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Cognitive artifacts as a window on design ☆, ☆☆

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ABSTRACT

We are investigating *information analysis* as a kind of problem solving in which teams are presented with a collection of facts regarding people, places and events, and then identify underlying connections, patterns, and plans in order to draw specific conclusions. The teams spontaneously created a variety of *artifacts* to hold and organize problem information, and *practices* to simplify and regularize their collaborative interactions around these artifacts. In this paper, we analyze the artifacts and practices as a potential source of insight into how this problem solving activity could be supported by an interactive system design.

1. Introduction

When people work in complex environments, they support their own intellectual activity by designing *artifacts* to hold and organize problem domain information and *practices* to simplify and regularize interactions. For example, people create descriptive names for their personal files and, in managing file systems, they develop file naming schemas to guide and facilitate the generation of new filenames, and to enhance subsequent retrieval and recognition interactions with files and filenames [5]. This is a simple example of distributed cognition: People creatively shape and leverage the external world to be a more effective resource for their own subsequent activity [22].

Spontaneous ad hoc designs are of course not necessarily optimal designs, or even good designs. Non-designers often inappropriately reuse existing designs [21]. Command languages that users designed to operate robots were used effectively *by those users*, but the user-designed command languages often incorporated linguistic properties known to evoke command language performance problems for people generally [5].

We are investigating *information analysis* as a kind of problem solving in which teams are presented with a wide array of information regarding people, places and events, and must try to identify underlying connections, patterns, and plans. This is a difficult area to work in because practitioners are often specifically inaccessible to the public because of the security classification of the problem content they address. In a field study of information analysts in the US National Geospatial-Intelligence Agency (NGA, but at that time called the National Imagery and Mapping Agency) only a few participants could be identified, each was only able to devote a couple hours to the study, and all had to be interviewed by proxy, since our team did not have appropriate security clearance to talk to them [27].

We created a *reference task* [35] involving 222 facts pertaining to a set of campus crimes involving stolen laptop computers. We observed teams of three students working to identify suspects, to develop theories of the crimes, and to predict the next likely crime in the series. In addition to problem information, we provided the teams with standard office supplies. Most teams used these physical materials to create ad hoc information artifacts in the course of working on the problem.

In this paper, we describe the artifacts that were spontaneously created, and then consider these ad hoc

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designs as expressions of tool requirements for this problem solving activity. We use this analysis of the artifacts and practices of the student teams to guide a requirements analysis for the design of an interactive system to support the information analysis task. This is analogous to our earlier investigation of emergency management planning [6,28], which we subsequently used to design and evaluate interactive system support for that activity [18].

2. Background

A premise of our work is that studying the artifacts people spontaneously create to support their own activity can be a window into their cognitive and collaborative process. This premise is informed and supported by bodies of research in *distributed cognition*, which regards artifacts people use in carrying out work activity as elements of the overall cognitive system [22,25], in *cultural psychology*, which regards the externalization of thought into the material world as a core strategy for both coping with complexity and for learning [16,33], and in *experience design/embodied interaction*, which regard the materiality of tools and other cognitive resources as critical to their role in human activity [20,36].

Research in cognitive psychology argues that diagrams and graphics are less expressive media than text, particularly with respect to abstractions and relationships, making them easier to understand, often interpretations can be perceived instead of deduced [24,31]. Self-generated external representations function as memory aides, both with respect to the content represented and the person's analysis and interpretation of it [19].

Chin et al. [14] studied five professional information analysts working both individually and as a group. The analysts first made simple annotations in their source materials to highlight purported facts about people, places and events, then they constructed various artifacts to hold and present facts, and finally they tried to identify patterns or connections among facts. The analysts had distinctive and strong beliefs about the artifacts they created and used, and while they believed they could achieve better results by collaborating with others, they also said they would not trust another analyst's artifacts, but would need to review the original source material.

We want to analyze spontaneously created artifacts as a way of gathering and developing implicit design requirements for technology support. Artifacts that people spontaneously generate might suggest or embody "natural" ways of representing problem domain information, and therefore might be worth considering as design starting points or design metaphors. More specifically, observed efficacies or difficulties that people experience in using their spontaneous artifacts might suggest approaches to elaborating those artifacts as digital tools [18].

Taking cognitive artifacts as a window on design has known limitations. It is a situated approach, so the artifacts generated in a given problem context may be strongly bound to that context [17]. One way to address this is to try to articulate artifact analyses at a "basic level" of generality [26]. Another limitation is that artifacts spontaneously generated by people may be suboptimal or even poor representations created to support performance, but perhaps undermining it [15]. One way to address this is to try to link artifact designs with user experiences and performance outcomes, that is to emphasize representational factors that enhance performance and/or experience, but to mitigate or eliminate those that diminish outcomes for people [7]. For example Schafer et al. [28] showed that maintaining awareness was a key problem for regional emergency planners, which was confirmed and elaborated in laboratory studies. Support for awareness was therefore emphasized in the design of software tools, which indeed did support better performance [18]. Finally, the artifacts people spontaneously generate might function effectively as tools *for those people*, but not necessarily as effective tools for others; this is a version of the "generation effect" [5].

3. Study design

Our task scenario is an analog of the US Navy's Special Operations Reconnaissance (SOR; [34]) scenario in which three information analysts collaboratively synthesize and make sense of a complex information space of people, locations and events. We remapped the scenario content to concern a series of laptop thefts in and around a college campus. This was to better leverage local knowledge of our college student participants (e.g., regarding town and campus geography), and to enhance their engagement in the study.

Each team member was assigned a specialized role with distinct responsibilities regarding information sources: the *Interview Analyst* manages information obtained from interviews with persons of interest (POIs) or witnesses; the *Records Analyst* manages information from reports or files, such as bank/credit transactions, class schedules, police records, etc.; the *Web Analyst* manages information from Facebook, Twitter, EBay, and other online resources. The problem scenario includes 222 pieces of information, or facts, about relevant people, locations, and events regarding the crimes; the 222 facts were evenly distributed among the team members through role-specialized intelligence documents. Participants had to read and analyze these intelligence documents in order to identify the 222 facts.

The mission was organized into three phases, with a specific objective for each phase; the performance scoring rubric is indicated in parentheses. Phase I introduced 105 facts, mainly regarding schedules and relationships of POIs. In this phase, the teams were asked to narrow down a list of 26 POIs to a list of the eight most likely suspects (8 points). *Opportunity* was the main factor for this phase: proximity to the crime scene at the time of the theft.

In Phase II, teams were given 48 further facts. Participants were asked to identify thieves for each of four thefts (4 points), the instigators of each theft (8 points), motives for stealing the laptops (4 points), and whether there were connections among the four thefts (1 point). For this phase, solutions were determined by opportunity and motive: the thieves were one of the eight most likely suspects who either (1) were near the crime scene at the time of the theft and had motive based on their social