

# Effects of Awareness on Coordination in Collaborative Information Seeking

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Communication and coordination are considered essential components of successful collaborations, and provision of awareness is a highly valuable feature of a collaborative information seeking (CIS) system. In this article, we investigate how providing different kinds of awareness support affects people's coordination behavior in a CIS task, as reflected by the communication that took place between them. We describe a laboratory study with 84 participants in 42 pairs with an experimental CIS system. These participants were brought to the laboratory for two separate sessions and given two exploratory search tasks. They were randomly assigned to one of the three systems, defined by the kind of awareness support provided. We analyzed the messages exchanged between the participants of each team by coding them for their coordination attributes. With this coding, we show how the participants employed different kinds of coordination during the study. Using qualitative and quantitative analyses, we demonstrate that the teams with no awareness, or with only personal awareness support, needed to spend more time and effort doing coordination than those with proper group awareness support. We argue that appropriate and adequate awareness support is essential for a CIS system for reducing coordination costs and keeping the collaborators well coordinated for a productive collaboration. The findings have implications for system designers as well as cognitive scientists and CIS researchers in general.

## Introduction

A typical collaborative project comprises many phases and processes, and coordination is one of these essential components (Shah, 2009; Taylor-Powell, Rossing, & Geran, 1998). Malone (1988) defined coordination as follows: "The additional information processing performed when multiple, connected actors pursue goals that a single actor pursuing the same goals would not perform" (p. 5). Often, such

additional processing is considered to be nonessential effort, and attempts are made to minimize it as much as possible. For instance, Olson, Olson, Carter, and Storrosten (1992) found from studying design meetings that only about 40% of time was spent in direct discussion related to the project, with 50% of the time spent on taking stock of their progress so far or coordinating meetings. A common way of reducing coordination efforts is by providing proper awareness support to the collaborators (Dourish & Bellotti, 1992), because often coordination in a collaborative project is done to update and inform collaborators about the group's existing status and future directions.

In this article, we investigate how different kinds of awareness support affects collaborators' coordination behavior in an information-seeking project. We present a laboratory study with three conditions, based on the kind of awareness provided on the interface. For studying the effects of these three conditions on coordination, we identify and code the messages exchanged between the participants of each group as those relating to the past actions and results (past), current status (present), and discussion on next steps (future). With various quantitative and qualitative analyses, we demonstrate that the *right* kind of awareness keeps the collaborators well coordinated, while reducing the efforts for doing coordination.

The reported work reflects and validates findings from earlier works with systems such as Ariadne (Twidale & Nichols, 1996) and SearchTogether (Morris & Horvitz, 2007), which also provide support for awareness in doing effective coordination. However, studies such as SearchTogether have focused on one kind of interface design and only one usage. In contrast, we present a large-scale laboratory study that looks at coordination efforts in a CIS project over two sessions, with a setup in which three conditions are clearly defined based on the kind of awareness provided on the interface. These design decisions have allowed us to investigate the effects of coordination with respect to specific support of awareness in CIS with richer data and deeper insights. It is a natural expectation (and a

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standing hypothesis) that those with *more* and/or *better* awareness should spend less effort in coordinating. However, in our study involving three awareness-based conditions, we demonstrate that it is the *right kind of awareness* that really helps in reducing coordinating efforts.

The rest of the article is organized as follows. The next section provides a detailed background of the work presented here, specifically focusing on related research on awareness and coordination in collaboration as well as clearly indicating how the current article is related to and different from a previously published work in Shah and Marchionini (2010). Following this, a section on method is given that provides details on the laboratory study conducted. Various analyses using quantitative and qualitative techniques are followed in the Analysis section. The article concludes with a summary of findings and their implications for studying CIS and system designs as well as pointers for the future research.

## Background

Several works have identified coordination as one of the essential parts of collaboration and awareness as one of the core components of a collaborative information seeking (CIS) system. This section provides a brief overview of CIS, coordination and awareness in CIS, and our experimental CIS system, showing how different kinds of awareness are manifested.

### *Collaborative Information Seeking*

Collaboration is a desirable, useful, and often necessary component of complex projects (Denning, 2007; Denning & Yaholkovsky, 2008). This applies, of course, to more sophisticated, involved projects, such as engineering infrastructure, for example, a family planning a vacation, coauthors working on a scholarly article, an engaged couple designing their wedding, or a recruitment committee working on a new hiring project. All of these situations require people to come together with intention, looking for and sharing information, and making sense out of it to reach their common goals. Morris's (2008) survey of knowledge workers found that the majority of them wanted to work collaboratively. She also demonstrated that collaboration in many situations is vital to the success of the task at hand (Morris & Horvitz, 2007).

For seeking and synthesizing information, collaboration could be a wise choice were it adequately supported. Twidale and Nichols (1996), however, found a lack of support for collaboration in libraries. They argued that introducing support for collaboration into information retrieval systems would help users to learn and use the systems more effectively. Levy and Marshall (1994) produced a similar argument for information seeking in general. Hansen and Järvelin (2005), based on their extensive study of patent office workers, concluded that the assumption that information retrieval is a solitary activity

needs to be reconsidered. Twidale, Nichols, and Paice (1997) showed that users often want to collaborate on search tasks, and argue that browsing is a collaborative process, unlike the single-user process presented by a majority of search engines. Morris (2007a, 2007b) proposed that four features of exploratory search experience—coverage, confidence, exposure, and productivity—could be enhanced by providing explicit support for collaborative searching and subsequent sense-making processes.

To clarify, *CIS* here means not only searching and retrieving but also browsing, sharing, assessing, and synthesizing information in collaboration. Many definitions and conceptual understandings exist in the literature (Foster, 2006; Hertzum, 2008; Shah, 2010c). For the purpose of this article, we use the definition provided by Shah (2009) that referred to CIS as a process of information seeking “that is defined explicitly among the participants, interactive, and mutually beneficial” (p. 1).

### *Coordination in Collaboration*

We often find people using the term *collaboration* in various contexts and interchangeably with terms such as *coordination* and *cooperation*. Denning and Yaholkovsky (2008) suggested that coordination and cooperation are weaker forms of working together and that all of these activities require sharing some information with each other. Taylor-Powell et al. (1998) added another component to this—contribution—as they realized that to have an effective collaboration, each member of the group should make an individual contribution to the collaborative. Using communication, contribution, coordination, and cooperation as essential steps toward collaboration they showed how a true collaboration requires a tighter form of integration.<sup>1</sup>

Based on these two works, Shah (2009) synthesized a model of collaboration, called the *C5 model* (see Figure 1). This model has the following five sets: (a) communication (information exchange), (b) contribution, (c) coordination, (d) cooperation, and (e) collaboration. Considering notions of sets, the model shows which activity is supporting another. For instance, coordination is a subset of collaboration, which indicates that, for a meaningful collaboration, we need to have some way of coordinating people and events. Collaboration is a superset of cooperation, which means to have a true collaboration, we need something more than cooperation. These five sets are described below in more detail.

- *Communication*. This is a process of sending or exchanging information, which is one of the core requirements for carrying out collaboration or maintaining any kind of productive relationship for that matter.
- *Contribution*. This is an informal relationship by which individuals help each other achieve their personal goals.

<sup>1</sup>Available at [http://www.empowerment.state.ia.us/files/annual\\_reports/2001/Collaboration.pdf](http://www.empowerment.state.ia.us/files/annual_reports/2001/Collaboration.pdf).

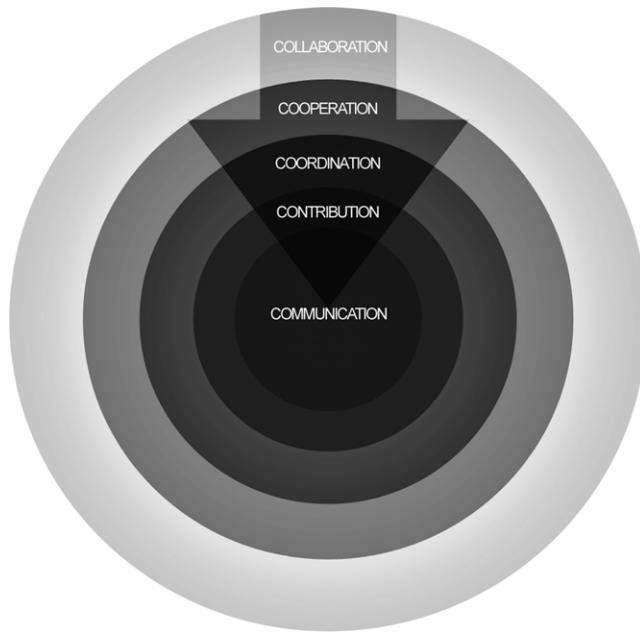


FIG. 1. A set-based model of collaboration.

Note. An inner set is essential to or supports the outer set.

- **Coordination.** This is a process of connecting different agents together for harmonious action. This often involves bringing people or systems under the same set of rules or guidelines at the same time and place. During this process, the involved agents may share resources, responsibilities, and goals.
- **Cooperation.** This is a relationship in which different agents with similar interests take part in planning activities, negotiating roles, and sharing resources to achieve joint goals. In addition to coordination, cooperation involves all the agents following some rules of interaction. What extends several cooperative acts to collaboration is an active session of interaction in which both parties work together to solve a problem. Austin and Baldwin (1991) noted that while there are obvious similarities between cooperation and collaboration, the former involves pre-established interests, whereas the latter involves collectively defined goals.
- **Collaboration.** This is a process involving various agents that may see different aspects of a problem. They engage in a process through which they can go beyond their own individual expertise and vision by constructively exploring their differences and searching for common solutions. In contrast to cooperation, collaboration involves creating a solution that is more than merely the sum of each party's contribution. The authority in such a process is vested in the collaborative rather than in an individual entity.

In summary, there are clear distinctions between concepts such as coordination, cooperation, and collaboration. For a true collaboration to be successful, it needs to have appropriate support for all its underlying activities (communication, contribution, coordination, and cooperation). In this article, our focus is on coordination and how awareness plays a role in providing appropriate coordination support for an effective collaboration.

## Awareness in Collaboration

Awareness is often considered to be one of the three pillars of collaborative systems along with control and communication (Rodden, 1991). In an information-seeking situation, it refers to the information seeker being aware of various aspects of the searching and sense-making processes, including the task and its context, past and present actions, and various attributes of the information objects and the system. This may not be very helpful when a single information seeker is doing quick searching that lasts a short session, but it becomes a salient aspect to consider when an information-seeking process lasts several sessions and/or is conducted in collaboration. For instance, when a lawyer is researching a case, collecting as much information from the available literature as possible, the process may span multiple sessions. It is crucial that the lawyer is aware of his past searches and found information (relevant or nonrelevant) and the overall context of the case. If such a project is done in collaboration with other people, then the issue of awareness becomes even more critical as the involved parties may have to keep track of not only their own processes and objects but also that of others. Often this is done by exchanging messages and sharing resources in ad hoc manner, thus inducing additional cost, often referred to as the collaborative load (Fidel, Pejtersen, Cleal, & Bruce, 2004). In this article, we investigate this cost of coordination that is done specifically for facilitating awareness, with an objective of deriving design guidelines to help us reduce such cost and enhance awareness in CIS.

Awareness is one of the most important issues that is identified and addressed in the Computer-Supported Cooperative Work (CSCW) literature. One of the questions often asked about awareness in CSCW is "awareness of what?" Schmidt (2002, p. 288) argued that we should talk about awareness not as a separate entity, but as somebody's being aware of some particular occurrence. In other words, the term *awareness* is only meaningful if it refers to a person's awareness of something. Heath, Svensson, Hindmarsh, Luff, and Lehn (2002) suggested that awareness is not simply a state of mind or a cognitive ability, but rather a feature of practical action, which is systematically accomplished within developing course of everyday activities.

Several related terms and definitions are used in the CSCW literature to refer to awareness in collaborative projects. For instance, Dourish and Bellotti (1992, p.107) defined awareness as "an understanding of the activities of others, which provides a context for your own activity." Dourish and Bly (1992, p. 541) suggested the following definition for awareness: "Awareness involves knowing who is around, what activities are occurring, who is talking with whom; it provides a view of one another in the daily work environments. Awareness may lead to informal interactions, spontaneous connections, and the development of shared cultures—all important aspects of maintaining working relationships which are denied to groups distributed across

multiple sites.” It should be clear from these definitions that awareness is strongly linked with coordination.

A set of theories and models for understanding and providing awareness emerged in the early works reported in the CSCW literature. Gaver (1991) argued that an intense sharing of awareness characterizes *focused collaboration* in which people work closely together on a shared goal. He further claimed that less awareness is needed for division of labor, and that more casual awareness can lead to serendipitous communication, which can turn into collaboration. Bly, Harrison, and Irwin (1993, p. 29) also identified the importance of such general awareness by saying the following: “When groups are geographically distributed, it is particularly important not to neglect the need for informal interactions, spontaneous conversations, and even general awareness of people and events at other sites.”

Some of the early works reported using ethnographic field studies in CSCW (e.g., Harper, Hughes, & Shapiro, 1989a, 1989b; Heath et al., 2002) identified the need to seamlessly align and integrate the activities of the participants of a collaborative project. Although they did not refer to it as awareness, soon the term *awareness* was adopted to address such practices that support connecting collaborators without the activities of asking, suggesting, requesting, ordering, or reminding.

Similarly, the fields of library and information science (LIS) and computer-mediated communication (CMC) have presented their own approaches to addressing awareness. For instance, several early works argued that providing audio-video communication channel could suffice for awareness (Gaver et al., 1992; Mantei, Baecker, Sellen, Buxton, & Milligan, 1991). However, the use of communication as a substitute for awareness turned out to be very limited in its applicability (Gaver, 1992). Another line of research focused on providing awareness using *computational environments* based on “event propagation mechanisms” while collecting, disseminating, and integrating information concerning collaborative activities. Some of the notable works in this stream of research include awareness models based on a spatial metaphor by Rodden (1996) and Sandor, Cristian, and Bowers (1997).

There are several ways of defining and implementing awareness. Various research projects have used their own taxonomy and interpretation of awareness for creating frameworks and systems. For instance, Gutwin and Greenberg (2002) classified awareness in two types—*situational* and *workspace*—and suggested that situational awareness underlies the idea of workspace awareness in groupware systems. Their definition of workspace awareness included how people interact with the workspace, rather than just awareness of the workspace itself. A detailed discussion on situational awareness can also be found in Endsley (1995), in which such awareness is shown as specifically influenced by attention and working memory. Simone and Bandini (2002) identified two kinds of awareness, *by-product awareness*, which is generated in the course of the activities people must do to accomplish their collaborative tasks, and *add-on*

*awareness*, which is the outcome of an additional activity, and is a cost for the collaborators to what they must do and discretionary in that it depends on collaborators’ evaluation of the contingent situation. Chalmers (2002), likewise, divided the awareness in two kinds: awareness of *people* and of *information artifacts*. He suggested implementing activity-centered awareness tool, in that it focuses on presenting the ongoing appearance and activity of people. For the purpose of the work reported here, a comprehensive and well-accepted taxonomy of awareness, which addresses four kinds of awareness (Liechti & Sumi, 2002) will be used.

- *Group awareness.* This kind of awareness includes providing information to each group member about the status and activities of the other collaborators at any given time.
- *Workspace awareness.* This refers to a common workspace that the group members share and where they can bring and discuss their findings and create a common product.
- *Contextual awareness.* This type of awareness relates to the application domain, rather than the users. Here, we want to identify what content is useful for the group and what the goals are for the current project.
- *Peripheral awareness.* This relates to the kind of information that has resulted from personal and the group’s collective history and should be kept separate from what a participant is currently viewing or doing.

### *Coordination and Awareness in CIS*

Providing awareness is highly important for a CIS system. Because the users of a CIS system will be working with different sources, documents, queries, snippets, and annotations of varying kind, they need to keep everyone in the group aware of all such objects as they are collected and modified. In addition to this, it is important to show various attributes associated with an object. For instance, it is useful to indicate on the interface that a document has already been viewed. Several systems supporting collaboration have identified the issue of awareness (along with control and communication) as critical to their design (Rodden, 1991). For instance, Farooq, Ganoe, Carroll, and Giles (2009) presented a collaborative design for CiteSeer, a search engine and digital library of research literature in the computer and information science disciplines. Based on a survey and follow-up interviews with CiteSeer users, the authors presented the following four novel implications for designing the CiteSeer collaboratory: (a) visualize query-based social networks to identify scholarly communities of interest, (b) provide online collaborative tool support for upstream stages of scientific collaboration, (c) support activity awareness for staying cognizant of online scientific activities, and (d) use notification systems to convey scientific activity awareness.

Gaver (1991) used awareness as a factor to identify different situations for collaboration. He claimed that less awareness is needed for division of labor, and that more casual awareness can lead to serendipitous communication, which can turn into collaboration. Awareness, therefore, is an important dimension to consider.

The amount and the kind of awareness provided in an environment with a group of people depend on several factors, including the cost and benefit of such awareness, available technology, and privacy. On one hand, services such as Netflix and Amazon connect multiple users without making them aware of one another. In Google Docs, one has workspace awareness, whereby one can work with the group's artifact in collaboration, but does not see his collaborators' individual contributions. Cerchiamo (Golovchinsky, Adcock, Pickens, Qvarfordt, & Back, 2008) provides a system-driven collaboration, where the users have limited and filtered access to their collaborators' actions and results. Our system called Coagmento, at the other extreme, provides a very transparent interface, in which a user can be aware of the task at hand, the shared workspace, and the group's history and products. This system is described in the next subsection.

### Coagmento

Different CIS systems have different ways of providing awareness to the collaborators depending on the domain and the kind of application. Take, for example, Ariadne (Twidale, Nichols, Smith, & Trevor, 1995), developed to support the collaborative learning of database browsing skills. To facilitate complex browsing processes in collaboration, Ariadne presents a visualization of the search process. This visualization comprises thumbnails of screens that look like playing cards and represent command-output pairs. Any such card can be expanded to reveal its details. The support for awareness, in this case, is driven by the specific domain (library) and application (catalogue search).

SearchTogether (Morris & Horvitz, 2007), on the other hand, was based on information seeking (application) on the web (domain). It instantiates awareness in several ways, one of which is per user query histories. This is done by showing each group member's screen name and his or her photo and queries in the "Query Awareness" region. The access to the query histories is immediate and interactive, as clicking on a query brings back the results of that query from when it was executed. The authors identified query awareness as a very important feature in collaborative searching, which allows group members to not only share their query terms but also learn better query formulation techniques from one another. Another component of SearchTogether that facilitates awareness is the display of page-specific metadata. This region includes several pieces of information about the displayed page, including group members who viewed the given page, and their comments and ratings. The authors claim that such visitation information can help one either to choose to avoid a page already visited by someone in the group to reduce the duplication of efforts, or perhaps choose to visit such pages, as they provide a sign of promising leads as indicated by the presence of comments and/or ratings.

To study specific kinds of awareness listed in the previous subsection and their impacts on coordination (and in

general, collaboration), we developed Coagmento,<sup>2</sup> a CIS system that allows multiple people to work together in synchronous or asynchronous mode, and colocated or remotely situated, for online information-seeking tasks. Coagmento is implemented as a plug-in for Firefox, allowing one to perform various information-seeking and synthesis as well as communication activities from right within the browser (Shah, 2010b). The design and implementation of Coagmento is inspired by similar systems, such as Ariadne (Twidale & Nichols, 1996) and SearchTogether (Morris & Horvitz, 2007), as well as several design studies and cognitive walkthroughs (Shah, Marchionini, & Kelly, 2009).

A screenshot of Coagmento is given in Figure 2. As can be seen, it includes a toolbar and a sidebar. The toolbar has several buttons that help one collect information and be aware of the progress in a given collaboration. The toolbar has the following three major parts:

- *Buttons for collecting information and making annotations.* These buttons help one save or remove a webpage, make annotations on a webpage (Figure 3), and highlight and collect text snippets (Figure 4).
- *Page-specific statistics.* The middle portion of the toolbar shows various statistics, such as the number of views, annotations, and snippets for the displayed page. A user can click on a given statistic and obtain more information. For instance, clicking on the number of snippets will bring up a window that shows all the snippets collected by the collaborators from the displayed page.
- *Task-specific statistics.* The last portion of the toolbar displays task/project name and various statistics, including number of pages visited and saved, about the current project. Clicking on that portion brings up the workspace where one can view all the collected objects (pages and snippets) brought in by the collaborators for that project.

The sidebar features a chat window, under which there are three tabs with the history of search engine queries, saved pages, and snippets. With each of these objects, the user who created or collected that object is shown. Anyone in the group can access an object by clicking on it. For instance, one can click on a query issued by anyone in the group to re-run that query and bring up the results in the main browser window.

To relate this system design to the kinds of awareness, we note that (a) contextual awareness is provided using the task and page specific information through the toolbar, (b) workspace awareness is implemented using the common workspace where one could view and work with team's collected objects, (c) peripheral awareness is provided using the sidebar, and (d) group awareness (e.g., seeing instantly what is on the collaborator's screen) is omitted from this design.

Linking back to the example of lawyers doing information seeking (see the subsection Awareness in Collaboration), here is how various features of Coagmento could help in promoting awareness in their CIS project. Using the

<sup>2</sup>In Latin, Coagmento means working or joining together.

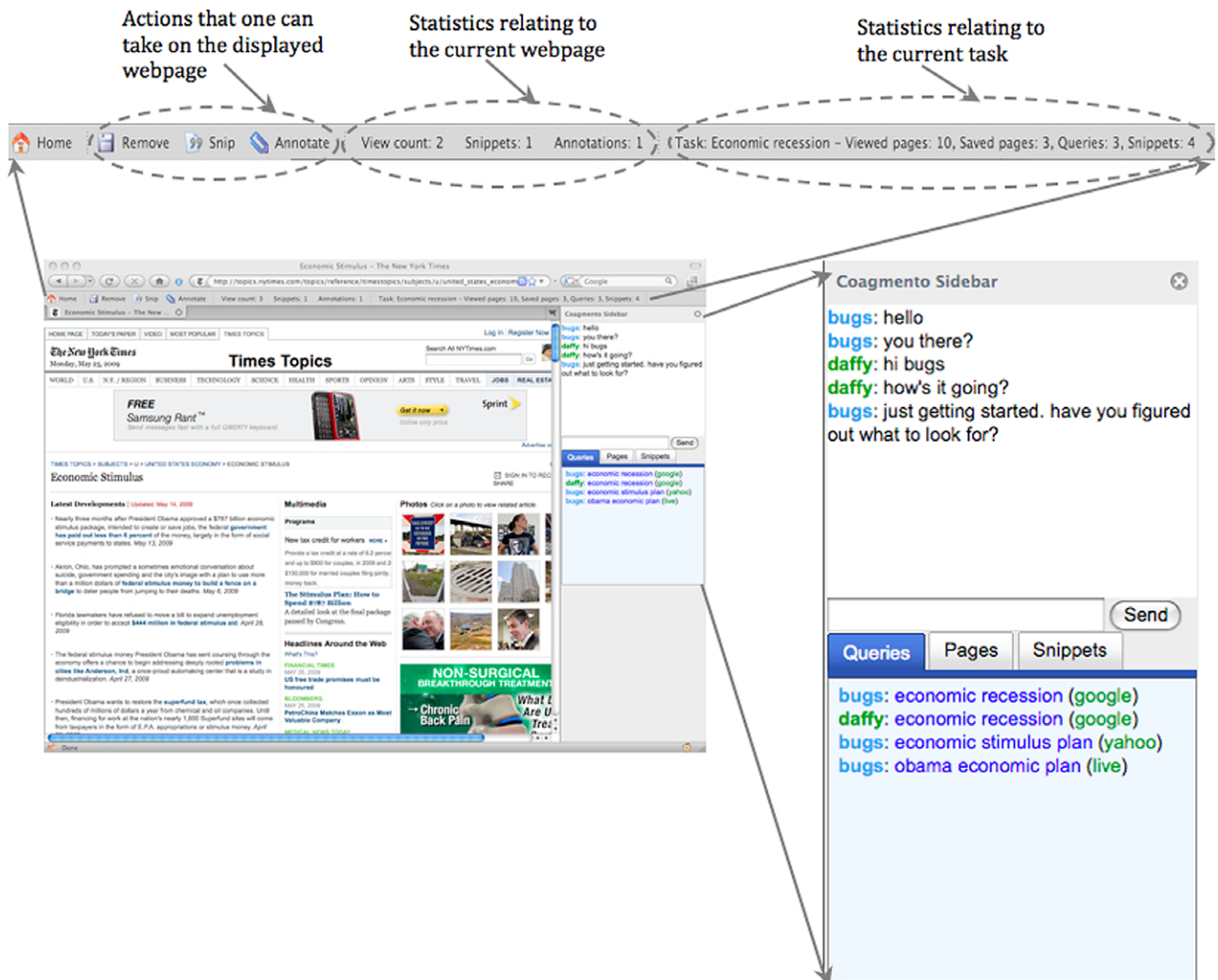


FIG. 2. A screenshot of Coagmento with enhanced views of its toolbar and sidebar. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

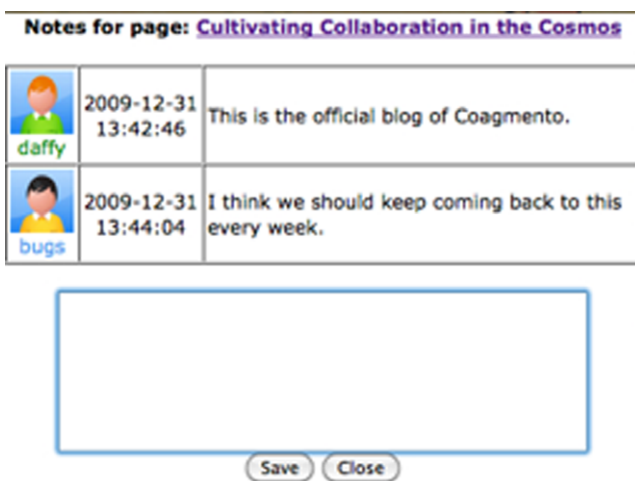


FIG. 3. A screenshot of annotation window. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]



FIG. 4. A screenshot of snippet collection window. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

project/task name on the toolbar the users (lawyers) can be aware of the current project they are working on (contextual awareness). This can be quite helpful when one is working on multiple projects at a given time. Clicking on the project/task name brings up more details about it, thus helping with task-related awareness. To be aware of past processes and objects of everyone in the team, one could go to Coagmento workspace. Here, the user can see all that information that has been collected, along with annotations and relevance judgments (workspace awareness). Finally, one does not need to switch to a different view or go to a specific site just to be aware of who has done what. Users can have this information in a quick glance in Coagmento sidebar (peripheral awareness).

### *Current Work in the Context of the Past Research*

In the past we have presented our work from the same laboratory study reported here focusing on how awareness plays a role in CIS (Shah & Marchionini, 2010). The results of that work can be summarized as follows: (a) personal awareness is required, but not sufficient; (b) group awareness support helps the participants be more efficient, engaged, and aware without raising cognitive load; and (c) one needs to provide adequate and appropriate support for awareness given the task and the situation.

The current article takes several details from that past work, including experimental setup, system (Coagmento) design, and a general framework for evaluation. However, it also differs from our previous work significantly, as shown below with specific points.

- Our previous work has primarily studied awareness support in CIS by evaluating efficiency and effectiveness of users working through an information-seeking task with the help of one of the Coagmento interfaces. The current work, on the other hand, focuses specifically on coordination efforts (dependent variable) in the light of awareness (independent variable).
- The results in Shah and Marchionini (2010) simply counted the number of chat messages exchanged between study participants without looking at what those messages contain. The present article shows qualitative analysis in which different coders went through thousands of messages looking for (a) those that correspond to coordination effort and (b) coding them for specific kinds of coordination.
- The current article also studies the whole session of coordination activities in an attempt to obtain a holistic view of how coordination plays out throughout a collaborative project (see Figures 6–12).
- Finally, in contrast to any of the previous works on studying awareness in CIS, we focus specifically on the connection between coordination and awareness. Our findings suggest that a good system design could actually help us do so by providing the *right kind of awareness*, not just more awareness, but more awareness that is more appropriate. In other words, contrasting with previous work, the current article keeps coordination as the center of investigation and demonstrates how good system design could help us cut costs and boost productivity.

The present work, on the other hand, is concerned with investigating how various forms of awareness affect coordination efforts, and what it means for CIS in general. To do so, we focus our analyses on various actions performed by the participants while coordinating and consolidating past actions, present status, and future plans. Specifically, we study the behaviors exhibited by the participants, as evident in the messages they exchanged with their teammates.

## **Method**

To study the differences in coordination behavior with respect to the kind or amount of awareness provided, we conducted a laboratory study involving 42 pairs, each given two exploratory search tasks and asked to work through two sessions. The details of this study are provided in the following subsections.

### *Participants*

We recruited 84 participants in 42 pairs from the University of North Carolina Chapel Hill. These participants were asked to come to the lab for two different sessions, which were 1 to 2 weeks apart. Because the participants had to sign up in pairs, both the participants in a given pair already knew each other. In addition to this, it was required that the participants in a given pair should have done some collaborative work with each other before, thus making sure that they knew each other and were comfortable working with each other on a collaborative project. The approval of a pair's participation in this study was based on these criteria. We acknowledge that this requirement may affect the outcome of the study, but we wanted to make sure that the recruitment process followed a consistent protocol. A different study can be done in the future where random people are assigned to each other for working in collaboration, which is likely to produce different results than what are reported here.

Participants were compensated \$25 each for their participation in two sessions. Of the 84 participants, 27 were male and 57 were female, and ranged from 17 to 50 years of age, with a median age of 21. Several of the pairs were coworkers or spouses. A majority of the participants were undergraduate or graduate students, whereas a few were university employees.

### *Conditions*

The participants were assigned to one of the three conditions randomly (14 groups per condition). These conditions were defined based on the provision of different levels of awareness-related support to the participants. They are as follows.

- *Baseline* ( $CI_{BASELINE}$ —Figure 5): support of contextual awareness (current task name and topic description) and workspace awareness (where the team can see their collected

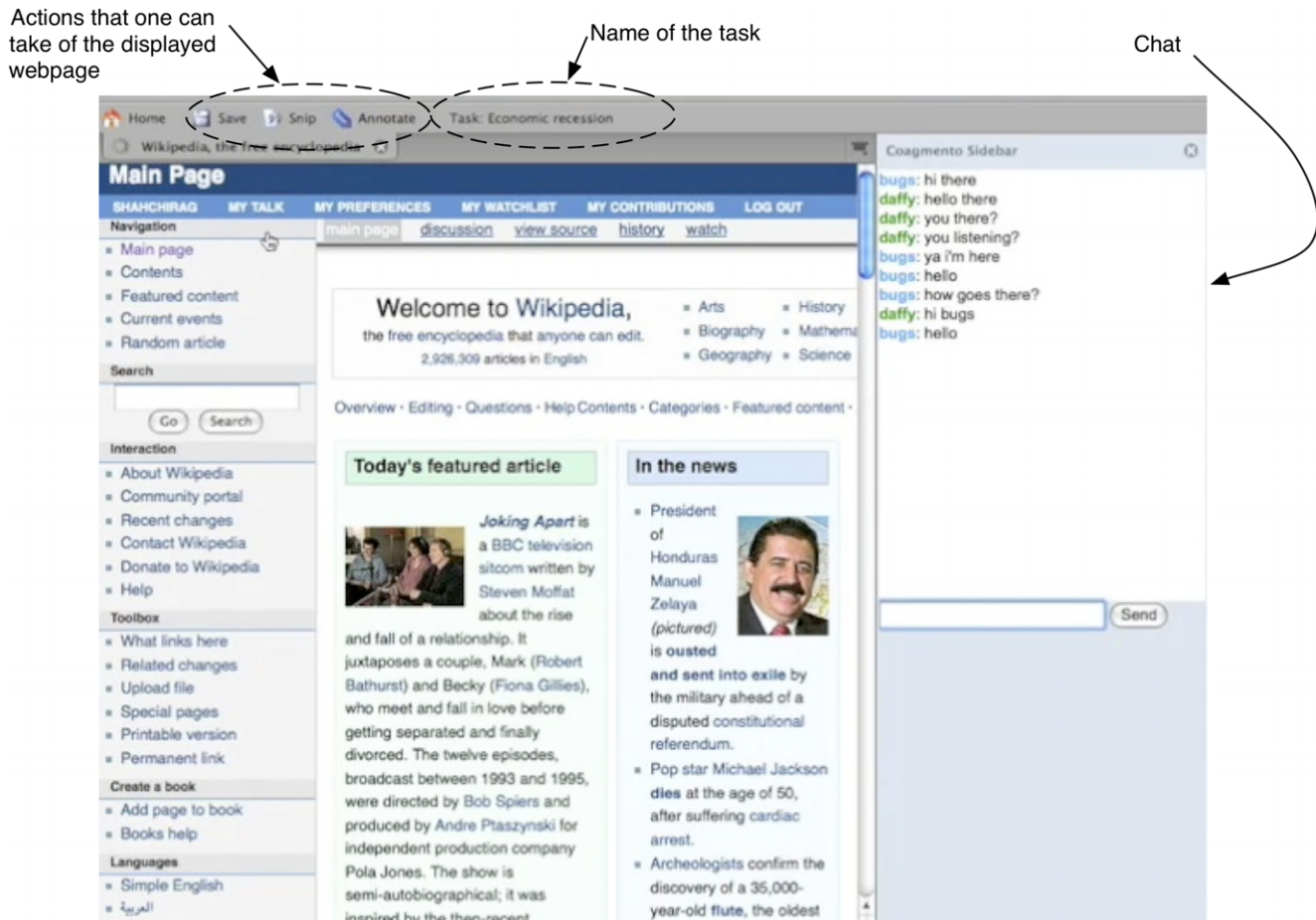


FIG. 5. Interface for C1<sub>BASELINE</sub>, the baseline condition. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

objects—webpages and snippets—collected for the task). We chose this as the baseline because it represents a typical scenario of two people remotely working without any specific support. In this condition, a user will have a minimal addition to his/her web browser (a small toolbar to aid with running the study session, and a sidebar with a chat window).

- *Personal peripheral awareness* (C2<sub>PERSONAL</sub>—Figure 6): support of personal history (documents and snippets saved, queries used, etc.) in addition to the support provided in the baseline.
- *Group peripheral awareness* (C3<sub>GROUP</sub>—Figure 7): support of group history (documents and snippets saved, queries used, etc.) in addition to the support provided in the baseline.

Thus, the main independent variable here was the kind of peripheral awareness provided (1 = *none*, 2 = *personal*, 3 = *group*). All the conditions provided support for communication, contextual awareness (current task and goals), and workspace awareness (a shared space where one could see and organize group's collective information). No condition had the traditional kind of group awareness (where a participant can see exactly what another collaborator is doing at a given time). This was due to two main reasons. First, because the participants were required to work on the same

task at the same time, they knew the other person was not only online, but also working on the same task. This realization eliminated the need to know the immediate status of one's collaborator. Second, introducing this additional condition would weaken the statistical power of the study. Therefore, it was decided to omit the traditional group awareness feature from this study interface. However, participants in each of the three conditions had the same support for communication, which could be used to check each other's specific status.

Note that peripheral awareness does not indicate the nature of the information, but how it is presented. For the purpose of this study, it is divided into personal and group peripheral awareness, corresponding to the information relating to personal and group history, respectively. Both C2<sub>PERSONAL</sub> and C3<sub>GROUP</sub> had the same components and presentations for instantiating peripheral awareness, but the information displayed there was different.

We acknowledge that although there are several ways in which awareness is defined and classified, we selected one that was most appropriate for our work. From the four kinds of awareness we identified previously, we decided to focus on peripheral awareness for two reasons: (a) other three

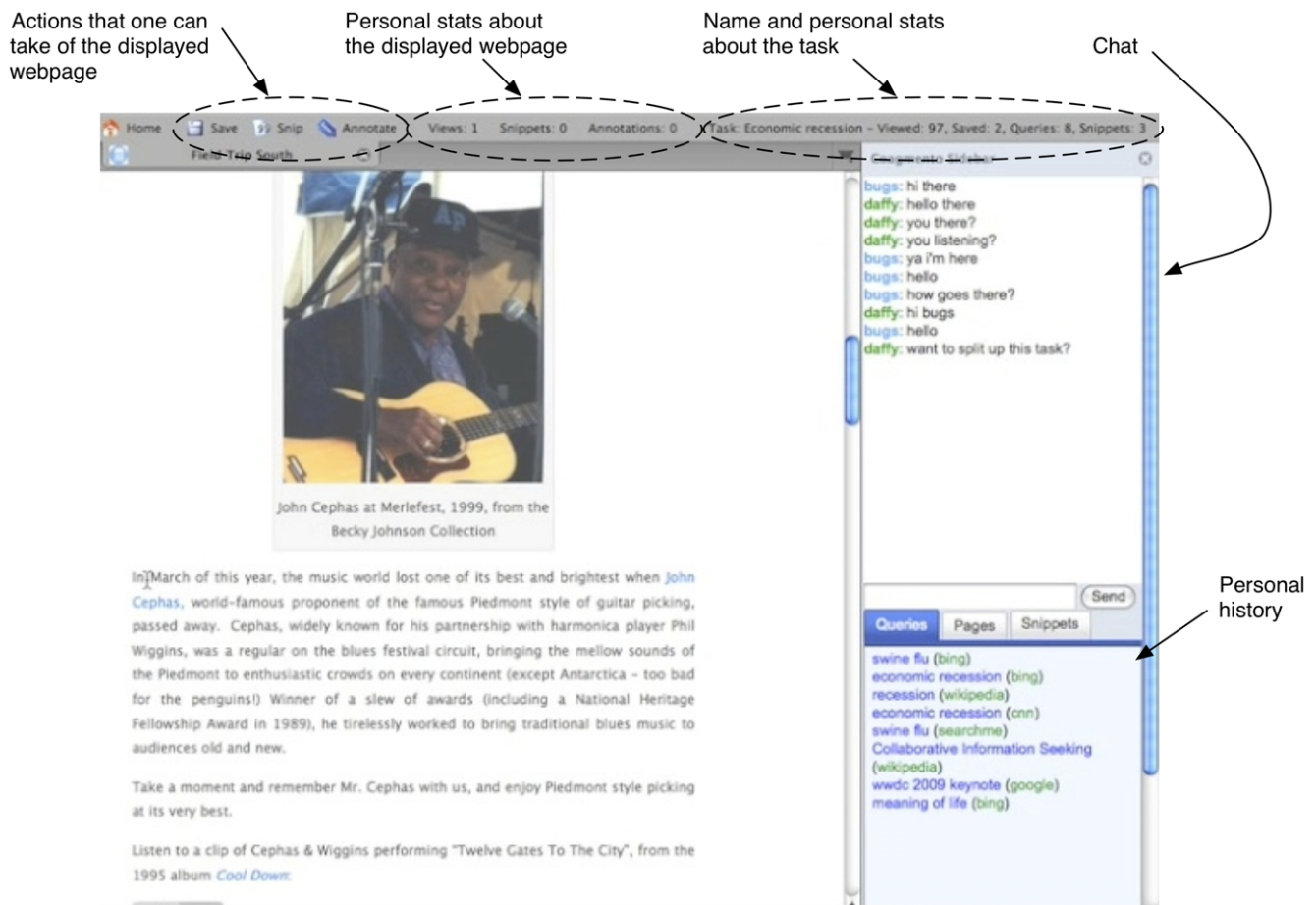


FIG. 6. Interface for C2<sub>PERSONAL</sub>, the personal peripheral awareness condition. [Color figure can be viewed in the online issue, which is available at [wileyonlinelibrary.com](http://wileyonlinelibrary.com).]

kinds of awareness were not very meaningful to vary due to study setup (synchronous and remote collaboration), and (b) varying more than one kind of awareness will pose serious threat to study design and analysis power. Commenting specifically on C2<sub>PERSONAL</sub>, we wanted to simulate a situation in which one has personal history available without any group-related support. The design of this condition would allow us to comment on the situation in which we simply have more information/awareness on a CIS interface.

### Sessions

Each individual pair of participants came to the lab for two sessions that were 1 to 2 weeks apart. Each session lasted about 1 1/2 hours. The flow for each session is depicted in Figure 8. The participants were made aware of this flow, especially emphasizing how they would be working with each other sitting in different rooms and working on two different tasks over two sessions.

During the first session, the participants were shown a video tutorial demonstrating the use of Coagmento and the process of collecting relevant information (snippets of text). After the tutorial, the participants were placed in different rooms so that they could not talk to each other directly or see

what the other person was doing. Both participants used typical mid-end PC workstations, running Windows XP, with Ethernet connectivity and 19" monitors. The supervisor (a researcher) took his place outside, stationed so that he could see both the participants. Once the participants logged in, they filled out a demographic questionnaire and began working on the first task.

As discussed in the model of collaboration previously, coordination is an integral part of collaboration, and thus the cost of coordination should be studied for the entire length of a collaborative activity. We will do so by analyzing chat messages exchanged between the participants of each team. In addition, we also decided to explicitly ask the participants to coordinate and use the time taken and the accuracy of their reporting as ways to measure the cost of coordinating at that specific moment. To do so, about 20 minutes into their work the researcher sent out a message via the sidebar chat asking them to stop the task and fill in a set of online questionnaires, which asked about their progress on the task, as if their supervisor had requested an update. This questionnaire included specific questions about the number of webpages they had viewed and bookmarked, the number of search queries they had used, and the number of snippets they had collected, as shown next.

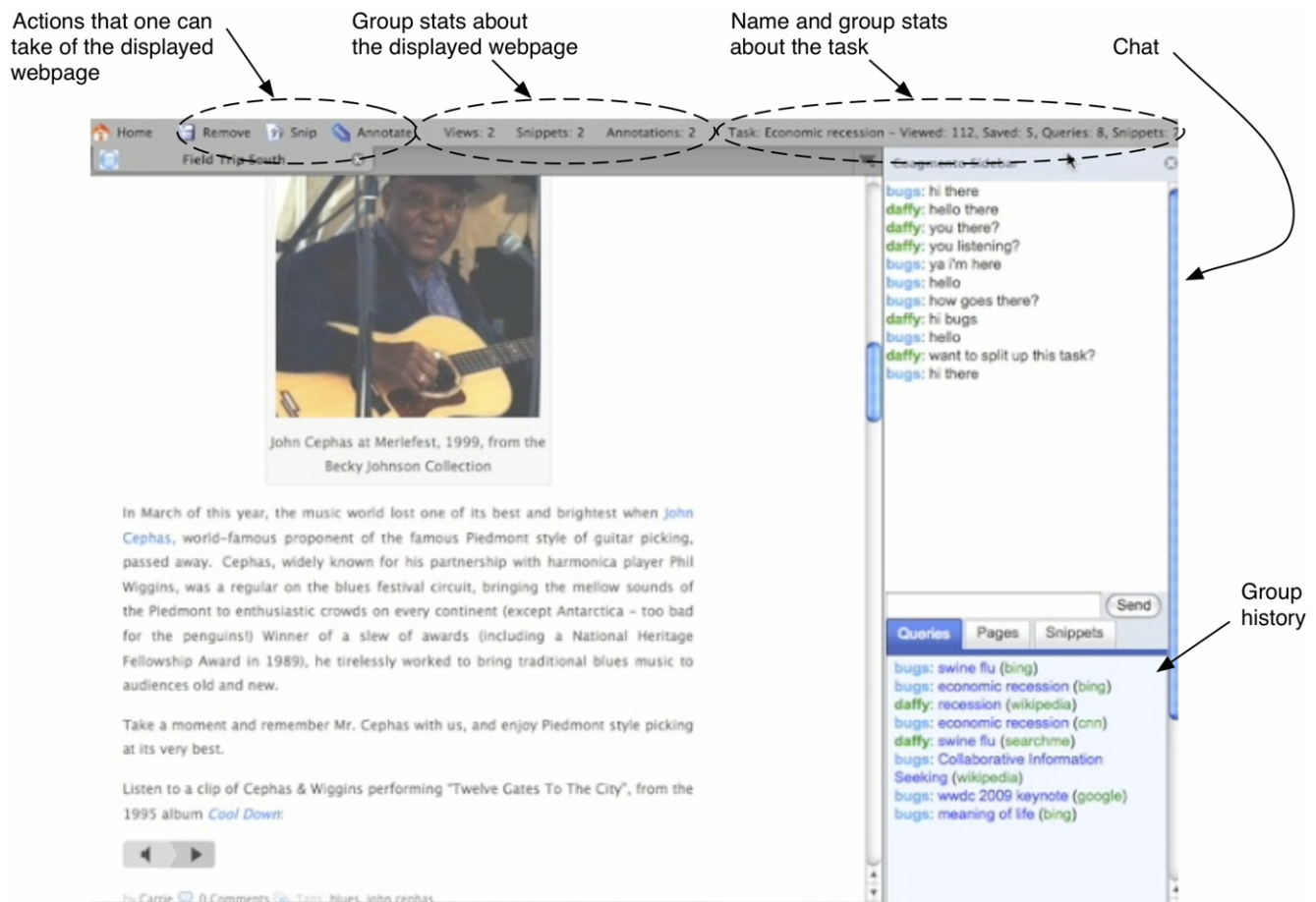


FIG. 7. Interface for C3<sub>GROUP</sub>, the group peripheral awareness condition. [Color figure can be viewed in the online issue, which is available at [wileyonlinelibrary.com](http://wileyonlinelibrary.com).]

- Q1. How many webpages do you think you viewed?
- Q2. How many webpages do you think your team viewed?
- Q3. How many webpages do you think you saved?
- Q4. How many webpages do you think your team saved?
- Q5. How many snippets do you think you saved?
- Q6. How many snippets do you think your team saved?
- Q7. How many queries do you think you used?
- Q8. How many queries do you think your team used?

Once the participants finished their individual questionnaires, they were asked to start working on the second task. The participants were once again interrupted about 20 minutes later and asked to complete the same questionnaires for that task. For the second session, the participants were given a refresher of the system and were shown how to compile their final report by visiting the workspace and grouping their collected snippets into different categories for a given task. The categories were presented in the task statement and corresponded to different aspects of the work task (see task statements below).

After 15 minutes of additional work on task 1, they completed the posttask questionnaire with questions on cognitive and physical efforts (for details, see Shah & Marchionini, 2010). They were asked to organize their

collected snippets by placing each relevant snippet in one of the categories for a given task. When they had finished organizing their snippets, they worked through the second task, including collecting their information, posttask questionnaire, and organizing the snippets.

### Tasks

The participants were asked to collect relevant information for two exploratory tasks that were designed to be realistic work tasks that might be of interest to the participant pool (Borlund & Ingwersen, 1999). Rather than asking participants to create their own organizations for the pertinent snippets, the task statements identified specific issues that should be addressed, and these issues were used as organizing bins for the collected snippets. The task descriptions as given to the participants are provided below.

*Task 1: Economic recession.* A leading newspaper has hired your team to create a comprehensive report on the causes and consequences of the current economic recession in the United States. As a part of your contract, you are

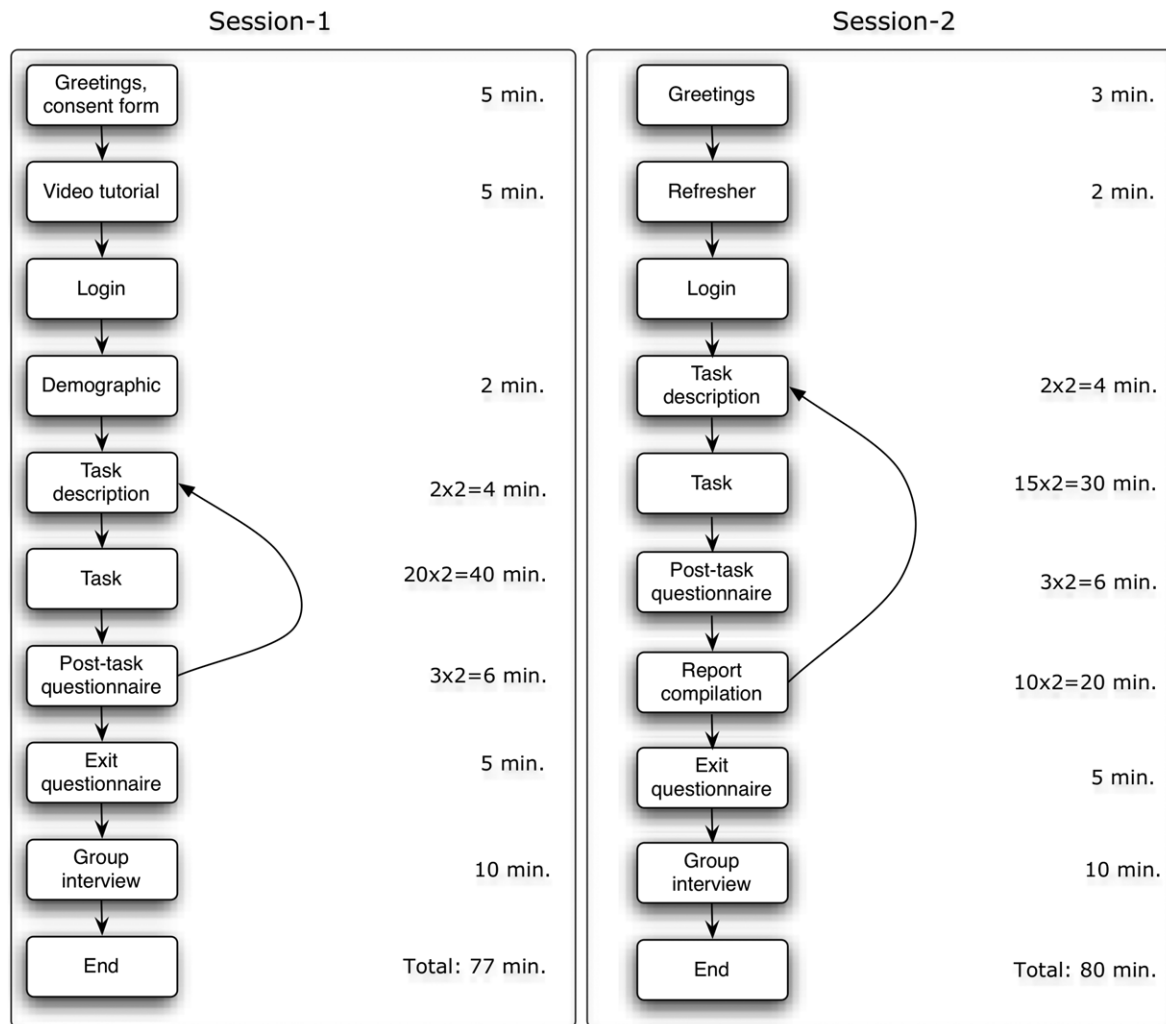


FIG. 8. Flow of the sessions.

required to collect all the relevant information from any available online sources that you can find.

To prepare this report, search and visit any website that you want and look for specific aspects as given in the guideline below. As you find useful information, highlight and save relevant snippets. Later, you can use these snippets to compile your report. You may also want to save the relevant websites as bookmarks, but remember your main objective here is to collect as many relevant snippets as possible.

Your report on this topic should address the following issues: reasons behind this recession; effects on some major areas, such as health-care, home ownership, and financial sector (stock market); unemployment statistics over a period of time; proposal, execution, and effects of the economy stimulation plan; and people's opinions and reactions on economy's downfall.

**Task 2: Social networking.** The College Network News Channel wants to do a documentary on the effects of social networking services and software. Your team is responsible

for collecting various relevant information (including statistics) from the web. As a part of your assignment, you are required to collect all the relevant information from any available online sources that you can find.

To prepare this report, search and visit any website that you want and look for specific aspects as given in the guideline below. As you find useful information, highlight and save relevant snippets. Later, you can use these snippets to compile your report. You may also want to save the relevant websites as bookmarks, but remember your main objective here is to collect as many relevant snippets as possible.

Your report on this topic should address the following issues: emergence and spread of social networking sites, such as MySpace, Facebook, Twitter, and del.icio.us; statistics about popularity of such sites (How many users? How much time they spend? How much content?); impacts on students and professionals; commerce around these sites (How do they make money? How do users use them to make money?); and examples of usage of such services in various domains, such as health-care and politics.

The participants were instructed to collect as much relevant information as they could in the given time, knowing that it would not be enough to get *everything*. They also knew that they would have a chance to continue working on each of their tasks in the second session.

## Analysis

We used different instruments and methods for analyzing coordination behavior during the study. As noted in the study design, at the end of each task the participants were asked to report the status of their current task. This required them to coordinate with each other, making sure their individual reporting was consistent. In addition, we also coded all the chat messages exchanged to identify not only the messages used for coordination but also the kind of coordination. Both of these analyses were done across the three conditions as reported below.

### Coding Chat Messages

Several works in CSCW literature have reported studying IM or chat messages in groups. Because of the high variability in study conditions and context, each of these works uses its own scheme for coding and analyzing chat messages (e.g., Handel & Herbsleb, 2002; O'Neill & Martin, 2003). We decided to find chat messages that were used for coordination purpose. Such messages may involve a question asking for one's status, an answer to that question, a confirmation, or a reaction. We further divided such messages to those relating to coordinating based on past actions (past), current status (present), and future actions or strategies (future).

Past code represents a message relating to what has been done so far. Such a message may be a question or an answer. A sample conversation segment, with messages for doing coordination based on past actions (past), is given below. Note that these examples are verbatim and that errors in grammar and spelling have not been corrected.

User-27: how many webpages did you view?  
User-26: 15  
User-26: how about you?  
User-27: like 10

Current represents a message relating to updating each other about what is going on or simply connecting with each other. A sample conversation segment, with messages for doing coordination based on current status (present), is given below.

User-26: how's it going?  
User-27: It's been somewhat slow but its picking up a bit

Future includes messages that are about what one wants to do next. A sample conversation segment, with messages for doing coordination based on future actions or strategies (future), is given next.

TABLE 1. Summary of coded messages for teams in different conditions.

|                              | None  | Past  | Present | Future | Total |
|------------------------------|-------|-------|---------|--------|-------|
| <b>C1<sub>BASELINE</sub></b> | 817   | 1,020 | 461     | 512    | 2,810 |
| <b>C2<sub>PERSONAL</sub></b> | 751   | 638   | 429     | 277    | 2,095 |
| <b>C2<sub>GROUP</sub></b>    | 453   | 165   | 355     | 252    | 1,225 |
| <b>Overall</b>               | 2,021 | 1,823 | 1,245   | 1,041  | 6,130 |

Note. Each condition had 14 teams.

User-27: do you want to divide the questions up?  
User-26: sure  
User-26: would you rather do causes or effects?  
User-27: Effects  
User-26: sounds good

We provided detailed guidelines to three independent coders (including the author) about how to label each message with these three labels, or identify it as a noncoordination message with label "None." The coders were trained through examples and discussions of more than 192 messages exchanged between the participants of one of the teams. Then the coders independently coded 52 messages of another team. Their codings were compared and found reliable with Cohen's kappa = 0.762 (averaged over pairwise values). We then divided up all the messages and let the coders code their individual parts, each with about 2,000 messages. A summary of the coded messages is provided in Table 1.

As we can see, more than two thirds of the messages were related to coordinating. We also found statistical differences among the different kinds of coordination messages ( $\chi^2 = 253.15$ ,  $p < 0.05$ ), with a large portion of the messages used for updating each other about the past actions and results. In addition, we found differences in the kind of coordination messages exchanged between conditions 1 and 2 ( $\chi^2 = 34.23$ ,  $p < 0.05$ ), conditions 2 and 3 ( $\chi^2 = 223.56$ ,  $p < 0.05$ ), and conditions 1 and 3 ( $\chi^2 = 142.57$ ,  $p < 0.05$ ). This indicates that there was a difference not only in the kind of coordination the participants were trying to achieve overall but also in the kind of awareness support they were given. These finding are explored further in the following subsections.

### Overall Coordination

To study coordination efforts within a team, we analyzed the coded messages per session. Because each of the two sessions lasted for about 60 minutes (discounting the preparation and the ending phases), we divided up each team's session into 60 segments, each roughly reflecting 1 minute, and looked at the three kinds of coordination messages in each of those segments. The combined plots for all the 42 teams for their two sessions are presented in Figures 9 and 10. Let us qualitatively analyze these plots by studying the most prominent parts, viz., the peaks. Note that these peaks

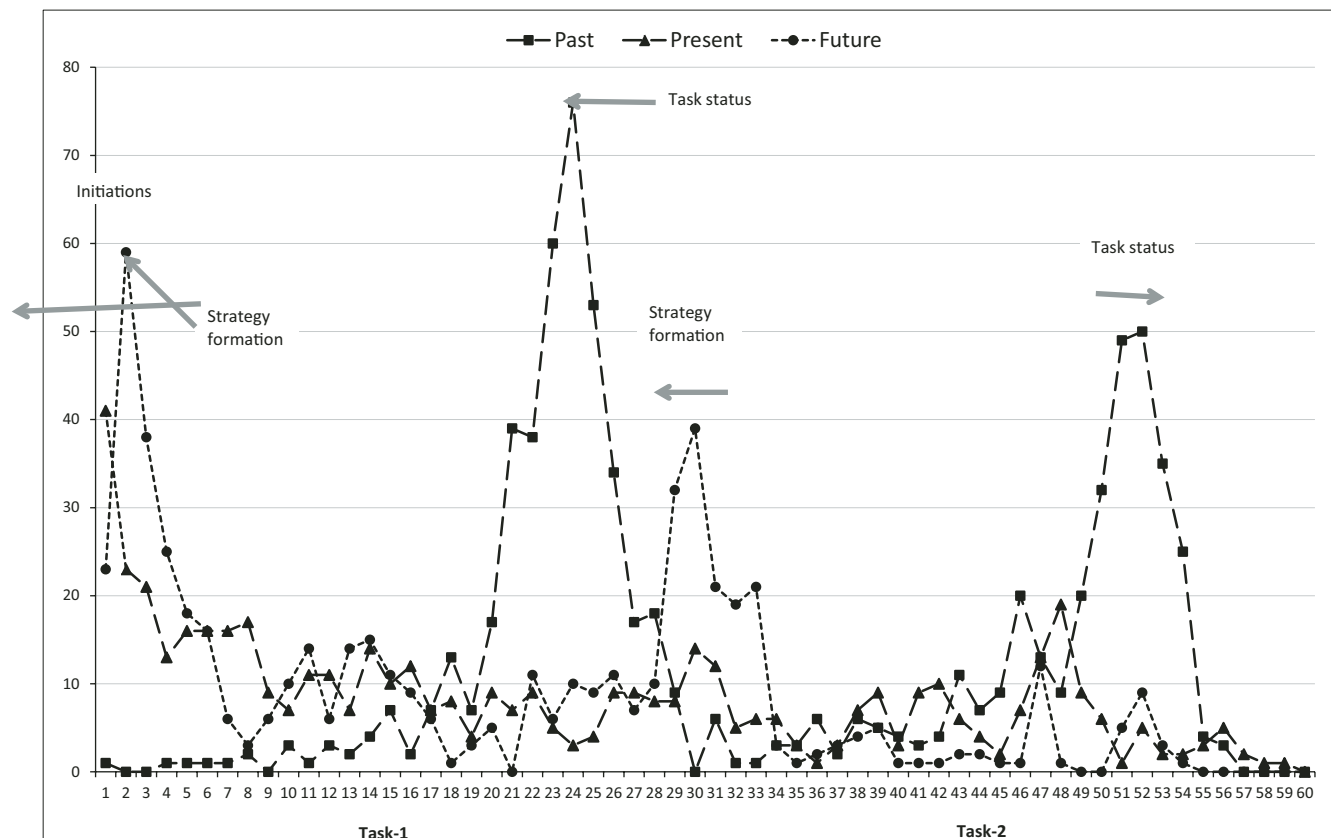


FIG. 9. Plot of coordinating messages for all the teams for session 1.

were more or less consistent within a condition, and not caused by just a handful of teams (see Tables 2 and 3 for variance and other statistics).

In the beginning of the first session, the participant exchanged messages to make sure their partners were available and ready to begin. This is labeled in Figure 9 as “Initiation” (messages coded with present). Immediately after this, we can see a peak for future. This is when the participants coordinated their strategies to tackle the task at hand. Once they devised a strategy (often, divide-and-conquer), their communication for further coordination dropped notably. Then we see a tall peak of past, which is when the teams were asked to provide the status of their task (around segment 20, roughly minute 20), driving them to update each other on how much they had accomplished individually and as a team. A new task is given right after that and we can see similar patterns for the second task as well. Note that there was no restriction placed on the amount of time the participants could take while responding to the questionnaires. We observed that those in C1<sub>BASELINE</sub> took longer than the other two conditions while responding to the status questions (for details, see Shah & Marchionini, 2010). However, because the results depicted here are proportionate segments instead of absolute times, these figures still provide a reasonable comparison among the three conditions.

Session 2 exhibits more complex coordination strategies (Figure 10). Here, we see there are four peaks for task status; the first and the third appear around the pretask questionnaires (in which they were asked to recall and report the status of their task before starting it), and the second and the fourth take place around the posttask questionnaires. We also see the heights of these peaks decreasing with time. This can be attributed to the participants’ increased familiarity with the system and questionnaires. This also explains a huge spike around segment 3 (roughly minute 3) for session 2 (Figure 10), as it was the first time in session 2 that the participants were asked about recalling the details of their task. Similar trend can also be seen in session 1 (Figure 9), in which the participants exchanged less numbers of messages while reporting status for task 2 compared with task 1.

For session 2, we can further note the small peaks, labeled “reality check” and “strategy formation,” which appear right after the pretask questionnaires for both tasks. This is the time when the participants, having reported what they had already done for the given task in their first session, reflected on what they had at that time and where they needed to go next. During this phase, the participants often verified and/or revised their original strategy as well as their individual assignments.

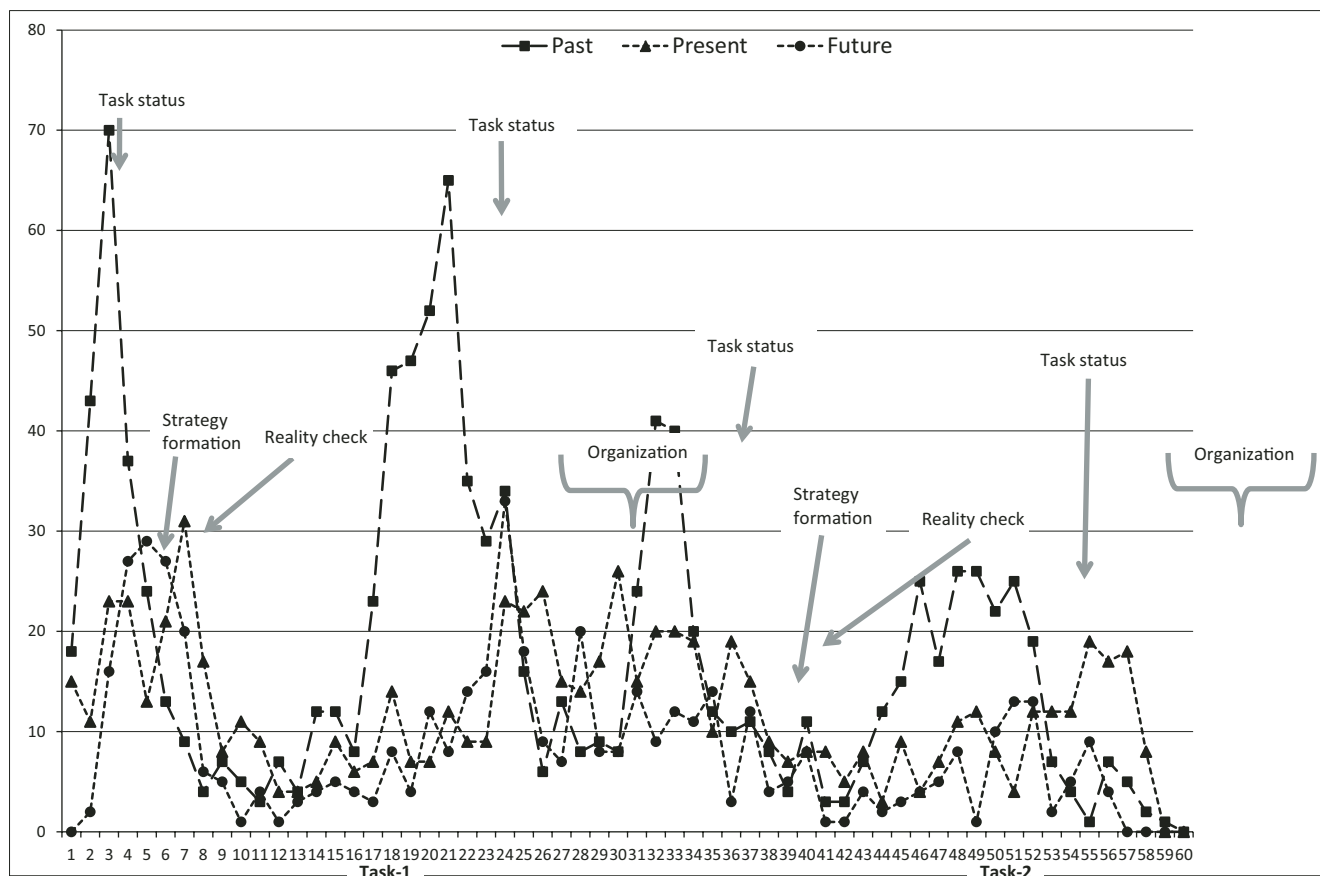


FIG. 10. Plot of coordinating messages for all the teams for session 2.

TABLE 2. Average number of coordination messages exchanged within a team relating to past, present, or future activities.

|                                                   | C1 <sub>BASELINE</sub> |       | C2 <sub>PERSONAL</sub> |       | C2 <sub>GROUP</sub> |       |
|---------------------------------------------------|------------------------|-------|------------------------|-------|---------------------|-------|
|                                                   | Mean                   | SD    | Mean                   | SD    | Mean                | SD    |
| Past <sup>a</sup><br>( $F = 9.863, p < 0.001$ )   | 72.86                  | 52.97 | 45.57                  | 28.77 | 11.79               | 18.76 |
| Present<br>( $F = 0.348, p < 0.708$ )             | 32.93                  | 11.68 | 30.64                  | 26.16 | 25.36               | 31.58 |
| Future <sup>a</sup><br>( $F = 4.544, p < 0.018$ ) | 36.57                  | 21.78 | 19.79                  | 14.58 | 18.00               | 16.82 |

Note. SD = standard deviation. For one-way analysis of variance, between groups degree of freedom ( $df$ ) = 2 and within groups  $df$  = 39.  
<sup>a</sup>Difference across conditions was statistically significant ( $p < 0.05$ ).

After each posttask questionnaire in session 2, the participants were asked to organize their collected snippets using the integrated workspace. We can see that during this phase, labeled as “organization,” there are small peaks for present and future messages. These messages were primarily discussing and verifying the information the participants had, as well as devising a strategy to organize it.

TABLE 3. Average number of coordination messages exchanged within a team relating to past, present, or future activities while reporting task status.

|                                                 | C1 <sub>BASELINE</sub> |       | C2 <sub>PERSONAL</sub> |       | C2 <sub>GROUP</sub> |       |
|-------------------------------------------------|------------------------|-------|------------------------|-------|---------------------|-------|
|                                                 | Mean                   | SD    | Mean                   | SD    | Mean                | SD    |
| Past <sup>a</sup><br>( $F = 9.866, p < 0.001$ ) | 58.07                  | 42.44 | 38.86                  | 27.27 | 7.50                | 15.15 |
| Present<br>( $F = 0.453, p < 0.639$ )           | 7.29                   | 10.39 | 6.07                   | 7.58  | 3.93                | 10.11 |
| Future<br>( $F = 1.271, p < 0.629$ )            | 5.64                   | 6.63  | 4.86                   | 7.60  | 2.00                | 4.39  |

Note. SD = standard deviation. For one-way analysis of variance, between groups degree of freedom ( $df$ ) = 2 and within groups  $df$  = 39.  
<sup>a</sup>Difference across conditions was statistically significant ( $p < 0.05$ ).

Several interesting observations can be made when we analyze each of the three conditions separately. Figures 11 to 13 depict plots of coordinating messages for session 1 for the teams in different study conditions. We can observe the same kind of peaks as in Figure 9, viz., initiation in the beginning of the session, strategy formation in the beginning of each task, and task status at the end of each task. However, the peaks clearly become less pronounced from

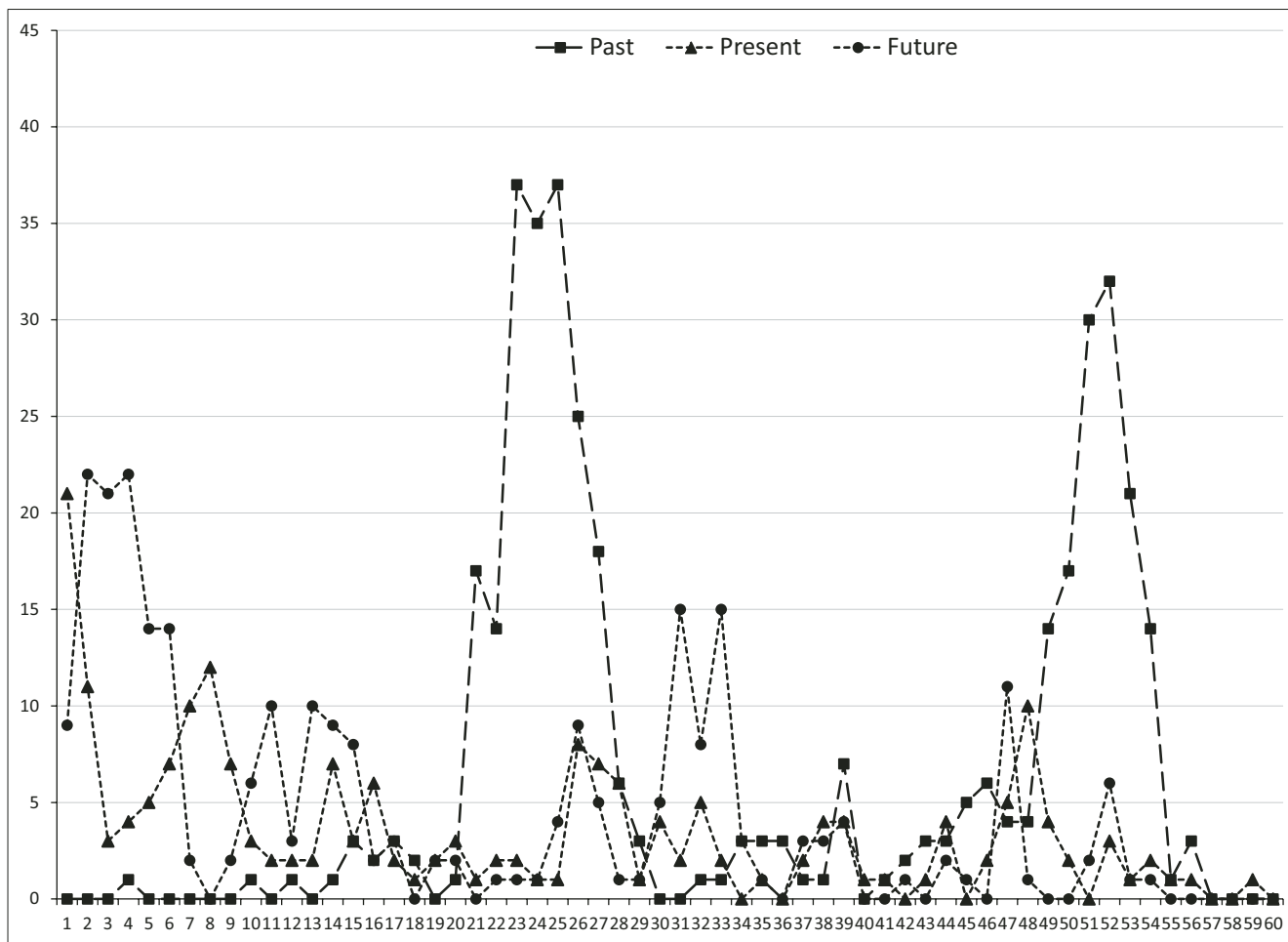


FIG. 11. Coordinating messages for teams in C1<sub>BASELINE</sub> for session 1.

C1<sub>BASELINE</sub> to C3<sub>GROUP</sub>. In fact, for C3<sub>GROUP</sub>, the highest peak is relating to future strategy, and not task status as seen for the other two conditions.

Looking at the coordinating messages for session 2, we observe similar patterns (Figures 14 to 16). Once again, we see that as we go from C1<sub>BASELINE</sub> to C3<sub>GROUP</sub>, there is a lesser need for the participants to exchange coordinating messages, especially those relating to the past actions and results.

Quantitatively, comparison among the three conditions for the coordinating messages exchanged is given in Table 2. Using one-way analysis of variance (ANOVA), we found differences for the past and the future coordinating messages. Doing Scheffé's post hoc tests revealed that those in C1<sub>BASELINE</sub> exchanged more messages than those in C3<sub>GROUP</sub> for past ( $p < 0.001$ ) and future ( $p < 0.033$ ).

#### Coordination While Reporting Task Status

Let us now narrow our analysis down to the part when we asked the participants to report their task status, thus explicitly encouraging them to coordinate. Table 3 gives a

summary of different coordinating messages exchanged by the teams in each condition during the time they were reporting the task status. As we can see, a majority of these messages are labeled past. This has already been indicated in Figures 9 and 10. Using one-way ANOVA, we found statistical differences for these past messages among the three conditions. With Scheffé's post hoc test, we learned that the teams in C3<sub>GROUP</sub> exchanged fewer messages than those in C1<sub>BASELINE</sub> ( $p < 0.001$ ), and C2<sub>PERSONAL</sub> ( $p < 0.034$ ). This indicates that C3<sub>GROUP</sub> participants had less need to know their team's status based on the past actions.

An interesting question to ask here is whether the reporting of individual participants in a team matched with each other. As described in the Method section, the participants were asked to report the number of webpages viewed and saved, queries used, and snippets collected. Each participant in that team reported these numbers for the team's status individually. It should be noted that the participants were allowed to communicate with each other during this reporting. After analyzing the responses on this questionnaire, we found that we could create a single value index with high statistical reliability of  $\alpha = 0.759$ . Table 4 reports one-way

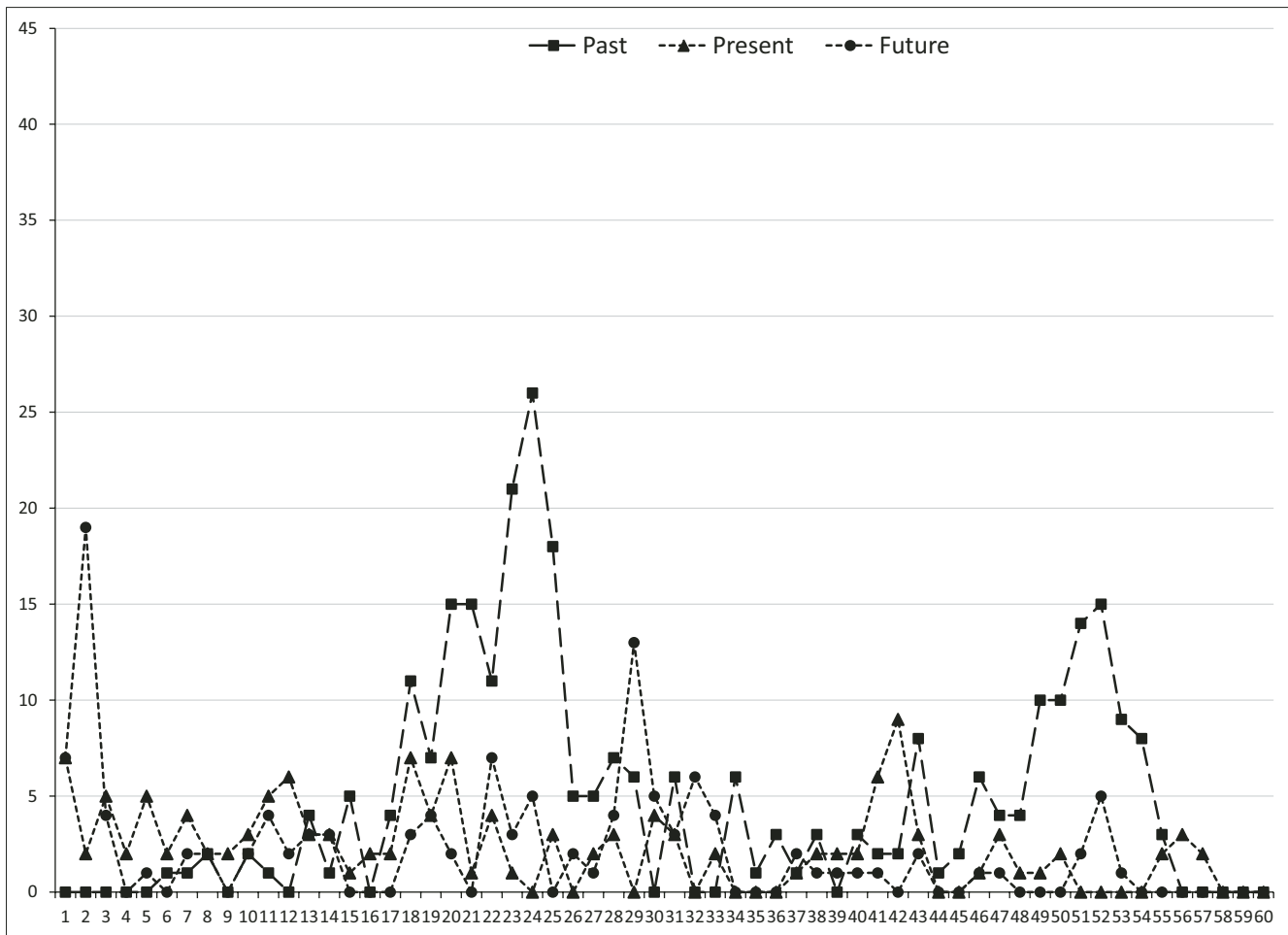


FIG. 12. Coordinating messages for teams in C2\_PERSONAL for session 1.

ANOVA on this index between the three conditions, which turns out to be statistically significant. Sheffe's post hoc test revealed that those in C3\_GROUP had less difference in their status reporting than those in C1\_BASELINE ( $p < 0.024$ ), and C2\_PERSONAL ( $p < 0.001$ ). In other words, teams in C3\_GROUP were better coordinated than the rest of the teams.

We also looked at the time taken by each team to report their task status. This is given in Table 5. Here also, we find statistically reliable differences, with those in C3\_GROUP taking less time compared with the teams in C1\_BASELINE ( $p < 0.001$ ) and C2\_PERSONAL ( $p < 0.001$ ). This clearly demonstrates that with appropriate awareness support, collaborators do not have to spend much effort or time to coordinate with each other.

The motivation behind asking the participants to report various statistics about the state of their project was to force them to coordinate with their teammates and measure the time taken, as well as the accuracy, while reporting their status as a way to calculate coordination cost for that moment. It is clear from Tables 4 and 5 that coordination cost was the least for those in C3\_GROUP, as they spent the least

amount of time reporting their status and achieved the highest accuracy and consistency in their reporting.

## Discussion

The previous section described *what* happened in our experiments. In this section, we explore *why* it happened, using our interpretations of the results without making any claims.

We begin by noting that there were very few differences among the interfaces used for the three conditions used for our study (see Figures 5, 6, and 7). Yet, as reported in the previous section, we found statistically significant differences among the coordination behaviors of these conditions. Specifically, there was a noticeable change in past messages between C1\_BASELINE and C2\_PERSONAL. Although C2\_PERSONAL had information about personal actions only, it is a big part of doing collaboration (and thus coordination) here. Note that because of the nature of the task (recall-oriented, dividable), the participants often worked independently, making personal actions highly important part of collaboration.

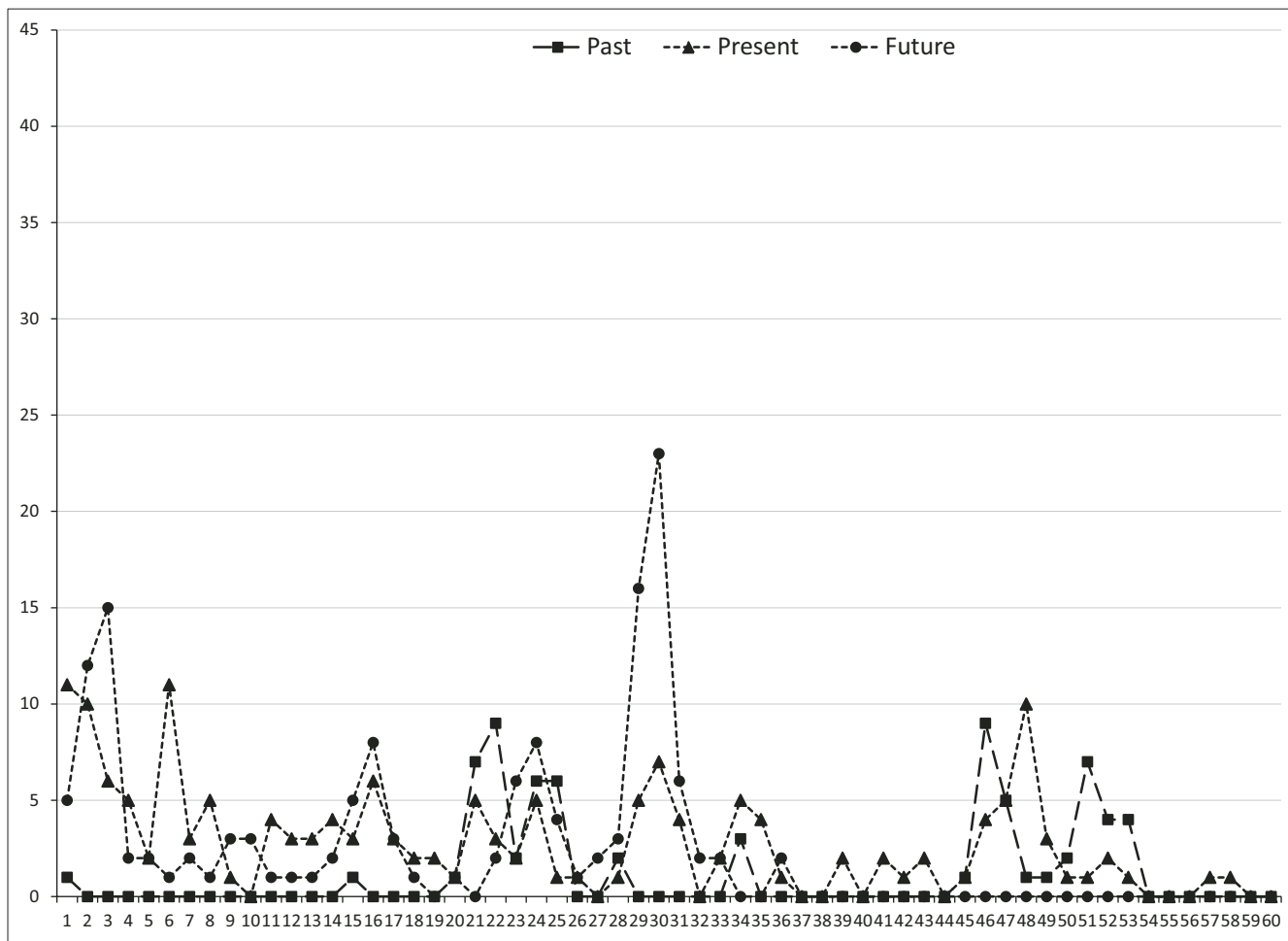


FIG. 13. Coordinating messages for teams in C3GROUP for session 1.

Thus, while reporting the status of their collaborative project, those in C2<sub>PERSONAL</sub> had an edge over C1<sub>BASLINE</sub> as far as reflecting on and reporting personal progress and contributions go.

Similarly, those in C3<sub>GROUP</sub> had an advantage over C2<sub>PERSONAL</sub> (as well as C1<sub>BASLINE</sub>) because they had information about personal as well as group actions. Collaboration, as defined earlier, involves individual contributions as well as group processes. In an effective collaboration, the authority is vested in the collaborative rather than the individual participants. C3<sub>GROUP</sub> interface facilitated this by keeping the participants aware of not only their individual activities but also those of the group processes. This helped them reduce efforts in reporting past contributions, present status, and future directions.

The differences in coordination behaviors are noticeable between the two sessions across the conditions. This can primarily be attributed to learning effects in the participants. Specifically, when the participants came to the second session, they were familiar with not only the tasks and the interface but also the questionnaires. Because of this, they could respond to questions using fewer and more concise messages.

In the next section we take this discussion further to comment on what these findings mean, tying them back to the notions of awareness, coordination, collaboration, and CIS.

## Conclusion

Coordination is considered to be a highly valuable and essential part of any successful collaboration. Often, however, coordination may pose the issue of unwanted cost. In this article, we presented a laboratory study that looked at the effects of providing different kinds of awareness on coordination while working on time-bound CIS tasks. We created the following three conditions: (a) no provision of progress awareness—C1<sub>BASLINE</sub>; (b) provision of personal progress awareness—C2<sub>PERSONAL</sub>; and (c) provision of group progress awareness—C3<sub>GROUP</sub>. We considered coordination cost comprising the following three components: (a) number of messages exchanged throughout the collaborative project that relate to different forms of coordination activities, (b) amount of inaccuracy while reporting team's progress, and (c) time taken to coordinate with the teammate while reporting team's status. Using qualitative and

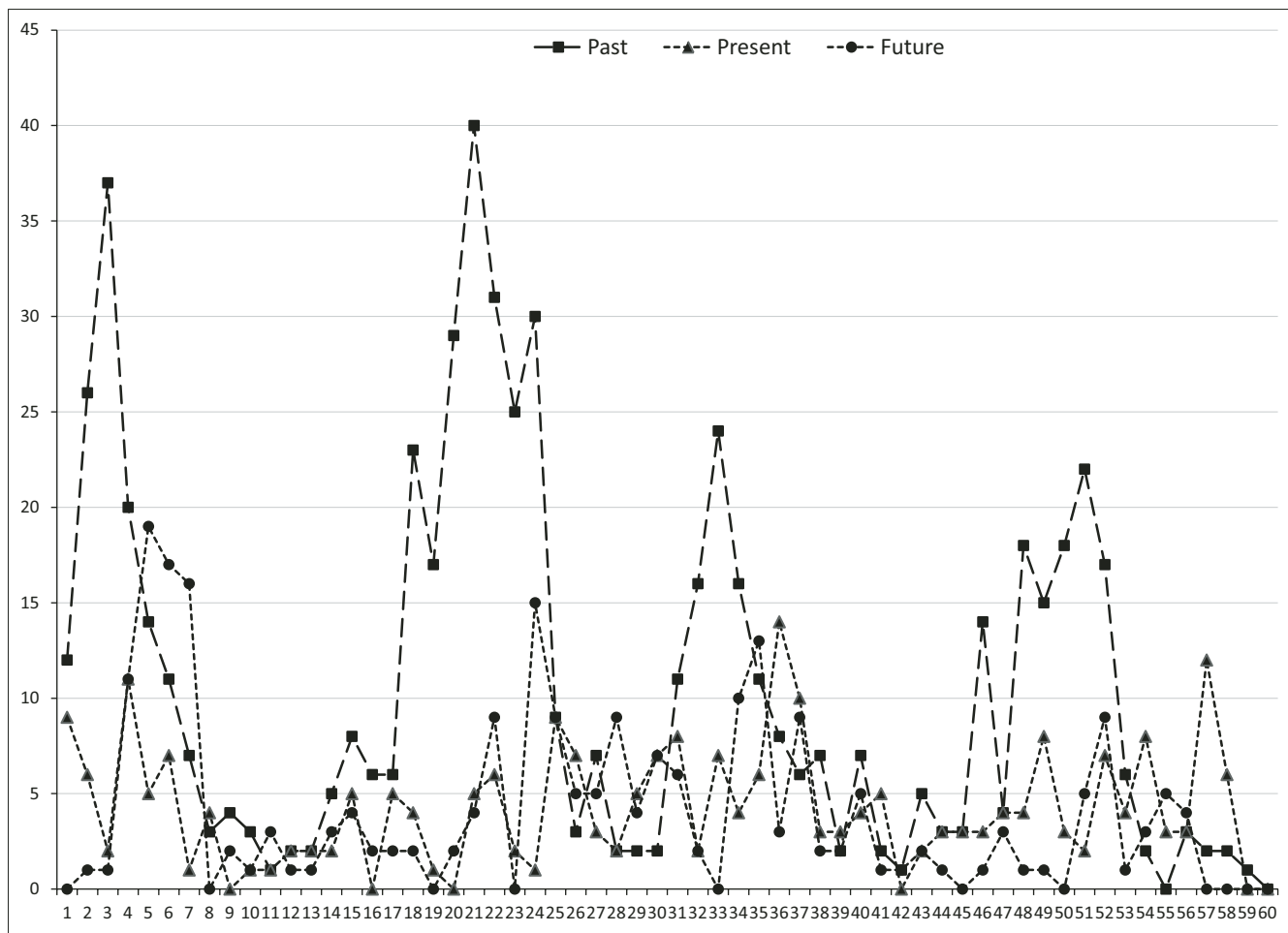


FIG. 14. Coordinating messages for teams in C1<sub>BASELINE</sub> for session 2.

quantitative analyses, we found that those in C3<sub>GROUP</sub> were better coordinated than those in the other two conditions while spending less time and communication for coordination. In other words, we demonstrated that providing *right kind of awareness* helps in reducing the effort for coordinating group and work status as well as project progress and strategies.

The notion of *right kind of awareness* bears further explanation. Those in C1<sub>BASELINE</sub> had no provision of progress awareness. They should have been provided more awareness support. C2<sub>PERSONAL</sub> participants had more awareness information than those in C1<sub>BASELINE</sub>, but it reflected only personal progress. C3<sub>GROUP</sub> participants were given almost the same interface as those in C2<sub>PERSONAL</sub> (see Figures 6 and 7), but the kind of information provided in their interface was different (group progress instead of personal progress). Thus, C3<sub>GROUP</sub> had not only more awareness support but also more appropriate information for the given situation. In summary, *right kind of awareness* indicates *adequate* and *appropriate* kind and amount of awareness.

The results reported here help us validate some of the original motivations behind providing awareness. For

instance, several early ethnographic field studies (e.g., Gaver, 1992; Harper et al., 1989) identified the need for awareness to address practices that support connecting collaborators without the activities of asking, suggesting, requesting, ordering, or reminding (in other words, coordinating). It also confirms the findings of Dourish and Bellotti (1992) that passive (implicit) awareness allows users to effectively coordinate their work. Some of the past works have also demonstrated that the use of communication as a substitute for awareness has very limited applicability and should be substituted by other means of support (Gaver et al., 1992).

Finally, we demonstrated that a better understanding of the role of awareness in coordinating people and events can lead to more effective and efficient CIS systems, similar to the ideas presented by Cataldo, Wagstrom, Herbsleb, and Carley (2006) and Stoll, Edwards, and Mynatt (2010), in which the authors had looked at the implications of awareness for coordination in collaborative projects. More specifically, the work described here informs the CIS system designers by (a) demonstrating a direct link between awareness and coordination efforts, (b) presenting a way to study the costs associated with both of them, and (c) providing a

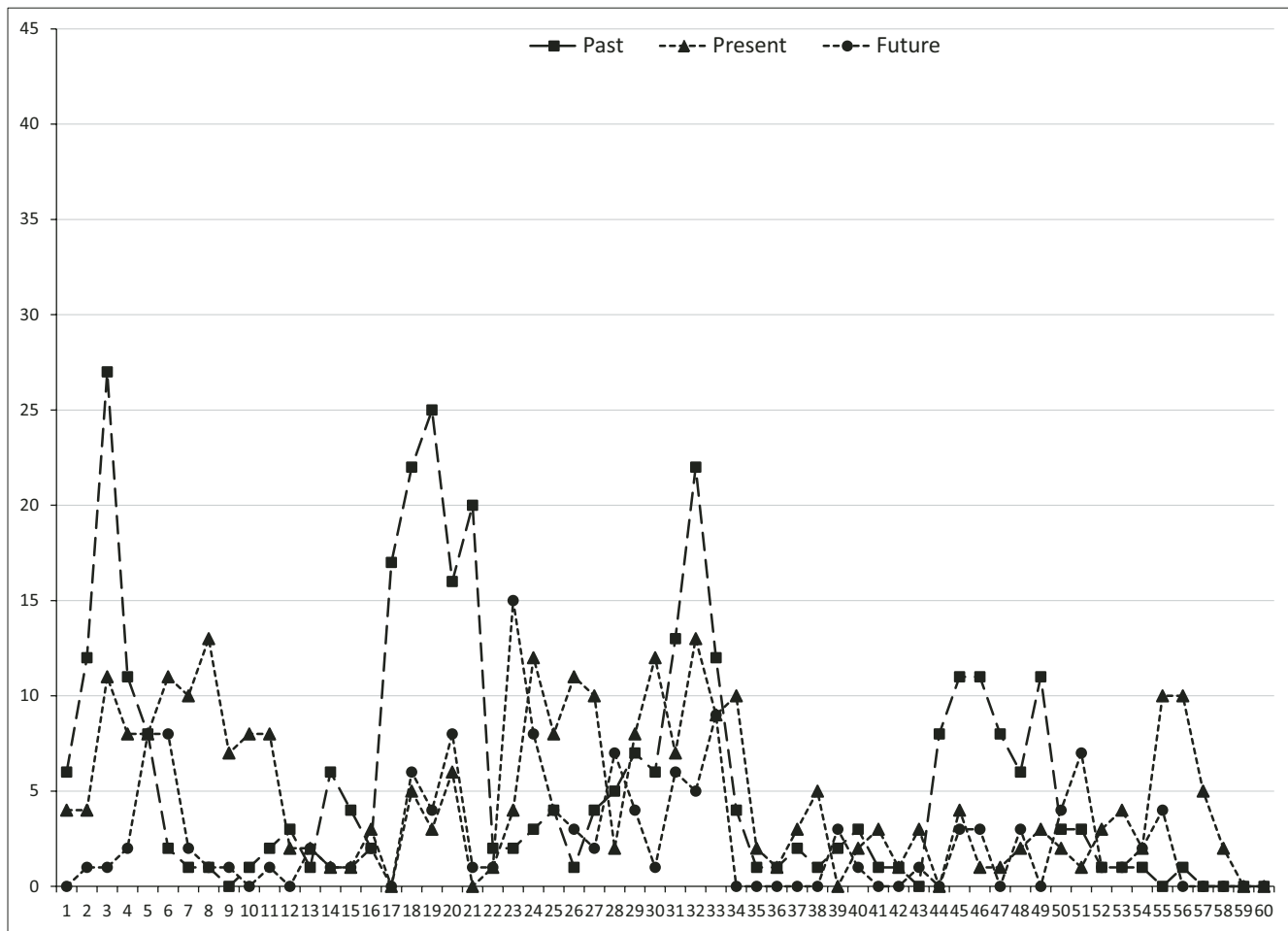


FIG. 15. Coordinating messages for teams in C2\_PERSONAL for session 2.

framework to evaluate tradeoffs with respect to the amount and kind of awareness to match the coordinating efforts in a CIS task. The work also helps CIS researchers and cognitive scientists to identify a critical component of collaborative load (Fidel et al., 2004), coordination effort, allowing them to study it independently and finding connections of such *cost* with other forms of *costs* that contribute to collaborative load.

We acknowledge that our work builds on some of the recent works showing the role of awareness in collaborative systems, such as SearchTogether (Morris & Horvitz, 2007) and CoSense (Paul & Morris, 2009). However, there are significant differences compared to them, rather than incremental improvements. These previous works identified awareness as the most valuable aspect, reporting history, ratings, and comments most used aspects for sense making. Our work, on the other hand, is not about improving these aspects, but testing the effect of them on user's coordination behavior as measured by their communication effort leading to implications for system design. In other words, we are not comparing two different system designs or trying to provide a better way of supporting awareness. We have tried to

understand the effects of providing different kinds of awareness as reflected in the CSCW literature to come up with awareness-based design choices that minimize the coordination cost and maximize user's productivity.

We also note that the present work considered variations in only one kind of awareness (peripheral). To understand the effects of other forms of awareness, experiments should be designed with different configurations. For instance, to understand the effect of group awareness in which one could get instantaneous access to his/her collaborator's view (e.g., his or her computer screen), one can imagine creating conditions with asynchronous collaborations.

## Acknowledgments

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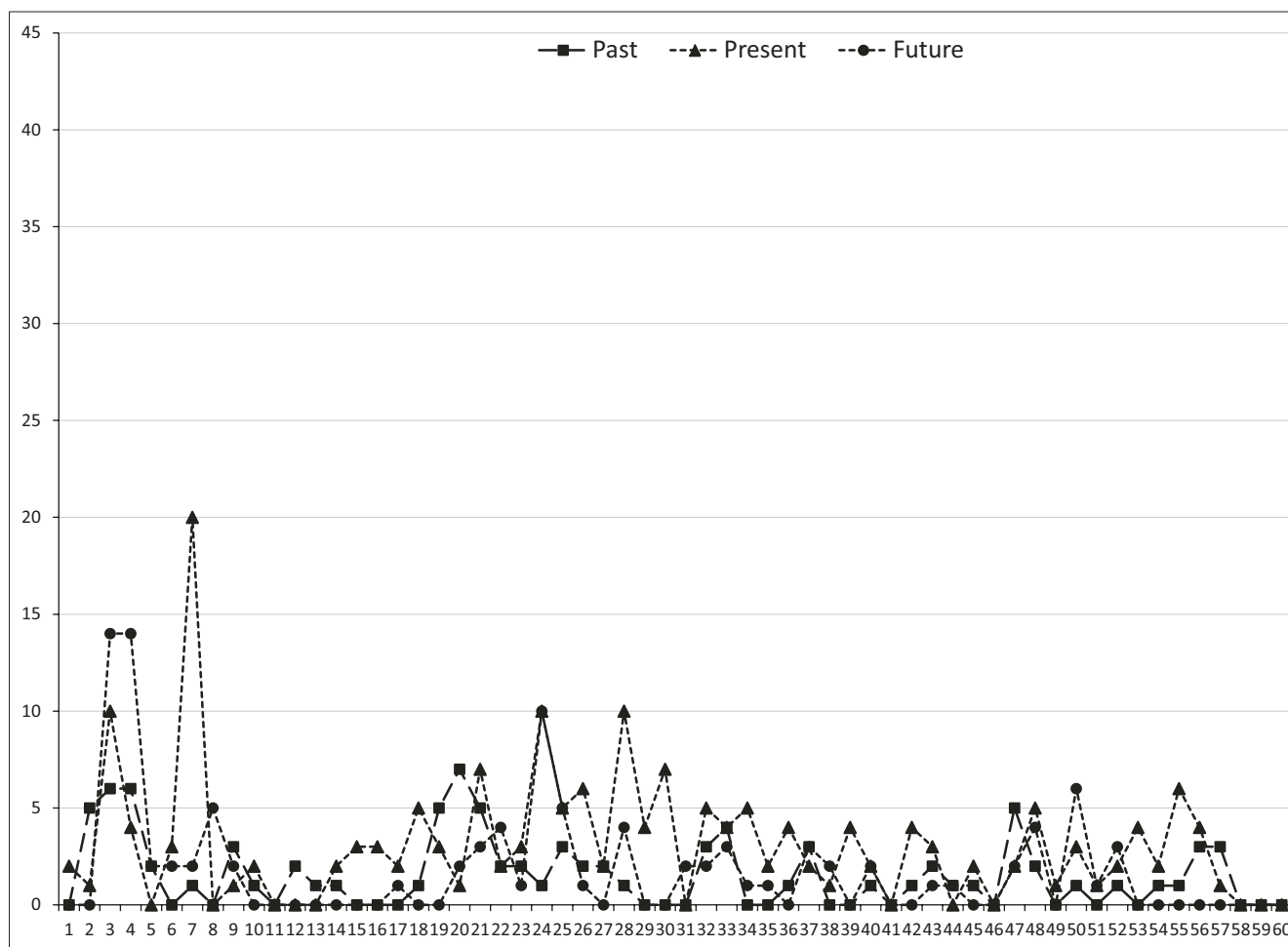


FIG. 16. Coordinating messages for teams in C3<sub>GROUP</sub> for session 2.

TABLE 4. Index for absolute difference between two collaborators' reported numbers for group's status over two tasks and two sessions.

|                                                          | C1 <sub>BASELINE</sub> |      | C2 <sub>PERSONAL</sub> |      | C2 <sub>GROUP</sub> |      |
|----------------------------------------------------------|------------------------|------|------------------------|------|---------------------|------|
|                                                          | Mean                   | SD   | Mean                   | SD   | Mean                | SD   |
| Report diff. <sup>a</sup><br>( $F = 13.827, p < 0.001$ ) | 2.38                   | 3.25 | 3.99                   | 4.89 | 0.59                | 0.75 |

Note. For one-way analysis of variance on the index, degree of freedom ( $df$ ) = 2 and within groups  $df = 165$ .

<sup>a</sup>Difference across conditions was statistically significant ( $p < 0.05$ ).

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TABLE 5. Average amount of time spent by a team while reporting task status.

|                                                        | C1 <sub>BASELINE</sub> |        | C2 <sub>PERSONAL</sub> |        | C2 <sub>GROUP</sub> |       |
|--------------------------------------------------------|------------------------|--------|------------------------|--------|---------------------|-------|
|                                                        | Mean                   | SD     | Mean                   | SD     | Mean                | SD    |
| Time (sec). <sup>a</sup><br>( $F = 1.714, p < 0.001$ ) | 198.18                 | 114.14 | 180.12                 | 130.62 | 123.04              | 71.00 |

Note. For one-way analysis of variance, between group degree of freedom ( $df$ ) = 2 and within groups  $df = 39$ .

Difference across conditions was statistically significant ( $p < 0.05$ ).

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