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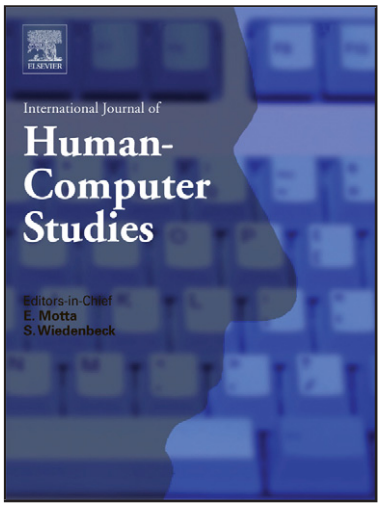

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Helen Sharp, Hugh Robinson

PII: S1071-5819(07)00137-1
DOI: doi:10.1016/j.ijhcs.2007.10.004
Reference: YIJHC 1424

To appear in: *Int. J. Human–Computer Studies*

Received date: 28 November 2006
Revised date: 14 September 2007
Accepted date: 5 October 2007

Cite this article as: Helen Sharp and Hugh Robinson, Collaboration and co-ordination in mature eXtreme programming teams, *Int. J. Human–Computer Studies* (2007), doi:10.1016/j.ijhcs.2007.10.004

Collaboration and Co-ordination in mature eXtreme Programming teams

Helen Sharp and Hugh Robinson

Centre for Computing Research

The Open University

Walton Hall

Milton Keynes

MK7 6AA, UK

Contact author: h.c.sharp@open.ac.uk

Tel: +44 (0)1908 653638

Fax: +44 (0)1525 404033

Abstract

Mature eXtreme programming (XP) teams are highly collaborative and self-organising. In previous studies, we have observed that these teams rely on two apparently simple mechanisms of co-ordination and collaboration: story cards and the Wall. Story cards capture and embody the user stories which form the basis of implementation, while the Wall is a physical space used to organise and display the cards being implemented during the current development cycle (called an iteration). In this paper we analyse the structure and use of story cards and the Wall in three mature XP teams, using a distributed cognition approach. The teams work in different commercial organisations developing different systems, yet we find significant similarities between their use of these two artefacts. Although simple, teams use the cards and the Wall in sophisticated ways to represent and communicate information that is vital to support their activities. We discuss the significance of the physical medium for the story cards and the Wall in an XP team and discuss the considerations that need to be taken into account for the design of technology to support the teams.

Keywords: distributed cognition, story card, information radiator, agile development

1. Introduction

eXtreme Programming (XP) is one of the lightweight software development methods called agile (Beck, 2004). XP (along with the other agile methods) supports the Agile Manifesto (http://www.agilemanifesto.org/) which emphasises the importance of individuals and interactions, working software, customer collaboration, and responding to change (Highsmith, 2002). To support the need for close collaboration and interaction, XP teams (including testers, customers and developers) are often co-located. In previous work we have observed that co-located XP teams are highly collaborative, relying heavily on interactions between team members and their environment rather than on documentation (Sharp and Robinson, 2004; Robinson and Sharp, 2005). In Sharp et al (2006) we used the distributed cognition framework (Hutchins, 1995) to investigate the role of two key mechanisms supporting one mature XP team's collaboration and co-ordination activities. These mechanisms are the story card (an index card typically no bigger than 5x7 inch on which the users' requirements are written) and an area of physical space where the story cards are organised and displayed which we call 'The Wall'. Photographed examples of these two artefacts are shown in Figure 1.

This paper extends the original analysis to include two further mature XP teams, and to discuss in more detail the significance of the paper-based nature of these artefacts.

Figure 1. Example story cards and Wall from a mature XP team

In this paper, we present a detailed analysis of three mature co-located XP teams and their use of story cards and The Wall, and discuss the significance of the physical nature of these artefacts. Section 2 provides a more detailed description of XP practice in order to set the context for the remainder of the paper. Section 3 describes the data collection and analysis approaches we have used. Section 4 introduces the teams and their use of physical co-ordination and collaboration mechanisms. In Section 5 we summarise the collaboration and co-ordination activities we have observed, discuss these findings in the context of other research which has focused on the nature of paper to support collaborative work, and raise issues that might be faced by those working in a distributed agile environment. We end with some conclusions.

2. XP Practice

eXtreme Programming (XP) was first taken up as a recognisable method by software practitioners around 1999, and its use is becoming more widespread with large corporations and small start-ups being equally interested in adopting its practices (e.g.

Hanly et al, 2006; Da Silva et al., 2005). A key driver for XP was to tackle the fact that change in a software development project is inevitable, and it did this in several ways: recognising that altering the scope of a development project is a powerful way to accommodate change, shortening the time between implementation and customer feedback, and constantly reviewing and improving the development process, among others.

Beck (2004) describes 13 primary practices (including pair programming, continuous integration and test-first programming) and 11 corollary practices (including real customer involvement, shared code and daily deployment). In this paper we focus on the primary practices of Stories and Informative workspace. Although we draw on the latest text by Beck, it should be noted that the teams we study below all started practising XP when the seminal text was Beck (2000) which contained only 12 practices.

User stories are the mechanism used to communicate user requirements to the development team. They represent "units of customer-visible functionality", and have become a central focus of many agile teams. Much has been written about how to develop and maintain user stories (e.g. Cohn, 2004). Jeffries (2006) suggests that there are three aspects (the three 'C's) to a story: the Card, the Conversation and the Confirmation.

> The Card: Stories are usually written on 3"x5" index cards. Cards are small, physically independent entities. Their size constrains the amount of information that can be written on it, while its independent nature means that it can be annotated and manipulated during meetings or discussions.
>
> The Conversation: Because the card can only hold a limited amount of information, the development team has to talk to others in order to explore the detail of the story and to refine their understanding of it.
>
> The Confirmation: Testable and measurable user acceptance tests are agreed between the customer and the development team, so that everyone concerned understands when a story has been implemented successfully.

Although such cards are usually referred to as user story cards, we have found that an XP team uses the story to capture developer-initiated functionality (concerned with technical matters) as well as customer-initiated requests (concerned with customer-visible functionality). In addition, the story is often broken down into smaller units, called 'tasks', and hence a story card may be about customer-visible functionality, developer-initiated modifications, or smaller units of development activity which relate to a story. In figure 1 the left hand photograph shows one user story card and one related task card. The story card reads "Show travel news headlines & details for London"; the task card reads "Create WML travel news pages", which is a subtask of the associated story.

The efficacy of story cards is also supported by the team's environment. In explaining the Informative workspace primary practice, Beck states (2004, p39) "Make your workspace about your work" and goes on to say that "An interested observer should be able to walk into the team space and get a general idea of how the project is going in fifteen seconds". He mentions the fact that many teams do this by putting story

cards on a wall[1]. Cockburn (2002, p84) echoes this idea through his definition of 'information radiators'. An information radiator "displays information in a place where passersby can see it". It should have two characteristics: information changes over time; and it takes very little energy to view the display. Thus, a wall where story cards are displayed in a public place conforms to the notion of an information radiator.

Development activity is partitioned into a series of short timeboxes, each called an 'iteration', which usually lasts between one and four weeks. Each iteration focuses on a subset of the developments or modifications to be made, and at the end of this time the system will have been enhanced to add value for the customer, will have passed acceptance tests, and will be ready for deployment.

The practice of XP development is a sophisticated achievement with a distinct set of rhythms (MacKenzie and Monk, 2004; Sharp and Robinson, 2004). These rhythms revolve around and depend upon increased awareness (Chong, 2005), and a shared purpose, understanding and responsibility which are supported by several regular and ad hoc co-ordination mechanisms including the planning game and daily stand-ups (Sharp and Robinson 2006).

At the start of an iteration, a planning meeting is held to determine which stories will be developed in the upcoming iteration. The stories have usually been written by customers, customer-proxies (such as business analysts) or developers in advance of this meeting; some may have been carried over from the previous iteration. The activities surrounding the development of stories are varied and complex and we do not discuss this here (for further information and further reading on this issue see (Davies and Sharp, 2006)). The planning game is a collaborative affair involving all team members. Customers are asked to prioritise stories for this iteration, and developers are responsible for estimating how long each story will take. Together, the team can thus determine how many and which stories can be accomplished within the iteration timebox. The prominence of the story cards is clear from the photograph in Figure 2.

Figure 2 The planning game table

Most of the development on an XP team is undertaken by pairs of developers rather than a single developer. There has been a lot of research into the efficacy of pairing versus singleton programmers, much of it conflicting (Arisholm et al, 2007). While

[1] It is interesting to note that the style of story card mentioned in his original book was more formal and contained more information than those used by our teams, and the Wall is not mentioned, suggesting the possibility that these techniques have developed through use of the original XP values and practices, and synthesis with other agile methods.

there are clearly some advantages in terms of shared understanding and team cohesion, we have also found that pairing has disadvantages including that it is very tiring and can make promotion difficult (Beecham et al 2007).

Each day begins with a stand-up meeting of the team, lasting no more than 15 minutes. During this meeting, each team member reports on what they did yesterday, what they'll do today, and any problems they encountered. The following is a description of a typical stand-up. It is based on notes taken during the observations of several teams, but represents a combination of observations rather than one specific instance. We have incorporated typical activities which we'd expect to see in any and all stand-ups.

> At 9.30, each member of the team stands up and congregates around a wall with a lot of story cards arranged on it. They start by completing the pairing ladder which records who paired with whom yesterday, then discussion moves to the cards. Jo says that he and Tony completed work on payment accruals yesterday, and points to the relevant story card's location on the Wall. He then picks up another card and suggests that he'd like to work on this one today. Tom then says that he has managed to get more tests in place for the log, but is having trouble working out how to make sure that the increasing instruments are tested in the correct order. Mike explains the approach he took with an earlier similar problem. While Beth is telling the team what she did yesterday, Paul picks up a card from the wall and holds it expectantly; when Beth has finished Paul comments that the story he's holding needs attention, and asks Beth if she'd like to work with him on that today…. Each person reports on issues from yesterday and suggests their work for today. When they are done, they go off in pairs to work on machines. This may involve going to the wall and picking one of the cards off the wall. Throughout the meeting all participants remain standing. The talk frequently refers to the cards on the wall. No one person is leading this discussion and everyone in the group says something at some point.

At the end of an iteration a retrospective is often held to consider what went well, what still puzzles the team and how to improve their process.

3. Data Collection and Analysis

All three teams discussed here were based in industry and were mature in their use of XP at the time of study. By this we mean that they had transitioned successfully to XP (a process that can take anything from a weekend to several months, depending on team size, organisational culture, team member attitude, and several other factors), and had been using all 12 of Beck's original XP practices for at least a year. In the following discussion, the teams are named A, B and C for confidentiality reasons. Team A and Team B were based in SMEs (Small and Medium-sized Enterprises) within the UK, while Team C was based in a large international bank. The teams were identified through personal contacts.

The data was collected using an ethnographically-informed observational approach (Robinson et al, 2007). Ethnography seeks to understand practice in its own terms, minimizing the impact of the researchers' own backgrounds, prejudices and assumptions. As such, researchers attend to the taken-for-granted, accepted and un-remarked aspects of practice, deliberately considering all activities as 'strange' (Hammersley and Atkinson, 1983). Consequently, no feature of practice is discounted

a priori and ethnography studies the totality of practice with all its 'messy' characteristics. In particular, our observational studies were informed by ethnography in two ways:

1. The essential nature of practice is not known *a priori* and, importantly, cannot be assumed to be the 'official' view.
2. Since our focus is on the practice of software development, as it is carried out in the real world in natural settings, we avoid any form of control, intrusion or experiment and so all our data were naturally occurring.

Each study lasted between 5 and 8 working days, plus one day at a later stage to re-visit the team and report our findings. All the studies were conducted at the XP teams' offices. The data gathered included extensive field notes, photographs, and copies of work artefacts. The observers did not intervene in the teams' day-to-day activities, but sought to observe normal activity in its natural setting. This involved attending meetings, shadowing members of the team, going for lunch, and having informal conversations with team members.

In the tradition of ethnography, a broad thematic analysis, seeking both confirming and disconfirming instances, was first carried out as a prelude to the detailed analysis informed by the framework of distributed cognition. Our detailed analysis employed DiCOT (Distributed Cognition for Teamwork (Blandford and Furniss, 2005)), a methodology to support the application of the distributed cognition framework. Distributed cognition (Hutchins, 1995) is a framework for analysing collaborative activity that regards collaborative work as one cognitive system. DiCOT utilises representations adapted from Contextual Design (Beyer and Holzblatt, 1998) to develop models based on observational data. It also collates 22 principles of distributed cognition which can be loosely categorised according to three themes. The three themes used in DiCoT are:

1. The *physical theme* which focuses on the physical environment such as office layout and adjacencies of co-workers, within which the cognitive system operates.
2. The *artefact theme* which focuses on the detail of the artefacts that are created and used in carrying out the activity under study.
3. The *information flow theme* which focuses on what information flows through the cognitive system, the media which facilitate that flow and how the information is transformed in the process.

For the current discussion, we focus mainly on the artefact theme of DiCOT, although elements of the physical environment are also pertinent and are mentioned in our descriptions.

4. Story cards and The Wall in three mature XP teams

Each of the three teams we studied used physical story cards and a physical Wall to support their co-ordination and collaboration activities. In this section, we present a summary of the team's interactions with, through and around these artefacts, together with artefact models that capture their structure.

4.1 Team A

Team A performs the only software development activity in the company, which develops and maintains travel information webpages and travel alerts for a variety of

customers in the UK. At the time of the study there were 23 developers in the team, who worked closely with a project manager, and two business development staff (who took the customer role). The team worked on one three-week iteration with three one-week iterations within it. The observational study covered the end of one three-week iteration, the start of the next, and one complete one-week iteration. For the iteration studied, the developers split themselves into three sub-teams called streams, and each stream took responsibility for a discrete set of stories to work on during the three-week iteration. Each stream self-organised during the three-week iteration.

The artefact models for the story card and the Wall are shown in Figure 2; photographed examples of these artefacts are in Figure 1.

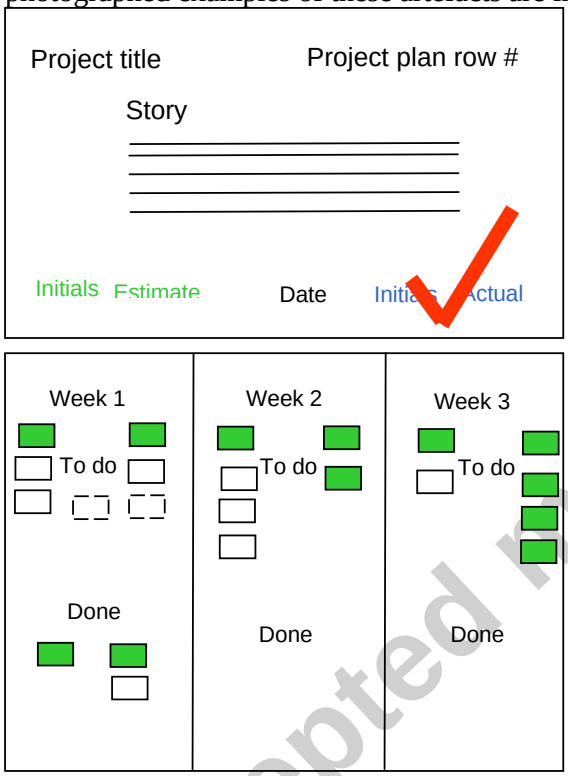

Figure 2 The story card and Wall artefact models for Team A

4.1.1 Story Cards

Each story card (which is green) may be broken down into several task cards (which are white). Each card is associated with a project (in the top left hand corner) and this is related directly to the company's overall work plan. Each story corresponds to a line in the company project plan spreadsheet, and the number associated with that line appears on the right hand side of the card (sometimes at the top, and sometimes at the bottom, and sometimes in between). This number is present on story cards and task cards. Cards are created during the planning meeting (in consultation with business development), the stand-up or paired development. Some stories focused on technical matters and were written by the development team while others came directly from client requests.

Whatever their provenance, cards were handled and annotated with great care, suggesting the story-on-a-card had a significant and enhanced reality for the team.

The story or task itself is written in the middle of the card. At the bottom left, in green, is written the estimate in days and the initials of the person who suggested that estimate. At the bottom right, in blue are sets of initials showing who has worked on the story/task, together with the date and how long they have spent on it. When the story/task is finished, a large red tick is written in, often over the top of the blue writing, but not always.

4.1.2 The Wall

The Wall in Team A is a glass screen which is used to display the cards being processed in the current three-week iteration. The organisation of the Wall is such that an impression of progress can easily be gleaned. Each stream has its own Wall.

The Wall for each stream is structured slightly differently, but the principle is the same in each case. The cards are divided into areas representing the three weekly iterations. Within these weekly iteration areas, the cards which have not yet been implemented are placed at the top of the area, and any task cards are placed immediately below the associated story card. Any cards that are 'done', i.e. have been through acceptance testing and integrated into the code base, are placed at the bottom of the iteration area.

4.1.3 The role of cards and the Wall in co-ordination and collaboration activities

At the start of a three-week iteration, the Wall is carefully constructed by members of the stream, according to the layout shown in the model. The stream team consider how the cards will be distributed across the three one-week iterations and construct the Wall accordingly. At the start of subsequent one-week iterations, the Wall is studied carefully and re-arranged as appropriate if the team has not completed all the stories initially allocated to the iteration just finished.

All stand-ups (see section 2) were conducted around the Wall. During the stand-up, individuals often pointed at the Wall or took cards from the Wall which seemed to act as tokens which gave the individual speaker's rights. The action of taking a card signalled that the individual wanted to speak, and also represented a form of ownership over the work it represented.

During the day, developers often looked at the Wall when considering progress, or the work left to be done. A card was taken off the Wall when a pair was working on it, and stuck on their monitor (see Figure 3). A 'ghost' of the removed card was drawn onto the glass so that the card's place on the Wall was maintained. When the card had been implemented, it was returned to the Wall in its new place to signify that it was 'done', and the ghost was removed.

At the end of a weekly iteration, cards that had not been completed were moved across to the next week.

Figure 3 Cards from the Wall are stuck to the pair's monitor during implementation

4.2 Team B

Team B are based in a small company developing web-based intelligent advertisements for paying customers. The software analyses the content of the current web page to determine the user's interest. The software then displays an advert relevant to this interest. For example, if the reader is looking at a page about childcare then an advert for the latest baby buggy might be displayed; if they are reading about home improvements then an advert about power tools might be displayed. As with Team A, this team performs the only software development activity in the company.

The company used all 12 practices of XP from the time they started in 1999. At the time of the study, there were eight developers, one graphic designer and one person who looked after the infrastructure in the XP team. The company employed four marketing professionals.

The artefact models for the story card and the Wall are shown in Figure 5; photographed examples of these artefacts are in Figure 4.

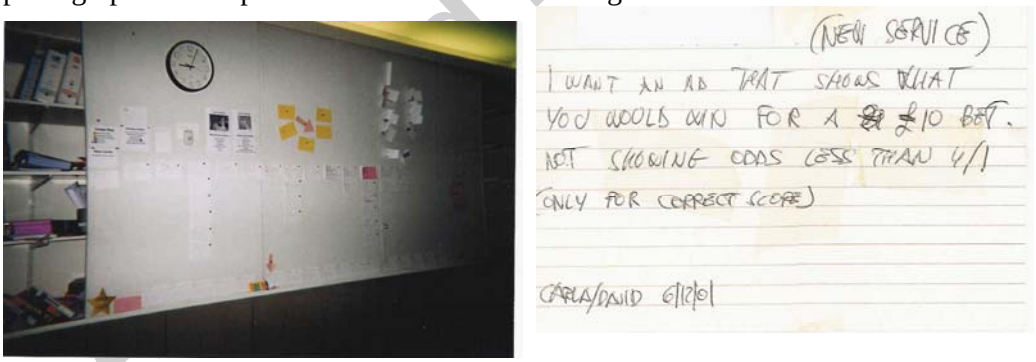

Figure 4 Photographs of the Wall and an example story card for Team B (note that the story card has not yet been estimated)

4.2.1 Story cards

User stories were written by the marketing people who had direct contact with the customers. These stories were marked by the initials and date of the initiator. Some technical stories were generated by the developers. During the planning game, stories were estimated by negotiation between the developers and the estimate was written on the bottom right of the card (see Figure 5). The test for a story is written on the back of the card.

Cards for the current iteration (at the time, they ran a three-week iteration) were placed on the Wall (called the Chekov Board in this team, see below). As the cards were worked upon, the status indicator (a coloured star sticker) in the top right of the card was changed. For example a red star indicated an unfinished card, yellow a card that has been finished by developers and is ready for acceptance test, green indicates that the change has been accepted by the customer. In addition, a blue star indicated that the card was a task card, i.e. an element of a story card. Stories and their associated task cards may be stapled together.

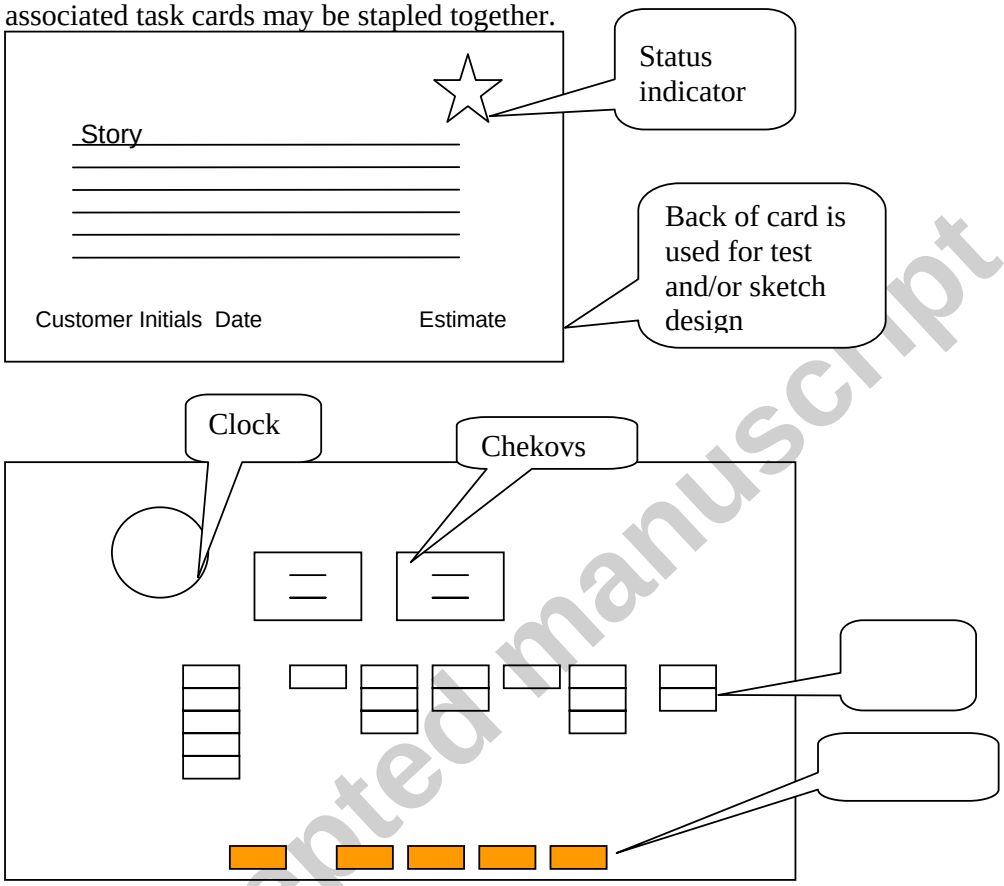

Figure 5 Story card and Wall artefact models for Team B

4.2.2 The Wall

The Wall here was dominated by pictures of two Chekov's, (Pavel Chekov and Anton Chekov), which was intended as a play on 'check-off'. Pavel Chekov headed a list of points for 'New Service' Chekov, such as 'has data source', and 'scraping definitions'. Anton Chekov headed a list of points for 'Finished Card' Chekov, such as 'unit test', 'automated test', 'refactor' and so on. There was also a Stand-up Chekov list and an 'exposed pair' Chekov list. The exposed pair were developers who could be interrupted by client requests or queries; in general, the marketing professionals did not interrupt developers who were pairing.

The Wall contained the story and task cards for the current iteration, together with notices of 'gold cards days', and the reminders listed above. Gold card days represent

times when a developer works on their own instead of working in a pair (Higman et al et al, 2001).

4.2.3 The role of cards and the Wall in co-ordination and collaboration activities

At the start of an iteration, the team gathered around a large table and the cards were spread out for everyone to see. The planning game then consisted of a discussion about estimating cards, and deciding which stories will be tackled in the upcoming iteration. During this process, cards were grouped and re-grouped on the planning table, according to clients, iterations and priority. The planning game mostly involved the developers, but marketing people would be called upon to explain stories.

After deciding which stories would be in the iteration, the cards were organised on the Wall, with story cards at the top of a column and associated task cards underneath it.

The daily stand-up meetings took place standing around the 'Chekov' board, and the information on the Board, particularly the list of stories and tasks was the central focus of the discussion. Pairs decided which stories or tasks they would work on, and took the relevant card from the Wall. It was usual for one person to say that they would work on a particular story, and then to find a volunteer to pair with. All pairing assignments were self-organised, i.e. no member of the team took control and told other developers what to do.

At the end of an iteration, the team wiki was updated with the list of stories completed, those added, those carried forward to next iteration, and the velocity. The cards themselves were stacked in a cupboard.

4.3 Team C

Team C worked in a large international bank, programmed in Java and were not the only software development team in the company. There were other XP teams also in this company, but a large part of development was conducted using a more traditional approach. Their project concerned the migration of database information from several large databases to one very large database.

Team membership was a little fluid but the core members were one project manager, five developers, two business analysts and one database administrator. Other business analysts worked with the team members as their expertise was required. The developers were all experienced in using XP, with more than 5 years XP experience each.

The artefact model for the story card is similar to that used by Team B, so we do not repeat this model here. The artefact model for the Wall is shown in Figure 7 and a photograph of the Wall is in Figure 6.

Figure 6 The Wall used by Team C

4.3.1 Story cards

The structure of the card was the same as that for Team B, except that there were no customer initials and date. Customer initials and date were not required in this environment because the stories for this team were structured around the database fields and parameters rather than being functional requirements from an external client, e.g. one story would relate to the migration of one database field to the new database.

Team C included business analysts and developers in their co-ordination activities. This was illustrated by the different coloured cards: green cards denoted the next elements to be analysed by the business analysts, pink cards represented groupings or categories of stories, while the white cards contained the stories themselves.

The story cards had little annotation on them, but once the team had completed a story, a green sticky blob was put on the corresponding card. However, comments may be added to cards to indicate stages of collaboration between developers and business analysts. For example, some task cards had comments such as 'Waiting for <business analyst 1> to confirm/check that …" and once this confirmation had happened, the developer wrote underneath "<business analyst 1> has <explanation of query outcome>".

Team C relied more heavily than Teams A and B on documentation other than the story cards, i.e. they relied on database schema and on documents produced by the analysts to show how the original database fields map onto the new database fields.

4.3.2 The Wall

The bank's management did not allow staff members to put anything on the walls and so Team C improvised in building their Wall – they used some filing cabinets located at the end of their desks. Because of its location, the Wall is not so easily viewed as in our other teams. For example, if someone were to walk up to the Wall it would be less obvious than in Teams A or B. In addition there are other people not part of Team C who regularly walk around in this area.

The Wall is used explicitly to support the business analysts as well as the development team, so it is divided roughly into four areas – one for the analysts, one

for the developers, one for system-related diagrams and one for jokes and notices. The developers' area of the Wall is arranged according to groupings associated with the database structures. Stories are placed on the Wall according to these groupings. For example groupings included "names and identifiers", "oddities", "flags", "waiting for" and "ideas and reminders".

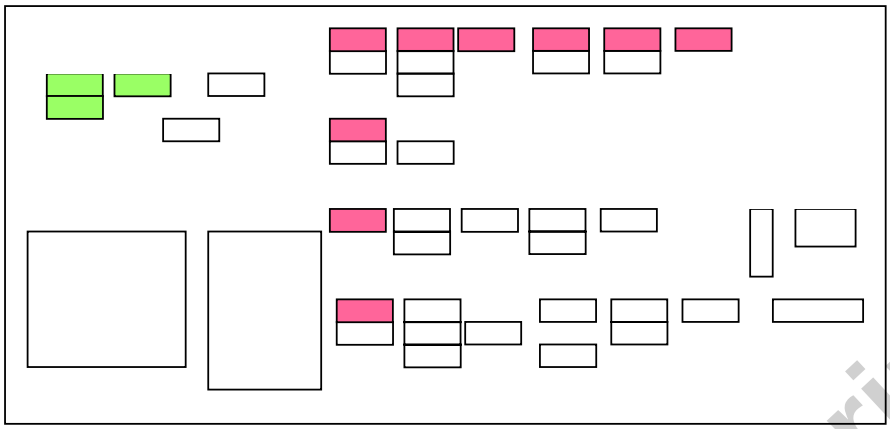

Figure 7 The Wall artefact model for Team C

4.3.3 The role of cards and the Wall in co-ordination and collaboration activities

The stories were developed from the overall project plan which was controlled by the project manager. The project manager would feed stories to the development team through the iteration planning meeting. Stories were prioritised through consultation with the business analysts and the developers. Once written on index cards, the stories were estimated and the cards displayed on the Wall.

The team's daily stand-up was divided into two parts. The first part involved only the developers, and the second part involved the business analysts as well. The stand-up was held by the Wall, but they had difficulty holding stand-ups in this area as it was in effect a corridor and people from outside the team often walked through the middle of the meeting.

The cards were routinely taken from the Wall and held by a pair at their desk while they worked on it. It was also common for the developers to take a story card to the business analysts to discuss its meaning. It was rare for the business analysts to approach the developers in this way.

The project manager had a set of index card boxes on his desk where completed story cards were kept.

5. Discussion

There are significant similarities between the ways in which cards and the Wall are used by all three teams. Inevitably there are also some differences due to local customisation, for example, Team A used the walls of the office extensively to display story cards, while Team C compromised on using filing cabinets because they were not allowed to stick anything on the walls. Similarly, the details of the Wall structures used by each team were tailored to their own requirements.

In this section, we discuss the co-ordination and collaboration activities supported by these artefacts, then consider their physical nature and the effect the medium has on these activities.

5.1 Co-ordination and collaboration activities

At one level, story cards and the Wall are simple, but this simple veneer masks a complex situation in which they are used in a sophisticated and disciplined way to support significant levels of co-ordination and collaboration. Their power lies in their simplicity, easy accessibility and in the way they support each other.

The story is the single thread which runs through software development, from requirements through to user acceptance. The story carries a sense of permanence and tangibility which is enhanced by the use of a card to represent it. Levy (2001) comments that physical artefacts communicate a sense of permanence, and this was definitely reflected in the way our teams related to the cards – they handled them carefully and stories seemed to take on an independent existence.

The card is annotated in strict ways as it progresses through the development cycle, but the card itself represents too small a chunk of development to stand alone – it is important to see the wider overall picture of progress and activity. The Wall provides this overview, and is designed spatially to carry extra information which complements the detail shown on each card.

Cards and the Wall are not just visible signs of progress for visitors, managers and team members – as one might suppose from a simple reading of Beck (2004) or Cockburn (2002) – they are also an information-rich focal point for co-ordination and collaboration which work in a complementary manner. Much of the mechanics we have described – card annotation, displaying stories on a wall, taking cards to a workstation when implementation has started etc – are focused on co-ordination of the team members' efforts. However the way in which this co-ordination is achieved underpins the collaborative nature of the team's work and makes it possible for such close collaboration to be successful. For example, the publicly visible nature of The Wall, the pen-and-paper annotations to the cards, and the ease and flexibility of manipulation of both representations all mean that it is straightforward for each team member to be aware of others' work and the current state of the project. This awareness in turn leads to a situation where people can collaborate easily with each other on estimating code or developing code with only minimal explanation.

Members of an XP team collaborate on a wide range of issues: estimating stories, implementing stories, developing and running tests, planning an iteration, talking to customers, solving problems, and so on. Our studies of mature XP teams reported here highlight several aspects of co-ordination and collaboration:

- The daily stand-ups are a key co-ordination point in the day. These take place around the Wall which is the focus of discussion regarding what's been done and what needs to be done. The ease with which the information on the Wall can be digested and immediately applied facilitates the stand-up.
- Taking a card down from the Wall when it is being worked on means that no-one else can be working on it at the same time. The fact that the card is stuck on a monitor shows clearly who is responsible for the story at that time, and increases awareness of activity.

- The use of different coloured cards and the disciplined annotation of cards provides detailed progress-tracking information. This in turn indicates what needs to be done next and how much is left before that story is complete.
- The structure of the Wall provides an easily-digested overview of the iteration's current status. This is usually indicated by the physical location of the story cards, and is also shown by annotations and different coloured cards and stickers. Usually, the structure of cards, e.g. story versus task cards, is maintained on the Wall. Only those cards on the Wall are of current concern; stories from other iterations are not displayed.
- During the stand-up (and at other times during the day too), cards act as tokens giving the holder speaker's rights, making it clear to others that they have something to say.
- Cards promote collaboration between developers and customers. As the card can hold only a limited amount of information, they need to talk to each other in order to clarify what needs to be done.
- The level of discussion promoted by the card as a token generates much activity and information exchange that is accessible, and hence supports the sharing of knowledge. This is turn helps team members to collaborate effectively on tasks.
- The Wall is available for view all the time, and is regularly being updated. This means that the information it displays is immediately relevant. The physical movement that continual updating generates raises awareness for others that things have changed.
- Code is developed by pairs of developers who sit together and collaborate on a task.
- Cards are independently 'dealt and shuffled' in support of group reasoning and discussion, i.e. they are moved about and clustered to indicate various groupings.

Story cards embody and convey meaning and power, and are central to collaboration and co-ordination between members of the team. One consequence of making the story the central focus of development is that updating the card and the Wall is integral to the work being done, rather than being an overhead. This is important in an XP context because an XP team will not tolerate easily having to complete documentation or other tasks which are extraneous to the central goal of producing working software.

'Simplicity' is one of the values supported explicitly by XP, so it is not surprising that the notion of simplicity underlies the activities described above. For example, the artefacts are easy to see and understand, the artefacts hold minimal information, and they are flexible, i.e. the structures can be easily and visibly changed if appropriate, cards can be moved around, are easy to carry and easily accessible, if necessary they can be ripped up and thrown away. Importantly, this simplicity works because the teams follow an agreed and disciplined approach to use.

5.2 The effect of medium

The difficulties of maintaining co-located teams has led to various (understandable) attempts to translate the physical artefacts into electronic versions for ease of distribution. However there has been little discussion about the impact on

collaboration and co-ordination activities that this change may have. Sharp and Robinson (2006) used a distributed cognition perspective to identify potential breakdowns in XP teams. One of the breakdowns identified involved a co-located team that used an online software system to store and maintain stories rather than physical story cards and Wall. The breakdown may have had various causes but it is noticeable that shortly after the study was completed, the team adopted physical story cards. This example does not appear to be unique. Beck (2004, p45) states that "every attempt I've seen to computerize stories has failed to provide a fraction of the value of having real cards on a real wall". Cockburn (p84) comments that "Hallways qualify very nicely as good places for information radiators. Web pages don't. Accessing web pages costs most people more effort than they are willing to expend, and so the information stays hidden."

So what is it about the physical nature of these artefacts that makes such a difference? Although research in the agile arena is limited, other researchers have investigated the role that paper and other physical artefacts and activities have in co-ordination and collaboration. As Luff et al. (1992) have noted, paper has an 'ecological flexibility' which allows it to be used as a focus for discussion, and for the co-ordination of social interaction. Luff et al. also point out that paper can be more easily interweaved into ongoing collaborative activity, as opposed to screen-based documents which cause interaction to be more localised and fragmented.

Sellen and Harper (2003) investigated the role of paper in two workplace situations. They found that even when very sophisticated electronic support tools are available, workers still rely on paper artefacts for certain collaborative tasks. They examine particularly the role of paper in coordination, information gathering, discussion and archiving group information. Whittaker and Schwarz (1999) compared two software development teams: one using an electronic schedule and the other using a physical wallboard schedule. They found that the medium used for the schedule had a major impact on the co-ordination problems faced by the teams and that large, publicly visible displays promote awareness and encourage collaborative work in a way that electronic systems do not. Bellotti and Rogers (1997) also found that paper persists in a newspaper production office even when much content is created and delivered online. They identified visibility, communicativeness, status, permanence and task-adaptedness as properties of physical representations.

It would seem, then, that there is evidence to suggest that the physical medium affects co-ordination and collaboration activities in a wide range of activities.

A key consequence of the physical nature of the cards and Wall is that activity is not easily hidden. Accessing the Wall or annotating a card requires no special privileges, or elite skills. An underlying philosophy of XP is that actions are shared – e.g. shared responsibility and common ownership of code – and physical artefacts supports this philosophy well. On the other hand, physical cards cannot be shared easily across distances, there are no security measures in place to prevent unauthorised access, there is no automatic mechanism to check that the story on the card relates to the code being worked on, and a physical card can be easily lost or placed in the wrong location. Using physical artefacts in the ways described above relies on trust and a highly disciplined team. There are arguments, therefore, for employing electronic-based co-ordination and collaboration mechanisms but to do this effectively, it is useful to understand the effect of the physical medium of these artefacts. The following arise from our observations so far:

- The overview of project status transmitted by the Wall is an active reminder of activity. Even if an individual team member is not directly looking at the display, s/he knows that it is available at all times, and when s/he does need to look at it, s/he knows where it is, and that it can be viewed at a glance. This ready availability means that team members are familiar with the Wall and its contents which makes collaboration during the stand-up more effective.
- The act of getting up from a workstation and walking to the Wall to update it when a story has changed status subconsciously raises the team's awareness of activity and progress. In contrast, the action required to update an electronic document is not distinguishable whether the user is typing a line of code, setting off a system build or reading their email. Physical artefacts promote physical activity, which in turn helps to create an up-beat environment. Whittaker and Schwarz (1999) found that the public and visible nature of a physical wallboard meant that schedule manipulations were often done in a social context, and that there was a permanent awareness of the work of others. Bellotti and Rogers (1997) also found tangible representations promote a general awareness of ongoing work and state-of-play that are not available through electronic tools that are principally for individual-user task requirements.
- When a pair decides to work on a story, they physically remove the relevant card from the Wall and carry it to their workstation. In this way, they signal to others that they have taken responsibility for the story (at least for the time being). This echoes findings from Bellotti and Rogers (1997) who studied a newspaper office, and found that physical artefacts sometimes represent tokens of responsibility. The sense of ownership engendered by possessing a physical card and carrying it away to their own workspace has more substance than clicking a box on an electronic form to log out an electronic story.
- XP developers spend noticeable time holding and manipulating the cards – during planning, at stand-ups, when annotating, and when setting up the iteration's Wall. Whittaker and Schwarz (1999) found that the manual process involved in manipulating artefacts encourages more thorough reflection, while the simpler activities involved in changing an electronic document reduces the level of reflection. In none of our teams did we find battered and dog-eared story cards. They all treated the cards with care, implying that they held them in high esteem. In Team A for instance the team wiki had a page entitled 'The Care and Feeding of StoryCards'. It was clear that the developers had great respect for the cards, the Wall, and what they represent.
- Jeffries comments that the story card's finite physical size is deliberate as it restricts the amount of information that can be written on it. This in itself promotes collaboration as developers and customers have to discuss the meaning of the story. We have observed this in action and can confirm that the need for clarification promotes collaboration. Sellen and Harper (2003) found that paper is sometimes used to hold knowledge that has to be explained before it can be shared. Electronic documents on the other hand have (relatively) unlimited storage capacity and so large amounts of data can be easily stored.
- The cards and the Wall are used in a disciplined manner according to agreed conventions. However, their physical nature means that they can be easily and flexibly manipulated. They can be stuck on the wall, marked up, moved about (shuffled and dealt), folded over, or thrown away. They don't need to be switched

on and don't suffer from power cuts – if the pen runs out, you can just pick up another one! If permanently available, they are easy to consult and less easy to ignore than electronic reminders, especially when the artefact is changing regularly (Bellotti and Rogers, 1997; Sellen and Harper, 2003). In contrast, manipulation of online documents can be relatively cumbersome and constrained.

- One of the tenets of XP is that processes should be regularly reviewed and improved as appropriate. The use of pen and paper materials is sometimes used to imply provisionality, e.g. in early stages of design, and in encouraging the consideration of alternative designs (Fish and Scrivener, 1990). Using low fidelity prototyping in interaction design is also popular because of the way it encourages users and designers to be prepared to change the design when appropriate (Sharp et al, 2007). Although story cards do not represent designs, and are not intended to be provisional, they are intended to be easily changed. Being based on card and pens, they are simple to modify, and promote the sense that change is acceptable.

5.3 Issues for Distributed Agile Teams

At a time when offshoring, outsourcing, homeworking and distributed team working is becoming more prevalent, and hence the pressure to abandon physical artefacts in favour of electronic forms of communication which do not rely on co-location is mounting, this issue becomes more pertinent. Given the emphasis of XP on co-location, it is important to identify how best to maintain the benefits of using a lightweight approach, while also continuing to benefit from distribution.

There are different issues faced by teams who are distributed but all located in the same time zone and those that are globally distributed, but they all face the problem of how to maintain the informal but disciplined collaboration and co-ordination structures that are a hallmark of agile teams. Lee et al (2006) studied 22 globally distributed software teams and suggest some coping strategies for others wishing to adopt agile processes. One set of strategies addresses task awareness and they suggest frequent visits between sites, use of shared project documents and project management tools. Ramesh et al (2006) studied three organisations who have adapted their practices to support agile globally distributed projects. One of the areas they identified concerned the need for more formal communication to facilitate knowledge sharing, e.g. by maintaining a project repository. Neither of these pieces of work addresses the more detailed day-to-day co-ordination and collaboration activities that the story cards and the Wall support. However some experiences have been suggested by others, including the use of video and web conferencing (e.g. Danait, 2005), instant messaging (e.g. Hogan, 2006), and staggered round-the-world stand-ups (e.g. Braithwaite and Joyce, 2005). These approaches can successfully support some aspects of distributed working, but it is not yet established how this experience compares to the use of physical artefacts.

The use of media spaces and video links to support office work has been researched over several years. Kraut et al (1990) evaluated a simple system using an audio-video link, and found that although many direct interactions between remote participants were indistinguishable from face-to-face conversations, there were differences. One difference was that they constantly referred to the video system itself (indicating that the system was a distraction from their main work). Another was a tendency to move towards the video link when wanting to interact with an individual only to move out of camera view, and thus disappear altogether from the conversant's view. More

recently, mixed reality architecture which links multiple virtual spaces and gives participants control over who they can be in touch with has been shown to support management of awareness, social interaction and privacy well (Schnädelbach et al, 2006). Neither of these was specifically designed to support the kind of team work found in XP teams, but the lessons learned from this and other work is that, although it is possible to provide computer-based support for collaboration, it is not easy to replicate the characteristics of co-location.

On the other hand, electronic tools designed to support co-located teams might be successfully deployed in a distributed setting, and there is evidence that they may be helpful. For example, FASTDash (Biehl et al, 2007) increases awareness of others' activities by visualising the state of a shared code base including which files are open and which team member is working on which module. The system may be run on a large wall-based display or on an individual's desktop. FASTDash has not been used in a distributed setting but in an evaluation with a co-located agile team it was found to increase awareness and decrease use of physical artefacts, although it is not clear that the team used story cards and a Wall before its introduction.

Practitioners will continue to be pragmatic and to make distribution successful, but the work reported here has highlighted aspects of paper use that teams grappling with a distributed situation need to understand and be aware of if they are to maximise the benefits of agile working. It is clear that just translating cards into a database or spreadsheet format, and replacing the Wall with a static display will result in a poorer atmosphere of co-ordination and collaboration than the physical artefacts encourage. We therefore suggest two issues that teams grappling with a distributed situation should consider:

1. *Interaction styles*. A key danger of translating these mechanisms into an electronic form is that activity may become 'hidden', and less easily accessed by all. There are several new and emerging interaction technologies that provide a very different user experience than that experienced via desktop systems, and which might provide a more appropriate interaction style to support co-ordination and collaboration in XP teams (e.g. see Sharp et al., 2007). For example, large displays and gesture-based interaction may be a suitable medium for the Wall; tangible interfaces may be an appropriate way to support planning activity (e.g. see Liu et al, 2005 for a prototype tabletop tailored to XP). Other technologies integrating the flexibility of paper with the mobility of pervasive systems are being investigated at present (e.g. CoPADD, 2006). But although moving to a different kind of interaction may provide a more comparable user experience, it may also be at the cost of simplicity and accessibility.
2. *Integration with the real work.* A key characteristic of any mechanism to support agile working must be that it is part of the real work, and doesn't distract from the main goal of producing correct software. By this we mean that no extra effort is needed to keep the mechanisms up-to-date and effective.

6. Conclusions

Co-ordination and collaboration activities in an XP team are highly inter-related. The kind of co-ordination that is undertaken by a team results additionally in a situation where collaboration is made easy because team members are very aware of others' work, overall project progress, and the state of the code base. Co-ordination and collaboration are supported by two key artefacts: the story card and the Wall. These

two physical objects work in a sophisticated and complementary manner and their physical nature is significant in underpinning the highly collaborative and self-organising style of agile teams. In particular, we note that current texts (e.g. Beck 2004; Cockburn, 2002) discuss the importance of information radiators and informative workspaces in terms of 'visitors' or 'passersby' being able to see clearly the state of progress within a team, but our analysis shows that these properties are crucial to the work of the team themselves

The significance attached to physical artefacts is not peculiar to XP teams, nor indeed to software development, as research has shown that paper is used for collaboration and co-ordination purposes in other domains ranging from air traffic control to newspaper publishers and police work.

Nomura et al (2006) found that the paper-use practices of pilots serve a set of important cognitive functions, and that these practices have a range of implications for the design of computer-based media to support pilots as they work in collaboration. In the same way, it is important for us to understand the significance of paper in collaboration and co-ordination activities of XP teams, so that we can enhance our understanding of how successful XP teams work, and so that we can inform the development of computer-based support systems.

Acknowledgements

We'd like to thank all of our collaborators for allowing us to spend time with them, and for their patience when we have asked stupid questions. We'd also like to thank Dominic Furniss of UCLIC for his support in our use of the DiCOT method.

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