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# 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.

**Author Keywords**

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 tools have been developed to help people preserve and restore them. [2, 3, 4]. The most progress has been made in restoring *digital* context as resumption aids make it easier to re-find previously accessed information and recreate prior desktop arrangements. However, these tools neglect the more critical task of helping

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people recover *mental* context, those ephemeral thoughts that guide and motivate their work.

Computational systems have potential to help people preserve and share mental context with their future selves and 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 programmers, 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 screen-recording where they were resuming a complex, creative activity and asked them to think-aloud while reviewing these moments during a post-recording interview (Figure 1). In total, we analyzed recordings and commentary of 50 episodes of activity resumption for the knowledge, artifacts, and strategies participants 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, and action [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 knowledge about other people, relationships between activity components, and the activ-

#### Mental context includes knowledge about:

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

**Collaborators:** Including their skills and knowledge.

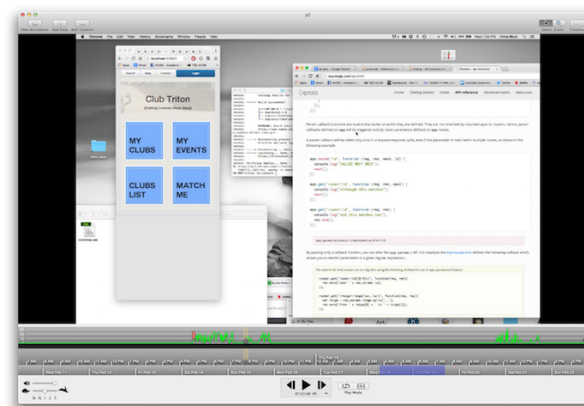
**Goals:** Including metrics and constraints that have to be met.

**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.



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

ity's history which had informed past decisions about goals, plans, and actions (see sidebar).

For example, our participants reinstated knowledge about *collaborators*. One programmer considered his partners' technical strengths before selecting his next action to ensure 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 to describe a complex concept before reworking a paragraph on the topic. This prevented her from repeating sentence structures and explanations that had failed in the past.

The need to reinstate such 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 first place. 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 participants used *explicit cues* to store and restore context. For example, programmers wrote inline comments describing where they got stuck and writers created lists of references to track articles to read. However, participants also leveraged *implicit cues* that were a byproduct of the activity itself. These cues did not have to be intentionally created and typically needed additional self-knowledge or knowledge of the activity's structure to be interpreted correctly. 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 show the programmer the current state of the project. Before deciding what to work on, she also needed to recall that the Task to Try was a critical part of their report and was usually



**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.

specified this close to the deadline.

### 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 as 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, work is done directly on the final product. In programming, however, edits are made to networks of files that have to be executed before their quality can be evaluated. As manipulation and evaluation got less direct, participants

had to navigate between more artifacts to assess the current state of of their activity and recall relationships between artifacts.

Another important factor was the *overlap of collaboration*. With graphic design and writing, collaborators often worked on different artifacts or portions of the activity. For example, one graphic designer had collaborators compile text into a Google Doc, which she later transcribed into an InDesign file. As she was the only one editing her InDesign file, the designer did not have to check if the file had been updated since she last touched it. However, in programming collaborators routinely work on the same artifacts so files can change drastically while they were away and have to reviewed more thoroughly.

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 programmers making more use of todo lists than writers or graphic designers, who more often recalled goals by reviewing or editing their key artifacts. For example, one writer we observed 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 context while pursuing everyday activities. We have gathered examples of mental

context for three types of computer-mediated activity and noted the artifacts and strategies people use to restore this information. Given the richness and prevalence of implicit cues, using computational aids to highlight implicit cues could make it easier for people to share mental context both with their future selves and collaborators.

Future work will explore how implicit 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.

### Acknowledgements

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