Thinking in 4D: Preserving and Sharing Mental Context Across Time

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Abstract
Creative activities are frequently interrupted, making it difficult to maintain complex trains of thought. This paper presents a preliminary study of the knowledge, artifacts, and strategies programmers, writers, and graphic designers use to preserve and restore mental context across time. Our findings inform the design of resumption aids that might help people share mental context both with their future selves and collaborators.

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context reinstatement; interruption; implicit cues

ACM Classification Keywords
H.3.3 [Information Search and Retrieval]: Search process

Introduction
Creative activities such as writing, programming, and graphic design involve the construction and manipulation of fragile physical, digital, and mental states. These states are easily disrupted and, as creative activity increasingly takes place on computers, a number of digital tools have been developed to help people restore them [2, 3, 4]. These resumption aids organize previously accessed information and restore prior desktop arrangements but neglect the more critical task of helping people recover those thoughts that guide and motivate their work. Computational systems

Mental context includes knowledge about:

Artifacts: Including their existence, location, and what information they contain.

Collaborators: Including their skills and knowledge.

Goals: Including metrics and constraints that have to be met.

Plans: Including courses of action and their resource requirements.

Actions: Including granular next steps and their resource requirements.

Relationships: Including dependencies between the above categories.

Activity History: Including the current, past, and desired future states of the above categories.

have potential to help people preserve and share this mental context, not only with their future selves, but also with collaborators. However, designing effective resumption aids requires a better understanding of how people currently restore context. In this study we sought to understand the knowledge, artifacts, and strategies programmers, writers, and graphic designers use to restore mental context.

Observational Study

We recorded the screens of ten programmers, writers, and graphic designers for two weeks as they worked. While past studies of mental context have focused on programers, we included writers and graphic designers as they have access to markedly different resumption strategies (e.g., writers and graphic designers cannot use compile errors or commit statements to mark where they left off).

We selected portions of each participant's recording where they were resuming a complex, creative activity and asked participants to think-aloud while reviewing these moments during a post-recording interview (Figure 1). We analyzed 50 episodes of participants' activity resumption for the knowledge, artifacts, and strategies they used to resume their work.

Beyond Goals, Plans, and Actions

Past descriptions of mental context cast people as information processors who need to recall their suspended goal, plan, action, and relevant artifacts [1, 5]. However, real-world activity is routinely more uncertain and complex than executing a sequence of predetermined actions. Our participants needed to reinstate and reconsider past decisions about goals, plans, and actions that depended on knowledge of other people, relationships between activity components, and activity history (see sidebar).

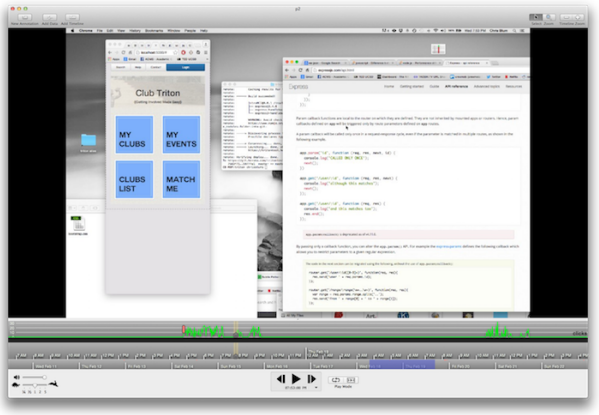

Figure 1: Participants described their resumption strategies while viewing screen recordings of moments when they were resuming a complex activity like programing, writing, or graphic design.

For example, our participants reinstated knowledge about *collaborators*. One programmer considered his partners' technical strengths before selecting his next action to make sure he was contributing in ways his collaborators could not. Participants also reconstructed *relationships* between project components. One graphic designer created a mental timeline of steps and stakeholders involved in drafting and printing a poster to decide if she could put off working on it or needed to contact a collaborator right away. Moreover, participants considered the *history of their activity*. One writer reflected on her past attempts at describing a complex concept before reworking a related paragraph. This prevented her from repeating sentence structures that had not worked in the past.

This varied knowledge reflects how creative activities differ from simple, well-specified ones. Participants needed

to reconstruct not only where they left off, but also how and why they were pursuing the activity in the past. Considering these motivations, justifications, and strategies helped them decide if they should continue their previous course of action, or formulate a new one. It also helped them situate their present activity in the context of their own and other's long-term efforts.

Rich Implicit Cues

All of our participants used *explicit cues* to store and restore context. For example, programers wrote inline comments describing where they got stuck and writers created lists of references to track articles they wanted to read. However, our participants also leveraged *implicit cues* that could only be interpreted with additional self-knowledge or knowledge of the activity's structure. These cues were often a byproduct of the activity itself and did not have to be intentionally created. For example, one writer was able to tell where she left off by searching for the line where her writing transitioned from fully formed sentences to an outline. This transition was an artifact of her normal writing process.

Implicit cues can be ambiguous, making them hard to interpret by anyone unfamiliar with the activity. Figure 2 shows part of a status report that a group of programmers were drafting right before a deadline. Seeing the blankness of the "Task to Try" section and the pink mark signifying her remote collaborator's cursor location helped one participant decide that her time was best spent designing a Task to Try (a demo her manager could use to test their code). The blankness and cursor alone were not sufficient to tell the programmer the current state of the project. Before deciding what to work on, she also needed to know that the Task to Try was a critical part of their report and was typically finished this close to the deadline.

Figure 2: Participants used implicit cues that required self-knowledge or knowledge of the activity to interpret. Here, while composing a status report with collaborators, one programmer used the blankness the "Task to try" section and the location of a collaborator's cursor to decide what to work on next.

Strategies Depend on Activity Structure

Participants used a number of general strategies to find and interpret explicit and implicit cues. These included reviewing and editing key artifacts such a program files, organizing artifacts such as todo lists, and referencing templates.

While participants' resumption strategies depended on individual habits, they also depended on the structure of the activity being resumed. One factor influencing resumption strategy was the *directness of manipulation*. In graphic design, edits are made directly on the final product. In programming, edits are made on networked files that must be executed before their quality can be evaluated. As manipulation got less direct, participants had to navigate between more artifacts to assess the current state of of their activity and spent more time reading and editing them to recall

relationships between artifacts.

Another important factor was the *overlap of collaboration*. With graphic design and writing, collaborators often worked on different artifacts or distinct portions of the activity. One graphic designer had a collaborator send her a list of talk descriptions as a Google document which she transcribed into an InDesign file. She alone edited her InDesign file and did not have to check if it had been updated while she was away. In programming tasks, however, collaborators routinely worked on overlapping goals and artifacts so files could change drastically while they were away and had to reviewed more thouroghly.

A final factor influencing resumption strategy was the *explicitness of goals*. In graphic design and writing, many of the goals are implied or hard to evaluate (e.g., lucid writing, credible sources, cohesive color scheme). In programming, more of the goals are explicit and testable (e.g., create a form with fields for Name, Address, and Email). Explicit goals are easier to externalize onto organizing artifacts such as todo lists. Thus, we observed web developers making much more use of todo lists than writers or graphic designers, who more often recalled goals by reviewing or editing their key artifacts. Whereas all the programmers we observed created todo lists for their projects, none of the graphic designers we observed did so. One writer, would start by articulating big goals on a todo list (e.g., revise chapter 3) and only be able to articulate smaller sub-goals once she had been writing for a while.

Future Work

Designing effective resumption aids requires a better understanding of mental context as well as the artifacts and strategies people use to restore it for everyday activities. Highlighting implicit cues that people currently use to restore mental context could make it easier for them to share this context with their future selves and collaborators.

We have gathered examples of explicit and implicit cues in digital artifacts that people use to restore mental context. Future work will explore how these cues are encountered in physical space, such as office arrangements, as well as how summary visualizations of past work activity can enable restoration of mental context.

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References

[1] Erik M. Altmann and J. Gregory Trafton. 2002. Memory for goals: An activation-based model. *Cognitive Science* 26, 1 (2002), 39–83.

[2] Jakob Bardram, Jonathan Bunde-Pedersen, and Mads Soegaard. Support for activity-based computing in a personal computing operating system. In *Proceedings of the SIGCHI conference on Human Factors in computing systems* (2006). ACM, 211–220.

[3] Victor Kaptelinin. UMEA: translating interaction histories into project contexts. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (2003). ACM, 353–360.

[4] David R. Karger, Karun Bakshi, David Huynh, Dennis Quan, and Vineet Sinha. Haystack: A customizable general-purpose information management tool for end users of semistructured data. In *Proceedings of the CIDR conference* (2005).

[5] Chris Parnin and Spencer Rugaber. 2011. Resumption strategies for interrupted programming tasks. *Software Quality Journal* 19, 1 (2011), 5–34.