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How Team Cognition and Cognitive Artifact Use Change During Agile Software Development Project Management

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ABSTRACT

This study examines how team cognition and use of cognitive artifacts change during the course of an agile software development (ASD) iteration to better understand team member interactions. Four case studies of four different agile teams were conducted. Results demonstrate a team cognition change from planning, managing, developing, and concluding tasks in an iteration in preparation for delivering working functionality. We see the cognitive artifacts used throughout the iteration change. This supports ASD tenets of frequent, short, continuous communication and interaction on ASD teams. The contribution to project management and ASD is a clearer understanding of how and when team cognition changes and the cognitive artifact interaction changes during an iteration as ASD teams use artifacts to manage their project. The interactions that ensue with these artifacts move from individual to social interactions as the iteration progresses.

Keywords

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

INTRODUCTION

Team cognition refers to the shared knowledge on the team about team members, team processes, and task-specific information (Fiore and Salas, 2004). This shared cognition explains how teams adapt their task processes when task conditions vary (Entin and Serfaty, 1999) and is a critical factor in team performance (Fiore et al., 2004). Drury-Grogan (2016) identified the cognitive artifacts used for the project management of agile software development (ASD) teams and related decisions. She also examined the richness of the communication media used to better understand the usefulness of the cognitive artifacts for team interactions as ASD team members preferred the richer media where more information was communicated accurately. Although distributed cognition helped the ASD team both make sense of tasks in order to complete them on time for the client at the end of the iteration and cope with the complexity, uncertainty,

and fast-paced nature of ASD (Drury-Grogan, 2016), it did not examine the team cognition related to these artifacts and how team cognition might change during an iteration.

Teams are often created to address difficult, complex, or ill-structured tasks and problems (Stout, Cannon-Bowers, Salas and Milanovich, 1999). ASD teams are small, collaborative teams (Dybå and Dingsøyr, 2008) with flexible, adaptable structures (Nerur, Mahapatra and Mangalara, 2005). The benefit of using teams to develop software in this manner is increased performance improvements from individual team member knowledge, skills, background, roles, and responsibilities (McIntyre and Salas, 1995).

ASD teams make complex decisions, and Naturalistic Decision Making (NDM) examines the cognitive processes of how people use their experience to make complex decisions in field settings (Flin, O'Connor and Crichton, 2008; Klein, 2008; Zsambok, 1997). We examine this cognition in action by examining the cognitive artifacts, the objects with significance to their users, used to make decisions and the distributed cognition that enacts these artifacts (Hutchins, 1995). Some research has focused on ASD distributed cognition and the tangible artifacts of index cards containing stories and tasks and the wall on which they are displayed (Sharp, Robinson and Petre, 2009; Sharp, Robinson, Segal and Furniss, 2006); and the multiple cognitive artifacts ASD teams use to plan and manage their iteration and the team interactions revolving around these artifacts (Drury-Grogan, 2016). Thus, this current research addresses the following research questions:

RQ1: How does ASD team cognition change as an iteration progresses?

RQ2: How do the cognitive artifacts the team uses change as the team cognition changes?

The contribution to the project management and ASD fields is a clearer understanding of how and when team cognition changes during an iteration to better understand how to form effective teams. Interactions with cognitive artifacts may also simultaneously occur as the team's cognition changes while ASD teams use these artifacts to manage their project. First the background literature to this research is examined. Then the methods used to both collect and analyse the data are discussed. The results are then described, followed by a discussion of these results. A conclusion of the key findings, limitations of this study and ideas for potential future research are included.

BACKGROUND LITERATURE

Team Cognition

Team cognition is the project team's shared knowledge of the team members, team processes, and task-specific information; it is a critical factor in team performance (Fiore et al., 2004). Relatedly, distributed cognition is a team's shared awareness of goals, plans, and details beyond that which a single individual grasps; it is the team's mutual understanding of the situation (Hutchins, 1995). Distributed cognition includes both social and structural interaction between team members and cognitive artifacts (Mangalara, Nerur, Mahapatra and Price, 2014). There are two types of approaches for measuring team cognition (Cooke, Gorman, Duran and Taylor, 2007). One approach looks at the individual cognitions on a team and aggregates them to find an approximate team cognition so that the team cognition is the sum or mean of the individual team members' cognition and is a shared mental model (Converse, Cannon-Bowers and Salas, 1991).

However, others believe this approach oversimplifies team cognition as it assumes team members all know the same thing and does not account for teams with members who have different skills, knowledge, and ability (Cooke, Salas, Cannon-Bowers and Stout, 2000). The second approach therefore views team cognition as arising from the team members' interactions, communication, and coordination behaviors. In this way, an expert team is not necessarily comprised of a team of experts because the team's cognition depends on the team members' interactions (Gorman, Cooke and Winner, 2006). Here team cognition increases over time as team members gain more experience interacting with each other. Experienced teams

have higher performance than inexperienced teams, which suggests that team cognition also transfers across different tasks on teams and increases over time (Cooke et al., 2007).

This current research follows the latter view of team cognition as emerging from the interactions between team members. Thus, team cognition depends on both the situation and context (Cooke, Salas, Kiekel and Bell, 2004). It is therefore both a process of communication and a product, e.g. a model of the team (Cooke et al., 2004). Researchers have found that certain types of team communication, e.g. phone calls and face-to-face meetings, facilitate greater team cognition than email communication. Likewise, gender diversity on teams seems to increase team cognition (He, Butler and King, 2007). ASD is a type of project management (PM) method where team members interact to plan, organize, implement, monitor, report, and control projects (Gannon, 1994). Meetings allow members to effectively share knowledge because not all team members will possess the knowledge for each of these PM activities (Chau, Maurer and Melnik, 2003) because each member has their own limited experience on which to draw (Drury, Acton, Conboy and Golden, 2011).

This research addresses the call for an increased focus on team cognition to better describe the collaborative cognition as teams are called upon to perform increasingly complex cognitive tasks; it also explores how adaptive teams interact, e.g. teams put together in flatter structures and who use collaborative technologies (Salas, Cooke and Rosen, 2008). ASD teams fit this call not only from their flexible structures but because they perform cognitively complex tasks by planning and delivering working functionality to their customers through a series of iterations as short as 2 weeks' duration (Fitzgerald, Hartnett and Conboy, 2006; Fowler and Highsmith, 2001). They respond quickly to changes in business environments (Henderson-Sellers and Serour, 2005) as they continuously incorporate feedback during the iteration (Nerur et al., 2005). By looking at ASD teams in an organization, this research also examines "teams in the wild", which is important because teams' process and outcomes are affected by the organizations within which they work (Salas et al., 2008).

Cognitive Artifacts

Team cognitive processes require complex coordination between internal and external resources. Internal resources include team members' memory and attention, whereas external resources include objects and artifacts (Hutchins, 1995). Cognitive artifacts are examples of these external resources used in distributed cognition. Cognitive artifacts are objects used to improve our cognition. At a simplistic level, examples of cognitive artifacts are calendars, lists, mental elements, and computers, although there is no widespread consensus as to bound the definition of cognitive artifacts (Hutchins, 1999). But each cognitive artifact item helps us perform a task, and the artifact requires knowledge for its use. Their most distinctive aspect is that they somehow contribute 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). In this research, we use the term "cognitive artefact" to identify tangible, hard copy items, such as Post-It tasks, specification documents, issues/bug lists from client, whiteboard planning board; soft copy items, such as burndown charts or task lists in project management software, instant messages, emails, and electronic dashboards; and meetings, such as Iteration Planning Meetings (see (Drury-Grogan, 2016) for a complete list of artifacts used in this research).

Research has identified the ASD cognitive artifacts used for project management and related decision making and found ASD team members prefer artifacts with richer communication media where more information was communicated accurately (Drury-Grogan, 2016). We also know that physical artifacts, such as story cards and design diagrams, play an increasing role in software development teams' feedback and communication (Mangalara et al., 2014). But we do not know how the cognitive artifacts used on an ASD team change during the iteration. It seems likely that an ASD team's cognition changes from when it

is planning the iteration to when it is managing the balance between customer demand for functionality and the team's ability to deliver working software at the end of each iteration. Understanding the cognitive artifacts and distributed cognition that takes place can help ASD teams better plan for and manage their resource constraints to develop working software on such a continuous, fast-paced schedule.

METHOD

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. Thus, this research conducted four in-depth, multiple exploratory case studies (Stake, 2000; Yin, 2003) with cross-case analysis to examine if findings are replicated across cases, which provides some foundation for generalization (Benbasat, Goldstein and Mead, 1987a; Yin, 2009). The goal was to examine ASD teams in their natural settings as NDM focuses on teams in natural rather than laboratory settings (Klein, 2008). Multiple case studies are more robust than single case studies (Benbasat, Goldstein and Mead, 1987b) and are a suitable approach for exploratory research (Yin, 2009).

Cases Studied

The ASD team was the unit of analysis for this study. In this exploratory research, the author purposely selected four different agile teams within the same organization (see Table 1) on the basis of their team composition, level and role to ensure a variety of experience and level to improve the generalizability across teams within one organization's culture (see Table 1). All team members were employees of the organization that is the market leader for corporate actions and custody solutions to the investment services industry. Their customer is large financial institutions that handle corporate action events. All agile teams we studied worked in two-week iterations. Three teams (Case 2, 3 and 4) were distributed teams between Dublin, Ireland, and Delhi, India, and included scrum masters (SM), developers (D), Quality Assurance testers (QA) and a business analyst (BA) or product owner (PO) role. Case 1 included the Head of Engineering (HE) and the Head of Product Design (HPD). Each team studied used a hybrid of Scrum and XP agile methodologies for a minimum of six months and had a minimum of three and a half years of experience in the software industry.

Data Collection

This study used multiple methods of data collection (Benbasat et al., 1987b). These data collection methods consisted of artifact analysis, 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, open-ended questions to allow respondents to freely express their views (Yin, 2009). The questions were semi-structured so that the author did not move strictly from one question to the next but rather allowed the conversation to flow between topics. Prompts were used to ensure consistency across cases when interviewees discussed question topics in a different order to the protocol or talked in more detail about some questions.

Interviews varied between 50 and 70 minutes in length. Each was audio-recorded with permission and later transcribed. Participants also described items such as documentation that helped them plan their iteration and complete their tasks. They were then asked to describe how their artifact use changed during the iteration, including when they used specific artifacts over others. This was meant to get them discussing the various artifacts used and identify and discuss cognition changes. They provided artifact examples.

Interviews were supported by direct observations of four Iteration Planning meetings, two Story Elaboration Meetings, and four Retrospective meetings across cases. These allowed the researcher to see and hear how the teams planned their work and managed iterations. The researcher documented observations from these

Table 1. Profile of Case Study Teams

	Case 1	Case 2	Case 3	Case 4
Team Distribution	Co-located	Distributed	Distributed	Distributed
Team Location	Ireland	Ireland India	Ireland India	Ireland India
Team Roles Interviewed	Head of Engineering (1) Head of Product Design (1)	Scrum Master (1) Business Analyst (1) Developer (4) Quality Assurance Tester (3)	Scrum Master (1) Product Owner (1) Developer (1) Quality Assurance Tester (1)	Scrum Master (1) Business Analyst (1) Quality Assurance Tester (1)
Meetings Observed		Iteration Planning (2) Story Elaboration Meetings (2) Retrospective (2)	Iteration Planning (1) Retrospective (1)	Iteration Planning (1) Retrospective (1)
Range of years of software development experience (median years)	12 - 16 years (median 14 years)	4.5 - 13 years (median 8 years)	3.5 - 6.5 years (median 5.75 years)	3.66 - 7 years (median 5.5 years)
Range of years of agile software development experience (median years)	2 - 3 years (median 2.5 years)	0.75 – 3.5 years (median 1.2 years)	0.5 - 2.5 years (median 1.25 years)	0.5 - 2 years (median 2 years)

meetings as field notes and sought clarification from team members after the meetings when required. A list of interviewees and the meetings observed are detailed in Table 1.

Analysis

The analysis strategy was designed to identify and code the cognition changes during the iteration and the cognitive artifacts used to plan iterations and manage the ASD project. The goal was to examine when different cognitive artifacts were used as the team cognition changed during the iteration. Multiple sources of data increased the rigor of the study (Benbasat et al., 1987a). Collecting interview data from members of different ASD teams ensured that different 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 analyzed the qualitative data. Each code represented a concept related to the questions asked about the data and comparisons were made between data (Corbin and Strauss, 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, email; and whiteboards. The first round of codes, the open codes, emerged from the cognitive artifacts interviewees specifically identified as using at different points of the iteration, when they were used, and how they were used. Studying the cognitive artifacts in this way 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, O'Connor, Klock and Cook, 2006). These open codes were then related to each other in the axial coding stage. Axial coding broke down the core themes in the open codes to better relate concepts to each other.

A second 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 if after reflection and discussion it did not relate specifically to that factor (see Fig 1). A glossary of terms is included to define aspects of Fig. 1 (see Table 2).

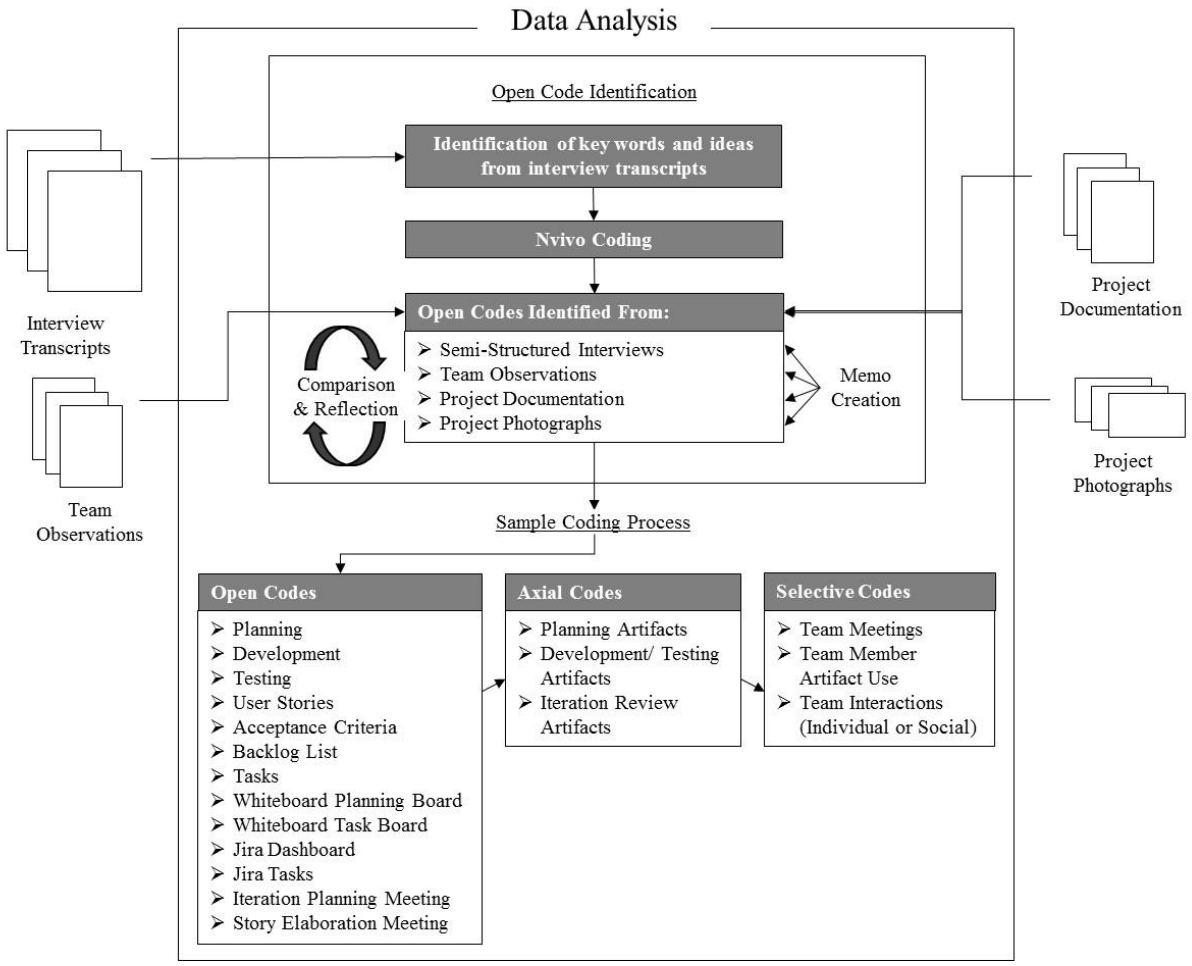

Fig 1. Data Analysis Method

RESULTS

The goal of this study was to examine the two research questions to first understand how ASD team cognition changes as an iteration progresses. We then examined how the cognitive artifacts used by the team change as the team cognition changes. These results are presented in this section.

ASD Team Cognition Change

The team cognition on the ASD teams studied focuses on three topics: the initial planning of the iteration in the first few days, followed by the developing and testing work during the middle days of the iteration, and concluding with the iteration review in the last days of the iteration. The cartoon below illustrates the team cognition and what roles are concerned with what topics (see Figure 2).

Table 2. Glossary of Terms for Fig. 1

Term	Definition
Nvivo Coding	Nvivo is a qualitative data analysis computer software used to code qualitative data from interview transcripts and rich text-based or multimedia data.
Memo	Note created to annotate data, e.g. interview transcript, image, or document, for clarity.
Open Coding	Open coding is the initial phase of the coding process in the grounded theory approach to qualitative research. It begins with the collection of raw data (e.g., interviews, field notes, reports, documentation) (Corbin et al., 2008).
Axial Coding	In grounded theory, axial coding is the breaking down of core themes during qualitative data analysis and relating codes (categories and concepts) to each other, via a combination of inductive and deductive thinking (Corbin et al., 2008).
Selective Coding	The final stage of the data analysis coding where previously identified concepts and categories from the open and axial coding phases are further defined (Corbin et al., 2008)
Interview Transcripts	Full transcriptions that are created for each interview conducted with participants.
Team Observations	Observations made by researcher at team meetings and random points in time during the iteration. These were documented as field notes.
Project Documentation	Documentation obtained from team members that they use on their project, e.g. HTML documents with use cases.
Project Photographs	Photographs taken of the project teams by the researcher to explain the interactions on the team. Photographs include images of planning and tracking whiteboards, team meetings, and team work stations.

The team cognition in the first few days focuses on aspects related to planning such as team availability, tasks for the new iteration, latent bug issues from previous iterations, and any client feedback received from the last iteration: "the first decision is what we are going to implement" (Case 2, D4) and "what can be achieved within the iteration" (Case 2, SM). They consider what was completed in the prior iteration as "backlog issues and bugs need to be completed first before new functionality" (Case 3, SM). Team members then "give an 'estimate' for each task" (Case 2, SM), which is their time estimate for how long tasks will take them.

During the iteration, the cognition shifts to developing functionality and tracking progress. Here, team members focus on how to create the new functionality. For example, when working on the user interface, a developer will "email those who know the interface code to ask their opinion on what they're doing and how they go about doing it" (Case 3, D). Team members are also concerned about customer feedback and issues that arise with the functionality, as well as their progress on their tasks. One commented, "I had literally no information other than my own sentiment and anecdotal evidence from the guys that backed this up… and the absolute unyielding focus from the executive to say, 'This is your priority and that's it'" (Case 1, HE).

Finally, in the last days of the iteration, the team cognition turns to a review of the iteration. They are now concerned with demonstrating their developed functionality, what tasks were not completed, new issues from the client or new bugs related to the functionality, and how to improve their progress in future iterations. They hold a Demo Meeting with all team members and the client to demonstrate the developed functionality for the client. To ensure the ASD team is ready for the Demo, they "review the test cases accepted…[this] helps the development stay on the right track, as well, if the test cases are based on the specification…It's kind of another safety net after the development takes place in that QA can actually find out if it is correct or not" (Case 4, QA). From the Retrospective Meetings where team members review the iteration and how to improve, they have modified their Demo Meetings to include "value stream mapping and cycle times. These show where we are adding value and where we are not adding value" (Case 1, HE).

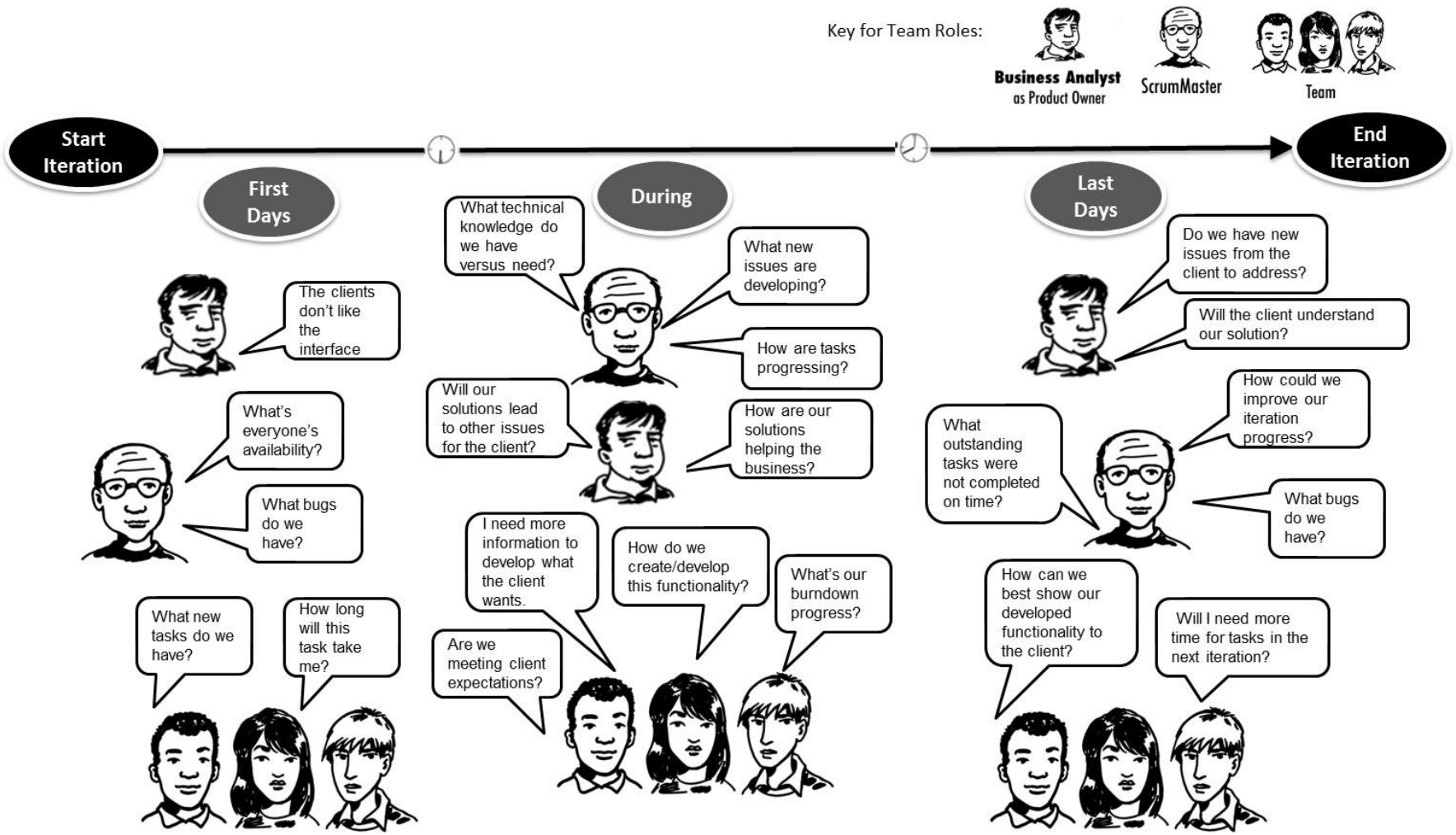

Fig 2. ASD Team Cognition Change as the Iteration Progresses

Cognitive Artifact Change as the Team Cognition Changes

The cognitive artifacts used by the ASD team change as team cognition changes during the iteration (see Fig 3). ASD teams use cognitive artifacts to plan their work for the iteration and manage the work during the iteration. Cognitive artifacts are used individually by team members and socially by the team as distributed cognition creates the ASD teams' shared understanding of the iteration's goals, plans, and details. Teams begin each iteration with an Iteration Planning Meeting (IPM) where they list out the tasks and team members' availability and review the task backlog from the prior sprint, issues or bugs requiring address, and user stories to determine the tasks for this iteration. Here there are two whiteboard artifacts: the planning whiteboard artifact "gives the proper visual of what has to be done…we plan tasks from there" (Case 3, SM) and the tracking whiteboard artifact publicly displays the "task owners and tasks as the team outlined them" (Case 2, SM). The team cognition is individual as members "consult the list of user stories" (Case 2, SM) and "backlog list" (Case 3, SM) to write the individual tasks for this next iteration based on what was completed in the prior iteration. The distributed cognition then becomes more social as team members discuss their tasks and their estimation for completing the tasks.

As team cognition changes from planning to actually working on tasks, the cognitive artifacts the team uses change. Now they need to understand the functionality to develop and test. They consult the use cases and acceptance criteria, which for these teams were written in HTML. This begins as individual work as team members first consult these artifacts to get a baseline of what they need to do. They look at the "HTML file of acceptance criteria and we do mock-up screens…This gives you a visualization of what you want and what the expected outcome is…To a developer they can kind of visualize what you're trying to get at and it helps put some sort of context around the functionality you want and it also helps to spot things that just won't work pretty early in the process…[The mock-up] shows how it should be presented to the user," (Case 2, BA). Here, the social interaction occurs between the BA who has the business perspective of the customer and the developers and SM who have the technical knowledge for how to develop the functionality. These team members work together to determine how to deliver what the client requires.

As members begin to develop, questions arise. This is where informal artifacts exist via email messages, ad hoc conversations, and instant messages to clarify information with the SM, BA, other developers, and other testers depending on their information needs. With complex pieces of functionality, team members organize a "Research Spike to flesh out any other areas that would need to be highlighted and decide the best approach" (Case 2, SM). These spikes, or time-boxed workshops to research a concept or create simple prototypes, clarify the tasks and what is needed to achieve them. During these sessions, the team members involved with the functionality would "show what they were doing…how they were implementing and get the answers they needed" (Case 2, BA). They would then decide the "implementation approach that outlined how they would design the functionality" (Case 2, BA).

As the iteration progresses, team member interactions with artifacts become more social than individual as team members interact to manage the work throughout the iteration (See Fig 4). Developers develop functionality and testers test it. The cognitive artifacts help members manage the work, especially during various meetings. Aside from the meetings discussed already, the Daily Stand-Up Meetings (DSM) occur as a checkpoint for each team member to give a brief update on their accomplished tasks, issues, and actions to address issues. This helps the team address issues immediately and respond more quickly to changes resulting from these issues. Even outside of the meetings, team members talk and interact with the cognitive artifacts: "We talk a lot…A lot of it is face-to-face. It's quicker to develop and we can talk immediately when there's a problem. We don't even wait for the 15-minute Daily Stand-Up Meeting" (Case 3, PO). Here the PO is referring to how the team members working in the same location meet frequently in person to discuss their work and interact with various cognitive artifacts. When team members are not in the same location, these discussions take place via email or instant message. The cognitive artifacts they use here are in soft copy form as they can each view them on their respective computer screens, for example when they look at project management software screens with burndown charts or tasks.

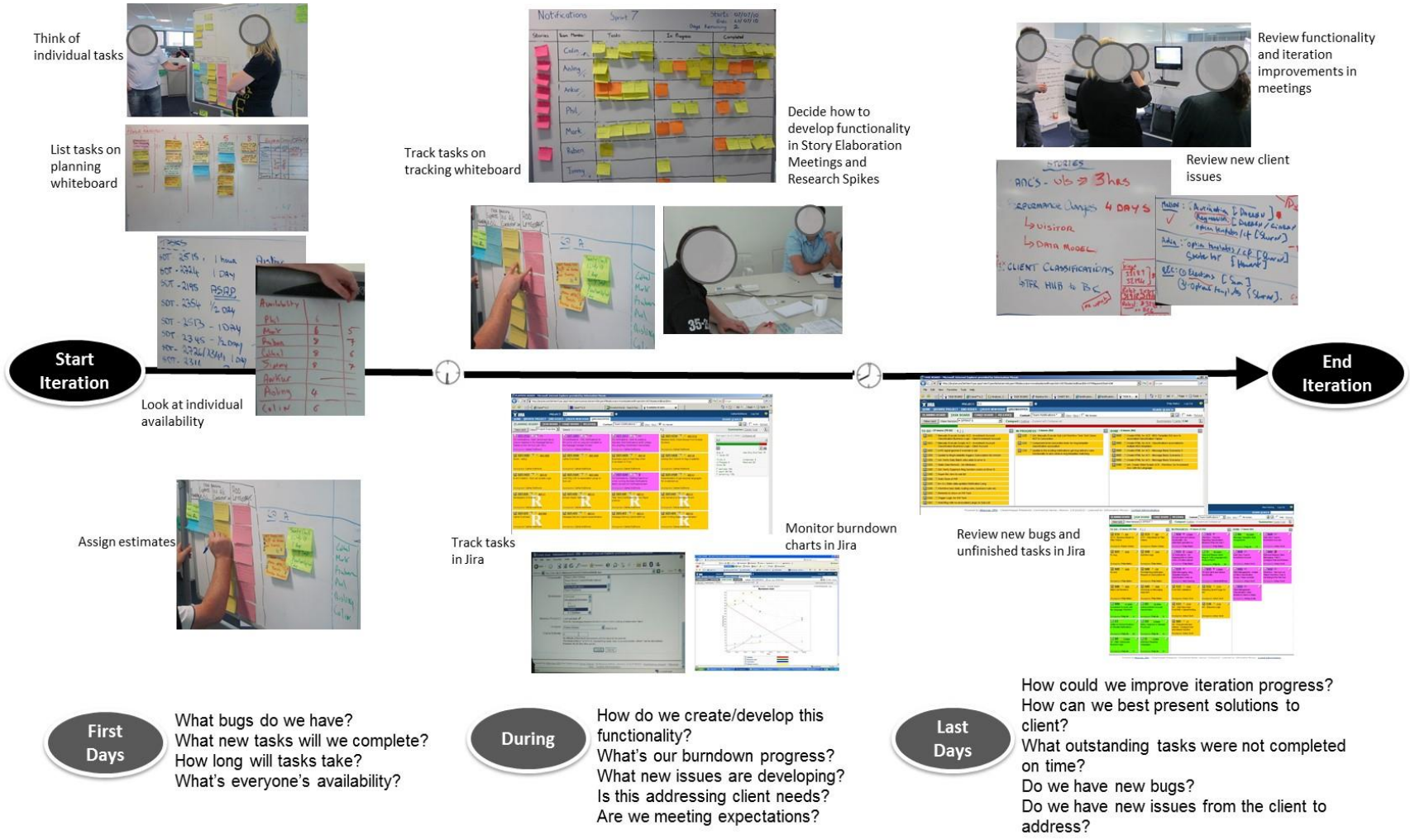

Fig 3. Team Cognition and Cognitive Artifact Change as Iteration Progresses

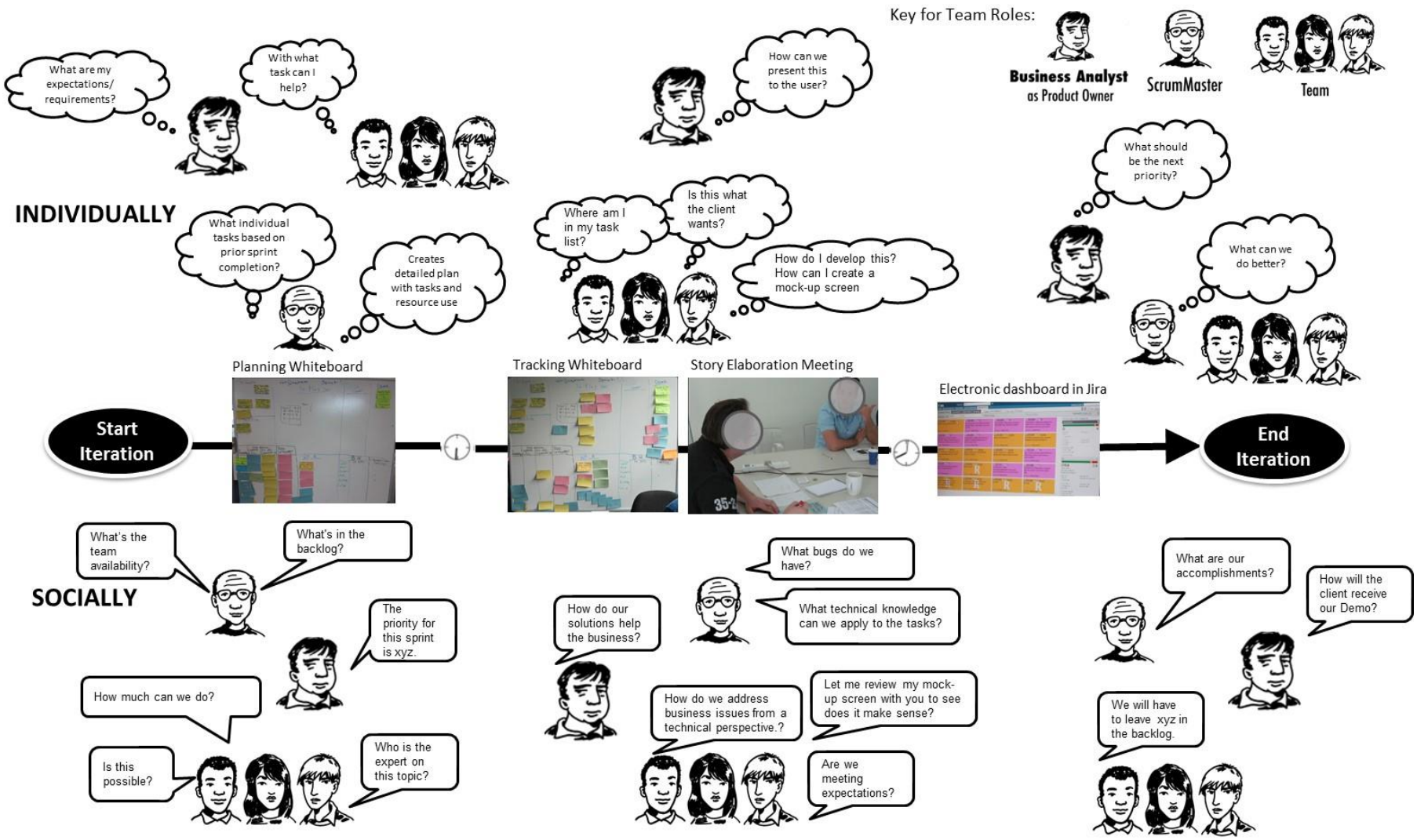

Fig 4. Team Member Interaction with Cognitive Artifact Becomes More Social as Iteration Progresses

DISCUSSION

This study helps ASD teams plan for and manage their work during an agile iteration by contributing to our understanding of how team cognition and the use of cognitive artifacts changes during an ASD team iteration. As an ASD team's iteration progresses, their team cognition changes from planning activities to developing and testing activities to review activities. Likewise, as the iteration progresses the team interactions become more social. At first, they begin thinking about their own availability, tasks they can complete, and estimation for the timing of their tasks. As the iteration progresses, they think about how to develop and test functionality individually. When they need additional information or to discuss how to develop something, they have more social interaction via face-to-face communication, instant messages, emails, and meetings. All team members use cognitive artifacts during these activities. These cognitive artifacts change from tangible hard copies of Post-Its with tasks, whiteboard lists, HTML acceptance criteria to soft copies of task tracking, burndown charts, team wikis with coding information, and electronic dashboards. The interactions that ensue with these artifacts move from individual to social interactions as the iteration progresses. Next we look at how these findings have implications for research and practice.

Implications for Research

The contribution to the project management and ASD fields is the understanding of how team cognition and the use of cognitive artifacts change during the course of an ASD team's iteration. Prior research identified the cognitive artifacts used for the project management of ASD teams and the richness of the communication media (Drury-Grogan, 2016). This current study extends on that work to examine how the use of cognitive artifacts changes as the team cognition changes during the agile iteration. It also looks at when cognitive artifacts are used individually and socially on ASD teams. Team cognition increased over time as team members gain more experience interacting with each other (Cooke et al., 2007). Their interactions became more social as the iteration progressed. This research now contributes a more extensive understanding of the various cognitive artifacts that an ASD team uses to plan and manage its iteration, as well as the distributed cognition that occurs as the ASD team members interact with each other and use these artifacts throughout the iteration. This paper therefore provides a methodological contribution to the study of ASD team environments for the planning and project management of an iteration.

Likewise, this study goes beyond simply a list of cognitive artifacts to a clearer understanding of how their use changes during an iteration and how team members interact individually and socially with these artifacts. This provides insight into the processes that produce cognitive effects by coordinating functional skills with various kinds of structures (Hutchins, 1999). We now see when ASD team members think about tasks from a planning perspective and a development perspective, including their consideration for client expectations, issues, and bugs to address. We see when they are looking at task priorities early on in the iteration for planning and later in the iteration in preparation for the following iteration's planning. The cognitive artifacts play a role throughout the iteration, and this research provided a stronger understanding of when team members use certain artifacts and how they interact with each other using those artifacts.

Implications for Practice

Understanding the cognitive artifacts and team cognition that takes place will help ASD teams better plan for and manage their resource constraints to develop working software on such a continuous, fast-paced schedule. We see more clearly how ASD teams' cognitive activity focuses on the tasks they need to complete for the client during that iteration, balanced with any issues that might arise during the iteration. Cognitive artifacts around tasks, availability, and time estimates help plan the iteration. Then documentation from the client helps team members develop and test functionality. Further cognitive artifacts exist when team members come together in meetings to think through how to best develop functionality and prioritize issues from the customer. While artifacts start as individual items, they quickly come together in a social aspect as the team uses them during the iteration to track their work, first on a hard copy tracking whiteboard and secondly in soft copy using Jira project management software.

As the iteration progresses, we see how the artifacts change as tasks are in progress. As team members move from planning the tasks to actually beginning the tasks, they interact socially with cognitive artifacts in meetings to determine how to best develop functionality. At the end of the iteration, they determine together what tasks will remain on the backlog for completion in future iterations. This is important for ASD teams to realize what artifacts and interactions help them manage, prioritize, and complete their work during the iteration.

LIMITATIONS

This study contributes to our understanding of how team cognition and the use of cognitive artifacts change during an iteration, albeit with limitations to this research. This research examines "teams in the wild", or teams in an actual organization work (Salas et al., 2008). This is important because we can see how actual project teams interact. But the data was based on observations and interviews which can be biased. The author did attempt to reduce bias in the interviews by using an interview protocol for each interview and observing agile practices several times across teams, capturing as much detail as possible during each observation and subsequently clarifying the meaning of certain events and behaviors to ensure that the researcher did not assign an incorrect meaning to an event as recommended by Corbin and Strauss (2008).

Future research could examine the concepts studied here with other ASD teams to validate the team cognition changes. Theory building from case studies is iterative and requires repetition to reach theoretical saturation (Eisenhardt, 1989); thus, future research should seek to validate the team cognition and cognitive artifact changes identified here. It could also further examine the social interactions that occur with the artifacts in various organizations to improve the generalizability of the findings.

CONCLUSION

In summary, our results demonstrate a team cognition change from planning, managing, developing, and concluding tasks in an iteration in preparation for delivering working functionality. We see the cognitive artifacts used throughout the iteration change, as well as the level of interaction increase to be more social rather than individual. This supports the ASD tenets having frequent, short and continuous communication interaction sessions (Cusumano and Smith, 1995; Hass, 2007) as team interactions focus on communication 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., 2001). The distributed team cognition helps the ASD team make sense of tasks in order to complete them on time for the client at the end of the iteration.

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