Temporal attributes of shared artifacts in collaborative task environments

Frank Spillers[1] and Daniel Loewus-Deitch[2]

[1]Experience Dynamics, 809 NE Imperial Avenue, Portland, Oregon 97232 USA
Email: frank@experiencedynamics.com

[2]University of California, Irvine, School of Information and Computer Science
444 Computer Science Bldg., Irvine, California 92697 USA
Email: dloewusd@ics.uci.edu

ABSTRACT

The following paper discusses artifact-sharing with an emphasis on temporal, social and cognitive influences in multi-user collaborative task environments. The need to understand the temporal and social attributes of tasks has intensified as information management responsibilities grow. The proliferation of information technology in traditionally low-tech environments has created an opportunity to understand the needs of collaborative users and user interfaces that are temporally distributed. Inquiries into the cognitive and social artifacts of collaborative workflow and subsequent fluctuations or exceptions caused by the task environment are essential to successfully modeling task requirements. Focusing on a key element of collaboration, *artifact sharing*, we discuss the temporal qualities that reduce error and increase productivity in collaborative task environments.

KEYWORDS

Tasks, artifact-sharing, temporal aspects, CSCW, task analysis, collaborative tasks, cognitive artifacts

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INTRODUCTION

There is little doubt as to the role time plays in task completion (Johnson and Gray 1996; Parker, 1997; Grant 1995a; Rex and Philip 1991). Temporal distinctions appear inherent in human work activity and seem to play a special role in collaborative task environments. The implications of temporal attributes as they inform usability of product design are significant (Johnson, Gray and Philip 1995).

To understand how temporal dynamics influence collaborative task completion requires a close examination of the artifacts utilized in task sharing. Artifacts play a central role in revealing temporal qualities that may be extracted by Task Analysis procedures and applied directly to user interface design problems (Spillers, 2003). Evidence and growing interest in how and why artifacts are manipulated and configured in shared workload situations is increasing rapidly in Task Analysis research (Stahl 2003; Wild, Johnson and Johnson 2003).

ARTIFACT SHARING

Artifacts are the instruments, objects and tools, both physical and mental, that users employ during task completion. Physical artifacts serve an important role in the sequencing, triggering and closure of a task or set of tasks. Cognitive artifacts (Norman, 1991) assist in representing task knowledge and procedures and help transcend barriers to problem solving and decision-making (Spillers, 2003). Zhang and Norman (1994) found that “a cognitive artifact does not modify the computational power of the human mind; instead it modifies the content of the knowledge involved in the elaboration process.” In group task environments, artifacts are employed to alter, extend or preserve group knowing, sense-making or decision-making (Stahl, 2003).

Artifacts are essential to human cognition in the sense that they extend or aid memory, attention and information processing. Hutchins (1995) defines cognitive artifacts as physical objects made by humans for the purpose of aiding, enhancing, or improving cognition. Stahl notes that meaning is not inherent in the artifact itself; rather meaning comes from the networks of reference in which the artifact is located. In actuality, artifact sharing can be viewed as a collective group problem-solving activity and an attempt to minimize errors and increase success.

Shared artifacts are used by actors in the distributed task environment to configure and facilitate group decision-making, thinking and communication. Artifacts are created within the cognitive and environmental task space and are used to further task completion (see Figure 1).

Cognitive artifacts are those elements whose function is to aid or simplify task success. The outcome of positive artifact manipulation includes task switching (artifacts used as triggers) (Pashler, Johnston, Ruthruff 2001 638); role switching (artifacts used to change roles); or closure (artifacts used to complete a task).

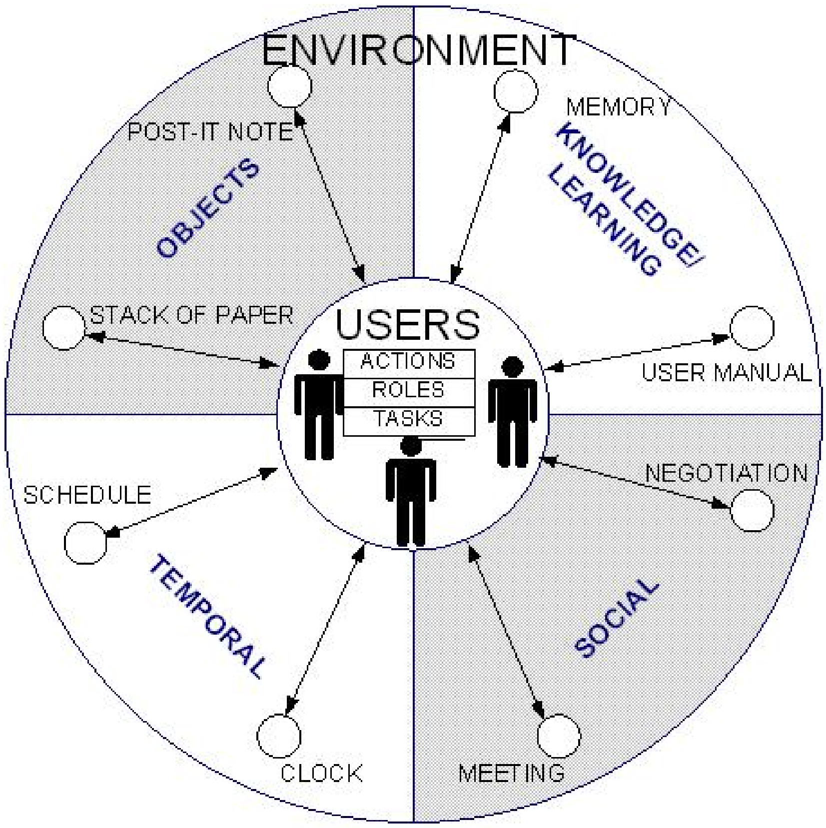

Figure 1: Artifact sharing between users where artifacts are projected into the task environment to reduce errors, shift focus and aid task accomplishment. Artifacts are represented above as circles with example artifacts for each quadrant of the task environment: Knowledge/Learning; Objects; Temporal; Social.

INTERRUPTION AND DISTURBANCE MANAGEMENT

In the distributed task setting, the multi-user environment plays a central role in knowledge acquisition and manipulation. Investigations into the costs incurred by task switching or "task-set reconfiguration" (Pashler, Johnston, Ruthruff; 2001, 639) have found that given enough preparation time, error and task failure can be greatly reduced. Similarly, understanding how and when users perceive temporal information in the task environment and what forms their expectations and perceptions can help designers better understand the costs assumed with "task switching" (Parker, 1997). Parker argued that there is a good case in investigating human temporal "disturbance management" in the retrieval of distributed information. To date temporal "disturbance management" research has focused primarily on process control and safety critical systems (Woods 1998).

Grant (1995a) noted that human error can not be generalized across domains. Time pressures differ based on task complexity and more observation should be given to the factors of attention and perceived context, according to Grant. One such implication of temporal "disturbance management" (Woods, 1991 cited in Parker), occurs when the user encounters what Grant (1995b) termed "unusual" or unfamiliar regions of the task space. Systems that can respond to error related to discovery of unusual areas can be built to assist users in preventing and responding to accidents caused by such task disturbances.

Artifacts that act as cognitive “safety nets” (Spillers, 2001) can be more easily created in distributed task environments since more actors can share responsibility. However, between multiple users the likelihood of error can be even higher due to system incongruities. Bardram (1997, 251) discovered gross inadequacies in Danish hospitals where manual and computer processes running in parallel (due to the social configuration of the technology) were sabotaging productivity, time and accuracy.

COLLABORATION AND CONTINUITY

When users collaborate within the workplace, there is often a significant amount of “cognitive overhead” (background knowledge, procedure, instructions) required for orienting individuals to new or ongoing activities. Individuals each have their own roles, goals, objects and required actions that must be satisfied (Macredie and Wild 2000). Throughout the duration of a cooperative task, collaborators will likely contribute at staggered times, depending on their roles in the task and the domain knowledge or skills that are required at each specific phase in the task. Clearly, it is not always efficient, cost-effective, or realistic to have all participants working on a task at the same time. Therefore, the question of how to bring participants in at intermittent times and orient them without disrupting the overall workflow of the task becomes crucial.

The nature of cooperative tasks requires individual skills and knowledge to be augmented and distributed across the multi-user environment. Hutchins (1991, 295) argues that “distribution of access to environmental evidence” is crucial for high performance and task success. The details are in the delegation of roles, responsibilities and the meaning interpreted from the “division of task labor” (Brazier, Treur, Wijngaards, Willems 1996).

In practical terms, collaborative teams appear to have a need for what we term “shared task continuity”. Users must feel connected to the knowledge and information shared across the task space. Actors do not necessarily require “all the details” when they join a task, since different roles require varying levels of detail. Regardless, the ability to reference, investigate, leverage and interpret from what the team knows collectively becomes essential to distributed cognition (cooperation, motivation and action).

BROKEN TASKS AND TASK TRIGGERS

It is common for a single individual to experience what Dix (2003) refers to as broken tasks. A broken task is essentially any task that cannot be completed within one, continuous session. Broken tasks can occur for a number of different reasons. For instance, the user may have been interrupted unexpectedly and had to temporarily abandon the current task. It is also possible that the task inherently requires some sort of pause before it can ultimately be completed. The individual must wait for an environmental response, either from another person (i.e. a reply to an email sent), or from a physical object related to the task (i.e. a biologist waiting for a culture to grow).

When a task is halted, there are some common "triggers" that can help catalyze its continuation (Dix and Wilkinson.; 1996; 1998). For example, a trigger might reside within temporal habits, such as checking the status of a system every day at the same time. The trigger may also occur in the form of an explicit external action (i.e. a reminder phone call) or, more subtly, in the form of an environmental cue. A trigger helps remind an individual of a task that still requires attention and completion, and can get the task process moving again towards completion. The ability of the triggers to direct the task process, preserve the appropriate sequence of actions, and maintain its natural temporal rhythm heavily depends on the robustness and redundancy of these triggers.

Within a collaborative environment, these triggers are also critical for preserving workflow integrity amongst the team members responsible for completing a task. Explicit, external triggers such as schedule items and direct requests for help are intermixed with implicit, internal triggers such as learned and habitual knowledge of how a collaborative task process is carried out. According to Stahl (2003), the "externalization of knowing in artifacts preserves the knowing for future uses by the creators, as well as by others". Experienced users associate roles with knowledge and knowledge with artifacts, while relying on both verbal and non-verbal triggers to alert them when it is appropriate to contribute. Stahl notes that these mechanisms are also used to negotiate and extend the group's abilities and knowing.

TEMPORAL COORDINATION AND RYTHMS

One specific source of implicit triggers is knowledge of the social rhythms that exist within a task environment or organization. According to Hill and Begole (2003), users follow temporal patterns, called "activity rhythms," in their day-to-day work schedules.

When users work together in the same space, they tend to become familiar with each other's rhythms over time. These temporal patterns can be extremely useful for predicting when a particular individual comes to work, takes breaks, when they are most receptive to unanticipated visits, and when they are typically available for working on certain types of tasks (Hill and Begole, 2003). Zerubavel (1979) extended this concept of rhythms to the social environment of the workplace. Using a hospital environment as a case study, he reveals the cyclical nature of work in an organization, and explains why temporal aspects are so critical in cooperative work.

Temporal coordination is considered an activity in itself. Baxter, Bernat, Burns, Filipe, Harrison, Monk and Wright (2001) offered the notion that manipulation of temporal variables allows users to sequence events, predict duration and gain perspective (past to future). Duration prediction, or the act of determining lengths of time in a task, according to Baxter, Bernat, Burns, Filipe, Harrison, Monk and Wright (2001) appears to be the most difficult calculation for humans to make. However, the miscalculation (e.g. creating a false sense of urgency) may be instrumental to the benefits incurred by having more time to conduct error prevention and task enhancement activities. It is still open for speculation whether distortions in perception of duration exist in order to trigger new or sub-tasks or provide closure to open tasks. Often, collaborative users will agree to "take a break" in order to gain perspective, quite possibly leveraging time as a mechanism to alter cognitive activity (concentration, attention, awareness).

Coordination of temporal attributes involves ad hoc synchronization, scheduling, and allocation of appropriate resources. External planning during temporal coordination is obviously critical for scheduling and allocation, but internal communication amongst team members is just as important for synchronization of actions and subtasks at the micro level. Stahl (2003) suggested a framework for internal communication and what he termed the building of group knowing. His framework included the following variables: Collaboration, Social awareness, Knowledge building, Knowledge management and Apprenticeship.

Bardram (2000) continued Zerubavel's (1979) analysis of social rhythms in hospitals by concentrating on coordination activities that exist amongst a team of workers within an organization. Using a surgical department as an illustrative model of these social rhythms, Bardram embraced Activity Theory to extend the analysis of temporality in coordination, to include subjective, sociological, and organizational issues. An operation in the surgical department requires the coordination of many different activities and actors. Actions must not only be taken in a specified sequence, they must also be done with appropriate timing. For example, certain lab tests must be completed far enough in advance so that the results will be available for the surgeon to analyze while he is making final preparations for the operation procedure.

SOCIAL RYTHMS AS ARTIFACTS

It is important to note that triggers and rhythms do represent many cognitive artifacts themselves. The difference here is that most of these artifacts provide only elementary information about a task. A trigger can help provide placeholder information, specifying the stage of the task that it is currently halted. A shared artifact used for temporal coordination, such as a clock or calendar, might help team members coordinate actions and activities, so that all the required resources are available at the appropriate time. What these elementary artifacts may not necessarily provide, however, is the contextual and case-specific information required by the team member who is on deck, waiting to perform his portion of the task. In addition, the incoming team member's responsibilities and actions are often necessarily dependent on information gathered by other members during previous stages of the task. The properties that govern the artifact include inter-related social activity, user goals of the task and the functional properties of the artifact (Cerratto, 1999).

Following on Zerubavel's concept of temporal patterns, Reddy and Dourish (2002) considered social rhythms as artifacts containing information essential to collaborative work. They suggested that information seeking is not a separate task, but rather it is tightly integrated into other mundane, operational working activities. Information is created through interactions with other team members, and this is where virtually all knowledge transfer and knowledge development takes place. Furthermore, becoming aware of others' goals and motivations is very important, when making decisions that affect the task environment as a whole. A lack of awareness about differing rhythms amongst team members can lead to communication breakdowns and crucial missed opportunities. Remaining in touch with the rhythms of other collaborators appears to be extremely important for maintaining the flow of pertinent and contextual information, as actors rotate and transition through multiple task roles and functions.

Work rhythms help medical personnel orient themselves to their designated roles and responsibilities within the multiple collaborative tasks that they play a part in. The hospital is a very large, information-rich environment with many actors and activities (Reddy and Dourish, 2002). It contains large amounts of vital, urgent patient data that personnel must keep up-to-date on because human lives depend on it. A hospital is a prime example of an organization with distributed knowledge. Within such an environment, temporal patterns can help actors organize and prioritize the information they need in a timely manner, so that they can proficiently take care of their patients and take the appropriate actions at the right time. For example, if a doctor is aware that the nurses check on his patients at 8 o'clock in the morning, he knows that 9 o'clock would be a perfect time to hold a meeting with other relevant hospital staff to begin mapping out the day's plan of action. He knows that all critical information and significant episodes have been recorded by the nurses. With the recently updated conditions of his patients readily available, he can now competently make decisions regarding his patients, such as preparing them for scheduled operations (Bardram, 2000) or stabilizing them and moving them out of the intensive care unit (Reddy and Dourish, 2002).

ROLE SWITCHING FUNCTIONS

It is clear from the work of Zerubavel (1979) and Bardram (2000) that there is a high degree of interdependency amongst the participants in a collaborative task. Participants each have their own objectives, goals, and required actions that must be satisfied, based on the role they play within the organization, the specific role they play in the task, and the skills or knowledge that they have. Still, in any given task, their contributions are also highly dependent on the expertise and work of others within a team. In fact, according to Coordination Mechanism (Schmidt and Simone, 1996), if a cooperative task requires any kind of coordination, then it inherently means that the actors are mutually dependent on each other. Without their team members' timely and accurate contributions, the collaborative endeavor will not likely result in successful task completion, and such breakdowns can potentially affect other coordinated tasks as well.

Triggers, as we discussed earlier, reveal the transition points in shared and broken tasks and may signal the need for role switching. In high stakes environments (aircraft, hospital, automotive), triggers form the basis for managing situation awareness and appropriate response. Dix (1998) pointed to status-event analysis as a means to decomposing "the process by which the knowledge and effects of events are propagated through a system". Dix highlighted the source of the event, the initiator of the interaction and the trigger as key elements in modeling events. Triggers in Dix's model seem to be a necessary component to understanding role switching.

In addition, temporal attributes may be critical to understanding role switching and changes to the cognitive (role) and task environment. Kirsh (1996) described users as changing their environments to assist in reducing the cost of mental operations, errors while increasing speed, accuracy and robustness in task performance. Through deliberate alterations to time (e.g. planning) and space (e.g. the task environment), users appear to configure the task environment to facilitate role switching and increase task success.

Shared artifacts also seem to mediate action and role orientation in contexts defined by temporal attributes. By seeking out collaborative artifacts, users suddenly are able to confront or narrow required actions. Kirsh (1999) noted that physical alteration of the task environment serve the purpose of saving on attention and memory computation. According to Kirsh, users "recruit external elements to reduce their own cognitive effort by distributing computational load." In this regard, the functions of sharing artifacts, responding to task triggers, role switching or deliberate environmental changes would appear to serve the purpose of load-balancing the distribution and coordination of task effort.

CONCLUSION

Triggers, rhythms and role switching are certainly vital components of task analysis when designing systems to support cooperative work, but these components still cannot provide the entire picture on their own. Triggers reveal the transition points in shared and broken tasks. They help system designers to understand the environmental and internal stimuli that cause a task to be initiated or resumed after a pause (i.e. waiting for a response), an unexpected interruption, or a transition between actors (what we call *shared task continuity*). Social rhythms provide predictive information (Reddy and Dourish, 2002) about work behavior at the individual and organizational level and also expose the intricate details of temporal collaboration activities that are necessary in any sort of cooperative task (Bardram, 2000).

What is still missing in this task analysis framework are the mechanisms by which uninitiated team members become oriented to a task and all the historical information that has accumulated up unto the temporal point of entry, dictated by the individual's particular role in the task. This is where shared cognitive artifacts come into the picture. By seeking out these collaborative artifacts, we suddenly are confronted with many interesting and essential research questions: When it is time for a new team member to start her phase of the task, what artifacts are handed to her by the other team members who have already been involved in the task? What artifacts does she need to actively seek out and gather from the task environment? What kinds of information do these artifacts provide? How does she decide when she has collected and learned enough information through these artifacts to competently begin her phase of the task?

Analysis of artifact sharing can reveal areas of significance in the factors that constitute successful modeling of collaborative tasks. Temporal manipulation and perceived context can be better understood when evaluating artifacts during task shifting and role switching phenomenon. Understanding the cognitive artifacts that are shared between team members and the configuration of those artifacts (Stahl 2003) may help CSCW system designers understand how to create mechanisms to minimize the static points required when bringing new actors (or a distributed "virtual" team) into an ongoing project that already has a significant history of actions, pertinent information, and critical issues (Hill and Begole, 2003). Moreover, artifacts appear to mediate temporal relationships among tasks. Artifact sharing plays an important social and cognitive role in contextualizing meaning and knowledge in order to reduce error and memory costs while increasing task accomplishment and efficiency.

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