The increased awareness of cultural relativity and specificity in human computer interaction (HCI) research and practice is leading to a critical assessment of the unexamined mono-cultural assumptions. So far, empirical work in established fields such as computer supported cooperative work (CSCW), computer mediated communication (CMC) and in emerging fields of inquiry such as computer supported intercultural collaboration (CSIC) has sought to document cross-cultural differences in users' interactions with computers [e.g., 63, 75]. Against this background, our particular focus in this paper is on the phenomenon of intercultural collaboration in general and CSIC in particular.

The rest of the paper is organized as follows. First, four criticisms of cross-cultural positivistic HCI research are presented. Second, a socio-technical interactional theory of culture is offered. The theoretical framework is related to prior empirical findings showing cultural variation in behavior, communication and cognition. Third and last, implications for CSIC are discussed.

FOUR CRITICISIMS OF CULTURAL HCI RESEARCH

The majority of empirical work in the positivistic tradition of HCI has sought to empirically investigate cultural differences in social behavior, interaction, communication, and cognition in computer mediated communication and collaboration settings [e.g., 64, 77, 79]. Four specific criticisms of the current state of affairs are discussed below.

1. Inadequate Conception of the Phenomena: In CMC/CSIC, intercultural communication/collaboration is facilitated/mediated/supported by information and communication technologies (ICT). Issues in, and aspects of, CMC/CSIC crisscross the *psychologica*l (cognitive, cultural, ecological, cultural), *sociological* (micro, macro), *technological* (design, development, deployment, adoption, evaluation), and *interactional* (appropriation, enactment) fields. Given the nascent stage of development of the field, there are few integrative theoretical frameworks that inform a multi-faceted empirical study of intercultural collaboration as the central phenomenon of analytical interest. As such, it is difficult to disentangle the different effects in an empirical finding.

Further, prior empirical findings in behavior [30, 32], communication [24], and/or cognition[44] did not involve information and communication technologies (ICT) as important components in their instrumentation, measurement and evaluation. Interacting through technology is not unproblematic. First, it makes interaction

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more difficult [6, 48] . Second, it may not mean, feel and afford the same thing to everyone. In many ways, there is a productive tension between the future possibilities envisioned in "Beyond Being There" [31] and the present realities documented by "Distance Matters" [48]. ICT are often designed under the implicit assumption that members of different cultures equally view a given functionality as appropriate for carrying out a given act, or that another member observing a given act in an ICT environment interprets it as originally intended by the actor. In a technology driven world, it is no longer safe to operate under such assumptions. In this sense, we need to conceptualize intercultural collaboration phenomena from combined perspectives of socio-cultural, socio-cognitive and socio-technical paradigms.

2. Tautological Explanation of Culture: Given the checkered intellectual history of the concept of culture [75], the notion of culture needs to be rethought conceptually, methodologically, and analytically. If the concept of culture stands for everything from identity, to the subjectivity of a given group of people, to the "whole way of life", then it might lose its analytical power and potential to inform the research and practice of designing, developing, and evaluating socio-technical systems. Most, if not all, of the current explanations of cross-cultural differences in interacting with technologies are tautologies. The explanations start with *a priori* cross-cultural differences and then proceed to attribute the empirical differences found in the new application domain such as HCI, CMC or CSIC back to the a priori culture theories. In other words, systemic and systematic cultural differences found and cultural influences uncovered are often predicated upon and explained by empirical findings documenting cultural variation in behavior [30, 32], communication [24], and/or cognition[44]. This amounts to translation and transportation of culture theory in other academic disciplines to CMC and CSIC settings. However, this creates a perpetual loop of self-reference and self-inference. The transplantation of culture theory from other research domains creates a sense of theoretical coherence but empirical findings of cultural influences are divergent [see 50 for cultural usability, see 63 for CMC]. The tautological explanations based on transplanted theories from reference disciplines such as cross-cultural psychology do not advance the theoretical understanding of the core phenomena of interest to our emerging scientific community: intercultural collaboration. First-order theories of intercultural collaboration that adequately conceptualize phenomena of interest and seek to explain intercultural interactions in technology enhanced settings are needed.

3. Underuse of the Comparative Method: As Ragin [53] said, the comparative method is:

> especially well-suited for addressing questions about outcomes resulting from multiple and conjectural causes where different conditions combine in different and sometimes contradictory ways to produce the same or similar outcomes…

The comparative method has been applied in fields such as anthropology [40], psychology [1], sociology [51], biology [56], political science [8], and conversation analysis [65]- to name a few. For instance, in comparative social science,

> At a very general level, comparativists are interested in identifying the similarities and differences among macrosocial units. This knowledge provides the key to understanding, explaining, and interpreting diverse historical outcomes and processes and their significance for current institutional arrangements. [53]

There is a need for a methodological discussion on the suitability, applicability, and the inherent merits and demerits of various analytical methods, including the comparative method. Such a discussion will allow us to go beyond unicausal reduction and embrace "multiple conjunctural causation" in our explanations of intercultural collaboration phenomena. Multiple conjectural causation [53] posits a combinatorial relationship between causes and effects-multiple causes interact in different combinations to produce effects.

4. Inadequate Consideration of Cohort and Individual Differences: The fourth and final criticism is of the failure to consider cohort differences besides cultural differences, in the use of Internet and other ICT. In the era of globalization, researchers need to understand the differential possession of digital media skills, devices, psychological motivations, and societal incentives when generalizing from cultural differences found in studies across cohorts, cultures, and countries. Additionally, the internet is both a cultural artifact and a culture in itself [29].

As a result of the above, there is the danger of CSIC remaining phenomenologically opaque. As such, there is a need for a richer understanding of the "how" and "why" of cultural variation in informatics phenomena at the human-computer and human-information interaction [33] levels. In other words, we need a process theory of culture that is sensitive to socio-technical interactions. The analytical focus of such a process theory of culture should be on *in-situ* (actual-space and real-time) interactional dynamics of culturally similar and dissimilar individuals interacting with the technology and with each other through the technology.

In the next few sections, an outline of a socio-technical process theory of culture is offered with expositions of the key concepts. The primary purpose is to help jumpstart discussion and debate on different theories of CSIC.

THEORETICAL FRAMEWORK

Socio-technical interactions involve individuals interacting with (a) *technologies* and (b) *other individuals*. These two central socio-technical interactional aspects are theoretically conceived as (a) perception and *appropriation of socio-technical affordances* and (b) *structures and functions of technological intersubjectivity*. Briefly, socio-

technical affordances are action-taking possibilities and meaning-making opportunities in an actor-environment system bounded by the cultural-cognitive competencies of the actor and the technical capabilities of the environment. Technological intersubjectivity (TI) refers to a technology supported interactional social relationship between two or more actors.

The rest of this theoretical framework section is organized as follows. The first section discusses the concept of affordances, presents a brief history of its use in HCI and offers a philosophical discussion of the concept of affordance. Drawing from ecological psychology, formal definitions and expositions of socio-technical affordances and their appropriation are then offered. The second and last section discussed the concept of intersubjectivity. Drawing on philosophy, a definition and exposition of technological intersubjectivity is provided.

Affordances

The notion of affordance was introduced by J. J. Gibson [17]. Gibson was primarily concerned with providing an ecologically grounded explanation to visual perception. Affordance is a deceptively simple concept that hides a very radical hypothesis. Gibson wrote:

> "I have described the environment as the surfaces that separate substances from the medium in which the animals live. But I have also described what the environment affords animals, mentioning the terrain, shelters, water, fire, objects, tools, other animals, and human displays. **How do we go from surfaces to affordances?** And if there is information in light for the perception of surfaces, is there information for the perception of what they afford? **If so, to perceive them is to perceive what they afford. This is a radical hypothesis, for it implies that the "values" and "meanings" of things in the environment can be directly perceived.** Moreover, it would explain the sense in which values and meanings are external to the perceiver". [17, p. 127] [**bold** emphasis added].

Gibson viewed affordances as relational properties between an organism and its environment. Gibson was reacting against what he termed the overly subject-side analysis of information processing in the theories of perception in the cognitive sciences. The notion of affordance places an equal emphasis on environmental properties as it does on individual interpretive competencies in determining meaning and guiding action. Gibson's theoretical project was to account for the variant and invariant properties of the environment, and thereby provide adequate object-side analysis for the phenomena in visual perception. Gibson's theory of affordances is an ecological theory of meaning opposed to cognitive theories of meaning as interpretation.

Gibson's notion of affordance when taken together with his theory of "direct perception" is deemed problematic by cognitive psychologists in explaining higher order cognitive process like learning, [45] and particularly problem solving [47]. "Direct perception" is the theory that all an organism needs for perception is a perceptual system and an environment. The organism perceives affordances by "direct pick up of information" from the "circumambient arrays" of the environment. In the ecological view, the information for perception is out there in the environment, and there is no need for top-down interpretation as cognitive psychologists contend. Gibson was arguing for perception as a basic biological-ecological process. This theoretical framework is in partial agreement with Gibsonian view in that we bracket the "direct perception" thesis but adopt the affordance as relational property thesis.

In my reading of Gibson [17], the notion of affordance simultaneously specifies the two concurrent levels of meaning and action. *Affordance is a meaning-making opportunity and simultaneously an action-taking possibility in an actor-environment system in a particular situation, relative to actor competencies and system capabilities.* The evidence for the two concurrent levels of meaning and action comes from the "two-systems hypothesis" in neuroscience [4, 45]. Unlike orthodox cognitivist views of the representational nature of human cognition that posits "copying" the external world, the cultural-cognitive conception of socio-technical affordances and their appropriation views interaction as "coping" with the contingencies of the external world.

HCI and Affordances

Norman's introduction of the concept of "perceived affordance" [46] brought the notion of affordance into human computer interaction. Relevant literature includes: Gaver's seminal articles on technology affordance [14], affordances of media spaces [15], affordances for interaction [16]; Bradner's notion of social affordance [3]; Hartson's [26] taxonomy of affordances into physical, sensory, functional and cognitive affordances; McGrenere and Ho's [43] critical review of the notion of affordance and a structuration theoretical interpretation of affordances [78]. Affordances in HCI have largely been misunderstood as widgets, features and functionalities [70], despite a crucial intervention by Norman [47]. By drawing upon ecological psychology research, this paper attempts to address Torenvliet's [70] call to reclaim the notion of affordance.

The ontological foundations of the notion of affordances are materialist and dynamicist [72]. The ecological approach is dynamicist, but not dialectical and processual, holding that "*everything changes in some respects*, *but not in all respects"* [72, p. 175]. Turvey, [72, p. 180] citing Lombardo, [39] identifies *"the principle of reciprocity—distinguishable yet mutually supportive realities"* as the central insight of Gibson's ecological approach to visual perception.. The principle of reciprocity is highly relevant to technology supported collaboration as multiple individuals, each with a specific subjectivity and identity, shape mutually supportive interactional realities. In

computer-supported collaboration, each actor is both a user of the system as well as a resource for the other users. *Technology affordances* [14, 69] are action taking possibilities and meaning making opportunities in a user-technology system with reference to the actor. Similarly, *social affordances* [3, 36] are action taking possibilities and meaning making opportunities in a social system with reference to the competencies and capabilities of the social actor. In socio-technical systems that facilitate collaboration, technology affordances and social affordances amalgamate into *socio-technical affordances*.

Drawing upon foundational work in ecological psychology on the formal definition of affordances [67, 72], the following formal definition is offered for *socio-technical affordance*.

Definition of Socio-Technical Affordance

Let W = (T, S, O) be a socio-technical system (e.g., person-collaborating-with-another-person system) constituted by Technology T (e.g., collaboration software), Self-actor S, (e.g., artifact creator), and Other-actor O (e.g., artifact editor).

Let p be a property of T; q be a property of S and r be a property of O. Let β be a relation between p, q and r, p/q/r. β defines a higher order property (i.e., a property of the socio-technical system).

Then β is said to be a socio-technical affordance with respect to W if and only if:

(i) *W = (T,,S,O) possesses β*

(ii) *Neither T ,S,O, (T, S), (T,O), (S,O) possesses β*

There are three important features of the formal definition. First, formal definition of socio-technical affordance embodies the duality of individuals' perception with respect to the technology and with respect to other persons. The duality is essential and is present right in the middle of the tuple (T, S, O). Self-actor S needs Technology T to interact with the Other-actor O, and vice-versa. Technology, T should have the capabilities to support the interactional needs and dynamics of the actors S and O. That is, T should be able to support (by conscious or unconscious design) the interactional (communication and informational) needs and necessities of S and O. Moreover, the Self-actor S needs to have the social and technical competencies, and O needs to be in the intersubjective realm of S.

Second, the formal definition subscribes to property realism. Property realism is the claim that argues for the ontological existence of properties of objects and actors. Note that an affordance is a relational property between the properties of the technology, the self-actor and the socially other-actor. In this sense, the conception of culture in this theoretical framework is not a supraindividual entity. Culture is a particular incompletely shared set of properties at the demographic, biographic, geographic, societal and professional levels (teen-culture, ethnic-culture, national-culture, car-culture, football-culture, rocket-scientist-culture etc...). The formal definition of affordance doesn't contradict the dynamic process view of culture and socio-technical interactions. In fact, it supports the dynamic view by pointing out that perception of affordances is sensitive to the temporally unfolding ongoing interactional conditions and contingencies.

Third and last, the formal definition serves as a template to design experimental and field studies of intra- and inter-cultural computer supported collaboration by systematically varying the properties of the technology, the self-actors and the other-actors [e.g., 74].

Perception of Affordances (PoA)

Of primary theoretical importance is the tight coupling of perception and action in the ecological or enactive approach [12, 17, 45]. The enactive approach argues that "perception and perceptual consciousness depend on capacities for action and capacities for thought; perception is […] a kind of thoughtful activity" [45]. The **weak argument** for cultural variation in the perception of affordances operates at the psychological level and doesn't posit essential differences at the biological level. In other words, the weak argument sides with social conditioning rather than intrinsic biological differences in the "nature vs. nurture" divide as the basis for human cultural differences in the perception of affordances. On the other hand, the **strong argument** posits an essential variation at the biological level. That is, the strong argument posits innate neurological differences that render PoA across cultures non-commensurable. In this paper, a theoretical commitment is made to the weaker version of the argument. The weak argument remains agnostic that the perception of affordances varies essentially across cultures (that it is incommensurable between two culturally diverse actor-environment systems), but posits that it is the appropriation of affordances that varies.

Appropriation of Affordances (AoA)

Zhang [86, p. 181], after Gibson [17], agrees that "the end product of perception is not an internal representation of the environment; rather, it is the invariant directly picked up from the environment". Zhang, however, doesn't agree with the logical conclusion of "direct perception" theories that deny any active role for internal representations. He points to the "situated cognition" approach, which in his view emphasizes "the structures of the environment and people's interactions with them without denying the important roles of internal representations" [86, p. 181]. Cognition, in the ecological psychology sense, has been articulated as the "*cooperative appropriation of affordances*" [54, p. 135]. After Rogoff and Lave [57], "*cognition is something one uses, not something one has.*"

Although the perception of affordances can be accounted for on ecological grounds, the perception of events cannot be accounted for on strictly ecological grounds [66]. The perception of events has interactional consequences in technology supported collaboration. It is here that Gibson's

rejection of a role for higher order cognitive processes is problematic. Social interactional consequences from an individual's perception of affordances are influenced by a prospective projection into the future, as well as a socio-psychological imagination of the other. Interactions in socio-technical environments are a dynamic interplay between ecological information as embodied in artifacts and individual actions grounded in cultural schemas. The essential mediation of all interaction is the central insight of socio-cultural theories of the mind [82]. The conceptualization of interaction as being mutually "accountable" (observable and reportable) is the critical insight of ethnomethodology [13]. Following these two schools of thought, interactions in socio-technical systems are conceptualized as the *accountable appropriation of socio-technical affordances*. Adapting Stoffregen's discussion of behavior [67, p.125], appropriation is defined as "*what happens at the conjunction of complementary affordances and intentions or goals*.

Research into social aspects of HCI [55] has shown that even computer-literate users tend to use social rules and display social behavior in routine interactions with computers. Social interaction is grounded strongly in culture, as every person operates within patterns of thinking, feeling, behaving and potential interacting. Thus, participants in computer supported collaboration make culturally appropriate and socially sensitive choices and decisions in their actual appropriation of affordances. On these terms, the concept of appropriation employed here is similar to the notion of appropriation in adaptive structuration theory [9, 49] inspired by Giddens [19]. Appropriation in adaptive structuration theory refers to the informed appropriation of affordances.

Cultural Variation in the Perception and Appropriation of Affordances

Recent empirical findings in cross-cultural psychology cast doubt on the assumptions of a universal cognitive architecture in traditional cognitive sciences [44, see also 75]. They suggest that culture and cognition are not disassociated, and form the evidential grounds for cultural variation in the perception of affordances (PoA). The empirical evidence for cultural variation in appropriation of affordances is documented by the growing number of cross-cultural HCI studies [for selective surveys, see 63, 75]

This concluded the discussion of the "interacting with technologies" aspect of socio-technical interactions. The notion of technological intersubjectivity (TI) is discussed next. TI addresses the second aspect socio-technical interactions in CSIC: how participants interact with and relate to each other in socio-technical systems.

Technological Intersubjectivity (TI)

Information and communication technologies (ICT) and the Internet have changed our social relations with others and objects in fundamental ways. Our interactions are increasingly informed by the operational logic of technology, hence technological intersubjectivity. Technological intersubjectivity is the production, projection and ultimately the performance of intersubjectivity in socio-technical systems. Our psychological perception of and phenomenological relations with social others are being increasingly transformed by the advances in ICT and social software. For example, technology lets us assign distinct ring tones, images, or priorities to our significant others. Human beings are not only functional communicators, but also hermeneutic actors. In technological intersubjectivity, technological mediation can sometimes (but not necessarily always) disappear like in Clarke's third law of technology [7].

Definition of Technological Intersubjectivity

Technological intersubjectivity (TI) refers to a technologically supported interactional relationship between two or more actors. TI emerges from a dynamic interplay between the relationship of actors with technological artifacts and their social relationship with other actors.

From a functional perspective, psychological intersubjectivity doesn't require two or more persons to have the same or similar subjective experience. Put differently, having a collective phenomenological experience is not a necessary condition for psychological intersubjectivity. In psychological intersubjectivity, the other human being is always an object of our attention and an object in our awareness. We observe the other person for communicative cues and informational structures relevant to the ongoing interaction. Unlike in phenomenological intersubjectivity, there is no requirement for an empathetic relationship with the other person, and indeed intersubjectivity can be antagonistic [42]. However, in the emergent technological case, there is a dynamic interplay between these psychological and phenomenological aspects. In technological intersubjectivity, information processing entailed by computational support can enhance and enrich the communicative possibilities as well as the communion potentials of two or more human beings. Socio-technical systems and online communities have potential for both psychological and phenomenological intersubjective experiences, without the requirement that interacting persons be co-present in the same place and interact at the same time.

The concept of technological intersubjectivity attempts to go beyond the HCI notions of presence [38] and connected presence [37] and the humanities' notions of networked individualism [5], information subject [52] and time-space compression [27] to incorporate both the psychological and phenomenological aspects of interacting with others via technologies. Technological intersubjectivity deals with the ICT enabled capabilities to **place-shift** (i.e., to be physically embodied in one physical space but to be able to virtually embodied in a different place) and the ability to **time-shift** (i.e., to be able to refer back to earlier interactions or to be able to defer forward interactions). In

TI, the conception of interaction is not merely about HCI – i.e., *interacting with technology* – it is also about technological intersubjectivity (TI) – i.e., *interacting with people and information.* In summary, our objective is to offer TI as a rich construct to conduct a theory-based empirical study CSIC. Figure 1 offers an illustration of TI.

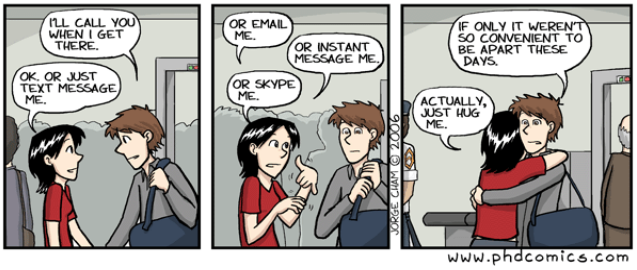

Figure 1: Psychological & Phenomenological Aspects of TI

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Structures of TI refers to the particular social, organizational or institutional configurations of social relationship. For instance, when two participants are collaborating using computers, the structure of TI refers to the social configuration of their interpersonal relationship [35] and the technical configuration of their multiple interactional realities [61, 62]. *Functions of TI* refers to the task-specific mechanisms and processes of a particular structure of TI. For instance, in the teacher-student dyad, functions of TI include learning and teaching in a particular domain, becoming a member of a community of practice, enculturation into a social system etc.

Cultural Variation in the Structures and Functions of TI

There is strong empirical evidence showing that both the structures and functions of TI such as *conceptions of self* [41, 71], *self-other relations* [35], *organizational expectations* and *interpersonal behavior* [25, 30, 32] vary across cultures. Prior empirical research has shown cross-cultural differences in traditional face-to-face intersubjectivity. Cultural variation in the structures and functions of technological intersubjectivity have received some empirical attention [see 77 for a report of the TI in an CSIC experimental study].

In the next section, the socio-technical interactional theory of culture presented above is related to prior findings on cultural differences in face-to-face seculture theory by means of the Comparative Informatics methodological framework.

METHODOLOGICAL FRAMEWORK

Integrating the three lines of empirical findings showing cultural variation in behavior [30, 32], communication [23] and cognition [44] and the socio-technical interactional theory of culture outlined above into the Comparative Informatics (CI) methodological framework, this paper puts forward two basic research questions:

R1: To what extent does culture influence the perception and appropriation of affordances in CSIC?

R2: To what extent does culture influence the structures and functions of technological intersubjectivity in CSIC?

Figure 2 presents a schematic diagram of the CI framework. The semantic explanation of the schematic follows below.

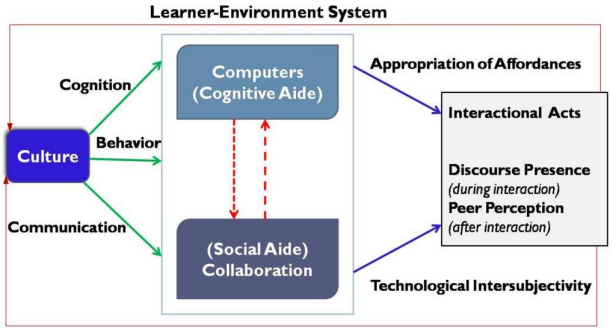

Figure 2: CI Methodological Framework

The analytical focus of the Comparative Informatics framework is on *appropriation of affordances* (interactuional acts) and on *technological intersubjectivity* (discourse presence and peer perception).

Culture is conceptualized as a cognitive schema [59] that modulates affordances and intersubjectivity , and therefore is treated as an antecedent to CSIC interactions. Cultural schemas and cultural models are what human beings bring to an interactional situation. Cultural schemas and cultural models are adaptive structures. Therefore, they are not rigid causal determinants of human behavior. However, they can exert strong influences on human behavior in appropriate situations and in acceptable contexts. This cognitive conception of culture as an antecedent to social interaction is identical to the social phenomenologist Alfred Schuetz's [61, 62] notion of "*biographically determined situations*". The *arrows* in the schematic are not unicausal determinants, but influence multiple conjectural causation. Human behavior is not pre-determined in an interactional situation. A cultural schema requires a concrete situation to be activated and to be realized as external behavior. As discussed earlier, an affordance [17] is the relational property between an actor and his/her environment (cognitive aide). Technological intersubjectivity is the relational property between the actor and the other actor (social aide). Since *culture influences cognition, communication and behavior*, it is predicted that in this socio-technical environment, *culture influences both the appropriation of affordances and the functions of intersubjectivity*.

The Comparative Informatics (CI) methodological framework *conceptualizes* the cultural influence (as a cognitive schema) on affordance by the notion of "appropriation of affordances" and *operationalizes* it as an empirically observable external record of interactional acts. CI methodological framework *conceptualizes* the cultural influence on intersubjectivity in technology mediated

environments by the notion of "technological intersubjectivity" and *operationalizes* it as an empirically observable external record of *discourse presence during interaction* and *peer perception after interaction*.

DISCUSSION

Taken together, appropriation of affordances and technological intersubjectivity are like the two sides of a coin. They are mutually constitutive of each other. Technological intersubjectivity is formed, transformed, and reformed through individuals' appropriation of affordances. Within this theoretical framework, prior empirical findings of cultural differences in communication [24] and cognition[44] are interpreted as systemic differences in the apperception, perception, and appropriation of affordances. On similar lines, cultural dimension models [30, 32], are interpreted as documenting cultural variance in the structures and functions of intersubjectivity. The comparative informatics methodological framework operationalizes the various concepts of the theory.

Based on the formal definition of affordances, an experimental study was designed that introduced a variation in the cultural background of individuals (S,O) by selecting participants from a nation-state based ethnically stratified random sampling frame but kept invariant the technological interface T and interactional setting [73]. The experimental study design consisted of three independent groups of dyads from similar or different cultures (Anglo-American, 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) as they worked on an intellectually challenging problem of identifying the cause of a disease outbreak The software environment provided multiple alternatives for appropriation of affordances and multiple ways to relate to the social other (the study partner). The research strategy was to provide participants with a feature rich collaborative environment with multiple alternates for action. For example, participants could discuss with each other using the threaded discussion tool or the embedded notes tool; use the knowledge-map objects to discuss the task at hand or any other topic of interest; refer to artifacts by deictic referencing (this, that, etc…) or use the cross-referencing feature of the threaded discussion; externalize the perceived relations between their concepts by creating external evidential relations between objects in the knowledge-map by spatial arrangement or by mentioning them in discussion. Participants also had multiple ways of sharing the information presented to them (threaded discussion, embedded notes, and knowledge-map). By incorporating systematic variation in the assignment of participants to the collaborative dyad based on their cultural background and gender, the experimental design measured and observed systemic differences in how participants used the tools and resources of the technology (research question 1, appropriation of affordances) and related to each other during and after their interaction (research question 2, technological intersubjectivity).

Based on theories of culture and empirical findings in cultural psychology documenting cross-cultural variations in behavior, communication and cognition, several research hypotheses were advanced. Empirical data were collected using demographic, culture and usability instruments; participants' self-perception and collaborative peer-perception instruments; screen recordings and software logs of experimental sessions. Statistical results showed that members of different cultures appropriated the resources of the interface differently in their interaction [74], and formed differential impressions of each other [77]. For example, on average, American participants of the experimental study 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 [74].

In order to thoroughly investigate 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 interactional sequence [11, 20, 21, 34, 60]. Current work is focused on the microanalysis of the experimental study data. Combining the computational architecture of the mind, representational guidance, and Gibson's theory of affordances [17, 80, 81], 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.

This analytical mapping of culture as a cognitive schema to computational machine instructions, ecological information to program data and sequential interaction to data structures used by computational machines takes the computational metaphor of the mind seriously and investigates the extent to which cognitive architectures are culturally relative.

Implications for CSIC Design

Based on the formal definition of socio-technical affordance, and informed by empirical evaluations [74, 76, 77], a framework of affordance classes is presented to inform the design of CSIC systems. Table 1 presents affordance classes and their theoretical sources.

Each affordance class provides a design dimension based on the formal definition of affordances. Designers can navigate this multi-dimensional design space either in an exploratory or a confirmatory mode. In the design dimensions tool kit, the perceptual affordances refer to the perceptual organization of artifacts in environment with reference to a user. Notational affordances are meaning-making opportunities of various notations. Representational affordances refer to action possibilities that are salient or constrained based on the technological implementation of external representations. Media affordances refer to the communicative possibilities of various media.

Conversational affordances of interlocutors influence the conversational dynamics of a socio-technical community.

Affordance Classes	Theoretical Sources
Perceptual Affordances	Gestalt Theory of Perception [28]
Notational Affordances	Cognitive Dimensions of Notations[22]
Representational Affordances	Representational Guidance [68]
Media Affordances	Grounding Constraints [6]
Conversational Affordances	Conversation Analysis [58]
Social Affordances	Culture Theory [23, 30, 44]
Interactional Affordances	I-PMR Framework [10] & Ethnomethodology [13]

Table 1: Design Dimensions for CSIC Systems

Social affordances provide action possibilities for social actors embedded in material and symbolic cultures. Interactional affordances structure the functional dynamics of collaborative interactions. A comprehensive discussion of the framework is beyond the scope of this paper and will be presented in upcoming publications.

Implications for CSIC Theory

What is presented here is just one candidate theory for CSIC and there is a need for other complementing and competing theories. We need process theories of culture that provide a micro-level (agentic) complement to the macro-level (structural) practice theories of culture in sociology and anthropology. In my opinion, a theoretically informed empirical exploration of the linkages between Gibson's [17] "affordance", Garfinkel's [13] "members' methods", Giddens' [18] "structuration", and Bourdieu's [2] "habitus" could be fruitful in building one such process theory of culture that furthers our understanding of cultural cognition in actual ongoing sequentially and temporally unfolding CSIC interactions. Further, the theory building enterprises should empirically re-examine and synthesize prior findings related to culture across the various disciplines. For psychology in particular, in my opinion, it could be fruitful to study the relationship between Herman Witkin and colleagues' [83-85] work on field dependency and independency, Nisbett and colleagues' [44] work on cultural cognition, Triandis' [71] work on the interdependent and independent senses of self, and Bartett's work on schemas [59] in socio-technical settings

Open Research Questions

There are several open research questions to investigating intercultural collaboration phenomena from a socio-technical perspective.

- What is the distribution of ecological, social, cognitive, and affective information and how is information structured in a given interactional phenomenon of analytical interest?
- How is information perceived, made sense of and acted upon?

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