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A discourse analysis technique for charting the flow of interactions in online activity

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Abstract

The theory of ecological constructionism specifies the interaction framework that integrates information systems with the individual's psychological operations that conform to group practices in communication and information exchange. Social and communicative interactions always involve these three psycho-biological systems of the individual: sensorimotor, cognitive, and affective. The model does not make use of theories about private hypothetical processes but relies on the ethnomethodological and constructionist approaches by defining unobservable mental processes in terms of variable and unique individual procedures that are managed by the person to count as a communicative act in a social group or work team. Content analysis of samples of different types of user comments are analyzed to show how they provide objectified customer feedback to product designers and businesses about consumers' feelings, intentions, and attitudes.

Keywords

Content analysis; User comments; Constructionism; Affective; Cognitive; Sensorimotor

Introduction

This article introduces a method of analyzing the discourse or comments of users in a technological environment. Prior research on user discourse will be described. The theoretical purpose of such analysis is to show in what way users are integrated in the technological environment, and as well in the social environment of online communication and collaborative activity. The approach identifies three components of this human-tecchnological integration, namely, social, technological, and individual-biological.

The theory describes the flow of this integrated activity showing that users behave online in a way that takes into account their knowledge of the other users, especially what is considered normal interaction in the group. Sufficient detail will be given to allow others to replicate or use the same thechnique of user discourse analysis. The model that is proposed falls in the area of constructionist theory and a review of this literature is provided. The novel element of this proposal is the view of the user as a biological organism composed of three distinct systems, each of which must be integrated into the social group and the technological facilities.

Method of diagramming user interactions

The theory of ecological constructionism (Nahl, 2006; 2007a, b; Tuominen & Savolainen, 1997, 2005) specifies the interaction framework that integrates information systems with the individual's psychological operations that conform to group practices in communication and information exchange. The process of becoming a normal member-in-good-standing of a social network or task group requires the individual to perform sensorimotor operations (e.g., noticing, perceiving), cognitive operations (e.g., appraising, planning), and affective operations (e.g., evaluating, intending). Social and communicative interactions always involve these three psycho-biological systems of the individual: sensorimotor, cognitive, and affective (Nahl, 2007b).

In the process of interacting with others through the mediation of technological affordances (facilities), individuals adjust these psycho-biological operations within limits that "satisfice" the group practices. In other words, other members in the collaborative group recognize each other's psycho-biological operations and accept them as "normal" for the group. Novice users or new members are spotted because they have not yet achieved normalcy in their operations. For example, they may not notice (sensorimotor) something others consider significant (cognitive), and may react emotionally (affective) in an inapprorpriate manner for that situation. In that case, others cannot satisfice the person's behavior as normal for the group.

The theory of ecological constructionism (Nahl, 2007a) identifies two types of operations for each of the three human psycho-biological systems: sensorimotor, cognitive, and affective. Figures 1 and 2 identify what they are.

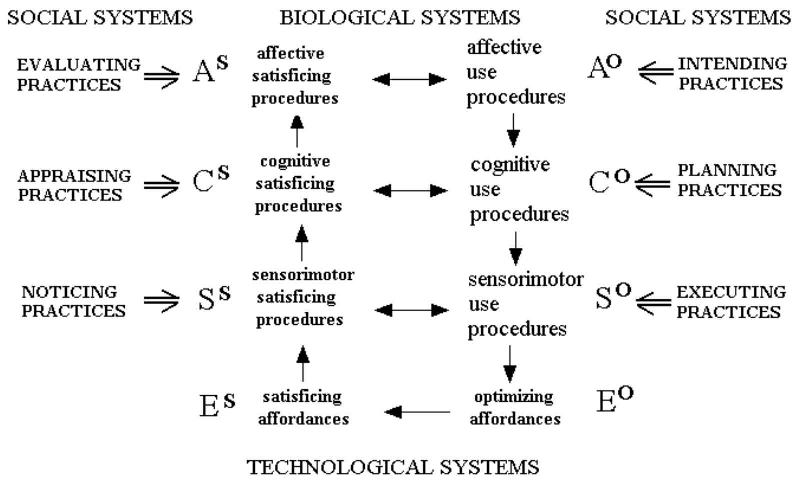

Figure 1. Ecological Constructionism Model

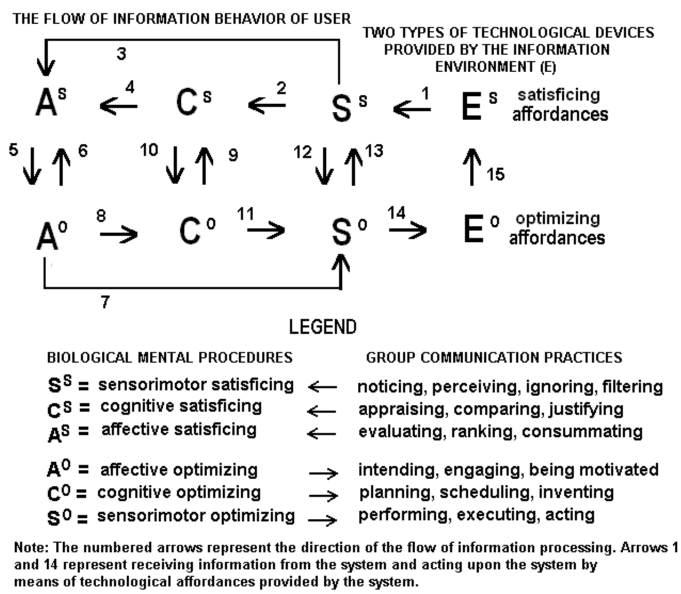

Figure 2. The Possible Interactions

Information reception involves, first, sensorimotor satisficing procedures [S^S] that count as *noticing* some information that is displayed through satisficing affordances [E^S] such as the components of a display screen, or a warning beep. Second, information reception also involves *appraising* what has been noticed by using cognitive satisficing procedures [C^S] such as analyzing and meaning making procedures that are normally practiced in the group. Third, information reception further involves *value-attaching* satisficing procedures (affective) [A^S] that invovle making bi-polar evaluative judgments like good-bad, fun-boring, useful-useless, etc. Once the information is value-attached (or evaluated), it has been received. These biologically based mental operations vary characteristically for each unique individual, but the stylistic variations are held by each member within limits that satisfice group practices. Information reception within a group or team involves the logic of satisficing (Simon, 1967; 1956).

Once information has been received and satisficed by the individual, the reverse sequence of operations can be performed to optimize the information. First, affective optimizing procedures that count as *intending* or motivational *goal-setting*. Second, cognitive optimizing procedures that count as *planning*. Third, sensorimotor optimizing procedures that count as performing actions with optimizing affordances.

To illustrate, we can apply ecological constructionism to Norman's widely quoted model (2004:51) that defines a "gulf of execution" as "the difference between the [user's] intentions and the allowable actions." This relationship is depicted on Figure 1 as the relation between intentions $[A^{O}]$ and the use of optimizing affordances $[S^{O}E^{O}]$. The model makes it clear that the gulf of execution is determined by the cognitive planning procedures $[C^{O}]$. When users are already performing appropriate group practices in cognitive optimizing $[C^{O}]$, there is no gulf of execution. Users already know how to get something done on the computer $[A^{O}C^{O}S^{O}E^{O}]$. This user skill includes satisficing procedures of noticing the appropriate information on the screen $[E^{S}S^{S}]$, appraising it according to group practices $[C^{S}]$, and feeding this information to optimizing planning procedures $[C^{S}C^{O}]$.

The successful elimination of the gulf of execution depends on the repeated interaction between evaluating the information from the satisficing affordance. Here is an illustration of one such procedure that eliminates the gulf of execution:

$[E^{S}S^{S}]$ noticing the information on the screen through sensorimotor satisficing procedures

$[S^{S}C^{S}]$ appraising the noticed information according to group practices through cognitive satisficing procedures

$[S^{S}C^{S}]$ evaluating the appraised information through affective satisficing procedures (works well or not)

$[S^{S}C^{S}]$ feeding the satisficed evaluation to affective optimizing procedures called having an intention or being motivated to interact with the computer

$[S^{S}C^{S}]$ eliciting planning operations through cognitive optimizing procedures

$[C^{O}C^{S}C^{O}]$ appraising the planning procedures before executing them

$[C^{O}S^{O}E^{O}E^{S}]$ executing the plan through sensorimotor optimizing procedures that manipulate the system

$[E^{S}S^{S}]$ noticing the changes on the screen

$[S^{S}C^{S}]$ appraising the consequences

$[S^{S}C^{S}]$ feeding the new information back to evaluation $[C^{S}A^{S}]$, or forward to continued planning $[C^{S}C^{O}]$ and execution $[S^{O}E^{O}]$.

In collaborative efforts with social software two or more users are plugged into the circuit shown above. Communication problems then arise potentially at each node in Figure 1. For instance, collaborators may be exposed simultaneously to the same satisficing affordances [E^S] but not notice the same information [$E^S S^S$], or, they may be appraising the same information differently [$S^S C^S$], or, evaluating it from different standards [$C^S A^S$]. These differences may alter the optimizing intentions [$A^S A^O$], or the planning moves [$A^O C^O$], and consequently the execution procedures with the computer [$S^O E^O$]. To the extent that this occurs, to that extent the collaboration suffers efficiency or effectiveness. Design features that identify to collaborators the location of such problems can help restore efficiency.

Dwyer (2007) examines the "social construction of joint sense-making activity" (p.30) during collaborative interactions of individuals doing things together by means of technology. Interacting individuals each manage their own noticings [$E^S S^S$], appraisings [$S^S C^S$], and value-attaching procedures [$C^S A^S$] in such a way as to achieve a mutual interdependence that allows them to continue interacting with each other. The success of each participant in the collaborative activity, depends on the group practices involving satisficing procedures. This refers to the perception one participant has of another participant's particular action, and whether this action appears normal for the conditions or situation. Whenever some action appears not normal, participants do not satisfice it. Also, users assess the appearance of their own action and avoid performing actions that would appear to be not normal.

Hence, satisficing actions in social settings is an important aspect of managing the continuation of collaborative interaction. According to the theory of ecological constructionism (Figs. 1 and 2), the accomplishment of satisficing is achieved through the construction of distinct psycho-biological procedures that are constrained by each participant and kept within categorical limits defined by the specific group practices. Social communication exchanges cannot be managed or accomplished by individuals in the absence of specific group practices regarding the three psycho-biological systems involved in all conscious action. These are portrayed in Figures 1 and 2 as noticings, appraisings, and value-attaching procedures that each individual carries out by means of the sensorimotor, cognitive, and affective systems, respectively.

Satisficing is therefore an essential component of social interaction. Dwyer (2007) examined the particular mechanisms people make use of when they manage to do something together that they consider meaningful. He confirms the fact that achieving a joint task is accomplished by participants when they "make themselves accountable to each other, and their observable appropriation of environmental elements make that part of the interaction available for analysis." (p.20).

Interactional constructionism

Otero et.al. (2011) discuss the challenges of constructing “seamless-learning environments” in the design of educational technology and conclude that in order to understand how learning takes place in these technological contexts, research needs to investigate how socio-affective factors come to the fore and influence the co-construction and use of common representations. The importance of affective activity for users was shown in an experiment by Hayashi, Matsumoto and Ogawa (2012) in which an online “conversational agent” provided affective feedback to the interactants, resulting in significant improvements in learning performance. Seaba and Kekwaletswe (2012) show that e-collaboration environments are driven by awareness of social presence that promotes the intersubjectivity of togetherness. Stevens, Boden and von Rekowski (2013) propose design aspects for socially-oriented constructionist learning and collaboration environments. These include socially oriented enhancements in interactions and in self-expression for mutual appreciation. Chan and Van Aalst (2011) argue that there is a need for developing social constructivist assessments of student learning in collaborative online environments.

In connection with the constructivist method described in this article prior evidence for ecological constructionism made use of the analysis of “user discourse” (Nahl, 2007a), which allows the identification of people’s enactment of the three-step process of satisficing. It showed that people’s noticings of satisficing affordances [E^SS^S] are accomplished by managing their sensorimotor procedures that are practiced in common with others in that setting, e.g., the pattern of eye movements across a display screen, or, when inspecting a scrolling directory. In the same way, people manage their cognitive procedures during appraisings in a way that avoids procedures that are not normal for the situation. Value-attaching practices are satisficed by managing to apply a template of bi-polar judgments that are normal for the situation, including the calibration of intensity of affect (Nahl, 2007c). According to Dwyer (2007) “social order is self-organizing in this respect – each participant simultaneously evaluates and is evaluated in terms of accountability” (p.24).

The mechanisms of “interactional construction” (Dwyer, 2007:25) can be better understood when the behavior of participants is distinguished into the threefold psycho-biological system shared by all human beings. Ecological constructionism recognizes all interactions in two distinct phases of joint accomplishment or “co-construction” (Dwyer, 2007:24), namely, performing satisficing procedures (information reception) and optimizing procedures (information use). Whenever a participant alters the environment by enacting a particular expression or speech act [S^OE^O], the significance or social meaning of the act is noticed and appraised mutually in common by the actor as well as the other participants [$E^OE^SS^SC^S$]. All involved must then co-construct a value-attaching procedure that allows all to satisfice the new information that constitutes the actor’s intervention (expression or speech act: [$S^OE^OS^S$]).

Note in Figures1 and 2 that for something to count as an interaction, it must be satisficed according to group practices. This requires a feature of the interactional environment called "satisficing and optimizing" affordances" (Nahl, 2006; 2007a), which give people the ability of modifying the social environment in such a way that others can notice it and value-attach it (Gibson, 1979; Gibson & Pick, 2000; Gaver, 1996). Satisficing affordances [E^S] are technological features of the social order that help insure detectability of a user's intervention (reaction). The interface devices that are available and known to users create a symbiotic integration beween the human psycho-biological system and the technological system. Specifically, the sensorimotor procedures that count as noticing [$E^S S^S$], the cognitive procedures that count as appraising what has been noticed [$S^S C^S$], and the affective procedures that count as evaluating and receiving [$C^S A^S$]. Optimizing affordances [E^O] are features of the technological environmental that have been designed with knowledge of the target social order and made manipulable by users' sensorimotor procedures, e.g., typing, writing, verbalizing, gesturing, picking up something, pointing to something, using indexicality speech acts like "it" and "before that", etc. [$S^O E^O$].

Note that producing a modification of the social order in the detectable collaborative 'space' or environment [$S^O E^O$] is preceded by affective optimizing procedures such as goal-setting intentions [A^O] that give motivation and direction to cognitive procedures that count as planning [C^O]. Ecological constructionism as depicted in Figure 1 is a specific theory of what each participant accomplishes in the group context or setting. It shows that the group collaborative effort, coherence, integration, and productivity are achieved by members thjrough cooperation with each other in the joint construction of an interactional ecology that is symbiotically integrated between human and machine. This interactional environment is realized or embodied in specific group practices that allow each participant to act upon this joint environment through optimizing affordances keyed to the human body's sensorimotor system. The other participants are able to detect or notice such changes in the joint environment through the satisficing affordances that it provides for information reception.

As described in Figure 1 the process of collaborative production has two distinct spheres of interaction, one external (technological, environmental, ecological), and the other internal (biological, psychological, mental). Satisficing and optimizing affordances are communication devices in the technological environment (interface, application program) that participants can use to modify the jointly constructed environment, and to detect these changes, either *synchronously* (e.g., looking at and discussing a shared online document), or *asynchronously* (e.g., reading email or messages). Note that group practices identify and delimit what constitutes affordances. For instance, in an ordinary social setting, there are numerous modifications to the environment that do not count as enacting a communicative act through affordances, and are therefore not attended to, but ignored, and thus do not count as a noticing procedure, e.g., clearing the throat, casually touching oneself, fidgeting, taking a drink, wiping the dust off, etc.

The collaborative product is an outcome of a socially constructed and jointly managed sequence of interactions by the participants and involving each participant's threefold psycho-biological system – affective, cognitive, and sensorimotor. When there is a superiority of the collaborative outcome over any individually produced effort, it can be attributed to the enrichment of the information environment in which participants are immersed. Working alone restricts and constrains the use of affordances in comparison with those produced interactionally by two or more collaborators. For instance, partners, team members, and contributors construct speech acts or visuals that are noticed, appraised and value-attached [$E^sS^sC^s$] by the others. This additional and enriched information reception can be optimized by participants in goal-setting and planning operations. In this way participants in collaborative effort are mutual influences on each other, allowing new sequences to be enacted that are inventive and productive in relation to the group's goals. The concept of the "distributed mind" in HCI refers to this enrichment of the environment, which is absent when the individual is working alone (Suthers, 2005). The collaborative influence can be synchronous (face to face or online), as in a real time working team, or asynchronous, through sequential or cumulative processing of a document by several designated individuals.

Figure 1 describes a social-biological environment inherent in all collaborative communication. The social aspects are embodied in the group practices of participants that constrain their individual psycho-biological procedures within limits of what counts and what is to be ignored in that specific environmental setting or information niche. A collaborative product is the constructed outcome of coordinated interactions by members, each of whom enacts sensorimotor, cognitive, and affective procedures that are adaptive to each other. When members notice a communicative act through a satisficing affordance (e.g., a member is heard saying "All right. But what about that one?"), they enact cognitive satisficing procedures of appraising this information, and then evaluating it (e.g., relating this new information to what another member previously said about it), and then value-attaching it as an issue that needs to be taken care of right away. This adaptation operation is shown in Figure 1 as information reception: [$E^sS^sC^sA^s$]. This adaptation process constitutes the first phase of coordination by members to each other.

The second phase of coordination is that of optimizing the received information, which produces modifications in the environment through affordances. These two phases of joint construction determine what's going on moment by moment in the collaborative exchanges. Activity in a group emerges as it is constructed by members who maintain coherence of coordination by adapting to each other's modifications of the joint environment (satisficing phase), and then optimizing the coordination through goal-intentions that are inventively enacted for the other participants [$A^oC^oS^oE^oE^sS^s$]. This alternating sequential process of satisficing and optimizing, endlessly repeated, constitutes the collaboration. The available and known optimizing procedures allow the agreed upon intentions and goals to direct the inventiveness of each member's cognitive planning procedures, and thus mutually influence one another at all levels.

Figure 1 is a specific theory of how collaborative interaction produces "shared understanding" that itself enables individuals to be members. This reflexivity is a characteristic of all constitutive systems (Searle, 1995). Collaborative construction is accomplished by each individual maintaining sensorimotor, cognitive, and affective procedures within satisficing and optimizing limits. This shows that social communication practices in a group are embodied in the coordinated interactions of members along the threefold psycho-biological system each uses individually. Hence it is important theoretically and practically to identify the sequence of this jointly managed activity. Figure 1 offers a methodology for doing this.

The social process that transforms an individual into a member can be represented as the process of participating in the joint construction of the collaborative 'space' or ecology. When people join a collaborative group, others recognize them as novices. This means that members tolerate activity by the novice that does not contribute to the joint construction of the interaction environment. Increasingly and progressively, the novice is perceived as contributing to the coordination of activity. This appearance is maintained by the novice by managing satisficing and optimizing procedures using the affordances members use, until the novice status vanishes from the ecology, no longer supported and embodied by the novice's non-normal activity.

Objectifying intersubjectivity or group mind

The concept of intersubjectivity has been recently applied to the construction of shared understandings in collaborative teamwork (Suthers, 2005; Dwyer, 2007). Figures 1 and 2 explicitly shows how intersubjectivity is jointly constructed out of the threefold psycho-biological system that is managed by each individual. The figure shows how affective optimizing procedures [A^O] are managed by each participant through goal-setting intentions, and as a result there emerges a group affective intersubjectivity that is maintained by participants through mutual adaptation by means of satisficing procedures [$A^S A^O$]. This theory represents intersubjectivity as a biological activity involving the three systems known as affective, cognitive, and sensorimotor (Nahl, 1997, 2001, 2007b).

What has been discussed in the literature as "sense-making" (Dervin, 1999) and "meaning making practices" (Dwyer, 2007:39) is depicted in Figure 1 as having both a cognitive satisficing activity [C^S] and a cognitive optimizing activity [C^O]. In the process of collaboration, members interpret each other's enactments or communicative acts, as these are relayed and detected through the affordances made available by the information ecology or setting, which is the situated context. When the ecology involves computers there are technological affordances provided by the software environment. These include satisficing affordances such as files and display screens, and optimizing affordances such as keyboard and wireless transmission. The collaborative 'space' or information ecology then encompasses a human-machine symbiosis (Nahl, 2006). According to Suthers (2006) "intersubjective meaning-making takes place when multiple participants contribute to a composition of inter-related interpretations. In other words, the joint composition of interpretations is the gist of intersubjective meaning-making.

Figure 1 shows explicitly how human-machine synergy is achieved through the sensorimotor system and the interface, through the cognitive system as the construction of shared understandings, and the through the affective system as the construction of group cohesion and joint goals. The theory describes two phases in the process of constructing biological intersubjectivity within each member of the group. Alternating satisficing and optimizing activities are required when constructing an intersubjective information ecology. Neither by itself can do so. This model may be called socio-biological technology since it shows the intersection of three aspects that create or build the information ecology. This intersection is depicted in Figure 1.

Satisficing the procedures of a member's acts is accomplished when the other members perform sensorimotor procedures that count as noticing something. Individuals have to manage their eye movements, their facial appearance, their motor readiness to react, the components of their gestures in context, etc. These sensorimotor procedures are maintained by each individual by enacting the limits of noticing. For instance, it is not normal behavior to ignore the fact that a member has asked a question, and if this is done, group intersubjectivity is broken. New activity now has to ensue to reinstate the 'space' of intersubjectivity.

The construction of an intersubjective ecology through collaborative interaction is the attainment of what might be called 'group mind' as depicted in Figure 1. The group mind of intersubjectivity is part of the reflexivity built into the model. From a biological perspective, the processes that establish the group mind is the same as the processes that establish the individual mind. Vygotsky (1978) proposed the process of "internalization" by which the interpersonal becomes the intra-personal. This psychological process of attaining mental maturity is the reverse of constructionist intersubjectivity, which is based on simultaneous reflexivity of the individual mind and the group mind. The two are both embodied in the interactions as defined in Figure 1.

Mead (1934) defined the "objective self" as the individual's construction of self jointly with group practices applied to each other. Thus, seeing oneself as others see me. Objective self-assessment is the application of the evaluation scales [A^S] to oneself that others use for each other. This is the meaning of objectifying intersubjectivity, namely, of applying the dynamics of Figure 1 equally and simultaneously to self and others. Collaborative construction of social reality is the continuous activity that makes group and community possible. The collective concepts such as "group mind" or "national consciousness" or "being a fan" can be understood objectively with reference to the social-biological procedures in Figure 1.

Participants need not be face to face, need not know where the other members are located physically, or even who they are in their own social niche. The intersubjective ecology embodied in the label "*It's my favorite game*" is constructed simultaneously with the satisficing and optimizing procedures of many scattered others as they play that game individually or in their own groups. Their activity of playing the game embodies the consummatory affective value-attaching procedures [A^{S}] such as “This is fun.” “I love this.” “ Don’t you love this?” “Let’s play again.” Etc. The activity also embodies the motivational intentionality of planning game strategy [$A^{O}C^{O}$].

The construction of this intersubjective information ecology is greatly accelerated and deepened in complexity when the game lovers receive technological affordances that allow them to accelerate the rate of interactions through social technologies like online discussion groups, blogs, or instant messaging. It is hypothesized that intersubjective construction depends on the rate of interactivity, and the cumulative number of total prior interactions. Interactivity and interactions are defined as single situated events. All possible events are defined in Figure 1 or 3.

The sequence of activity involving the alternation between satisficing and optimizing procedures for each individual mind, is the same alternating sequence between members mutually, hence for the group mind. For instance, one member’s optimizing act, such as proposing a date for something [$C^{O}S^{O}E^{O}$], is noticed, appraised, and value-attached by another participant [$E^{S}S^{S}C^{S}A^{S}$], and immediately optimized by a counter-proposal from the other participant [$A^{O}C^{O}S^{O}E^{O}$]. This in turn is satisficed by members, then optimized. The cycle of satisficing-optimizing is descriptive of the activity for both the individual mind and the group mind of intersubjectivity. The flow of communication within a group is the same as within each member.

This is the basic reflexivity of all biological organisms, and hence the social groups they construct with each other. The group mind is not a copy of the individual mind. Rather, both are separate constructions achieved through the same constructionist procedures. The model in Figure 1 provides for the objectification of intersubjectivity.

Information ecologies support the use of symbolic interactionism in the joint cyclical construction of intersubjectivity. Participants construct representational messages for each other through the available technological interfaces or affordances (tools and artifacts). Technological systems for social networking or collaborative tasks are designed to provide support for the construction of messages (optimizing affordances) and their dissemination to specific targets (satisficing affordances). Context sensitive group practices determine which affordances are for normal and preferred use in any situation or intention.

Nahl (2007a, b) examined the communicative messages that one participant constructed for others in an asynchronous medium. The intention of the messages was to describe for others how to do something on the Web, like shopping for a specific item or locating a specific online database among electronic resources. This type of communicative construction was termed user discourse, also known in constructionist theories as interpretive discourse (Nahl 2006; 2007a). Discourse analysis of user discourse was applied by categorizing the discourse elements into the threefold psycho-biological system defined in Figure 1. Results showed that participants create for each other verbalizations that are segmented in units of meaning or reference that describe specific interactions with the technological affordances made available by the interface.

Social-biological technology

Ecological constructionism supports the current focus in HCI on *situated enactments*, that is, context sensitive meaning jointly constructed through mutual and cyclical interaction. The current model provides a social-biological framework that integrates with the technological affordances that create the information environment or communicative space. The model avoids the deep methodological problems involved in making theories about cognitive and affective processes that cannot be observed. The model in Figure 1 does not make use of theories about private hypothetical processes. It relies on the ethnomethodological and constructionist approaches by defining unobservable mental processes in terms of variable and unique individual procedures that are managed by the person to count as a communicative act in a social group or work team. It is not possible, nor necessary, to try to specify or represent the mental procedures. It is only required that we specify the social interactional practices that create and maintain a group or team as an evolving or developmental process.

This model identifies the social practices in interaction groups in relation to the three biological systems that are universal to all people. Sensorimotor procedures that interact symbiotically with satisficing affordances [E^sS^s] are managed by each individual to count as normal noticing practices. The model shows that sensory perception and motor response are tied to each other through environmental affordances, which may be an electronic interface or an artifact (written note, pointer, reproduction). A communicative act does not exist except as it is embodied in the person's intentional and goal-directed modification of the interactional environment through affordances [$A^oC^oS^oE^oE^s$]. Intending a goal is achieved through affective optimizing procedures [A^o], which give direction to cognitive optimizing procedures [C^o] that count in the group as planning practices. These are enacted mutually for one another through sensorimotor optimizing procedures that act symbiotically with available optimizing affordances [S^oE^o].

Lewis and Fabos (2005) observed group practices in instant messaging, confirming other researchers, that participants "enact particular versions of self at particular times." Online identity has a situated definition as "temporary attachments constructed within discursive practices." The identity exists in the embodiment of the individual's enactments that count to the group "as though they are stable and cohesive." In other words, social identity is constructed by enactments to which others attach values of cohesion and progressive development. Figure 1 gives one level of specification to what are the interaction mechanisms that are involved in the joint construction of collaborative identity. It shows that three satisficing and three optimizing channels of human enactment are involved in the effective collaboration of participants.

Each participant does individually the enacted mental procedures, and they do with each other the same enactments as alternating cycles of interaction involving the six phases. The model's reflexivity provides a built-in turn taking mechanism related to that of conversational interaction (Sacks, 1992; Garfinkel & Sacks, 1970). The potential for greater productivity and satisfaction in the collaborative effort can be explained in terms of these alternating cycles of mutual interactions within each of the three biological systems. For instance when one participant proposes a planning operation [$C^{O}S^{O}E^{O}E^{S}$], there follows three satisficing phases enacted by the others: first, they notice that a proposal has been made by a particular member [$E^{S}S^{S}$], second, they appraise it in relation to shared understandings as to what's going on at this point, and what the implications might be [$S^{S}C^{S}$], and third, they value-attach it with reference to group defined bi-polar evaluations that apply to this situation [$C^{S}A^{S}$]. Once value attached, the existence of the proposal has been confirmed and categorized. This tree-step psycho-biological process constitutes the individual's adaptation to the information ecology. This adaptation process is also called a *coping mechanism* and involves affective and cognitive load (Nahl, 2005).

Viewing information reception as a biological adaptation process requires that the individual reverse the three-phased biological sequence into an optimizing process. First, the value-attached information, which is an affective *consummatory* function [A^{S}], is integrated with an affective *conative* function [A^{O}] (Nahl, 2007b). All biological systems provide these two affective functions. The procedures of attaching information to group defined values [A^{S}] is called consummatory because the process has a built-in termination sequence when reaching maturity. Affective evaluation and judgment are bi-polar procedures of allocating affectivity to some information, object, or activity, which attaches feeling components to it – attraction, interest, fun vs. dislike, disinterest, boredom, and each at specified intensities, as for example something rated on a bi-polar scale like the semantic differential (Nahl, 1987). Each of these qualitative affective characteristics are consummated for a particular information, once the values have been attached to it.

The consummation of the affective satisficing procedures [A^{S}] is spontaneously integrated with the affective conative system [$A^{S}A^{O}$], which involves the biological motivation to maintain or alter the satisficed information. The individual who is having fun interacting with others through technological systems [A^{S}] is motivated to optimize this interaction by engaging the system in a way that allows the continuation of the cycle of consummation. Investigating the [$A^{S}A^{O}$] connection may indicate what kind of group practices and technological affordances support and encourage interactional sequences. When the technology or the communication practices are hostile to the [$A^{S}A^{O}$] dynamics, both involvement [A^{S}] and engagement [A^{O}] are inhibited or destroyed. In collaborative or team effort, the continuation or persistence of the alternating interactions, can intensify the dynamics of the [$A^{S}A^{O}$] mechanism. When this dynamic is encouraged by the ecology through its affordances [$E^{O}E^{S}$], cognitive procedures [C^{O}] become progressively more inventive and effective under the motivation and direction of newly constructed intentions [A^{O}].

Charting the activity in intersubjective ecology

The design of collaborative technology can address specifically the support of users' alternating cycles of satisficing and optimizing procedures through the affordances it makes available to interactants. To do this, designers need to have a way of tracing or charting communicative acts in relation to the three biological systems with which every individual must operate. Figure 1 is suitable for capturing the flow of interaction that constructs the intersubjective space of the collaborative ecology. Nahl (2006; 2007a,b) has demonstrated that Figure 1 can chart the flow of procedures at the individual level by analyzing user discourse in terms of the six phases.

It is predicted that communicative practices in a collaborative ecology or constructed environment, can be similarly traced by analyzing the interpretive discourse of participants, oral or written. Interpretive discourse is defined as communicative acts that each participant constructs for others when the intention is reflexive, that is, when the topicalization activity by members regards their group practices. Common instances of interpretive discourse include written instructions to users, help and advice, electronic user discussions, email questions to user support, and user interviews. Interpretive discourse plays a critical cohesive function and is achieved by participants through the interaction mechanisms specified in Figure 1.

Figure 2 charts an individual's clicking behavior on a particular occasion. Table 1 specifies the semantic range of group practices that are enacted by individuals through the six psycho-biological procedures. This may be useful to those attemting to make use of the discourse analysis approach described here.

Table 1. Common Terms Referring to Social Communication Group Practices
Portrayed in Figure 1
I, II, III are Satisficing Procedures
IV, V, VI are Optimizing Procedures

(III) Value-attaching Practices (performing affective satisficing procedures) [A^S] value-attaching (evaluating) prioritizing agreeing vs. not approving vs. not consummating feeling attracted vs. not	**(II) Appraising Practices** (performing cognitive satisficing procedures) [C^S] analyzing interpreting justifying attributing comparing explaining keeping track of limiting listing	**(I) Noticing Practices** (performing sensorimotor satisficing procedures) [S^S] identifying ignoring locating perceiving recognizing sensing
(IV) Goal-setting Practices (performing affective optimizing procedures) [A^O] goal-setting regulating striving intending engaging implementing	**(V) Planning Practices** (performing cognitive optimizing procedures) [C^O] predicting designing imagining inventing managing problem solving setting objectives	**(VI) Acting Practices** (performing sensorimotor optimizing procedures) [S^O] performing verbalizing inspecting producing purchasing waiting

Dwyer (2007) studied the interaction mechanisms of small groups working together on assigned tasks requiring joint discussion. He looked at transcripts of debriefing interviews after the task was completed. One sample of user discourse is the following (p.92):

> *Um…well, at first I was thinking like the priority Green is the highest, yellow is the middle and red is the one we don't care about the most. Then I saw him linking them up with these so I was like, O.K., we're going to use*

Um…well, at first I was thinking like

[CS] performing cognitive satisficing procedures

according to group appraising practices – justifying and explaining the sequence of one's reasoning leading up to something

the priority Green is the highest, yellow is the middle and red is the one we don't care about the most.

[A^S] performing affective satisficing procedures according to group value-attaching practices – prioritizing a color scheme for assigning value to items

Then

[C^S] performing cognitive satisficing procedures

according to group appraising practices – keeping track of the sequence of acts

I saw him linking them up with these

[S^S] performing sensorimotor satisficing procedures

according to group noticing practices – identifying the action of a member of putting items together

so I was like, O.K., we're going to use

[C^O] performing cognitive optimizing procedures

according to group planning practices – enacting a problem solving sequence that leads up to the prioritizing scheme

The above user discourse analysis makes visible the flow of the psycho-biological interactions in a group that are involved in jointly constructing an intersubjective information ecology. This sample verbalization act spoken by one member, contains five identifiable segmented speech acts that identify the flow of interactions:

[C^S A^S C^S S^S C^O],

or in words:

[appraising, value-attaching, appraising, noticing, planning].

Nahl (2007a) found that not all social-biological interactions that are going on are indexed by the discourse exchanges. In this sample, the two collocated speech acts [$C^S S^S$] -- *Then* [C^S] *I saw him linking them up with these* [S^S]. The shortest available flow of interactions going from [C^S] to [S^S] is [C^S C^O S^O E^S E^S S^S]. Four interactions (underlined) actually occurred (according to the arrows in Figure 1) but only two are explicitly mentioned in te member's verbalization act. The unmentioned interactions are [$C^O S^O E^O E^S$], or [planning, executing]. The reconstructed verbalization would be something like this:

"*then* [C^S] since my plan was to keep track of what he does [C^O], I kept my eye on him and [$S^O E^O E^S$], *I saw him linking them up with these* [S^S]."

There are evidently group practices in topicalization, regarding what gets mentioned or not in a specific context. One such practice is to avoid mentioning what is already indexically evident to all through the member's role enactments. However, even if some interactions are routinely not mentioned, they nevertheless are going on in the exchange. When one member says "*I saw him linking them up*" he is seen by others as having noticed and kept track of it. Without these unmentioned interactions, also counting like the mentioned ones, the intersubjective ecology could not be negotiated and jointly built up.

Face to face task team

Here is a sample from a face to face group engaged in a collaborative task (Dwyer, 2007, p.164):

Lee: *So one of the issues we had was um ... to what extent did we get into the stuff on the left side of the table.*

Chris: *So, to what extent are we evaluating the project, and to what extent are we evaluating the* […] *part*?

Lee: *Yeah. Yeah, I think that was the left-right distinction was ...*

The analysis of the above:

Lee:

So one of the issues we had was um ...

[C^O] performing cognitive optimizing procedures

to count as planning – <u>enacting the interaction that he is going to present a proposal</u>

to what extent did we get into the stuff on the left side of the table.

[C^O] performing cognitive optimizing procedures

to count as planning – <u>enacting a problem solving sequence that leads up to an evaluation of what's going on so far</u>

Chris:

So,

[C^{O}] performing cognitive optimizing procedures

to count as planning – enacting the interaction that he is going to present a proposal

to what extent are we evaluating the project,

[C^{O}] performing cognitive optimizing procedures

to count as planning – enacting a problem solving sequence that leads up to an evaluation of what's going on so far

and to what extent are we evaluating the […] part?

[C^{O}] performing cognitive optimizing procedures

to count as planning – doing the same thing with the second topic

Lee:

Yeah. Yeah,

[A^{S}] performing affective satisficing procedures

to count as value-attaching – enacting approval of Chris's proposal

I think that was the left-right distinction was …

[C^{S}] performing cognitive satisficing procedures

to count as appraising – following up on the implications of Chris's proposal by identifying the related components

In the above user discourse analysis several analytic elements are highlighted:

(i) The transcripted interactional discourse is in italics, and is segmented into minimal speech act units (Nahl, 2007b)

(ii) the biological categorization indexed by each speech act is given in square brackets in relation to Figure 1

(iii) the group practices to which the individual procedures conform are given in bold (refer to Table 1)

(iv) The situated act is underlined.

All four analytic units participate in the joint construction of the intersubjective information ecology. The ethnomethodological reflexivity of the construction (Garfinkel, 1957; Sacks, 1992) is made clearer when one compares the interactions within one individual mind with the interactions of participants with each other. For instance, in the above transcript event, Lee is presenting a proposal that leads up to a progress evaluation [$C^{O}C^{O}$]. Chris takes the next talking turn to reiterate Lee's proposed plan for doing a progress evaluation [$C^{O}C^{O}C^{O}$]. Lee then takes the next talking turn to approve of Chris's involvement and follows up on it by identifying related issues [$A^{S}C^{S}$]. In other words, inter-subjectivity in the group can exist only because it is biologically constructed in the same way as intra-subjectivity (within each member).

To make this principle more explicit, one needs to use Figure 2 to reconstruct the actual interactions that are involved in each talking turn, thus within the individual (intra-subjective). Consider Chris's talking turn:

> Chris: *So, to what extent are we evaluating the project, and to what extent are we evaluating the […] part?* [$C^{O}C^{O}C^{O}$]

Figure 2 shows what are the unmentioned intra-subjective interactions that Chris performed: [$C^{O}C^{S}C^{O}C^{S}C^{O}$] or, [9, 10, 9, 10]. Note that two appraisal interactions (underlined) took place but were not mentioned. The activity of planning involves the performance of cognitive procedures and the diagram shows that it must involve both satisficing and optimizing procedures.

Note that the reconstruction of interactions from discourse enactments is a hypothesis to be confirmed with additional methods of investigation. For instance in this case, another way that Chris could have accomplished his role enactment is the following circuit on Figure 2:

> [9, 4, 5, 8, 9, 10] or [$C^{O}C^{S}A^{S}A^{O}C^{O}C^{S}C^{O}$]

The unmentioned interactions (underlined) now include affective satisficing and optimizing interactions. In other words, Chris not only reiterated Lee's proposal for doing an evaluation, but value-attached it [A^{S}] and formulated a motivated intention with it [A^{O}]. The interactions that Chris goes through in himself (intra-subjective), are also the interactions he goes through with Lee (inter-subjective), and vice versa. The constructed group mind is constructed in the same way that the individual mind is constructed. Both are social, biological, and ecological. By doing with others what one does with oneself, people are able to create a larger human structure, or group mind, that acts and reacts as one person. The mechanisms that produce such an enlargement intersect along three zones – the social, the biological, and the technological (or artifactual). When the interactions that create the group mind are electronically transacted, as with social software, there is a three-way synergy between culture, biology, and technology. The human, the machine, and the community form one symbiotic operating unit.

The role enactments of each participant have an equal dual function – for self and others. Here is how a college student described an error he made while searching for a particular journal in an electronic database (James and Nahl, *work in progress*):

> *I misspelled Journal for the Scientific Study of Religion* [S^{O}] *in my search.* [C^{O}] *I made this error just by mistake* [C^{S}] *and it was a typo.* [C^{S}] *I had to* [A^{O}] *go "Back"* [S^{O}] *and re enter the article name.* [S^{O}]
>
> [$S^{O}C^{O}C^{S}C^{S}A^{O}S^{O}S^{O}$]
>
> [$S^{O}\underline{E^{O}E^{S}S^{S}C^{S}}C^{O}C^{S}\underline{C^{O}}C^{S}\underline{A^{S}}A^{O}S^{O}\underline{S^{S}}S^{O}$]
>
> [$\underline{14, 16, 1, 2}$, 10, 9, $\underline{10}$, 9, $\underline{4, 5}$, 7, $\underline{13, 12}$]

Segment with two participants

Here is a brief segment of a transcript from a recorded exchange that took place between two adults (James and Nahl, *work in progress*). It exhibits how two interacting individuals jointly construct an intersubjective information ecology by mutual coordination of each other's satisficing and optimizing operations.

A: *So what exactly do you want me to search for?*

B: *Look for Los Angeles Lakers tickets for any upcoming game.*

A: *OK? Well I'm not sure how to do that so I guess I am just going to google search* it. [She begins to type on the computer.]

The user discourse analysis:

Transcript lines are italicized. Individual biological procedures are in square brackets and relate to Figure 1 or 2. Group practices are in bold. Situated actions are underlined.

A:

So [C^O]

cognitive optimizing procedure counting as **planning** (enacting the start of the joint activity)

what exactly [C^S]

cognitive satisficing procedure counting as **appraising** (starting a negotiation interaction for constructing shared meaning)

do you want me to search for? [A^O]

affective optimizing procedure counting as **intentional goal-setting** (establishing a joint goal and intentionality for the joint search activity)

B:

Look for [A^O]

affective optimizing procedure counting as **intentional goal-setting** (establishing a joint goal and intentionality for the joint search activity)

Los Angeles Lakers tickets any upcoming game [C^S]

cognitive satisficing procedure counting as **appraising** (describing the search object to establish shared meaning)

A:

OK? [A^O]

affective optimizing procedure counting as **intentional goal-setting** (establishing a joint goal and intentionality for the joint search activity)

Well [C^O]

cognitive optimizing procedure counting as **planning** (enacting the start of a joint search strategy)

I'm not sure how to do that [A^S]

affective satisficing procedure counting as **evaluating or value attaching** (negotiating for a joint categorization framework for the search strategy)

so [C^O]

cognitive optimizing procedure counting as **planning** (enacting the start of a joint search strategy)

I guess I am just going [A^S]

affective satisficing procedure counting as **evaluating or value attaching** (negotiating for a joint categorization framework for the search strategy)

to google search it. [C^O]

cognitive optimizing procedure counting as **planning** (enacting the start of a joint search strategy)

The chart of the sequence of interactions for this transcript segment may be represented as follows:

$[C^O C^S A^O A^O C^S A^O C^O A^S C^O A^S C^O]$

Reference to Figure 2 allows the reconstruction of the unmentioned interactions in this chart sequence:

$[C^O C^S \underline{A^S} A^O \underline{A^S} A^O \underline{C^O} C^S \underline{A^S} A^O C^O \underline{C^S} A^S \underline{A^O} C^O \underline{C^S} A^S \underline{A^O} C^O]$ or

$[9, \underline{4}, 5, \underline{6, 5}, \underline{8, 9}, \underline{4, 5}, 8, \underline{9, 4}, \underline{5, 8}, \underline{9, 4}, \underline{5, 8}]$

There were 11 mentioned (M) interactions in this transcript segment vs. 8 unmentioned (U) ones (underlined). Nahl (2007b) found with hundreds of similar transcript segments that the M/(M+U) ratio in user discourse was approximately .50 (equal number of mentioned and unmentioned interactions). It is not theoretically clear what accounts for such a ratio, but one hypothesis is that it has to do with the properties of affordances. For example, for the current sample the ratio is 11/(8+11) or .58. We can assume that when the interface is more effective in its support of participant interactions, less mentioned speech acts are needed in the interactions.

For example, assuming (M+U) to remain the same at 19 interactions in another segment, a system with more effective affordances might allow less to be mentioned, e.g., 8 (instead of 11, as above). The ratio would then be 8/(8+11) or .42. A still more effective system might allow the mention of only 4 interactions (instead of 11 or 8). The ratio would then be 4/(4+15) or .21. The more effective the system is, the smaller is this ratio. Effectiveness of affordances makes it unnecessary for many interactions to be mentioned explicitly, which therefore also means, less information to be attended to in the construction of the intersubjective ecology. The unmentioned interactions have no information value to members since they are predictable or obvious through the system. These interactions do not need to be negotiated and hence, they do not contribute to the progressive development of the interactions, that is, the collaborative productivity. Norman (2004, 1986, 1981) has pointed out that good or effective affordances have a design that make their main functions obvious, hence no speech acts instructions are needed to explain them.

According to Suthers (2006; Suthers and Hundhausen, 2003) "knowledge construction" depends on an individual actively creating meaning and not merely "receiving it from others." In the case of "collaborative knowledge construction" it is the group in context that is engaged in "meaning-making." This group construction accounts for "intersubjective learning" and "specifies that the process of meaning-making is itself constituted of social interactions." Further, "knowledge building requires that this group-based meaning making is being done intentionally." In the case of the M/(M+U) ratio discussed above the unmentioned (U) interactions do not contribute to the group-based meaning making as they are not intentional. Further research needs to clarify this relationship.

Take for instance the last two speech acts in the transcript above:

> *I guess I am just going* [A^S] *to google search it*. [C^O]

With reference to Figure 2, there is an intervening unmentioned interaction (underlined):

> *I guess I am just going* [A^S] <u>to pursue our goal</u> <u>[A^O]</u> *to google search it*. [C^O]

It is evident that the unmentioned interaction must have occurred and that it does not appear to contribute to the collaborative construction of the intersubjective understandings, as do the other two speech acts that are mentioned. Thus, [A^S] counts as negotiating for a joint categorization framework for the search strategy, so that both can orient to the searching activity. And [C^O] is enacting the start of a joint search strategy, as it is immediately followed by typing, with the other looking on, enacting the following jointly witnessed and constructed interaction loop:

> [$S^O E^O E^S S^S S^O E^O E^S S^S$] or [14, 15, 1, 12, 14, 15, 1]

The speech acts analysis discussed in all of the data presented shows that the process of establishing group intersubjective intentionality and common understandings, consists of a series of satisficing and optimizing interactions that are dynamic, progressive, and developmental with regard to collaborative knowledge construction and group productivity in an information ecology that is mediated by computers or artifacts. Each speech act (in italics) is the embodiment of a particular identifiable psycho-biological procedure (in square brackets) that is enacted so as to count as the normal social order established and maintained by group practices. The speech acts of a participant in a talking turn coalesce to count as a situated activity (underlined description). This intersubjective coherence is due to the ongoing group practices (in bold) that constrain the individual biological procedures within limits imposed by 'what counts as what' in the situation. Situated acts are the unique objectified outcome of each interaction. While each outcome or intersubjective embodiment is unique in the stream of behavior, the social, psycho-biological, and technological mechanisms involved in producing them, are standardized routines known as the established and mutually maintained "social order."

Theoretical issues and directions

Intersubjective information ecologies

Suthers (2006) raises an interesting and critical issue for the constructionist approach in HCI: "Do cognitive phenomena exist transpersonally? How is it possible for learning, usually conceived of as a cognitive function, to be distributed across people and artifacts? (Salomon, 1993). The social-biological technology that is described in ecological constructionism (Figures 1 and 2) is a blueprint for the charting process needed in answering "how participants … actually go about doing learning" (Koschmann, et al., 2005; quoted in Suthers, 2006).

Future research needs to investigate whether Figure 1 is suitable for tracking what people are learning in a collaborative group. According to this orientation "learning" can be defined as the normal accomplishment by an individual of maintaining membership in a collaborative dyad, group, or community. The accomplishment of appearing to others as a normal member, is achieved by each individual through being engaged in normalizing the interactions between each other. Since an ongoing social group is always dynamic and progressive, the intersubjective activity of collaborative knowledge construction is also at the same time the knowledge construction of each participant. Maintaining normal membership in a collaborative community is *ipso facto* the evidence that individual learning has taken place. The reflexivity of ecological constructionism is therefore well suited to track individual learning in terms of the group's achievement and productivity.

According to Suthers (2006), "Intersubjective meaning-making takes place when multiple participants contribute to a composition of inter-related interpretations. In other words, the joint composition of interpretations is the gist of intersubjective meaning-making. This conception provides an alternative to "going from unshared to shared information" as the gist of cooperative learning." The model of ecological constructionism specifically charts how participants actively maintain intersubjective coherence (meaning-making) through enacting for each other how each interprets what is going on in terms of the normalized group practices each maintains with the others.

Further, the model specifies how the process of intersubjective ecology integrates technology into itself through affordances (devices) that are specifically designed for satisficing and optimizing activity performed by members in their mutual interactions. Computer support or mediation is defined and measured by means of the affordances made available by the technology. Future research needs to investigate how computer mediated communication affects the charting of the interactions in comparison to face to face communication. It is possible that for some types of collaborative groups computer mediated communication creates a more supportive learning environment than face to face groups. It may not always be necessary to try to replicate or match the "multi-modality" characteristics of face to face collaborators who are co-present, such as gestures and gaze. Such research would indicate how computer mediated collaborative groups make use of interaction procedures that are contrastive with face to face procedures.

Future research can address the relationship between "collaborative knowledge construction" (Suthers, 2006) and the development and maturation of intersubjective information ecologies that come into being through social-biological interactionism with technological affordances supplied by collaborative software. Suthers &

Hundhausen (2003) report that technological affordances can "guide interactions towards ideas associated with the afforded actions" (Suthers, 2006). Design architectures for social technologies can be informed by the social-biological model that categorizes all affordances according to satisficing and optimizing procedures of users. Satisficing affordances enable participants to value attach the enactments of others, while optimizing affordances enable the engagement of intentionality as situated acts.

A critical issue concerns "uptake acts in which one participant takes up another's contribution and does something further with it." (Suthers, 2006). The activity of taking up another's contribution can be charted through affective satisficing procedures [A^S] that count as value attaching, while doing something further with it is charted by affective optimizing procedures [A^O] that count as goal-setting and intending. For instance,

- "A says P and B expresses (dis)agreement,"
- "A makes object O available, and B attends to O,"
- "A has created object O1; B has changed it to O2,"
- "A has created O1 and B has created O2; now A combines O1 and O2 in such a manner"

These interaction types mentioned by Suthers (2006) fit the following sequence on Figure 2:

$[S^O E^O E^S S^S C^S A^S A^O C^O S^O E^O]$ or [14, 15, 1, 2, 4, 5, 8, 11, 14]

The uptake relation is located at the underlined location in the interaction string. The verbalization initiated by individual A [$S^O E^O$] is either noticed or ignored by person B. A factor that increases likelihood of uptake is the extent to which the satisficing affordance is symbiotically integrated with sensorimotor satisficing procedures that count as noticing.

Cognitive theory

Brunswik (1943) distinguishes between three types of ecological issues. One involves the "distal-proximal correspondences" in the environment. And this consists of detectable information. He calls this the "intraecological" issue. In ecological constructionism

(Nahl, 2006; 2007a,b) detectable information is defined in relation to the information environment as *satisficing affordances* [E^S] (Figure 1). The "distal" in this case is the computer software while the "proximal" is the system interface as detectable by users [$E^S S^S$]. Detectability or perceptibility are closely allied ideas (Dwyer, 2007) which relate to *noticing practices* in a group. For instance, when typing one can use highlighting strategies for selected text elements, such italics, underlining, bold, font type and size, in order to increase the notice value of an element in the display. To highlight some selected text by the typist is to make use of an *optimizing affordance* [$S^O E^O$] (Figure 1) that is accomplished through the design of word processors connected to keyboards. But the screen display of the typist's highlighting intentions [A^O] are satisficing affordances that can be noticed by others [$E^S S^S$].

Brunswik's second ecological issue is called the "proximal-peripheral correspondences" which refers to the organismic interface between the sensorimotor system of the individual and the physical environment. In ecological constructionism there are two organismic interfaces – sensorimotor satisficing procedures that count as noticing [S^S], and – sensorimotor optimizing procedures that count as enacting or executing [S^O]. When A proof reads an email message to B, the optimizing enactment (bolding text) and the satisficing enactment (proofing it) are activities performed by one individual in interaction with the technological environment, but when the message is received and read by B, the interaction becomes intersubjective by the fact that A's intentions of emphasis for selected text becomes B's noticing, appraising, and value-attaching [$E^S S^S C^S A^S$].

Brunswik's third ecological issue involves the "peripheral-central correspondences" which are called "intraorganismic." In ecological constructionism the intraorganismic element is specified in terms of the three psycho-biological systems that form the individual's infrastructure for activity and adaptation. Every individual interfaces with the environment through sensorimotor procedures. These are of two kinds, organs that function for adaptation and reception through sensory modalities [S^S], and organs that function for engaging and manipulating the environment through motor activity and its coordination [S^O]. Intraorganismic and ecological always need a third component that relates to social or cultural. The three aspects together create both the individual mind and the group mind called intersubjectivity. Without the social practices, intersubjectivity would not be possible, hence neither society nor community.

Bruner (1957) described the cognitive satisficing procedures [C^S] that people perform to make it count as appraising. He referred to it as "going beyond the information given" (p. 42) or "to fill in gaps" (Bartlett, 1951). An instance of going beyond *sense data* is to identify the class of things it belongs to by making inferences. Bruner's explanation of categorizing what has been noticed was in terms of identifying the "defining properties or cues" that belong to "membership of a category." Another way people go beyond the information given is to fill in the missing or incomplete elements, once they have adapted to a situation and "learned the probability texture of the environment" (p.43). "Set" is another important technique used in the appraising of information. The cognitive satisficing procedures [C^S] people perform during appraising will be influenced by porior "induced sets" originating from "situational instructions."

Bruner discusses a biologically based factor that influences the appraising process under the rubric of "drive level" or "need state" (p.53ff). When people are hungry they will notice more food related items around them. They value-attach information in relation to their affective need state [A^S]. As need states change, what they notice and how they appraise it, also changes. Certain affective consummatory "drive states" [A^S] like stress or negative emotions, interfere with normal recognition and identification performance [$E^S S^S C^S$]. Nahl & Bilal (2007) present consistent evidence showing diverse ways in which affective states influence information behavior under various contexts.

Heider (1957) defined "making sense of the environment" as "assimilating to it," which means "transforming it into our own terms…from one system into another system" (p. 71). The "intraorganismic" procedures that accomplish this are identified in Figure 1 as sensorimotor satisficing procedures [$E^S S^S$], which operate in symbiosis with satisficing affordances made available by the technological interface.

The dual function of cognitive operations was long recognized in psychology as "the relation between behavior and cognition" (Festinger, 1957). In Figure 1 this duality is specified through the cognitive satisficing procedures that count as appraising [C^S], and cognitive optimizing procedures that count as planning [C^O]. Festinger (1957) quotes and supports Scheerer (1954) that "Cognitive theory might be expected to deal with the problem of how man gains information and understanding of the world about him, and how he acts in and upon his environment on the basis of such cognitions." The activity of "gaining information and understanding of the world" is specified on Figure 1 as the satisficing phase: [$E^S S^S C^S A^S$] or [noticing, appraising, value-attaching]. The activity of "acting in and upon the environment" is specified as the optimizing phase: [$A^O C^O S^O E^O$] or [intending, planning, executing].

Ecological constructionism makes it clear that all three biological systems have this dual function of receiving information or adapting to the environment (satisficing phase), on the one hand, and on the other, engaging the environment or acting upon it (optimizing phase). Festinger (1957) makes it clear that cognition does not operate on its own but only indicates "the path that will lead to the end desired" (p.128). On Figure 1 cognitive optimizing procedures [C^O] are directed or motivated by prior affective optimizing procedures [A^O]. There is no planning activity [C^O] without an intended goal or "end" to be achieved [A^O]. Festinger's theory proposed that cognitive operations "will be governed, at least, in part, by the actions which a person takes" (p.128). This was considered at the time a new idea, but today it is made explicit in HCI through the ideas of interactionism and embodiment, as discussed above in this paper.

Festinger demonstrated that executing a plan and acting upon the environment modified cognitive procedures that were "inconsistent with" the action. For instance, heavy smokers tend to discount the strength of the link between smoking and cancer. When they are exposed to the information about the health hazards of smoking, they value-attach it as "unproven claims", which allows them to continue the behavior of smoking. Festinger found that the more people smoke, the more they discount the validity of research indicating a link with cancer. Festinger's hypothesis was that "there exists a tendency to make consonant one's cognition and one's behavior" (p.129). Sometimes it is the cognitive satisficing procedures of appraising that change [C^S], and sometimes it is the planned behavior [C^O]. Figure 2 indicates that there is also a direct interaction between these two [$C^O C^S C^O$] (arrows 9 and 10).

Festinger identified various strategies people use to modify their cognitive procedures to count as appraising practices. One is "by selective exposure to relevant features of the environment" (p.131). In other words, sensorimotor and cognitive satisficing procedures [$E^S S^S C^S$] will be modified to be consonant with a different type of noticing and appraising practices. In ecological constructionism this "cognitive dissonance" effect can be understood as a shift in membership practices for noticing and sense-making (appraising). Smokers and non-smokers belong to different groups and part of group membership is to re-adjust one's cognitive procedures to count as normal in the new group, given that the information reception practices of heavy smokers are different from light smokers or nonsmokers.

User modeling and affective computing

The basis for the expanding technologies in HCI known as "adaptive," "augmented," and "intelligent," rests on the system's ability in monitoring and categorizing the user and the user's behavior. Common types of information about users that is of interest to designers include:

- scrolling habits, eye-scan patterns, mouse pressure, click sequence, recurring actions, display of emotions and facial expressions, voice recognition

  [S^O] sensorimotor optimizing procedures that count as executing or engaging the system

- what content they select to view and inspect vs. content that is skipped or ignored

  [CSCO] cognitive satisficing and optimizing procedures that count as appraising and planning

- user affect and involvement, i.e., "valence" (positive/negative), "arousal" (also: activation, affectivity, intensity)

  [A^S] affective satisficing procedures that count as value-attaching

- user discourse in questionnaires, discussions, or help requests

  [ACS] affective, cognitive, and sensorimotor satisficing and optimizing procedures

Figure 1 gives designers a social-biological model that images the symbiotic construction of procedures enacted by users in interaction with machines or systems. A distinct advantage of the model is that the ongoing flow of activity depicted applies to three situations for computing: human alone, human to human, and human to machine. Understanding this three-way reflexivity is critical for creating intelligent and adaptive architectures. Suchman (1987) introduced the idea that a "situated action" derives its social significance from the interaction within which it is embedded. Not all cognitive optimizing procedures count as planning in any specific group or community. The "plan" and its "rationality" are jointly constructed by the participants, either present or not. There is no planning apart from that which is constructed jointly or socially, thus, intersubjectively.

The model of ecological constructionism can inform user modeling approaches, allowing them to narrow the complexity of monitoring endless numbers of user states that could occur. It shows in "real-time" steps the mental activity that is "contextually emergent" (Hutchins, 1995) from the interactions – both intra-organismic (mental) and intersubjective. The model clarifies the notion of "communities of practice" (Lave & Wenger, 1991), showing how learning is both an immersion in and an outcome of social interactions. The model can deal with the development or emergence of relationship, identity, meaning, and performance, all of which are important elements in the life of communities of practice. When new systems are introduced in a collaborative group the model can help track the changes in interactions that occur, and whether they are supportive or disruptive of the work process.

Associated networked computing activities are increasingly pervasive. Efforts in computer-supported cooperative work (CSCW) are providing groupware designed to support the flow of coordination between collaborators and team members. Computerized support for the work process depends on the designer's accurate understanding of how the intersubjective information environment parallels the intra-subjective procedures carried out by each member. Collaborative effectiveness and productivity depend on group cohesion, which is maintained by the joint construction of the information ecology through situated acts as depicted in Figure 1.

Data mining: Charting and monitoring intersubjective space

Romano et. al. (1992) review the content analysis efforts involving the rapidly accumulating mass of online text or discourse, such as in chatrooms, news groups, product related discussion groups, and email archives. They conclude that "Internet conversation text can yield meaningful information about consumers' wants, needs, and attitudes toward products" (p. 218). Businesses have found it useful to rely on this kind of qualitative content analysis of customer feedback or inquiry to make needed design changes in their products. Romano et.al. also refer to "Japanese firms" that use quality control techniques to identify and eliminate problems with products and services. One such technique is the "murmur technique" which involves listening in on customers discussing their experiences. The frequency and quality of customer murmurings is then used as an index of their affective satisficing procedures [A^S].

Romano et. al. (1992) show how this type of content analysis can be automated for large volume processing of Web text and visually examined as "MindGraphs." They rely on user discourse analysis involving four components: (1) "Cognition," which involves appraising the product [C^S]; (2) "Frame of Reference," which involves performing affective satisficing procedures [A^S] that are based on standard bi-polar rating practices; (3) "Evaluation of positivity or negativity," which involves performing affective satisficing procedures [A^S] that are based on ranked bi-polar rating practices; (4) "Affect or intensity of feelings," which also involve affective satisficing procedures [A^S].

Research needs to explore to what extent *constructionist discourse analysis* can be automated. When such a software capability is developed, businesses, organizations, and online groups that typically produce a 'paper trail' of user discourse, can monitor the affective, cognitive, and sensorimotor interactions that are ongoing. Research can discover the utility of charts produced by this means. An illustration can be provided with data obtained with college students who were assigned various online tasks to complete and then to type out the steps they performed for the benefit of other students who will also be assigned the same tasks. Constructionist user discourse analysis based on Figure 1 was applied in the same way as done with the samples presented above.

Table 2 illustrates one type of data mining analysis arranged by task for the same three individuals. When the entries are color coded (e.g., green for S, blue for C, and red for A), it is possible to visually notice patterns more easily. Statistical distributions can also separate random fluctuations from significant differences and trends. With large data mining operations various contrasts are possible. The following are examples that apply to charts for any individual or for groups. Probes can be obtained live while the participants are engaged in the task, or through data mining archives segmented over date, time, type of ongoing activity, identity or type of participants engaged, etc.

(1) **TP**: total number of separate mentioned procedures

This measures involvement with details of task performance.

(2) **TBP**: total number of procedures within each biological system

This measures interactional focus, both intra-organismic and intersubjective.

(3) **LSP**: length of speech acts

This measures complexity of communicative involvement overall, or within each psycho-biological modality (affective, cognitive, sensorimotor).

(4) **S/O**: satisficing/optimizing ratio.

Table 2. User Discourse Analysis Comparative Chart

Individual A	Individual B	Individual C
Task 1: Creating a file for the report and registering on the Web as a Lab User		
$[S^{O}]$ $[S^{O}]$ $[S^{O}]$ $[S^{O}]$ $[S^{S}S^{O}]$ $[S^{O}]$ $[S^{O}]$ $[S^{O}]$ $[S^{O}S^{S}]$ $[C^{O}S^{O}S^{O}S^{O}S^{O}S^{O}S^{O}S^{O}C^{S}]$ $[S^{O}]$ $[C^{O}C^{S}C^{S}C^{O}A^{O}S^{O}S^{O}]$ $[C^{O}C^{S}C^{O}A^{O}S^{O}S^{O}]$	$[C^{O}S^{O}C^{O}S^{O}]$ $[S^{O}]$ $[S^{O}C^{O}S^{O}]$ $[S^{O}S^{S}C^{O}S^{O}S^{S}C^{O}S^{O}]$ $[S^{S}A^{O}]$ $[S^{O}A^{O}S^{O}C^{S}C^{O}S^{O}C^{O}C^{O}]$ $[S^{O}C^{O}S^{O}C^{O}S^{O}C^{O}S^{O}C^{O}C^{O}C^{O}S^{O}]$ $[S^{O}S^{O}S^{O}S^{O}C^{S}C^{S}S^{O}]$ $[C^{S}C^{S}A^{O}A^{O}S^{O}C^{O}S^{O}C^{S}A^{S}]$	$[S^{O}]$ $[S^{O}]$ $[S^{O}]$ $[S^{O}]$ $[S^{O}]$ $[S^{O}]$ $[A^{S}]$
Task 2: Locating two specified journal articles in electronic resources on the Web		
$[S^{O}]$ $[S^{O}S^{S}]$ $[S^{S}S^{S}S^{O}]$ $[S^{S}S^{O}]$ $[S^{S}S^{O}S^{S}]$ $[S^{S}S^{O}S^{S}]$ $[S^{S}C^{S}]$ $[S^{O}S^{O}]$ $[S^{O}]$ $[S^{O}]$ $[S^{O}S^{O}C^{S}]$ $[C^{S}]$ $[S^{O}S^{O}S^{O}S^{O}]$ $[S^{O}]$ $[S^{O}C^{O}]$ $[S^{O}S^{S}]$ $[S^{S}C^{S}]$ $[S^{O}S^{S}]$ $[S^{O}]$ $[S^{O}S^{O}C^{S}]$ $[C^{S}S^{S}]$ $[C^{S}S^{O}S^{O}S^{O}S^{O}]$ $[S^{O}]$ $[C^{O}A^{S}C^{S}A^{S}]$ $[C^{O}S^{O}A^{O}A^{S}C^{O}A^{S}C^{O}C^{O}]$	$[S^{O}C^{O}C^{O}C^{S}S^{O}C^{S}C^{O}S^{O}S^{S}S^{O}]$ $[S^{O}C^{O}]$ $[C^{O}S^{O}S^{S}]$ $[S^{O}]$ $[S^{O}S^{S}]$ $[S^{O}]$ $[S^{O}C^{O}C^{O}]$ $[S^{O}]$ $[C^{O}S^{O}]$ $[S^{O}S^{O}S^{O}S^{O}]$ $[S^{O}C^{S}C^{O}]$ $[C^{O}C^{O}C^{O}S^{O}S^{O}]$ $[S^{O}]$ $[S^{O}S^{O}]$ $[S^{O}S^{O}S^{O}S^{S}C^{O}A^{O}]$ $[A^{S}S^{O}C^{O}S^{O}C^{O}C^{O}S^{S}S^{O}C^{O}S^{O}]$	$[S^{O}]$ $[S^{O}S^{S}]$ $[S^{O}S^{S}]$ $[S^{O}]$ $[S^{S}S^{O}A^{O}]$ $[S^{O}]$ $[S^{O}S^{O}]$ $[S^{O}A^{O}]$ $[S^{O}]$ $[C^{O}S^{O}]$ $[S^{O}S^{S}]$ $[S^{O}]$ $[S^{O}A^{O}]$ $[S^{O}]$ $[S^{O}C^{S}]$ $[S^{O}S^{O}C^{S}]$ $[S^{O}C^{O}]$ $[S^{O}C^{O}]$ $[S^{O}]$ $[S^{O}]$ $[S^{O}]$ $[S^{O}]$ $[S^{O}A^{O}]$ $[S^{O}]$ $[S^{O}C^{S}]$ $[S^{O}S^{O}C^{S}]$ $[A^{S}A^{O}A^{O}]$

For instance, from Table 2 one can derive these descriptive statistics for each individual (A, B, C) by task:

	TASK 1 Creating a file for the report and registering on the Web as a Lab User						TASK 2 Locating two specified journal articles in electronic resources on the Web					
	SAT	OPT	A	C	S	Total	SAT	OPT	A	C	S	Total
Ind.A	6	28	2	9	23	34	25	37	4	14	44	62
Ind.B	9	43	5	20	27	52	6	51	2	20	35	57
Ind.C	1	6	1	0	6	7	8	39	7	7	33	47

The above frequencies reveal differences related to individuals and to tasks. Discussing how to do Task 2 was more involved and complex than Task 1 for individuals A and C but not for B. Mentioning optimizing procedures (OPT) was more frequent than mentioning satisficing procedures (SAT) for all three individuals. All three individuals focused primarily on sensorimotor procedures [S] and least on affective procedures [A]. Many other relationships of interest can be investigated in data mining efforts such as the effect of gender, age, expertise, type of collaboration, situated context (type of shopping, type of discussion group, type of email communication, folksonomies, wikis, particular communities of practice, information settings, collaborative teams, etc.).

The idea of charting and monitoring intersubjective space is applicable to dyadic interactions (as in the sample analysis above), to work groups or teams, to customers of a particular organization, and to entire populations. For instance, the social-biological flow diagram in Figure 2 can be applied to chart *customer behavior* and other forms of *information behavior* since the same general procedural circuits are involved. Customers behave by satisficing their wants by means of optimized goal procedures. Simon (1956) demonstrated that this behavior cycle actually accounts for people's financial decisions, as well as the economic 'models' or 'schemata' by which business managers operate. Simon argued that managers want to optimize their profitability, while satisficing their survivability. They won't make risky optimizing moves that threaten their job survival. In the same way, customers want to satisfice their needs and desires [A^S], but because they also want to optimize their savings [A^O], they will shop around for the best buy that gives them the minimum that they would settle for ("satisfice"), that is, what they consider to be good enough for the situated conditions. Similarly, people engaged in *information seeking* want to satisfice their information need just enough and no further (Prabha et. al., 2007), which they try to optimize by expending the least amount of time, effort, and money to do it, in accordance with the affective load involved in continuing the search effort (Nahl, 2005).

Romano et. al. (2007) give samples of different types of Internet text to show how its content provides valuable information to product designers and business outlets. The data segments will be coded using constructionist discourse analysis according to the schema in Figure 1. From an email message by a customer:

I'm thinking about buying a new (product).

affective [A^O] and cognitive [C^O] optimizing procedures that count as goal-intending and planning practices

I can't decide between a brand X model 100 and a Brand Z model 727.

cognitive [C^S] and affective [A^S] satisficing procedures that count as appraising and value-attaching practices

Can anyone help?

sensorimotor optimizing procedure [S^O] that counts as requesting help practices

The above discourse sample has the following chart signature:

Mentioned path: [$A^OC^OC^SA^SS^O$]

Unmentioned path: [$A^OC^OC^SA^SA^OC^OS^O$]
or (8, 9, 4, 5, 8, 11) on Figure 2.

Here is a data segment from another customer:

How can I identify the size of a fly line that came without any indication of its weight?

affective optimizing procedures [A^O] that count as goal-intending (*to identify size of a product*), and cognitive optimizing procedures [C^O] that count as problem solving planning about a potential product deficiency (*came without indication of weight*)

I know that weights are determined by the last 30 feet of the line, but what weight indicates what line size?

cognitive satisficing procedures [C^S] that count as appraising with prior knowledge about a potential product deficiency (*I know that…*), connected to cognitive optimizing procedures [C^O] that count as problem-solving planning practices (*but what weight…*), and performed as sensorimotor optimizing procedures that count as verbalizing a question (*what weight indicates what line size?*).

The above discourse sample has the following chart signature:

Mentioned path: [$A^OC^OC^SC^O$]

Unmentioned path: (same) or (8, 9, 10) on Figure 2.

Romano et. al. (2003) review the literature and conclude that "Internet conversation text can yield meaningful information about consumers' wants, needs, and attitudes toward products" (p. 218). Businesses have found it useful to rely on this kind of objectified content analysis of customer feedback or inquiry to make needed design changes in their products.

Here is another data segment from a *Usenet* discussion group:

Hi!

sensorimotor optimizing procedure [S^O] that counts as greeting practices in that setting.

I am about to buy a power miter saw and a table saw for misc. projects

affective optimizing procedure [A^O] that counts as goal-intending practices and sensorimotor optimizing procedures [S^O] that count as telling what the products are.

I am not a pro, but

affective satisficing procedure [A^S] that counts as self-evaluation regarding one's expertise

I want to buy something that is going to last me some time.

affective optimizing procedure [A^O] that counts as goal-intending, connected to cognitive optimizing procedures [C^O] that count as planning for the product to last long

The above discourse sample has the following chart signature:

Mentioned path: [$S^OA^OS^OA^SA^OC^O$]

Unmentioned path: [$S^OE^OE^SS^SC^SA^SA^OC^OS^OE^OE^SS^SC^SA^SA^OC^O$]
or (14, 15, 1, 2, 4, 5, 8, 11, 15, 1, 2, 4, 5,8) on Figure 2.

Conclusion

The charting method presented in this article is based on universal features of human biology and community. It is therefire "culture free" and applicable to all cultural groups. Further research will establish additional applications in business and online marketing. The theory may also be useful to help technology administrators provide users with facilities that enhance their ability to collaborate and communicate. Intense new developments in intelligent and augmented technology rest on their ability to monitor and categorize user thinking and user behavior. The model presented in this article can help in such monitoring through analysis of user comments, and in categorizing by reference to the universal human psycho-biology of the mind. The focus components of this psycho-biology are specified as the affective (e.g., feelings, emotions, enjoyments), cognitive (e.g., comprehending, planning, categorizing), and sensorimotor systems (e.g., seeing, listening, moving the hands). These are precisely the components that user discourse analysis uncovers showing that the users' feelings, thoughts, and sensations form the basis of their online activity.

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