Articulation Spaces: Bridging the Gap between Formal and Informal Coordination

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ABSTRACT
The high complexity of knowledge-intensive work such as software development makes it beneficial to have spaces for formal and informal articulation work. Existing information systems (IS) tend to treat these different aspects of coordination separately, resulting in problems of awareness and coordination. To bridge this gap, we present the concept of Articulation Spaces which combines aspects of Coordination Mechanisms and Common Information Spaces (CIS) in order to provide a room for mediating between the formal and informal aspects of coordination. Based on a design study in the form of a lightweight public display that has been tested in a medium-sized German software company, we show how Articulation Spaces provide information for meta-coordination, encourage ad-hoc coordination and support decision-making processes. Our findings provide insights into the design of support systems for flexible and coordination-intensive contexts such as software development work.

Author Keywords
Lightweight Displays; Software Development; Small Companies; Coordination; Formal and Informal Communication; Articulation Work; Common Information Spaces; Coordination Mechanism.

ACM Classification Keywords
H.5.3 [Group and Organization Interfaces]: Computer Supported Cooperative Work.

INTRODUCTION
Workgroups in knowledge-intensive areas such as software development demand efficient team coordination and knowledge exchange [2]. Small and medium-sized enterprises (SMEs) have particular needs in this regard, as they often follow business models that depend on close cooperation with the customer and on high flexibility [10]. Arguably, this means that responsiveness, both to customers and to each other, is a more pressing problem. Certainly, there is some evidence that SMEs typically embed more flexibility and informality, for instance, in their customer relations (see e.g. [18]). In practice, such demands can be problematic and call for adequate organizational and technological solutions. This is especially important with regard to managing in-situ coordination and learning, which have turned out to be important success factors of such forms of work [34].

We have investigated coordination and the related use of information systems (IS) in software teams in previous studies in two small German software companies. Both studies have already been published [8, 9]. In summary, our studies revealed a complex interrelationship between the formal protocols of using systems like source-code repositories and the informal practices to contextualize them. The information systems used did not support these problems very well, as they tended to focus on formal aspects, while neglecting the informal parts of coordination. As a result, awareness about changes of plans was often less than adequate, and further informal communication was needed to raise awareness and announce the changes in the team—a difficult and time intensive task, which often led to problems, for example when changes went unnoticed or details were overlooked. Common problems concerning the use of IS in software development recognized in previous work reference the fact that the information in these systems is often not up to date and not self-explanatory, requiring informal communication and coordination in order to make sense of and contextualize it against the background of the specific work context [8, 9].

The CSCW community has developed numerous analytic concepts for understanding and supporting coordination in complex work contexts, such as Coordination Mechanisms [39] and Common Information Spaces [19, 20]. Based on this prior work, we have developed the concept of *Articulation Spaces*. It aims at bridging the gap we found in our empirical studies by integrating diverse information sources and communication channels that have become separated in current IS applications and providing a space for mediation between them. In this paper, we present findings from a design study in which we tested an implementation of our

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concept over a period of seven weeks in a medium-sized German software company. We chose software development as an example due to its high reliance on heterogeneous IS systems, but we think that the concept can be easily adapted to other application areas. The design intervention allowed us to get a better understanding of our concept, as well as of how it can be implemented in knowledge-intensive areas of work such as software development.

RELATED WORK

Tools for supporting coordination of software development work can be roughly divided into two different areas [2, 8]: the first includes tools for information management such as bug-trackers or version control systems. They provide the basic infrastructure for working on source-code and managing tasks for software developers. The second includes tools for personal communication such as Instant Messaging, micro-blogs or Email. Both fields differ not only with regard to their focus on informal versus formal forms of coordination, but also with regard to the social protocols that guide their usage. While the information stored in bug-trackers or in project planning tools is usually considered to be rather formal, standardized and obligatory, information shared in personal communication is usually rather more informal, unofficial and often subject to changes in the course of projects [27]. However, there can be a crossover of both forms: informal information can be formalized if its context is changed, for example, by posting private chat-logs into an official and public bug-tracking ticket—a process that can change the character of the information substantially. Equally, formal information can be discussed in informal contexts, and actors can decide ad-hoc to re-interpret or ignore formal information without necessarily updating the status of information systems. In our own studies, we found that while formal systems played a very important role for the coordination of the development work, their use was highly embedded in informal discussions that took place before, during and after the tasks mandated in the formal systems were accomplished. The informal discussions were crucial for the actors in order to make sense of the information stored in the formal systems, which was often rather abstract and needed to be interpreted against the context of the current situation of the projects [9].

Frameworks such as "Continuous Coordination" combine the benefits of formal and informal coordination to stimulate communication, provide context, and raise awareness [14]. The authors of this framework developed different tools like Palantír, an artifact centered workplace awareness tool, or Ariadne, which visualizes the socio-technical relations between software artifacts [34]. Similar solutions for practitioners focus on organizational practices that are closer to agile methodologies [43], and on the use of specialized tools that attempt to support group awareness by analyzing socio-technical congruency between actors and artifacts [37]. Hence, coordination is meant to be supported by making predictions about possible breakdowns and notifying developers thereof, ideally preventing the breakdown from occurring in the first place. Problems with such approaches include that they rely on up-to-date information in the IS (thus often focusing on the formal side), and that they can be annoying in the case of inaccurate predictions because notifications can be intrusive and cause interruption [36]. Hence, the problem of visualizing the information is one of the main challenges of implementing such systems in practice.

Several tools try to address the problems of visualizing coordination-related information in software projects by embedding collaboration and communication features directly into the development environments, namely IBM's Jazz or Microsoft's CollabVS [17]. Such approaches are promising, but have the disadvantage of focusing on the individual workplace tools of software developers, which can lead to problems of acceptance, and are subject to space limitations on the screen. At the same time, they often tend to provide all-in-one solutions at the cost of excluding other established development tools (cf. [10]). Other approaches provide information on (semi-)public displays placed at central places in companies. For instance, approaches such as CommunityMirrors support peripheral awareness and serendipity [32] and provide a shared working context for cooperating actors [17]. In software development, a special approach of using public displays has been tried in the form of "dashboards" that represent project related information [7, 45]. Usually, such approaches are rather focused on formal aspects of the project, which can be easily obtained from the deployed Information Systems. Despite the apparent advantages of using public displays for supporting group awareness in companies, they are hardly established in practice [35].

The concepts described above provide interesting approaches for fostering awareness and supporting coordination in software development. They will play an important role for the implementation of our concept that we will present in the next chapter. The studies of Redmiles et al., in which design aims to support "Continuous Coordination" [34], and also approaches for providing dynamic forms of awareness in software teams with public displays are particularly valuable. We want to contribute to this stream of research by paying closer attention to the interconnections between formal and informal aspects of coordination, and by presenting a concept for a support tool that provides a space for mediating between the two forms.

THE CONCEPT OF ARTICULATION SPACES

Analytically, we can distinguish between formal and informal practices of coordination in the sense that the formal is often institutionally sanctioned and mediated by mandated IS systems, while the informal involves any practical means of getting the work done [4]. However, while there is a clear analytical distinction between formal and informal forms of coordination, in practice both are interwoven in quite complex ways [34]. Our Articulation Spaces concept

explicitly integrates two existing CSCW concepts, in order to address these complex interrelations between formal and informal forms of coordination: Coordination Mechanisms, and Common Information Spaces.

A Coordination Mechanism can be defined as "specific organizational construct, consisting of a coordinative protocol imprinted upon a distinct artifact, which, in the context of a certain cooperative work arrangement, stipulates and mediates the articulation of cooperative work so as to reduce the complexity of articulation work of that arrangement" [39]. The concept is based on the theoretical framework of articulation work, introduced originally by the sociologist Anselm Strauss, and based on his studies of medical work in hospitals [42]. Articulation work describes a kind of meta-work that is needed to coordinate different tasks and responsibilities of cooperating actors. The practical application of Coordination Mechanisms itself requires articulation work, as these mechanisms are often constructed in a way that allows them to be interlinked with each other [39].

Common Information Spaces (CIS), on the other hand, promote the meaning and interpretation of artifacts as a core aspect of supporting teamwork [38]. In early studies, CIS were mainly understood as relevant to local control rooms and similar settings. Studies in this field increasingly concentrate on distributed contexts and teamwork where the collaboration takes place asynchronously or infrequently [6]. The emphasis on these studies is the distinction between the common access to information and the interpretation of this information, and the way it needs to be communicated (or, in Strauss' terms, articulated) to make team coordination successful. From this perspective, providing rich information channels is not enough [22], as different perspectives and interpretations of information need to be taken into account—a thought which has also been discussed in the context of "second generation" knowledge management studies [1]. Instead of just providing a shared access, group awareness systems should support different perspectives.

Articulation Spaces refer to these two concepts with the aim of improving the visibility of articulation work by identifying and filtering individual articulation work events in the existing communication media and development IS and presenting them on a shared display or a similar device (such as a Media Space). There are already some research projects in the field of practical support of cooperative work through Common Information Spaces that rely on public displays. One example using public displays as the output medium is the concept of tickets-to-talk, which was developed for academic conferences [30]. The concept of awareness cues also fits into this category [33]. It has been shown that these approaches can support social interaction and animate the knowledge exchange of actors by providing relevant contextual information. Our concept extends these ideas to solving the problem that articulation work is often invisible for the team [41]. At the same time, it aims to improve the traceability of articulation work, which often is hard to reconstruct by referring to the formal coordination tools and artifacts, like bug-trackers or project plans [10]. While most components of Articulation Spaces have been discussed in the literature before, we think that the combination of the different concepts can be seen as a new paradigm of supporting flexible and knowledge intensive work, such as software development.

At its basis, the concept of Articulation Spaces relies on an "articulation pipeline" which, similar to an awareness pipeline [23, 25], aggregates and filters information about articulation work events from the various tools, media and artifacts. It provides interfaces for in- and outputs and a back channel to the deployed artifacts, IS and communication media (see Figure 1). Due to its flexible nature, an Articulation Space allows for individual appropriation, for example with regard to which sources of information are connected. Relevant design considerations concern similar issues as the discussion on providing awareness, including filtering at the input-side (to ensure privacy), but also the appropriate visualization at the output-side and the avoidance of information overload [23, 24, 28].

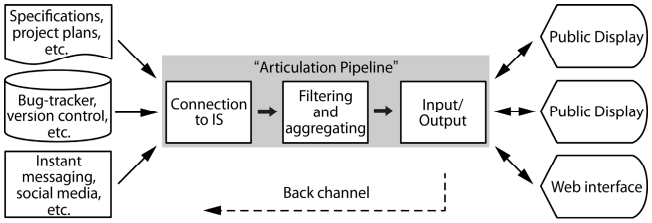

Figure 1. The concept of Articulation Spaces.

The gathered information is presented on an output device such as a wall mounted display, which might, for instance, be placed in a public or semi-public space in the company, such as a coffee kitchen. Design decisions in this regard are related to the debate on Media Spaces, which has a long tradition in the fields of HCI and CSCW, following the early studies at Xerox PARC at the end of the 1980s [26]. Media Spaces usually use large wall displays to support synchronous collaboration of small and distributed teams by means of video and audio links. The underlying concept holistically supports distributed cooperation by a virtual enhancement of the room, by means of different communication channels [31] and the support of group awareness through concepts such as peripheral visualization (like colored lights, which represent the status of a project [5, 44]). Articulation Spaces visualize information by means of technology that has been developed in the context of Media Spaces, but rather aim at sharing small chunks of information that provide hints towards what is going on in the company and who could be asked for which problems, than to provide fully self-sufficient and codified knowledge in form of a public repository. At the same time, Articulation Spaces do not focus on providing as much information as possible, but on putting the available information into context [22]. Hence, like CIS they should not be designed as central knowledge

repositories [21], but should allow practitioners to order the information as it fits their work contexts.

In the next section, we will present a specific implementation of the Articulation Space that we have developed in order to study how practitioners appropriate the concept in practice.

DESIGN & IMPLEMENTATION

Based on the conceptual considerations outlined above, we have implemented an Articulation Space that consists of a small public display, which presents information from the development IS, as well as other sources such as blogs and news forums in the form of "sticky notes". The system is designed to be used by software developers in small teams, and aims to raise awareness about formal and informal aspects of their cooperative work, provide a space for mediating between the two aspects of coordination, and facilitate the flexibility we have argued is necessary.

Overview

The system was implemented as client-server architecture. A middleware acts as an articulation pipeline that aggregates RSS and Atom feeds from different sources, such as bug-trackers or version control systems. It combines these formal items with information of tools used for informal communication and external sources, such as newsfeeds of blogs and websites. The items are managed via a micro-blogging server, using account names that correspond to the information sources (for example, news items from a bug-tracking tool are posted on an account that is called "bug-tracker").

A (semi-public) display serves as client for the micro-blogging server and regularly requests the server for updates. If available, new entries are presented as sticky notes on the display. In addition, the server also can be accessed by a web interface or off-the-shelf micro-blogging clients, allowing users to read the messages individually. If needed, multiple displays can be connected to the server, for example to support distributed work groups. Micro-blogging is an interesting metaphor to implement an Articulation Space related solution, as this technology seems to combine several advantages of Instant Messengers (informal character, not intrusive, etc.) with a better traceability and visibility [13, 47].

In the next sections, we give a more detailed description of the different parts of the system.

Client

According to the concept of Articulation Spaces, we have used a public display for visualizing data and providing awareness in teams. (Semi-)Public displays have considerable advantages in this regard compared to desktop applications, as they allow information to be presented in an unobtrusive way, hence providing for peripheral awareness [29]. At the same time, they can be used cooperatively and thus provide a shared context for cooperative work [46]. In order to address the flexible nature of the software development work that we aim to support, we used a standard tablet PC as display device (in our case an iPad 1, see Figure 2a) that was attached to the wall by a Velcro fastener (see Figure 2b). The display software was developed using Adobe Flash CS 5.5 and packaged as an App by including the Packager for iOS and the runtime environment Adobe Air 3. All functions of the software can be used by standard touch gestures. The lightweight form factor makes it easy to install the device in different rooms or to simply carry it around (for example taking it to a meeting). If the battery is charged overnight, the display can remain turned on for a whole working day, thus making the display very flexible.

In accordance with the conceptual argument above, we wanted to create a design that reflects the users' different perspectives on their shared work context, is open to everyone and invites people to interact with the device. Based on our concept of sharing small chunks of information in a non-linear way and on the results of an internal design workshop, we decided to implement our prototype in the form of a bulletin board [15], presenting all messages as sticky notes on the display (see Figure 2). A bulletin board allows for other types of interaction (compared to the usual timeline view of micro-blogs), as messages can be rearranged, can overlap each other, and can show new (or important) items at the top or next to each other. Users can browse through the messages and arrange notes on the display by dragging them around, overlapping them with each other, or by scaling or deleting them via a context menu (triggered by a long touch on a note). The context menu also provides links and corresponding QR codes to the source of the messages, e.g. an entry in the bug-tracking system, or a blog post (see Figure 2c).

These simple interaction mechanisms provide users with the possibility of highlighting messages they find important, and covering (or deleting) unimportant ones. Users can also create new messages directly on the display by touching a button, which opens the standard iPad keyboard. If users want to post messages from their own accounts, they have to use a client or the web-interface, as we wanted to make the use of the display as easy (without needing to log-in) as possible and to stress the status of the frontend as a device that is free to use for all team members.

New notes appear on a pile in the upper left corner of the display, and have to be rearranged by users. This stimulates interaction with the display, and increases the peripheral awareness for new project related news. There is also the possibility of answering notes on the display; in this case, the corresponding note appears just next to the first one, in order to show the relation between the two. Also, there is an auto-sorting feature in case the pile of new messages gets too big in order to be useful, which can be called by touching a button on the side of the display.

In order to visualize the different sources to which the notes are related, we use different account names as well as

different colors for the notes (e.g. the different IS systems). The color codes make it very easy to recognize important messages even from a distance (for example, new bugs are displayed in red). After a certain time, the notes begin to disappear by becoming transparent, providing hints towards the immediacy of the message. Users can also make transparent messages visible again by simply touching them. As there is a (configurable) limit to the number of notes that can be displayed at the same time, older notes disappear automatically from the display after a while, depending on the amount of messages that are created.

Server

The server of our prototype is based on the micro-blogging server StatusNet (www.status.net) and a middleware that acts as an articulation pipeline. We decided to use micro-blogging to manage and store events because of the many similarities to the Instant Messengers that users demonstrably preferred for in-situ coordination and knowledge exchange [11]: micro-blogging is informal, easy to use, not intrusive, and makes it easy to share links to web resources or the IS. At the same time, micro-blogging has some advantages with regard to Instant Messaging, as it allows for fine-grained control of what is displayed (filtering by users, groups, hash-tags), and offers a shared timeline for all users—besides the also possible direct messages, which remain private.

Hence, micro-blogging seems to be an interesting technology for supporting informal coordination within work groups, without introducing high overheads to use [13]—thus making it the ideal base for design with regard to the problems we have identified in our previous studies [10, 11]. Due to its Twitter-compatible API, StatusNet also can be easily integrated with other systems such as our own middleware, but also with Instant Messaging solutions. As the server can also be accessed via several freely available standalone clients, as well as a usable web interface, it enables a very high integration into the work of the software developers, even apart of the display.

The aggregation of different sources of information is handled by a middleware that we have developed to serve as an articulation pipeline. It parses XML feed sources (e.g. RSS or ATOM feeds) on a regular basis and searches for new items. RSS feeds are provided by most recent Information Systems (such as bug-trackers or version control systems), but also by a number of websites, making it easy to connect formal systems for team coordination and relevant news (such as from the company website) with more informal sources such as interesting blogs and news forums.

The middleware also filters and publishes items to the micro-blogging server which serves as a repository that is accessible via the client. Before they are published, postings are reformatted, supplied with corresponding hash-tags and afterwards sent via special user accounts that resemble the sources of the information. Users can enter new feeds into the system (or delete unwanted ones) by using a simple web interface. For sources with many new items each day (such as highly active news blogs) there is also a special "digest" mode that only posts messages from these feeds to the server when no new message has been posted in the last couple of hours, in order to prevent a spamming of the display (and the timeline) and to keep the display active even during times with hardly any user interaction.

DESIGN INTERVENTION

Methodology

For our design intervention, the system was tested for seven weeks in a web and software development company that employs about 110 people. We provided practitioners with our implementation of Articulation Spaces, consisting of an iPad running the client software. The server was hosted on a virtual machine at the authors' University, giving full access to server logs and to all sent messages. The team consisted of five employees who used our system in a small project that aimed at the concept development of an E-learning platform for a local public institution. For doing so, the display was positioned at an open space in the office, close to a water dispenser (see Figure 2b). The project manager took responsibility for taking care of the display in terms of charging it overnight.

We used empirical qualitative methods, notably participant observation and interviews to investigate the usage of our prototype during the study. The main focus of our investigation was how the design was used for formal and informal forms of coordination in the project. Further foci were the appropriation of the lightweight form factor, its influence to the team communication and coordination, as well as the usability of the display in everyday work situations of the project members.

The investigation started with a small workshop during which two members of our research team presented the prototype to practitioners, explaining its features and the main vision of our concept. The aim was to give practitioners a basic idea about the aims and possibilities of our system, and to stimulate a discussion about how the company could integrate the prototype into their daily work routines, where the display could be placed, and how it could be integrated into the technical infrastructure of the project. During the workshop, the team members expressed

Figure 2: (a) The display, attached to a wall with Velcro fastener, (b) The display in the field, (c) Close-up of the Application.

their need for improved and up-to-date communication by collecting different kinds of information on the display, and also their interest in discovering relations between different tasks by presenting them on the screen. Through the semi-public character of the design intervention, the actors were also hoping for serendipitous participation on the part of colleagues who were not part of the project team by allowing them to make suggestions or post critical comments. After the workshop, the system was rolled out in the company, and one of the researchers visited the company regularly one day per week in order to observe usage of the platform. Furthermore, we checked the timeline and log data of the micro-blogging server on a daily basis to see how the system was used. At the end of the design intervention, we conducted qualitative interviews with all project participants in order to understand their view of the design (30 minutes each). We also performed 90 minutes design workshops with two of the participants in order to collaboratively scribble and discuss ideas about possible improvements of our prototype. All interviews were transcribed and analyzed together with field notes and other materials, such as server log files. For doing so, we followed a grounded theory-oriented approach, which consisted of sessions of iterative coding and concept-building based on the material until a theoretical saturation was reached.

Results

During our design intervention, the practitioners mainly used the system as a digital task board for their agile SCRUM software development practices, for informal communication within the team and (as a mobile display) in meetings. For doing so, the project manager created a new StatusNet account with the name "Sprints" for posting tasks as notes on the public display. During their regular meetings, the practitioners discussed these tasks and arranged them on the display according to their priorities, or grouped tasks that belonged together. The notes then served as means for coordinating the development work in a similar fashion to conventional SCRUM task boards used in the company. These, we should note, were regarded as rather inflexible, and so the company often used Excel sheets for managing SCRUM tasks prior to our intervention.

In that regard, the practitioners liked the fact that that the virtual sticky notes did not crumple, fall down or get lost. At the same time, despite its small size, the display allowed the display of all tasks at once. The possibility of automatically creating notes by adding RSS feeds from formal development systems or websites that we had included was not substantially used by the practitioners during the field trial, as they preferred to focus on the SCRUM-related tasks: *"For me as a project manager this was a possibility to communicate the tasks and their statuses—done, not done. I could have done that with Excel too, but this way it was more comprehensible in a graphical sense"*. In this context, we learned from our observations that messages from tools for formal coordination can be recognized as unfriendly: *"Sometimes you get several bugs, but it's always the same problem. For example an image for a button that appears at several places and only needs to be replaced once"*. This also hints at the importance of informal communication, or a different visualization of formal incidents: *"People are annoyed by getting a lot of Jira-bugs and sometimes they get angry about it. This needs to be friendlier"*. The display was also used to coordinate the work tasks that were shown via the "Sprints" account: *"How far did we get with sprint 3?"* Feedback to the work tasks could be found in statements like the following: *"Today we continue with the visualization of the use cases within our #prototype"* and informal, sprint related comments: *"First thoughts to the activity streams [sprint 3]. Who sees what, how, where, and why?"*

The users also used the display to communicate with their colleagues in different ways. For example, one user sent a request for suggestions to the colleagues over the display: *"To all spontaneous - creative people, answer this question: How shall we name the online-community for studying, teaching & learning at the (local public institution)?"* Other messages were notifications about current tasks in the project, such as: *"Today we will work on the #prototype. On the agenda are the starting pages of the learning rooms."* For posting such messages, the web-interface played a more important role during the field trial than the input interface of the display itself. Users expressed the view that they could well imagine posting messages to the display via the web client from the home office, in order to stay in touch with their colleagues and thus coordinating their work in a more informal way. The

possibility of integrating the prototype into an Instant Messenger was also deemed interesting for sharing extracts of chat protocols in an easy and informal way with the team.

With regard to the general usability of the display interface, the practitioners expressed a wish for further filtering and grouping options as well as more fine-grained color-coding of the notices. Our design study distinguished between different sources of notifications, but not between different user accounts. As much of the communication took place using the "Sprints" account, the practitioners also wanted to choose the color of the sticky note before sending it to the display. In this way it would be possible for them to build their own color-coding scheme for the messages. The possibility of grouping messages was perceived in different ways. On one hand peopled liked the easy and intuitive way of grouping and making stacks by dragging messages on the screen, but on the other hand the stacks were sometime recognized as annoying because it was difficult to find a note within a stack. Another issue was the number of messages displayed on the screen: users complained the display became chaotic when too many messages were displayed. The possibility of enlarging messages on the display to highlight their importance was used by the team members to overcome this problem when the screen was crowded. Nevertheless, users expressed the wish to mark messages with different levels of priority. The users would also have liked the possibility of archiving the content of the display (i.e. the state of how the messages were arranged). The functionality of deleting messages or using QR codes to save links was not used during the design intervention.

Regarding the form factor of the display, our study also showed that the lightweight character of the iPad allowed for a very flexible usage of our system. The position of the display near the water dispenser turned out to be less serendipitous than expected, as the time taken for perusal was far lower than expected at this place in the office. However, the possibility of taking the display from the wall and using it in a different location alleviated this disadvantage. As the strong battery made the display more or less independent from electrical outlets during a workday, the display could be used in different contexts such as the aforementioned SCRUM meetings. This strongly suggests that the use of our device was seldom casual and almost always associated with specific purposes. On one occasion the practitioners even took the display with them to a meeting at the customer's site to show the progress of the project and coordinate the next steps of the development work—an interesting practice that would not have been possible with a heavier wall-mounted display.

DISCUSSION

The results of our design intervention are creating new challenges for the (re-)design of the implementation and raise new questions regarding the concept of Articulation Spaces. During our study, we were able to observe both formal and informal use of the provided system, which combined both aspects on a common surface for the team members.

With regard to the former, the actors used the display for coordinating their development tasks according to the formal suggestions of the SCRUM development approach. Even though this manual kind of usage had not been anticipated by us, the role of the messages for the ongoing (re-)articulation of the project work was quite similar to that of bug-trackers and project planning tools in our previous studies. In this way the team used the system to implement their own formalized Coordination Mechanism by the adaptation of an already used process model (SCRUM), but without connecting external sources. They used the display to assign tasks and visualize the work process in an official and—according to our conceptual understanding—formalized way. With regard to informal coordination of the work, the practitioners used the display for sending messages that were meant to provide a general awareness or related to specific tasks of the project organization apart of the actual development work (such as choosing a name for the software solution). By referencing more official, SCRUM related messages with questions or statements posted from a personal account, we have also seen aspects of mediation between the different kinds of coordination.

With regard to the underlying concept, this usage of the system can be interpreted in the sense of a CIS. Actors used the possibility to promote the meaning of coordination-relevant information by posting them as sticky notes on the display. Their colleagues again interpreted these artifacts against the context of their work and reacted to this information. In this respect, it became apparent that the formal and informal aspects of coordination are not independent from each other. For example, the possibility to annotate formal messages with informal notes was used by the actors to provide more detailed information or pose questions regarding the project progress as well as open tasks. It became apparent that the nature of the information could be changed by posting on the display, depending on the context or person posting. Due to the semi-public status of the display, it was not clear who would be able to see the message, implying a different context than for example directly talking to a colleague in the coffee kitchen. Even though this effect is similar to what we have observed with regard to the use of IS in our previous studies [8, 9], it was interesting to observe how the different form factor of our solution as well as the semi-public and playful context of our design intervention affected the negotiation of SCRUM tasks and the communication within the team.

Besides the SCRUM-related display postings, the use of the display and micro-blogging system was generally rather playful and non-mandatory. At the beginning of the design intervention, an anonymous user of the display (posts send by the display) wrote mainly jokey messages with regard to

the display itself but after a while the usage changed to a more organizationally relevant one: They used it to express their project related thoughts, asked coordination related questions, made appointments, asked project-specific questions to the team or the whole company, gave task related status updates, shared folder structures or announced meetings and visitors.

In this regard, we could find suggestions as to how far corporate culture and individual usage strategies are an important part of appropriation, as the system needed to address overall company requirements as well as the interests of the individual developers. As an open tool, the practitioners were able to use the system according to their individual needs. At the same time, due to the small team size, informal communication often took place directly, but with the indirect involvement of the display. For example, we observed that a question posted on the display addressing the whole company wasn't answered on the display, but the practitioner got plenty of feedback at a meeting scheduled later that day. Hence, the awareness that was raised by the message on the display can have positive impact on teamwork, even if not all communication is mediated by the artifact. Overall, the specific use practices that emerged were strongly related to the small number of team members in the given project, the immediate proximity of their workstations in the same office, and the clear arrangement of the project that only lasted a couple of months. The conceptual intention to provide a flexible system that is usable in dynamic software projects was certainly fulfilled, as the actors were able to adapt the system to their needs and use the display in the context of their work.

Our analysis of the appropriation of the system also showed some interesting insights with regard to the role of the lightweight form factor in the context of appropriating the Articulation Space. First of all, we found that the visualization of the content was of essential importance for a successful usage of a tablet computer as a "public display". Readability of content is a challenge given that public displays need to be seen from medium as well as close-range. For this specific operational scenario, smartphone and tablet Apps are generally not well suited and call for different design and presentation metaphors. The lightweight form factor also influenced the awareness for the display and the platform: while use of the display was strongly recognized by the entire staff of the office at the beginning of the experiment, the interest of colleagues that were not part of the immediate study faded over time. However, practitioners reported that absence or change of location raised awareness and brought the system back to peoples' minds. At the same time, the flexibility of the lightweight display helped to leverage the disadvantages of the chosen place for the display beside the water dispenser. Furthermore, the practitioners found it interesting that they were able to take the display with them to meetings in the company or at a customer, to show the progress of their work and coordinate the next steps.

The bulletin board metaphor of our system was accepted and understood in this regard, but participants requested that the visualization be even more "bulletin board"-like. In the design workshops, we also discussed different approaches to visualizing streams of messages on a tablet computer and providing the possibility of annotating formal messages with informal comments. While classic "timeline" approaches would be more orderly and scalable, the bulletin board had the advantage of allowing the visualization of connections between messages in a more tangible way (for example by overlapping them, or placing them next to each other) and being more flexible with regard to sorting and piling messages, as the participants did in the context of their SCRUM development. Non-linearity seemed to better support awareness of small chunks of information in regard of the Articulation Spaces concept. As a consequence, a hybrid system that combines the advantages of both approaches (for example by showing a bulletin board next to a timeline and offer possibilities for dragging messages from one into the other) might be a good idea.

The requests for grouping and sorting features were strongly based on the specific practices that emerged in the context of using the system as a SCRUM notice board. For example, practitioners also suggested adding functions for muting specific accounts during meetings to avoid interruption by informal messages, but still allowing new (for example) "Sprints" to appear on the display. Some requested possibilities, for instance for archiving messages and conversation or exporting functions into other software (e.g. Outlook Calendar), would probably change the character of the messages and the usage of the board to a more formal project management tool—an aspect that we want to explore in further studies.

CONCLUSION

There is a need for supporting formal and informal coordination in software development projects and, as importantly, mediating between the two. As we have suggested above, this is particularly important for small project teams, or small companies where there are additional demands for flexibility, and where "informality" of communication amongst members of the team and in "customer facing" aspects of the work, is more common. As both forms are not independent from each other, approaches are needed that take the complex interrelations between these aspects into account [10, 34, 40]. In this paper, we have outlined "Articulation Spaces" as a concept that borrows ideas from other fields like awareness tools [16], public displays [32], Common Information Spaces [19] and Coordination Mechanisms [39] and combines them in a specific way to provide a new space for formal, mandated coordination and more informal modes of communication. Our concept provides a level of integration

and ease-of-use in both formal and informal channels, serving as a central medium for negotiating coordinative practices deployed by members of software teams. During our design intervention in a small software company, the practitioners used the display for both formal and informal coordination, allowing us to learn more about the practical implications of our concept. The implementation of the Articulation Space allowed the sharing of information of varying content and from different sources, but with the same goal: the coordination of the software project. This involved formal aspects such as the organization of meetings, reports about the work progress, but also informal ones such as questions to team members, the announcement of visitors/customers, just to name the most important ones. In that regard, it is important to stress that it was not our aim to combine all formal and informal coordination in a single artifact, but to provide a new space for mediation in order to better understand the complex relationship between the two aspects of articulation work, and to test of novel ways of visualizing and interacting with coordination-related information in small, dynamic teams.

Interestingly, we observed that the use of the display changed over time, as the actors appropriated our provided system in the context of their work. In this context, we could observe how the system improved visibility of articulation work and raised awareness about current issues in the company, which guided of coordination and facilitated knowledge exchange between the team members in the sense of a tickets-to-talk approach. The related processes were triggered and supported by the display, which allowed for informal questions as well as formal announcements. At the same time, we observed that connections between the formal and informal messages remained often implicit, hinting towards the need for better forms of visualizing cross-connections as compared to the lightweight implementation of our design study. In this regard, our field study provided insights into combining public displays [7] with aspects of ubiquitous computing [14] for enabling new forms of team coordination with such devices by showing how our study also showed that actors dealt with the issue of filtering and sorting mechanisms by the re-arrangement notes or enlarging them for others to see. At the same time, the design metaphor of a bulletin board that we chose for our design study provided an equitable visualization of formal and informal information. For the design of CIS systems, the bulletin board metaphor seems to have some potential, as it allows for playful interaction and exploration, supporting the informal character of the prototype as well as serendipity and team communication [32], as we have seen in our design study. We are currently experimenting with different approaches to visualization that combine the advantages of a bulletin board with the classic timeline visualization, which we want to explore in further studies.

At a conceptual level, it became apparent, that our system could be used as classic Coordination Mechanism in the sense of a SCRUM-Board [39], but that it also served as a mediator for existing Coordination Mechanisms. Based on our findings, we conclude that the concept of Articulation Spaces can be characterized as an information space that aggregates information about Coordination Mechanisms commonly used by a software team (such as bug-trackers and source-code repositories) and allows actors to make sense of this information in the context of their work [3, 12]. Similar to Schmidt's and Simone's suggestion to use arrays of specialized Coordination Mechanisms for regulating articulation work [39], we see Articulation Spaces as a means to devise a Coordination Mechanism for this purpose. In other words, Articulation Spaces can serve as a "Meta Coordination Mechanism" that helps to understand the coordination steps that are made, encourages ad-hoc coordination and supports decision-making processes. In this regard, the mobility of the deployed display allowed the actors to enlarge the information space into different contexts. Taking the device to different rooms or to the customers' site allowed for a nuanced use and had interesting implications for the range of "awarenesses" that our concept might support, with clear implications for the design of CIS applications in other contexts with similar demands for flexibility.

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