

Informal Communication and Awareness in Virtual Teams

Why We Need Smart Technologies to Support Distributed Teamwork

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Abstract-This paper illustrates the importance of awareness and informal communication in work environments, and outlines the resulting implications for the design of future information and communication technologies. The paper starts by providing an introduction into intellectual teamwork, showing its benefits and explaining, why informal communication and awareness are decisive factors for successful teamwork. After a brief characterization of virtual teams, it is shown, how the lack of physical proximity effects distributed teamwork. The paper closes with an assessment of state-of-the-art communication media and illustration of why existing communication technologies are not adequate for supporting awareness and informal communication in future work environments.

Keywords-Communication; Awareness; Virtual Teams; Office Environments; Smart Technologies

I. INTRODUCTION

In addition to the introduction of flat hierarchies and the decentralization of decision making, employees of organizations working in teams was one of the most important organizational changes within the last decades [92]. Teamwork in general brings many benefits, ranging from a distribution of workload over enhanced participation and involvement to increased well-being of the workers. From a psychological and socio-psychological point of view, team fulfills a variety of central human needs such as social contact, security, acknowledgement, and prestige. Team gives protection, strengthens the position of power, protects from anonymity, and improves the perception of reality [196]. From an economical point of view, Lurey and Raisinghani [134] argued that, a well-designed team-based organization could expect to achieve better problem solving and increased productivity, effective use of company resources, better quality products and services, increased creativity and innovation, and higher quality decisions. This was confirmed by Helmreich and Foushee [97], who analyzed the relevance of team performance in aviation and came to the result, that the breakdown of cooperation within teams is the main cause for many accidents. Even if these results are not of equivalent importance for all businesses, teamwork has to be seen as one of the major building blocks for the accomplishment of most projects. In addition to these more productivity-oriented benefits, teamwork also promotes the involvement and participation of individuals and contributes to the well-being of the employees.

A. Awareness and Informal Communication in Teams

With more and more employees working in teams, the role of communication in the workplace becomes increasingly important. The precondition for the successful completion of a task is the existence of a shared mental model, which serves

as the basis for a common understanding of responsibilities and information demands of single team members [27][148][179]. As a consequence, missing or insufficient communication leads to the inability to build up the required shared mental models [149]. Several studies (e.g., by Donchin et al. [47]) proved that the communication among team members has a strong influence on their performance.

One of the characteristics of today's work is communication intensive [150]. Managers and professionals have many, mostly informal, interactions with multiple individuals during the day in order to scan their environment, to exchange information, and to request or provide advices [162]. Recent empirical studies showed that managers spend most of the daily working time (over 60%) on oral communication [196].

Besides the goal-oriented exchange of task-related information, communication within the workplace serves also social purposes [221]. Social communication refers to the interpersonal exchange of messages, thoughts, and feelings, which is a compelling requirement for people working in teams [196]. Based on empirical investigations Kraut et al. [120][121] distinguish between four different categories of conversations (Figure 1):

- conversations that are previously arranged (scheduled);
- conversations in which the initiator sets out specifically to visit another party (intended);
- conversations in which the initiator planned to talk with other participants sometime and took advantage of a chance encounter to have the conversation (opportunistic);
- spontaneous interactions, in which the initiator had not planned to talk with other participants (spontaneous).

They found that a large part of the conversations in R&D environments (nearly 90%) were informal, either being intended, opportunistic or spontaneous. Other estimations based on questionnaire data [121][150][195] indicate that, depending on the type of job, office workers spend between 25% and 70% of their daily working time on face-to-face interactions. Similar results were obtained in studies conducted by Grinter [78] or Kraut and Streeter [119].

Since the portion of the scheduled communications in the workplace is rather small compared to other forms, the focus of this paper will only be on informal communication. In addition, the effects of spatial distribution on formal and task-related communication among team members are not as serious as on informal communication and awareness.

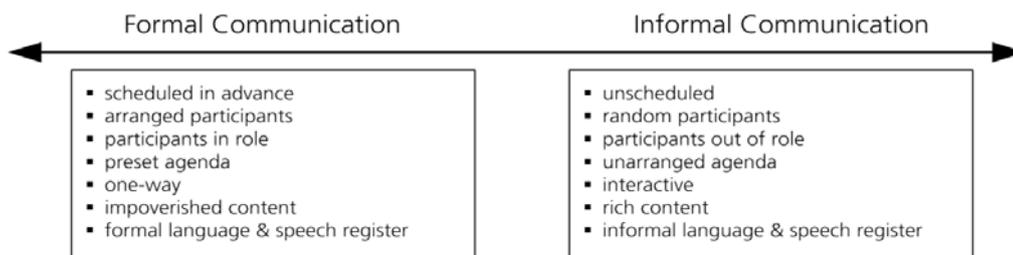


Fig. 1 The formality dimension of communication according to Kraut et al. [120]

The following two sections take a closer look at informal communication and awareness. It is important to note that awareness and informal communication are interrelated. On the one hand informal communication is an important vehicle for maintaining awareness and creating social capital [231], on the other hand, awareness often leads to informal interactions and spontaneous communication [48][104].

1) *Informal Communication:*

Informal communication is characterized by being spontaneous, interactive and rich [121], and hence differs greatly from other forms of office communication, such as phone or e-mail conversations. Informal conversations generally only last a few minutes [121][162][225], and as the purpose is seldom achieved in one interchange, occur over intermittent episodes [225], with participants on average interacting with each other two-and-half times per day [121].

Numerous studies (e.g., [59], [121] and [224]) have shown that informal communication is vitally important in organizations. Without informal communication, much collaboration would not occur and others would break up before becoming successful [121]. According to Henn (see [165]), 80% of innovative ideas created in offices are a result of informal communication among colleagues, despite worldwide data and communication networks. In addition, informal communication also satisfies social needs which are of particular importance for intellectual teamwork. The more competency a virtual team has, regarding the planning and coordination of tasks, the stronger the need for interpersonal exchange [116].

The importance of informal communication for the success of distributed teamwork was demonstrated by Kraut et al. [121] in an experiment, comparing two small work groups. One group was able to use both formal and informal communication means, while the other was limited to relatively formal communication channels. The results showed that the suppression of informal communication opportunities among members of the virtual team had considerable negative effects on their work. Lacking opportunities for informal interaction forced the members of the distributed team to rely on more formal, scheduled meetings to get their work done. Since scheduling meetings requires time and effort, a lower overall frequency of meetings resulted, which has to be seen as the major factor for the poor performance of the distributed team.

Informal communication supports a number of different functions, work-related as well as social, and plays a crucial role for the success of collaborative work. In a traditional work environment the major information transfer is done in short informal conversations, initiated by chances [198][199]. Those opportunistic interactions are crucial for coordination to occur [121] and are especially vital to the planning and

definitional phases of projects [225]. Besides this, informal collaboration contributes strongly to learning [37][56], effective knowledge management [59][120][206] and joint problem solving [225].

Hence, it is not surprising that several studies showed that the frequency of informal communication is higher in successful teams than in less successful ones and is accompanied by higher complacency and team identity [116]. The influence of informal communication on task performance was also shown by several case studies (e.g., by Jarvenpaa and Leidner [112]) and experimental simulations (e.g., by Moore et al. [139]), which correspondingly confirmed that mutual openness and conveying personal information can have significant positive effect on the success of virtual teams.

Besides these work-related benefits, increased informal communication among colleagues also leads to greater familiarity as well as to increased satisfaction with colleagues and their work [121] and contributes to the development of working and social relationships [56][121]. Teams with a high degree of social interaction are likely to have higher group cohesion than those with infrequent interactions [196]. In general, teams that are highly cohesive tend to demonstrate better performance than teams that are less cohesive [19][155]. This is also confirmed by a study of Tan et al. [200], which showed that information exchange is positively related to higher levels of cohesion in virtual teams.

In addition, improved social relations, better group cohesion, and increased trust among the team members also affect the team's performance as well as effectiveness. Studies by Lurey and Raisinghani [134] showed, that the relations among team members are strongly related to team performance and team member satisfaction. Results from empirical research on group behavior (e.g., [81] and [141]) indicate, that groups will also be more productive if they have a high level of cohesiveness.

2) *Awareness:*

Besides explicit verbal communication, especially implicit communication in form of mutual awareness is an important requirement for a shared understanding and knowledge about ongoing and past activities within the team. Thus, it is not surprising, that numerous studies about informal communication, e.g., by Heath and Luff [95] or Whittaker et al. [225], and design recommendations for work places [205] come to the conclusion that informal awareness about ongoing activities in the local work environment as well as a sense of community are vital aspects of work. Like Gutwin and Greenberg [86] and Sonnenwald and Pierce [193], most authors recurrently stress the importance of workspace awareness in computer-supported teamwork. In everyday usage, the word *awareness* generally has two meanings [227]:

- consciousness, cognizance, knowingness (having knowledge of)

In psychology the term 'consciousness' is commonly used to indicate a state of awareness of self and environment, see, e.g., Dennett [45].

- sentience (state of elementary or undifferentiated consciousness)

Sentience is the capacity for basic consciousness, the ability to feel or perceive, not necessarily including the faculty of self-awareness.

Hence, awareness includes both a perceptive component as well as the understanding of the perceived information. According to Gutwin et al. [87] awareness can be seen both as a product and a process. The product is the state of understanding processes and actions in the real world, that enables people to interpret events, anticipate needs, and act appropriately. The process is the continuous cycle of extracting information from the environment, integrating this information with existing knowledge, and using that knowledge to direct further perception [87].

It is important to note that awareness is continuously achieved while collaborating with others in a shared environment [96]. People incessantly accrue awareness information from subtle and implicit visual and auditory cues, sensed and tabulated at the periphery of their consciousness [23]. This process is neither planned nor involves a great degree of interaction and is rarely done actively [50][51][70]. Figure 2 shows the relation of awareness to more focused and actively performed forms of collaboration.

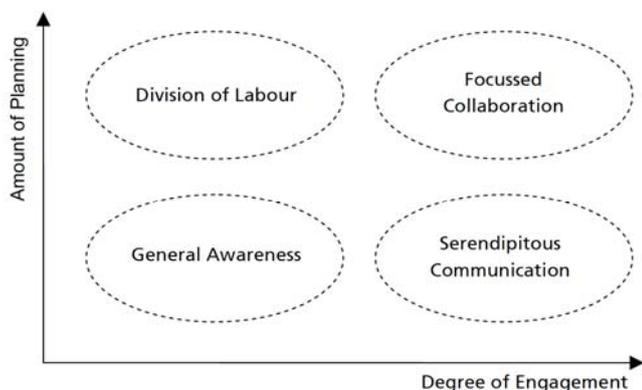


Fig. 2 Different forms of collaboration classified according to the 'Degree of Engagement', the extent to which a shared focus is involved, and the required 'Amount of Planning', the extent in which shared activities occur spontaneously or are planned in advance [70]

While most authors emphasize the passiveness of achieving awareness, Simone and Bandini [188] suggest considering two types of awareness: *by-product awareness* and *add-on awareness*. Referring to the additional effort required from the involved actors, they define by-product awareness as the stimuli conveying information about the state of the work setting, which are generated in the course of the activities people must do in order to accomplish their cooperative tasks. The costs, in terms of energy and intention, associated with these actions are practically irrelevant in relation to the costs of the primary activity. In contrast, add-on awareness is the outcome of an additional activity, which is a neat cost for the cooperating actors in relation to what they must do, and is directional in that it depends on the actor's evaluation of the contingent situation [188].

Within the field of computer-supported cooperative work (CSCW) and human-computer interaction (HCI), the term *awareness* is generally being used in the second sense, denoting a user's sentience to the state of affairs within a shared environment, as opposed to focused attention or knowledge derived from deliberate and explicit interactions such as conversations [184]. While the term is used with the same overall sense by most authors, many different definitions exist within HCI research. The definitions often overlap with other phrases, and the differences between phrases are rarely clear. For example, Dourish and Bellotti [49] use the terms *background awareness*, *informal awareness* and *peripheral awareness* interchangeably when referring to knowledge of ongoing activity necessary for maintaining informal communication [32]. While scanning through CSCW and HCI literature, Christiansen and Maglaughlin [32] identified 48 different awareness terms, which are currently being used (see Table I).

TABLE I
OVERVIEW OF A AWARENESS TEEMS CURENTLY USED IN CSCW AND HICI LITERATURE INDENTIFIED BY CHIRSTIANSEN AND MAGLAUHLIN [32]

Type	Used by
Active Awareness	Ogata and Yano [146]
Activity Awareness	Hayashi et al. [94], Lee et al. [127], Nomura et al. [144]
Asynchronous Awareness	Fuchs et al. [63], Nomura et al. [144], Sandor et al. [180]
Awareness	Ackerman [1], Baker et al. [7], Borges et al. [21], Dourish and Bly [50], Erickson and Kellogg [54], Fussell et al. [66], Gingerson et al. [72], Isaacs et al. [106], Kortuem et al. [117], Mansfield et al. [135], McDaniel and Brink [138], Reynard et al. [168], Rodden [174], Sakamoto and Kunifuji [177], Sarter and Woods [181], Smith et al. [190], Sohlenkamp and Chwelos [191], Vertegaal [214], Zhao and Stasko [229]
Background Awareness	Bly et al. [20], Dourish and Bellotti [49], Lee et al. [127]
Awareness of Others	Hayashi et al. [94], Roseman and Greenberg [176]
Casual Awareness	Gaver et al. [71]
Collaboration Awareness	Chen and Gellerson [29], Lee et al. [127]
Community Awareness	Budzik et al. [25]
Context or Contextual Awareness	Chen and Gellerson [29], Mark et al. [136], Pedersen and Sokoler [152]
Conversational Awareness	Vertegaal [213]
Coupled Awareness	Fuchs et al. [63]
Distributed Awareness	Dourish and Bly [50]
Expanded Awareness	Bly et al. [20]
Everyday Awareness	Shiozawa et al. [186]
Formal Awareness	Chen and Gellerson [29]
Gaze Awareness	Gale [67], Gaver [69], Ichikawa et al. [109], Kobayashi et al. [115], Lalioti et al. [124], Morikawa and Maesako [140], Sakamoto and Kunifuji [177], Vertegaal [215]
General Awareness	Bly et al. [20], Dourish and Bly [50], Gaver et al. [71], Lee et al. [127], Roseman and Greenberg [176], Sohlenkamp and Chwelos [191]
Group Awareness	Budzik et al. [25], Gutwin and Greenberg [82], Lee et al. [127], Sohlenkamp and Chwelos [191], Streitz et al. [199]
Indirect Awareness	Benford and Greenhalgh [14]
Informal Awareness	Gutwin et al. [90], Tang et al. [202], Zhao and Stasko [229], Röcker et al. [173]
Intentional Awareness	Pedersen and Sokoler [152]
Intervowen Situational Awareness	Sonnenwald and Pierce [193]
Knowledge Awareness	Ogata and Yano [146]
Levels of Awareness	Daneshgar and Ray [42], Sandor et al. [180]

Micro-Level Awareness	Vertegaal [213]
Mobile Awareness	Cheverst et al. [31]
Modes of Awareness	Sarter and Woods [181]
Mutual Awareness	Bellotti and Sellen [13], Benford and Greenhalgh [14], Benford et al. [15], Pedersen and Sokoler [151], Sandor et al. [180], Smith et al. [190]
Organizational Awareness	Hayashi et al. [94], van Laere et al. [212]
Participant Awareness	Banavar et al. [8]
Passive Awareness	Dourish and Bellotti [49], Fussell et al. [66], Ogata and Yano [146]
Peripheral Awareness	Ackerman [1], Kovalainen et al. [118], Lee et al. [127], Mark et al. [136], Pedersen and Sokoler [152], Pedersen [151], Tromp et al. [210]
Quality Awareness	van Laere et al. [212]
Shared Awareness	Fuchs et al. [63], Erickson and Kellogg [54]
Self Awareness	Lee et al. [127], Weisband et al. [222]
Simple Awareness	Gaver [68]
Situation(al) Awareness	Adams et al. [2], Baker et al. [7], Endsley [53], Flach [60], Gutwin and Greenberg [82], Salas et al. [178], Sarter and Woods [181], Smith and Hancock [189], Sonnenwald et al. [194]
Social Awareness	Gutwin and Greenberg [82], Tollmar et al. [207], Weisband et al. [222], Streitz et al. [198]
Spatial Awareness	Schmidt and Wegner [183]
Status Awareness	Weisband et al. [223]
Synchronous Awareness	Fuchs et al. [63], Nomura et al. [144]
Team Awareness	Ferscha [57], Poltrock and Engelbeck [159]
Uncoupled Awareness	Fuchs et al. [63]
Unintentional Awareness	Pedersen and Sokoler [152]
User Awareness	Banavar et al. [8]
Workspace Awareness	Ferscha [57], Greenberg et al. [75], Gutwin and Greenberg [82][83][84] [85][86], Gutwin et al. [88][89][90], Hayashi et al. [94], Nomura et al. [144], Vertegaal [214]
WWW Awareness	Sakamoto and Kunifujii [177]

To address the problem of unclear and contradicting definitions, and as an approach to classify the different types of awareness phrases, several conceptual frameworks were developed. For example, Christiansen and Maglaughlin [32] proposed the ‘WAGC-Framework’ for working environments consisting of four categories:

- *Workspace Awareness*
(Knowledge of who is working within a virtual space and what tasks they perform)
- *Availability Awareness*
(Knowledge about the availability of people and objects in real and virtual spaces)
- *Group Awareness*
(Knowledge and actions that give team members the feeling of belonging to a group)
- *Contextual Awareness*
(Knowledge about the physical, social and mental context)

Another framework for describing activity awareness in work environments was presented by Hayashi et al. [94]. They define activity awareness as an awareness, which gives workers indications of what is happening and what has happened recently in collaborative activities. Following their argumentation, activity awareness is gained by combining three rarer forms of awareness: awareness of others (information about tasks and activities of co-workers), organization awareness (information on the relation between

individual activities and organizational goals), and workspace awareness (information about activities in the virtual or physical work environment).

The most well-founded and convincing framework was developed by Gutwin and Greenberg [87]. They presented a descriptive framework for group awareness consisting of four types of awareness that applied to teams. To indicate that group awareness is made up of several kinds of knowledge about what is happening in a collaborative environment and to illustrate, that these different kinds of awareness overlap during group work, they use a Venn diagram shown in Figure 3.

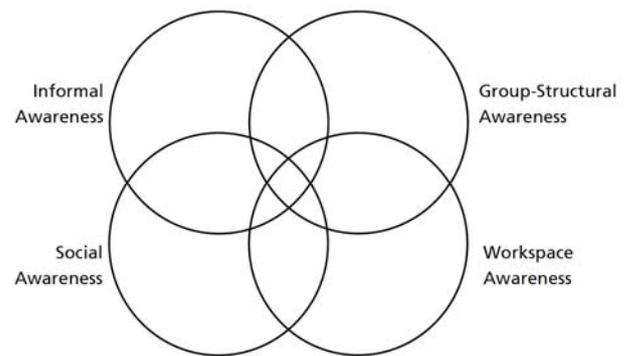


Fig. 3 Four types of awareness information that make up group awareness [87]

According to Gutwin et al. [87], group awareness is a combination of:

- *Informal Awareness*
Most authors (e.g., Gaver et al. [70], Dourish and Bly [50], Gutwin et al. [87] and Boyle [23]) define informal awareness as a general sense of the presence, availability, and activities of others in a shared environment. Gross [80] makes a further distinction between presence and availability awareness. He defines presence awareness as the pervasive experience of who is around and stresses its importance as a prerequisite for spontaneous interaction. In literature the terms *informal awareness* and *general awareness* are sometimes been used synonymously [22]. Gross [80] describes availability awareness as more specific information about the current disposition of other users, close to what Gutwin et al. [87] call *social awareness*.
- *Group-Structural Awareness*
Group-structural awareness involves knowledge about such things as people’s roles and responsibilities, their positions on an issue, their status, and group processes [87].
- *Social Awareness*
Social awareness is the knowledge about the status and activities of the other people in the surrounding [9][96][202]. It includes information like whether another person is paying attention, their emotional state, or their level of interest [87]. A very detailed classification scheme is presented by Sheldon and Johnson [185], who further divide social awareness in eight sub-forms.
- *Workspace Awareness*
Workspace awareness involves knowledge about how others interact with a shared workspace and includes information about the other participants' locations, their

present and past actions, and their intentions and possible future actions [80][82]. In this context, the term workspace denotes a system designed to support collaborative work, rather than the physical location or workplace where that system is used [32].

A variety of authors (e.g., Fuchs et al. [63]) have suggested other conceptual frameworks focusing certain types of awareness information for special application domains like, e.g., virtual reality environments or groupware applications. Due to their small relevance for this work and the limited space, they will not be introduced. The focus of this paper is on informal awareness in teams. Hence, when the term *awareness* is used, it refers to the pervasive experience of knowing who is around, what sorts of things they are doing, whether they are relatively busy or can be engaged, and so on [70].

Maintaining informal awareness of what is going on in the office and a sense of community are important features of work [55][119][154]. It does not only support informal communication (see, e.g., [9], [142], [143], [182] or [230]), but also brings a variety of other task-related benefits.

Informal awareness is an important precursor to establish common ground [147], which is essential for collaborative activities in a shared workspace [226]. By contributing to a common understanding about group processes, informal awareness acts as a foundation for closer collaboration [30][70] and supports coordination among team members (e.g., [48] or [107]). Although maintaining awareness is not the eventual goal of any collaborative activity, it enables people to collaborate more effectively and smoothly [120]. Several studies (e.g., by Isaacs et al. [108] or Cummings and Cross [39]) found that awareness significantly influences the performance of work tasks and, in case of proper enactment and support, significantly reduces human errors and increases the accuracy of work results [208].

Similar to informal communication, awareness does not only support a more efficient processing of project related tasks, it also improves personal well-being and a sense of community, which again have positive effects on the human capital of the organization. According to a study by Ivancevich et al. [110], the feeling of being aware of what is going on, seems to be important in terms of job satisfaction as well as organizational commitment. Informal awareness also plays a key role in keeping work groups motivated [107] and helps to establish a sense of community [142].

B. Higher Local Mobility through New Office Concepts

Since the introduction of office work in the beginning of this century, work environments are subject to a constant change towards higher organizational flexibility and personal mobility. The starting point of this trend was the Larkin Building, designed by Frank Lloyd Wright in 1904, which is also considered as the first office concept [128]. For decades it has typified the state of the art of office buildings, where tasks were processed according to the production line concept, mobility was restricted to documents and foremen. This situation did not change much until Robert Probst introduced the *action office* concept [197] in the 1960s. Probst introduced office landscapes with movable walls and furniture, where employees could dynamically adapt the environment to their current requirements. At about the same time the Schnell brothers came up with their approach to support information flow through mobile workplaces in open-plan offices. Both

developments have to be considered as the predecessor of the *individual office* [74] and the cube farms of the 1970s, where separated workplaces were installed in open-plan offices to support communication as well as awareness. The experiences with these concepts led to the *combined offices* [161], an office concept that unites individual and open-plan offices in one office landscape. At the beginning of the 1990s the concept of mobility changed fundamentally with the introduction of the desk-sharing concept, where employees and personal office utensils get highly mobile [33].

Observing the prevailing developments, one has to assume that future office environments will allow a much higher level of personal mobility as today's office concepts do. The most promising new development at the moment might be the business club concept, a derivative of combined office [157]. A business club consists of three areas: (1) a business center with meeting rooms, cafeteria, personal lockers and a secretary's office; (2) a team center with individual office desks, group spaces as well a team meeting room; and (3) a business lounge with a combination of relaxation and work zones.

Regardless of the predominant office concept, a continuous trend towards higher local mobility can be observed in most companies. Even if employees are within the office building, they spend considerable time away from their own desk, working in meeting rooms, other offices or in the hallway [102][125]. According to estimations, white-collar workers spend between 25% and 70% of their daily working time in conferences or meetings with colleagues [52][150][225]. Bellotti and Bly [11] studied local mobility in a design company and observed an even higher level of mobility with people being away from their desk for around 90% of the time.

To get a better understanding of the interdependency between mobility and teamwork, two forms of mobility are distinguished: local mobility and remote mobility. With the term local mobility, it is referred to the mobility of an individual within a building or organization, which is mainly determined by the organizational structure and the design of the work environment. In contrast, remote mobility describes the fading linkage of employees to a fixed workplace as a result of general globalization trends and technological development of networked mobile devices. The following section takes a closer look at local mobility and shows how the increase of local mobility in workspaces affects teamwork.

The advantage of local mobility, regarding the collaboration of the team members, has to be seen in an increased awareness about activities and occurrences in the surrounding of work place. Findings of Bellotti and Bly [11] led to the assumption that, the relevant information is received passively, as soon as a team member is in physical proximity to the activity. They came to the conclusion that, local mobility is imperative for communication within teams, and at the same time supports informal communication and awareness about local colleagues. The work of Kraut et al. [121], Whittaker et al. [225] come to similar results and additionally stressed the fact that informal communication plays a key role for collaboration within companies.

Regarding the working methods of many teams, higher mobility seems appropriate and natural: creative processes can not be initiated on command; they are independent of time and place. As a matter of fact, the most creative and inspiring

ideas are usually not born while sitting at the office desk [192]. Pelizäus-Hoffmeister [153] argues in the same way, and sees the most important benefits of higher mobility in a broader wealth of experience and the additional opportunities for new relationships.

II. DISTRIBUTED TEAMWORK

A. Definition and Characteristics

General globalization trends are observable everywhere and do not only force large companies to rethink their organizational strategies. The tendency towards higher personal flexibility together with the increased dynamic in the economical environment leads to changes in the organizational structure of most companies [64][113] with distributed teams, representing a fundamental component of these new organizational forms [156]. Today, it is increasingly common for organizations to have distributed workforces that span organizational, as well as geographic boundaries [55][93][101][116][123][126][172].

These changes are not limited to the reformation of the organizational structure within the company, but also affect the relationship between different companies. The number of organizations that consist of a dynamic network of companies, which temporarily cooperate for the production of goods or the marketing of services, is constantly increasing [10][24].

Piccoli and Ives [156] define virtual teams as groups of geographically and organizationally dispersed knowledge workers, brought together on demand across time and space through information and communication technologies, in response to specific customer needs, or to complete unique projects. Although a variety of other definitions exist (see, e.g., [46], [112], [129], [130], [134] or [211]), there is common agreement on the main characteristics of virtual teams. According to all authors virtual teams

- consist of team members that are distributed over space, time and sometimes organizational boundaries;
- and who work together on an ad hoc basis (for a limited time);
- from decentralized and delocalized places, and
- communicate through information and communication technology.

By bringing increased flexibility in working times and places, the growing prevalence of virtual teams is beneficial to companies, as well as workers. Organizing employees in virtual teams enables firms to take advantage of expertise around the globe, to continue work around the clock, and to create closer relationships with far-flung costumers, which

results in cost, time and flexibility advantages [5][101][116][160][163].

B. Effects of Physical Proximity

In traditional work environments, a wealth of information is constantly available and enables people to maintain awareness of others' locations, activities, and intentions relative to the task and to the space [87]. Informal awareness is easily gained when people are in close physical proximity [143]. When one person needs to communicate with others, their availability is assessed with a glance, and if they are not present or busy, it is easy to monitor their availability [158]. This enables colleagues, located within a convenient physical distance, to engage in short, but frequent casual interactions while trying to accomplish other tasks [231]. Hence, physical proximity has to be seen as the predominant factor influencing the frequency, quality, and cost of informal communication in the work place [133][204][225]. This was also shown in numerous studies, reporting that co-workers, who are physically co-located, are more likely to collaborate [3][58][120][121].

The same positive effects of physical proximity could be found for informal communication [59]. Studies by Kraut et al. [121] showed, that work place conversations are, in general, quite local events, usually involving people who are physically in close proximity to each other. They found, that 52% of all conversations involved people, located within the same corridor, and 87% of them took place among people, who shared the same floor in a building. This shows that even if team members are dispersed within one building, they have to cope with the same problems as teams, which are distributed over different cities or even countries. Hence, Allen [3] defines a Radius of Collaborative Collocation (Figure 4) of approximately 15m (50 ft.) as a maximum distance between members of a co-located team. If team members are dispersed in a wider area, the team is considered a distributed team.

Besides this, several studies (e.g., by Bergum and Lehr, [17] or Allport [4]) showed, that the mere presence of others affects performance on a variety of tasks [187]. The better results are explained by an increased arousal of the individual through the presence of others [228]. Later experiments could demonstrate these effects also for participants located in different rooms (see, e.g., [43] or [220]).

C. Problems of Spatially Distributed Teams

For members of co-located teams a variety of information sources are available, and especially awareness cues can be easily extracted out of the sight of colleagues and through informal communications. Hence, people sharing the same working environment rely heavily on those non-verbal cues to

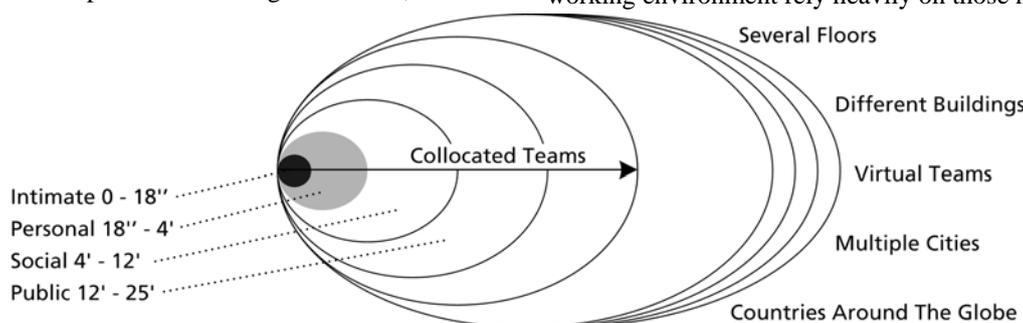


Fig. 4 Radius of collaborative collocation [129]

communicate a wealth of information, such as mood, attention, workload or stress [16][204]. When people are distributed over different locations, the information contained in non-verbal communication is lost. So people are forced to gain this information relying on forms of communication more explicit [154]. As most of the natural channels of social communication are eliminated, providing and consuming awareness information becomes an explicit burden [55].

As a result of higher communication costs, both the amount and the quality of communicated information decrease [3][5] [100][121]. This is especially true for informal and spontaneous communication, which are almost totally absent in spatially distributed teams [93][101][114]. A variety of studies (e.g., by Kraut et al. [120] or Allen [3]) showed that distance diminishes the richness of communication, causing the structure of communication to be much more formal [143][172]. Similar results were reported by Atkins et al. [5], who compared same-site and cross-site communication at twelve *Lucent* sites in Europe and Asia. They found, that cross-site communication networks are much smaller, and much less frequently exercised, due to difficulties of initiating contact and the ability to communicate effectively. The results indicated that cross-site work took much longer and required more people than comparable same-site work.

As communication is impaired, also awareness gained from informal communication deteriorates over distance [77][119]. Working in different offices causes team members to lose the visual reminders of each other's presence, as well as all the social information, that is obtained through aural and visual contact with co-workers [123]. This causes permanent awareness gaps among members of virtual teams [103][201], which, over time, results in a long-term lack of awareness of the activities at remote sites [55]. In a qualitative study of virtual teams, Atkins et al. [5] observed that people "do not know what's really going on" at the remote site and conclude, that there is greater cross-site tendency to miss important information. This is especially critical, since there is compelling evidence that the virtual context dramatically increases communication needs [156].

In the previous section it was shown, that co-located teams easily establish common ground, as they do not only share the cultural and local context, but also more micro context of who is doing what at the moment and what remains to be done [147]. Distance has a detrimental impact on this shared context [5][101], and causes difficulties for remote teams to develop a mutual understanding [35][65].

This gives rise to a number of difficult coordination issues [93], as the physical separation of team members is likely to limit the teams' ability to use means of coordination more implicitly [155]. Difficulties, coordinating actions and tasks and determining, who is doing what, are commonly reported problems in distributed teams [155]. Studying a geographically distributed software development team, Grinter et al. [79] found, that regardless of the way the team structured its work, people were constantly surprised and confused about the activities of their distant colleagues. Similar observations were reported by Goodman and Leyden [73], who found, that not being familiar with the work habits of other team members significantly increases coordination problems within the team.

As explained in the last section, physical proximity of people influences collaboration. Findings by Bradner and

Mark [24] indicate that the geographical distance of collaborating partners affects their willingness to cooperate initially, to be persuaded by, and to deceive that partner. This might explain why Kraut et al. [121] found that people, located closer in a building, were more likely to collaborate.

Reduced collaboration has a major bearing on the ability of virtual teams to work effectively [216], as poor or inadequate communication interferes with team performance [19]. Studies by Tan et al. [200] as well as Hightower and Sayeed [99] showed that information exchange is positively related to performance in virtual teams. Several authors, including Kraut et al. [121], Bellotti and Bly [11] and Luff and Heath [132], also observed that teams, which do not have the chance of spontaneous interactions, take longer and produce lower quality results, even if they have the same number of planned or intended interactions. These findings are in line with those of Weisband [222], who observed that teams, in which members periodically gathered information about others and revealed information about themselves, performed better than teams in which no informal communication took place. Churchill and Wakeford [34] explain this with interruptions of the *reciprocity* and the *rhythm* of the collaboration among team members, which are essential for the success of collaboration. If this evolves to a permanent situation, *discontinuities* and *breaks* emerge, which inevitably lead to isolation and community destroy processes [153].

In addition, social aspects of work are also affected, which indirectly take effect on team performance. Distance has a detrimental impact on familiarity and friendship among team members [101][116] and denies the development of shared cultures [50]. In a study by Lurey and Raisinghani [134], many of the participants addressed the need for more personal contact to establish supportive team member relationships, which have been recognized as critical to improving the success of teams. Other problems of geographically distributed teams include a lack of trust [101][172], reduced group cohesion [105], and missing willingness to communicate openly [5]. Especially trust problems are crucial, since virtual teams are required to rely on trust relationships in a much higher degree than traditional teams [163].

Besides this, there is the risk that the reduced personal contact, negatively effects the motivation of the team members [116]. It has been repeatedly shown, that teams will not, and for that matter cannot be effective, if the team members themselves are not satisfied with the way the team functions [134].

III. TECHNOLOGY-MEDIATED GROUP COMMUNICATION

Teams, which are geographically distributed, by their nature, are denied the informal information gathered, from a physical shared workspace [121]. The members of the team have to rely on different communication tools to explicitly communicate the information that is otherwise picked up passively by those present. This section takes a look at the communication tools that are currently used in offices and will assess their appropriateness for informal information exchange among members of distributed teams.

A. Forms of Group Communication and Communication Media

Exchanging task-related information is only one aspect of group communication. When collaborating over distance, it is

equally important to have informal interactions, spontaneous conversations, and awareness of people and events at other sites [20]. Therefore, it is important to distinguish between content-oriented and connectedness-oriented communication. Traditional communication technologies, like telephone and e-mail, focus on content and are not adequate to support a feeling of connectedness. In contrast, connectedness-oriented communication is intended to support and augment social relationships among people, by fostering a sense of connectedness among them [122].

The degree of connectedness is closely related to the social presence a communication media is able to mediate [187]. Social presence is defined as “the moment-to-moment awareness of co-presence of a mediated body and the sense of accessibility of the other being’s psychological, emotional, and intentional states” [18]. The more a communication media is capable to mediate the personality and non-verbal symbols of a remote person, the higher is its social presence. Face-to-face communication, for example, has the highest social presence, written text the lowest. Based on empirical studies and the basic idea of social presence, Daft and Lengel [41] developed the Media Richness Theory, which proposes the task performance will be improved when task needs are matched to a medium’s ability to convey information. Rice [170] and Reichwald et al. [164] extended the media richness theory to new communication media.

According to Reichwald et al. [164], rich communication media are not generally better than poor ones. Rather, there is a zone of effective communication (see Figure 5). If the chosen medium is too rich, it causes an *overcomplication* of the situation. Users get distracted by the richness of the medium, and unnecessary interpretation might generate artificial ambiguity. Using a medium that is too poor would result in oversimplification. Hence, the medium should be chosen in accordance to the complexity of the task [170]. To ensure effective communication:

- rich communication media should be used for complex, and
- poor communication media for structured task.

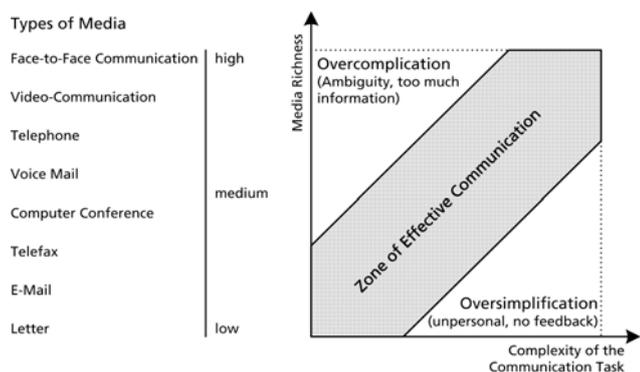


Fig. 5 Media Richness Model for tele-cooperation [164]

B. Awareness Mediation via Traditional Communication Devices

1) Telephone:

Informal communication is usually done verbally, either face-to-face or by telephone [116]. Hertel et al. [98] showed that people in general prefer face-to-face communication or telephone over text-based media, like e-mail or chat, and asynchronous speech-based media, like voice-mail. The same

results were reported by IJsselsteijn et al. [104] for non-working environments. Besides this, a series of analyses (e.g., by Cummings et al. [38] showed that people report telephone conversations to be of higher quality than text-based conversations. This might be explained, besides other factors, with an increased feeling of connectedness. When comparing instant messaging (IM) applications, e-mail, text messages and mobile phones, Rettie [167] found, that respondents generally felt most connected when using phones, followed by IM and text, with e-mail providing least connectedness. Even communication and awareness systems, especially designed for informal communication, cannot challenge the phone’s supremacy as the preferred communication device in the office. Evaluations of the *Electric Lounge* system [231] showed that people still preferred to use telephones, when they needed to talk to someone.

The main drawback, seen from the initiator’s point of view, is that telephones fail to provide availability awareness. Around 60 % of business phone calls fail to reach the intended party, either because people are not present, or they are already talking to someone else [145][169][202][225]. While mobile phones provide a technical solution for this problem, studies show that workgroup members often did not take mobile communication devices with them, when they worked outside of their personal workspace, especially for spontaneous or unplanned work [102]. And even if it is technically possible to be reached by phone, there is no way to know for sure, if someone is available for interaction. The only way is to call and interrupt him and thereby invade his solitude [23][62]. Once being interrupted, the receiver of a call needs up to fifteen minutes to recover and get back to his former work performance [26][111]. As having a prior knowledge of the communication availability of remote colleagues is critical factor for the success of communication, it is not surprising that Bellotti and Bly [11] found phone conversations between remote team members to be infrequent compared to the local interactions. They observed that people tended to save up a number of things to talk about, before they actually made a call. Due to the explicitness of the interaction, telephones are not appropriate for staying aware of each other [137], even if it is the preferred medium to contact remote team members.

2) Video Conferencing Tools:

The main benefit of video conferencing (VC) systems is that they provide additionally cues through mimic and gesture, giving further information about the state of remote persons. While many users feel very positive about the medium at first hand, they start to dislike video conferencing systems, when they know them better [28]. The reasons are of psychological as well as of technical nature. First, the user’s acceptance of being filmed all the time is very low. Furthermore, the picture and sound quality is often not very high, making conversations additionally exhausting. Therefore, VC systems are mostly used for scheduled appointments, helping teams to collaborate by enabling them to talk and synchronously use applications.

However, these systems provide little support for team awareness and community development by facilitating opportunistic interactions [158]. Besides this, the permanent confrontation with audiovisual impressions is not only considered as disturbing and distracting, it might also lead to stress and stress-dependent psychosomatic aches and pains [131].

3) Text-Based Communication:

E-mail is currently the most widely used form of computer-mediated communication in office environments and, as a storage-based and asynchronous communication medium, has several advantages for task-related communication. Nevertheless, e-mail has only limited potential for signaling awareness and availability to remote colleagues [93]. First, e-mail as a medium, is barely appropriate for personally sensitive communication [166]. Without a concrete request, it is quite unusual to tell remote colleagues about mood or current activities in an e-mail. This is partly due to the high effort of expressing sensitive information in an appropriate way, so that no misunderstandings occur. Second, e-mail is one of the major sources for interruptions in the office environment. Today, most e-mail users feel overwhelmed and daunted by the required time to read all incoming e-mails and to react appropriately [12]. In a study about e-mail usage, Jackson et al. [111] found that 70% of the observed e-mail users reacted to notifications of incoming e-mail within six seconds. After having read the e-mail, users, on average, took sixty-four seconds to "recover the mental thread" of what they were doing before, in order to be able to resume their previous tasks.

While instant messaging (IM) applications were originally developed for direct and spontaneous information exchange, IM is often used in indirect ways to create and maintain a sense of connection to others by monitoring the buddy list [142]. Most IM systems use varying font styles and different indicators associated with a text label to show, whether the remote buddy is online or busy [231]. The online and status information in the buddy list is commonly used to maintain continuous awareness about state of distant user, without necessarily planning to interact [9].

Despite the lightweight nature of IM applications, there are still several constraints on its usability and its capability to provide awareness [44]. Although IM systems try to estimate the user's presence based on keystrokes and mouse activity, more detailed awareness information, e.g., availability, has to be provided by the user. Keeping the personal status information updating requires a considerable effort from the user. The information, visible to others, does not necessarily reflect the current situation, what is especially true for short-term or irregular occurrences, like, e.g., incoming phone calls or informal conversations with local colleagues. These assumptions are confirmed in a focus group study by Washington [221] who showed, that presence data gained from the buddy list is usually not clean, and that panelists did not trust the validity of presence information. He also observed that users are likely to leave themselves logging on much of the time and forget to change their status even when they are away from their computer for extended periods of time.

While some authors like, e.g., Nardi et al. [142] argue that IM is less intrusive than calling on the phone or dropping by, empirical evidence shows, that upcoming IM notifications continuously draw the user's attention [93]. As IM systems rely on the discursive paradigm of interaction, people often feel obliged to respond, which results in an increased level of interruptions [9]. The prevailing use of IM for social and work-related communication has created a situation, where incoming messages often become a distraction to users, while they are performing important tasks [6]. Investigating the

impact of interruptions caused by IM applications, Czerwinski et al. [40] observed significant negative effects on overall processing time of different types of primary tasks.

But even if interruptions are mostly unavoidable and the costs of communication are quite high, IM system might be useful to support informal interactions. Several studies on IM use in the office environments (e.g., by Nardi et al. [142], Tang et al. [203] or Handel and Herbsleb [93]) have shown, that IM is widely used to negotiate availability for communication over more heavyweight communication channels (e.g., telephone). However, much of the daily work takes place away from the personal desk (see above), which collides with the requirements that the user must be in front of the computer, to be able to receive awareness information [44].

Drawbacks of Text-based Communication cannot be overlooked. Although text-based communication becomes more popular in offices, current systems are hardly appropriate for personally sensitive communication [166]. E-mail as well as IM systems currently lacks the ability to support awareness, opportunistic conversations and mobility, three important elements of distributed collaboration [107].

These shortcomings are partly due to the medium itself. Trevino et al. [209] reported that managers mostly use text-based media to demonstrate authority and status. Hence, it is not surprising that several studies (e.g., by Rice and Love [171] or Connolly et al. [36]) observed, that computer-mediated communication is generally less friendly and personal, and more task-oriented and business-like, compared to face-to-face communications. Handel and Herbsleb [93] conducted a content analysis of IM communication in offices and found similar results. IM communication was used overwhelmingly for work discussions, coordinating tasks, or negotiating availability. Another drawback is the high communication costs, already mentioned for e-mail communication. Some authors, including Walther [218][219], even argue that most problems, encountered in text-based communication systems, are a function of slow communication interaction due to extensive typing needs.

As a result, text-based communication is usually low in social presence [171] and lean in media richness [217]. This was also corroborated in several studies, for example, Flaherty et al. [61] reported, that face-to-face communication was rated higher than text-based communication for all motives, including social ones such as inclusion and affection. Comparing the effects of e-mail and telephone communication on knowledge sharing, Hinds and Bailey [101] found, that distributed teams communication over e-mail did not share their work context effectively, and developed less shared understanding than teams being co-located.

C. Common Problems of Traditional Communication Devices

In contrast to co-located work environments, the members of distributed teams have to communicate awareness information explicitly. The amount of information that is communicated is determined by the benefits users gain and effort they have to undertake, to provide the information to their remote team members. This explains why traditional communication tools, like e-mail or telephone, are only of limited appropriateness for supporting awareness in distributed teams. Communicating relevant information requires a comparatively high effort, and therefore will be used only for things, which are considered to be more

important, like time scheduling, task management or other work related subjects [12][91][175][198][199].

According to Markopoulos et al. [137], the main drawbacks of existing communication media for awareness support are their synchronous nature and their explicit interaction paradigm, requiring people to have a reason for contacting someone. In contrast, people, working in a shared office space, profit from the fact, that information is continuously available and can be picked up passively by those present. At the time of information reception it is mostly not predictable, which passively perceived occurrences will be an important resource for future activities. Since communication links with distant team members have to be initiated intentionally from both sides, the substitutions of local presence with traditional communication devices is very limited, and will never accomplish the same result.

As described above, an increase in local mobility leads to shorter and irregular attendance times of local team members at their individual desks. Since personal resources for supporting distributed teamwork, like e-mail or telephone, are in most cases only accessible at the individual desk, the enhancement of local collaboration is mostly paid at the expense of poor collaboration with remote team members [11]. This contention can be backed through a study by Whittaker et al. [225], in which 2/3 of all attempts to contact remote team members were not successful due to local mobility.

IV. CONCLUSIONS

Technology-mediated communication has become an essential part of many workplaces, with team members relying on e-mail, instant messaging, and phone calls to communicate with colleagues across the hall or across the world [62]. In this paper it was shown that the existing communication media are adequate means to support routine communication tasks and to help coordinate well-structured activities over distance [11][116]. However, as they were designed for communication purposes but not considering mediate awareness, existing communication devices only afford explicit communication rather than the kinds of implicit communication available through co-presence and mutual awareness [11][121][225]. While task-oriented communication tools have been quickly accepted and are being improved continuously, there are very few approaches to support awareness and informal communication among members of virtual teams. Today, appropriate communication and information infrastructure is an essential component in virtual organizations, and teams could be more effective if more advanced technologies are available. Hence, it is essential to conceptualize and implement new communication systems that offer lightweight and intuitive ways for supporting informal interactions and mediating awareness in distributed teams.

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