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Agile Cognition: Discovering the Cognitive Artifacts Used for Project Management in Agile Software Development

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ABSTRACT

Using naturalistic decision making, cognitive artifacts help us understand the cognitive processes that take place on teams. For agile software development (ASD) teams, we focus on cognitive processes that take place during an iteration. We conducted four case studies of four different agile teams. Using media richness and media synchronicity theories, results suggest that ASD teams use multiple cognitive artifacts to plan and manage their iteration. The interactions with these artifacts include examples of lean and rich media, with ASD team members preferring richer media where more information is communicated accurately. Distributed cognition helps the ASD team both make sense of tasks in order to complete them on time for the client and cope with the complexity, uncertainty, and fast-paced nature of ASD. Our contribution includes a comprehensive list of cognitive artifacts and ASD team interactions categorized by media type, level of richness, information purpose, synchronicity, and usage purpose.

Keywords

Project Management; Cognitive Artifacts; Communication; Team Communication; Agile Software Development.

INTRODUCTION

Naturalistic Decision Making (NDM) examines the cognitive processes of how people use their experience to make decisions in field settings (Klein, 2000; Zsambok, 1997). We see this cognition in action by examining the cognitive artifacts, the human-constructed objects with significance to their users, and the distributed cognition that enacts these artifacts (Hutchins, 1995).

NDM focuses on complex decisions by teams (Flin, O'Connor and Crichton, 2008) faced with difficult conditions of limited time, high uncertainty, inadequate information, high stakes, unclear and shifting goals, and unstable conditions (Klein, 2008), ill-structured problems, feedback loops, and input from multiple team members (Zsambok, 1997). Agile software development (ASD) teams experience said time pressure and high stakes by delivering working functionality to customers through a series of iterations (Fitzgerald, Hartnett and Conboy, 2006b; Fowler and Highsmith, 2001b). They respond quickly to changes in business environments and customer requirements by regularly adapting development processes (Henderson-Sellers and Serour, 2005) and incorporating rapid feedback (Nerur, Mahapatra and Mangalara, 2005).

Some research has examined cognitive artifacts on ASD teams, for example physical and conceptual artifacts for designer-developer collaboration (Brown, Lindgaard and Biddle, 2011); artifacts used for information flow on dispersed agile teams (Sharp, Giuffrida and Melnik, 2012); distributed cognition and the index card artifacts containing stories and tasks and their display wall (Sharp, Robinson and Petre, 2009; Sharp, Robinson, Segal and Furniss, 2006); and the anchoring and adjustment bias from reusing code and design as artifacts (Parsons and Saunders, 2004).

However, there has been little to no focus on the cognitive artifacts used for the project management of ASD teams Thus, this research examines the multitude of cognitive artifacts used by an ASD team to plan iterations and manage the ASD project. We consider the richness of the communication media used to better understand the usefulness of

the cognitive artifacts for team interactions. We show how the analysis of cognitive artifacts reveals the ASD teams' cognitive work and communication related to project management via the following research questions:

RQ1: What are the cognitive artifacts an ASD team uses for project management?

RQ2: How are cognitive artifacts facilitating team member interactions during ASD projects?

Our contribution to the project management and ASD fields is the categorized list of cognitive artifacts used by an ASD team. These artifacts reveal how interactions revolve around these artifacts as agile team members communicate using said artifacts. First we examine the background literature to our research. Then we discuss the methods used to both collect and analyze our data. We follow with a section describing our results. We include a discussion of these results and conclude our key findings and limitations of this study with ideas for potential future research.

BACKGROUND LITERATURE

This section presents literature on cognitive artifacts, media richness, and synchronicity for ASD team communication.

Distributed Cognition and Cognitive Artifacts

Distributed cognition is a team's shared awareness of goals, plans, and details beyond a single individual's grasps; it is the team's mutual understanding of the situation. Internal and external cognitive processes require complex coordination between internal and external resources. Internal resources include memory, attention, and executive function, whereas external resources include objects and artifacts (Hutchins, 1995). Cognitive artifacts are examples of these external resources used in distributed cognition and are typically human-made, physical objects used to aid, enhance, or improve our cognition. Examples of cognitive artifacts are calendars, lists, and computers (Hutchins, 1999). Artifacts helps us perform a task but require knowledge for their use. Their most distinctive aspect is contributing to a cognitive task as their function (Heersmink, 2013). Thus, the "cognitive artifact concept points not so much to a category of objects, as to a category of processes that produce cognitive effects by bringing functional skills into coordination with various kinds of structure" (Hutchins, 1999, pg. 127). Cognitive artifacts have been addressed in the medical field (Cook and Woods, 1996; Klein, 2000; Xiao, Milgram and Doyle, 1997) and include objects like schedules, display boards, lists, and worksheets that build a shared understanding of how teams in a healthcare setting dynamically plan to provide care as they manage the balance between both the demand for care and the resources available to provide it (Nemeth, O'Connor, Klock and Cook, 2006; Nemeth, Cook, O'Connor and Klock 2004).

This research applies a similar view for the ASD field where agile teams regularly plan for and manage the balance between customer demand for functionality and the ASD team's ability to deliver working software after each two-week iteration. ASD is a project management (PM) method where small collaborative SD teams (Dybå and Dingsøyr, 2008) work under extreme time pressure to design and develop products (Ballard and Howell, 2003) to deliver working software to customers in two-week iterations (Schwaber and Beedle, 2002). They only plan for one iteration at a time, and communication is important as members have their own limited experience and rely on interactions with others (Drury et al., 2011). Understanding the cognitive artifacts and distributed cognition that takes place can help ASD teams improve communication performance and better plan for and manage resource constraints to develop working software on such a continuous, fast-paced schedule.

Media Richness and Media Synchronicity

Media richness theory (MRT) states that communication channels differ in cue-carrying capacity, meaning the types and amount of information available for knowledge processing and effectively transmitted during an interaction vary depending on the communication channel used. When task information needs are matched with a communication channel's information richness, task performance improves (Daft and Lengel, 1986). Different communication channels, or media, fall on a media richness continuum anchored by rich and lean media at either end of the continuum (Chidambaram and Jones, 1993). Rich media generally have a high cue-carrying capacity by allowing multiple types and amounts of information to be transferred via verbal, paraverbal, and nonverbal channels (Daft et al., 1986). Types of rich media teams use include face-to-face communication or video-conferencing that allow

teams to collaborate synchronously as information technologies allow people to interact simultaneously (e.g., Baker, 2002; Drury and Williams, 2002). Lean media, on the other hand, is limited in terms of cue-carrying capacity because it restricts non-verbal and paraverbal cues (Straus, 1997). Researchers suggest teams exchange shorter messages through lean rather than rich media (Boyle, Anderson and Newlands, 1994).

Based on these findings about cue-carrying capacity, we associate rich media with ASD interactions and distributed cognition. A key tenet for ASD is having frequent, short, continuous communication interaction sessions (Cusumano and Smith, 1995; Hass, 2007) to convey information (Cockburn and Highsmith, 2001). Face-to-face communication is the most efficient, effective method of communication and interaction for ASD teams (Fowler et al., 2001a), and richer communication medium are emphasized over lean ones, particularly during the beginning of the development project (Green, Mazzuchi and Sarkani, 2010). While today's lean technologies have created more cost-effective ways to communicate over vast differences, they cannot fully replace the power of rich communication (Carmel and Agarwal, 2001).

Media synchronicity theory (MST) further extends media richness by including two primary purposes of communication: conveyance of information and convergence of meaning, in which the individual either transmits or processes information respectively. Here the synchronicity is most beneficial for the convergence process to support shared, coordinated behavior (Dennis, Fuller and Valacich, 2008). Synchronicity relates to transmission velocity, or the speed at which a medium communicates a message (Shannon and Weaver, 1949). This is important for ASD's collocation tenet (Green et al., 2010): teams work in close proximity to foster face-to-face communication, timely feedback, and informal social interaction, though they can experience a lack of team engagement when members feel a lack of decision ownership and empowerment (Drury, Conboy and Power, 2012). Proximity refers to the physical distance between people (Hinds and Kiesler, 2002), but ASD teams still must balance between rich and lean medium as organizations strive to reduce development timelines, deliver products to market faster, and leverage cheaper software development resources across the world (Green et al., 2010).

METHOD

This study conducted four in-depth, multiple exploratory case studies (Stake, 2000; Yin, 2003) as multiple case studies are more robust than single case studies (Benbasat, Goldstein and Mead, 1987b) and are suitable for exploratory research (Yin, 2009). Multiple-case studies facilitate cross-case analysis to examine if findings are replicated across cases, providing some foundation for generalization (Benbasat, Goldstein and Mead, 1987a; Yin, 2009). Additionally, the best way to capture detail and understand people's actions or motivations is to speak with people (Myers, 2009). This is appropriate in the ASD context where communication and interactions are complex, dynamic and highly social. The goal was to examine ASD teams in their natural settings as NDM focuses on teams in natural rather than laboratory settings (Klein, 2008).

Data Collection

This study used multiple methods of data collection (Benbasat et al., 1987b) with four different agile teams within the same organization. Data collection methods included artifact analysis from project documentation and photographs, team observation, and in-depth, face-to-face semi-structured interviews using an interview protocol. The interview protocol was developed and pilot tested prior to the study. This pilot test did not result in changes to the protocol but served to develop the codes used for data analysis across all cases. Interviewees were asked specific questions about how they planned for and managed the work during an iteration via open-ended questions to allow respondents to freely express their views (Yin, 2009). Questions were semi-structured, meaning the author did not move strictly from one question to the next but rather allowed the conversation to flow between topics. Prompts ensured consistency across cases when interviewees discussed question topics in a different order to the protocol or talked in more detail about some questions. Participants were asked what types of information they used, how and when they communicated this information, and how their experience helped them to manage the iteration. They were also asked to describe and show items such as documentation that helped them in this process to encourage discussion of the artifacts used.

The author then asked them to provide examples of items they used to plan and manage their iteration to aid in the artifact analysis. These items included documented information, email messages, code comments, verbal communication via instant messaging systems, HTML documents with acceptance criteria, screen shots of project management software with iteration information (e.g., task information, dates, and bugs), and screenshots of burn

down charts; and photographs of various project items (e.g., whiteboard content). The author's observations included photographs of various project items such as whiteboard content, meeting set-ups and notes, meeting audio recordings, and pictures of documentation used for planning.

Interviews varied between 50 and 70 minutes in length. Each was audio-recorded with permission and transcribed. Interviews were supported by direct observations of four Iteration Planning meetings, two Story Elaboration Meetings, and four Retrospective meetings across cases, allowing the author to see and hear how the teams planned their work and managed iterations. The author documented meeting observations as field notes, and reviewed interview and observation data immediately after each event. ensure a particular incorrect meaning was not assigned to an event (Corbin and Strauss, 2008), the author sought clarification of the meaning of certain events and behaviors from both the interviews and observations within two weeks of the interview or observation taking place.

Analysis

The analysis strategy was designed to identify and code the cognitive artifacts used to plan iterations and manage the ASD project to reveal the cognitive work on the team to make decisions related to project management. The multiple sources of data increased the rigor of the study (Benbasat et al., 1987a). Collecting interview data from members of different types of agile teams with different roles ensured that multiple viewpoints were obtained and validated the data gathered when two or more participants communicated the same or similar views. Empirical data was also collected from direct observations, which further validated the interview findings.

Coding effectively analyzed the qualitative data with each code representing a concept from the interview questions and making comparisons between data (Corbin et al., 2008). The data from each case was analyzed using standard coding techniques (Miles and Huberman, 1999). Sources of information included team documentation; team member experiential knowledge; verbal traffic shared through team interactions during observed meetings, conversations, email and instant messaging systems; and whiteboards. Figure 1 illustrates the coding process used and Tables 1 and 2 provide the stages of coding and a sample of the process.

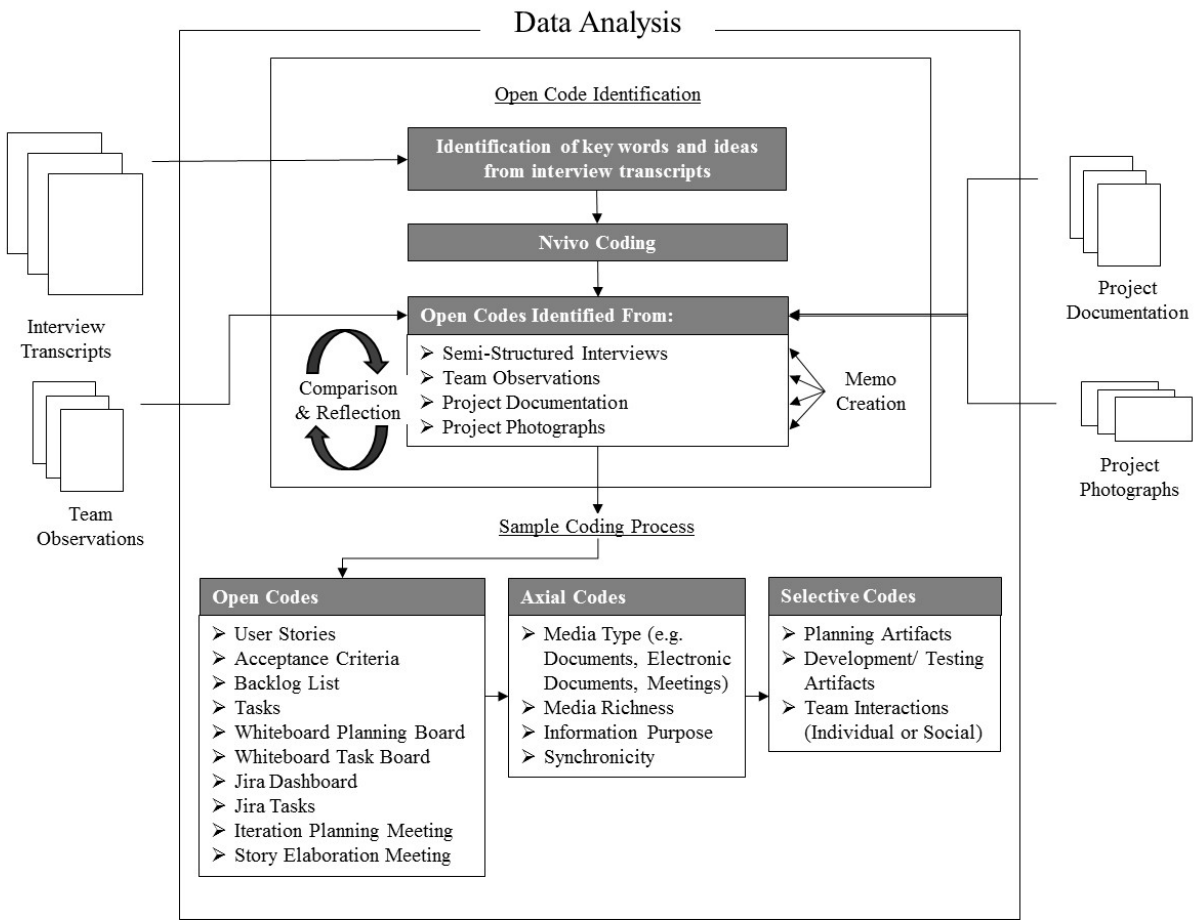

Figure 1. Coding Process for Data Analysis

Initial Open Codes	The first round of codes emerged from the cognitive artifacts interviewees specifically identified in the four sources (e.g. interviews, team observations, and project documentation and photographs). These included items such as task for completion, outstanding bugs, whiteboard tasks and owners, burndown charts, email and instant messages, and HTML acceptance criteria.
Emerging Codes	Eventually, additional codes emerged from the data, such as meeting minutes for planning work, pictures of whiteboards, screenshots of project management tools, and pictures of team meeting set-ups and interactions between members. Studying the cognitive artifacts in this way helps us to understand how teams plan and manage the balance between customer development demands and resource availability. It also provides insight into the nature of the actual artifact used, the technical aspects of the work situation, and the intentions for planning and managing that the artifact represents (Nemeth et al., 2006).
Axial and Selective Codes	To further analyze codes, the researcher imported the source documents (e.g. the interview transcripts and field notes) into NVivo, software designed to track and code qualitative research. The source documents were grouped by team. To address the research questions, the transcripts and field notes were read several times to obtain insight into each case. The cognitive artifacts were identified from a number of sources: some were explicitly stated by team members whereas others emerged from the interview data and observations. Each factor was coded to help organize the data and identify patterns and themes across the four teams.
Code Validation	A final round of coding was completed independently by two research assistants to identify any overlaps across the codes and to ensure there were no oversights in relation to the coding. This ensured the data was reviewed from more than one perspective and that it had not been miscoded or misinterpreted during the initial round of coding. Consequently, this resulted in the

	transition of some of the text coded to a different factor as it was deemed more appropriate. In some instances a section of coded text was removed from a factor as after reflection and discussion it did not relate specifically to that factor. Finally, we compared the data across cases to identify any similarities or differences across the teams studied.

Table 1. Stages of Coding Process