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Computer-Supported Cooperative Work

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Abstract. Computer-Supported Cooperative Work (CSCW) is an interdisciplinary research area concerned with developing computing technologies that facilitate, mediate, or regulate interaction between people engaged in cooperative work or similar kinds of sustained social activities. CSCW is a heterogeneous enterprise, addressing a motley of computational technologies and assimilating contributions from a host of scientific disciplines. What unites CSCW research is a shared concern with the fundamental problem of incorporating models of coordinative practices in computational artifacts and to do so in such a way that actors are able to deal with contingencies and are supported in that by the functionalities of the computational artifacts. Reflecting this shared concern, CSCW research is also united in a symmetrical commitment to ground design efforts in studies of actual work practices and to orient studies of actual work practices towards informing the development of collaborative technologies. As a field CSCW focuses on a variety of domains where complex cooperative practices occur. Due to the heterogeneity of the field and of such domains, a range of approaches and frameworks are applied to CSCW research. A notably established approach that has shaped substantial part of CSCW scholarship and had influence beyond the discipline are in-depth ethnographic studies of actual practices in their naturally occurring settings. In this regard CSCW has been influential in championing a hybrid approach to the study of computing systems encompassing concerns for understanding and for designing.

1 Introduction

Computer-Supported Cooperative Work (CSCW) is an interdisciplinary research area concerned with developing computing technologies that facilitate, mediate, or regulate interaction among people engaged in cooperative work or similar kinds of sustained social activities. As an organized research area, CSCW emerged in the 1980s in response to the then already ongoing development of an assortment of collaborative computing technologies, as an effort to ground their development in systematic knowledge of actual work practices. Arising in response to emerging technologies such as online transaction processing, computer conferencing, electronic mail, office automation, etc., CSCW was from the very beginning a heterogeneous enterprise, addressing a motley of computational technologies and assimilating contributions from a host of scientific disciplines, ranging from computer science and software engineering to sociology and anthropology, and comprising a profusion of theoretical and methodological commitments and approaches such as Ethnomethodology, Symbolic Interactionism, Distributed Cognition, and Ordinary-Language Philosophy.

As a research area, CSCW remains a bazaar rather than a cathedral (Schmidt and Bannon 2013). That is, it may better be conceived of as a loose coalition of research programs that all, in different ways, address how computing technologies are or could be incorporated in work practices and in similar complex social activities.

Such heterogeneity notwithstanding, what unites CSCW research is a shared concern with the fundamental problem of incorporating models of coordinative practices in computational artifacts and to do so in such a way that actors are able to deal with contingencies and are supported in that by the functionalities of the computational artifacts. Reflecting this shared concern, CSCW research, in its remarkable diversity, is also united in a symmetrical commitment to ground design efforts in studies of actual practices *and* to orient studies of actual practices towards informing the development of collaborative technologies (Bannon and Schmidt 1989; Greif 1988; Suchman and Trigg 1986).

2 Cooperative work, or the challenge of coordinative practices

When researchers initially formed the loose coalition that is now CSCW, they identified their common object of concern as that of ‘cooperative work’. While the term has a long history in political economy and the sociology of work, the term chosen was obviously picked as a placeholder for further explorations, clarifications and studies. Thus, at an early stage, authors recommended that the notion of ‘cooperative work’ as the designation of the common object of concern should not be prematurely defined in some rather specific sense (such as ‘small groups’, ‘teams’, etc.) or in terms of a certain mutual stance (e.g., egalitarian, altruistic) but

should be left open to be enriched by studies of actual work settings and by experiences with deployment of computational artifacts in such settings:

‘The concept of cooperative work does not imply a particular degree of participation or self-determination on the part of the workers, nor a particularly democratic management style. [...] The term “cooperative work” is the general and neutral designation of multiple persons working together to produce a product or service. It does not imply specific forms of interaction or organization such as comradely feelings, equality of status, formation of a distinct group identity etc.’ (Bannon and Schmidt 1989, p. 362).

At the same time, and in order to avoid watering down the concept of cooperative work by making it more or less congruent with the notion of social life in general, it was recommended to delimit the scope of the concept of ‘cooperative work’ to arrangements in which actors ‘are mutually dependent in their work and therefore are required to cooperate in order to get the work done’ (Schmidt and Bannon 1992, p. 13). Cooperative work is thus conceived of as constituted by activities performed by multiple actors that are interdependent in that the different actors, in turn or concurrently, change the state of some part of the world (Dix 1994; Schmidt 1994). That is to say, and very simply, for actor A to be able to do his or her work in accordance with the given requirements and constraints and with the requisite result, actors B and C etc. must do *their* work in accordance with the given requirements and constraints and with the requisite result (Schmidt and Bannon 1992). Each of them depends, in his or her contribution to the overall effort, upon the contributions of the others, and vice versa.

With respect to CSCW’s research program, the point of this is that it put the focus of CSCW research on the ways in which such interdependent activities are *coordinated*, namely the ‘articulation work’ required in arrangements of division of labor to mesh and integrate members’ distributed activities (Gerson and Star 1986; Schmidt and Bannon 1992; Strauss 1985). It puts the focus on the practices of *managing coordinative complexity* and is thereby, in as much as computing technologies offer great potentials for reducing exactly such complexities, consonant with the field’s commitment to ‘computer support’ for cooperative work.

The operational complexity engendered by interdependence in work gives rise to the development of often remarkably sophisticated ‘coordinative protocols’, that is, a predefined method of proceeding, typically expressed in associated specialized ‘coordinative artifacts’ (e.g., Bardram and Bossen 2005; Schmidt and Wagner 2004). These protocols and artifacts are a ubiquitous feature of modern workplaces (government agencies, hospitals, manufacturing plants, schools, trade unions, construction sites, museums, laboratories, etc.). Modern cooperative work settings exhibit a rich variety of such protocols and artifacts, such as, to mention but a few of the coordinative protocols that have been investigated in CSCW: flight progress strips in air traffic control; line displays and time tables in urban rapid transit control centers; production schedules, kanban systems, and job sheets in manufacturing; classification schemes and nomenclatures in the practices of ordering large-scale collections of artifacts such as plans and drawings, components and work-in-progress, files and records; clinical protocols and records; etc.

These protocols and artifacts are also, in developed industrial societies, a familiar feature of social life in general, for instance, in voluntary work settings such as community associations and other civil society settings, and even, increasingly, in domestic settings. To CSCW research, these settings all pose challenges in so far as they struggle with coordinative complexity.

3 Computer support, or computational artifacts

The concept of ‘computational artifact’, originally developed by Lucy Suchman (1987), is fundamental to the research program of CSCW. The concept of ‘computational artifact’ is closely related to the concept of ‘interactive computing’ but has the merit of not imposing the anthropomorphic notion of ‘interaction’ between human and machine. Avoiding such premature (and deeply problematic) assumptions, the concept of computational artifact suggested by Suchman foregrounds that a key feature of computational artifacts is their *reactivity*, that is, their capacity to react to and thus be an integral part of unfolding events. This presumes, first, the mode of operation historically referred to as ‘manual intervention’ or, in Suchman’s words, ‘the availability of interrupt facilities whereby the user can override and modify the operations in progress’ (Suchman 1987, p. 11), and, second, a response-time that is less than what in the given practice are considered significant state-changes, i.e., the artifact must be able to execute in ‘real time’. Moreover, computational artifacts are characterized by their ability to manipulate signs (letters, numerals, geometric elements, imagery, and sound) in step with external events. They can therefore be used as complements of semiotically constituted practices (calculating, computing, drafting, planning, writing, searching, etc.). In software engineering terms, a computational artifact is constituted by a structured set of ‘object classes’ and ‘objects’ (i.e., data structures with associated elementary operations). But it is thereby, at the same time, if useful, ‘inherently bound to a practice from which the categories represented by these objects and classes are derived and to which they are indigenous’ (Schmidt and Bansler 2016, p. 32). Finally, a computational artifact is not necessarily and is rarely confined to a distinct electronic entity, a chip, say, but may incorporate the behavior of multitude, physically distinct, elemental entities, perhaps distributed over multiple devices, but it nonetheless, ‘exhibits *functional unity* over these myriad events’, and, if successfully designed, ‘it does so by virtue of its being bound to a practice’ (Schmidt and Bansler 2016, p. 33).

The internal relationship between, on the one hand, object classes and objects and on the other the categories of the given practices is not unique to CSCW. It applies to Human-Computer Interaction as well. In fact, any computational artifact incorporates a model of ‘the world’ as conceptualized in the practice into which it is to be integrated as a technical complement. An ordinary single-user word processor, for instance, incorporates a ‘model’ of the essential categories of the practices of writing in the form of a set of digital object classes

and objects matching the essential categories of the given script such as letter, number, punctuation mark, word, space, sentence, paragraph, page, etc. These object classes and objects are the ‘primitives’, the elemental units, of the application. This set of primitives affords a user to type and edit text in terms of the practices of writing and editing: not only by generating text strings but by manipulating ordered chunks of text. The word processor also provides certain semi-automatic functions such as word wrap, in which a routine automatically keeps track of the number of points per line and, when a predetermined limit is reached, ‘flows’ the following text to the next line by dividing between two words (or by hyphenating a long word by syllables). Modern word processors also offer semi-automated functions such as auto-complete, spelling checker, hyphenation, page and figure numbering, etc.

Likewise, to support the *coordination of cooperative work*, or the orderly performance of interdependent activities, a computational artifact must incorporate, similarly, a model of the conceptualization of the given coordinative practice, that is, a digital complement of the coordinative protocol in the form of an ordered set of primitives corresponding to the categories of the protocol. Take, for example a group calendar. It must, like any computational calendar for a single user, incorporate categories such as hour, day, week, month, year, time zone, appointment, location. However, in order to support the cooperative ensemble in coordinating their interactions, it must also allow members to express personal identity (name, email address) and to accept or decline invitations. However, coordinative protocols are rarely as simple and well defined as those supported in group calendars. There may, for instance, be different organizational roles involved, such that only the holders of a certain role, e.g., manager or project leader, can call a meeting, or such that this authority can be delegated temporarily, or such that members can only decline the invitation pending approval. And so forth. The coordinative protocol then quickly becomes far more complex than the script underlying a word processor (Grudin 1988). That is, in CSCW, the relationship between the protocols of coordinative practices and their expression in computational artifacts is tenuous. Accordingly, for CSCW this very relationship — classically in the term ‘plans and situated action’ (Suchman 1987) — constitutes the defining axis of the research program, its *problematique*, and is manifested as a continual concern with the role of ethnography and other kinds of in-depth empirical studies of practices in the overall process of technology development and systems design.

4 The emergence of collaborative computing technologies

Collaborative computational technologies arose in response to a host of very practical problems in different domains and, consequently, predate the emergence of CSCW as an organized research area by decades, and so did the challenges that are motivating CSCW research today (Schmidt 2011 Chapter 11, 2015).

CSCW is not defined by a particular computing technology or a specific family of computing technologies; it is defined by a challenge arising for all computing when applied to supporting coordinative practices. Consequently, a myriad computing technologies are of potential, if not actual, relevance to CSCW, from shared online repositories to ‘media spaces’ to messaging to reminder systems to embedded computing. For the sake of simplicity, the myriad technologies can be seen as instances of three different technological paradigms, defined by the function of the computational artifact:

- *facilitate* cooperative work activities by means of a shared digital representation;
- *mediate* cooperative work activities by means of a computationally controlled medium for the (structured or unstructured) exchange of messages in various communication formats;
- *regulate* cooperative work activities by means of computational control the ‘flow of work’ (tasks, documents) among cooperating workers.

To illustrate these paradigms, a brief survey of the emergence of the technologies will be helpful.

Their origin can be dated back to the late 1940s, to the Whirlwind computer. It was released in 1951 as the prototype of what was eventually the command and control system for the air defense of North America under the name SAGE (operational in 1958). Whirlwind was revolutionary in several respects. It embodied the stored-program architecture proposed by Alan Turing, initially implemented in the ‘Manchester Baby’ computer (1948), and eventually the dominant computer architecture. Eminently reactive by design, the system provided a digital representation of the airspace of North America that was perpetually updated with input from radar stations, listening posts etc. and displayed sector-wise on the monitors of air defense operators at different stations and centers. It also introduced the ‘manual interrupt’ feature enabling operators to control the execution of the program. Using a light-pen for selecting aerial objects represented by dots on the computerized radar screen, operators could make the system track them and, when appropriate, direct fighter planes to intercept. As a suspicious target moved from sector to sector, the responsibility for monitoring it was transferred from one operator to the next. This was initially planned to be done automatically, but in prototype testing it became clear that operators would also need to be able to communicate horizontally and directly, and they were consequently issued with telephone lines so that they could contact each other and discuss what the system displayed.

While Whirlwind’s was the first computer architecture to offer ‘interactive computing’ (O’Neill 1992), it was at the same time and by the same token the first computer architecture to support cooperative work. It did so, basically, by providing a shared digital representation of the airspace that multiple operators could access simultaneously and to which each operator could introduce changes. That is, they collaborated by changing the state of a shared digital representation. It also provided rudimentary means of regulating the assignment of tasks among operators and, when required, transferring tasks between sectors. However, it was of little

assistance to the cooperating operators with respect to situations characterized by uncertainty or doubt: they could not, for instance, highlight on the display a suspicious object for further scrutiny and consultation. Instead, the operators had to revert to using a telephone connection to try to disambiguate and negotiate a resolution. This limitation was fundamental. For while the system incorporated computational primitives such as spatial coordinates, geographical entity, spatial sector, aerial object (identified or suspicious), flight vector, and so on, it did not incorporate primitives in terms of social organization, such as identity of individual operators, rank, etc. Tasks were assigned to sectors and only by implication to operators.

The Whirlwind architecture was made the basis of the ‘online transaction processing’ paradigm that is the model of systems such as airline reservation systems (first developed by IBM that also implemented the SAGE system) and later generalized as multiuser database systems such as accounting systems, CAD (computer-aided design) systems, or present online shopping systems (typically accessed via HTTP). This whole family of computing can be seen as continuing the rudimentary support of cooperative work: by providing a shared and continually updated digital representation of some part of the world (the airspace, the scheduled flights and the associated reservations, the inventory of the vendor) to which distributed actors can introduce changes for others to react to. The social organization of the cooperative work ensemble is only implicitly represented and the interactions of the actors are severely constrained: they can only introduce a limited set of changes to the state of the system (such as ‘select’, ‘track’, ‘put in shopping cart’, or ‘window type #23 here’). Ambiguities and contingencies must be handled outside of the system, for instance by meeting in the hallway or having a phone call.

However, beginning in the 1960s, this limitation was addressed in a series of technologies that in different ways include primitives of the social organization and at the same time offered more degrees of interactional freedom.

An important development of the rudimentary support for cooperative work facilitated by the online transaction processing paradigm is what was called ‘computer conferencing’. Instead of a database of, say, flight reservations, a computer conferencing system is a database of discrete textual comments that are related (typically, as a series of comments to a post). The first experimental system was designed by Murray Turoff and others. This is a sophisticated twist on the online transaction processing paradigm in that it retained the constrained set of interactional modalities (restricted to posting a comment and reacting to it) but combined it with the practically infinite degrees of (expressive) freedom offered by ordinary language). The computer-conferencing version of online transaction processing did not play a major role in the development of collaboration technologies until the introduction of the HTTP and HTML protocols provided highly general computational notations for constructing ‘hypermedia’ networks of interrelated and interrelatable messages (as exemplified by social computing platforms). While such systems today play an enormous role in public affairs, the limitations of the underlying technologies with respect to providing support to cooperative work are still present. The use of HTTP does not alter that, as it does not include primitives beyond the

address of the message. The social organization is represented by the identity of the interactants, messages can be interrelated by expressions of the type 'comment_on_<message_ID>', but actors are unable to add to or modify the computational protocol. This channel of structured message exchange offers little in terms of reducing the complexity of coordination of cooperative work.

A development of far greater significance is that of electronic mail or email. Email also originated as a twist on the online transaction processing paradigm, in that engineers involved in the development of time-sharing operating systems, in order to be able to communicate within the project, issued each project member's account on the host computer a special file to which everybody could write snippets of text while only the account owner could read it. The file was, consequently, called a MAILBOX file. It was not electronic mail in the modern sense, as the message text remained at the host computer. The mailbox principle was later generalized by engineers working on the development of ARPANET by appending the name ('address') of the residing host to the MAILBOX file name and was quickly modelled on the standard office memo (with fields such as from, to, cc, bcc, subject, and options such as reply-to, forward, attachments). Email has thereby given actors engaged in cooperative work and in socially organized activities in general the means of highly flexible written communication. But one limitation is related to the fixed general standard of the transmission protocol; the route of a message is determined by the content of the address fields and cannot be made contingent on changing circumstances (e.g., organizational conditions, message content).

These technical developments in the general area of computer-supported communication soon gave rise to studies of the use of these technologies with a view to understanding their possible impact, in the US typically under the label 'computer-mediated communication' (e.g., Kerr and Hiltz 1982; Kiesler et al. 1984), and in Europe mostly under the name 'teleinformatics' (e.g., Speth 1988). It soon became evident that the computer-supported communication paradigm has limitations when applied to the coordinative challenges characteristic of professional work settings. Indeed, actors engaged in cooperative work have to distribute their effort around objects (drawings, lines of codes, texts, sheets, ...) and this is where computing technologies offer great potential. To make 'the computer to work on our problems', as Greif puts it (Greif 1988), means devising computational artifacts incorporating a representation of the coordinative protocol so as to relieve actors of these often computationally heavy aspects of their work. For that to work, in practice, of course also requires shared digital representations of the world affected by the cooperative work effort (to *facilitate* the distributed effort) and message-passing technologies (to *mediate* the distributed effort); but the key issue for CSCW is that of regulating the distributed effort.

This challenge was first addressed squarely, beginning in the late 1970s and early 1980s, in the experimental development of computational notations for modelling and executing organizational protocols that, in principle, are visible to and modifiable by members of the cooperative ensemble (Ellis and Nutt 1980; Flores et al. 1988; Kreifelts 1984; Sluizer and Cashman 1984). This paradigm, with its emphasis on incorporating an explicit model of the

coordinative protocol (sometimes called a ‘process model’) in the computational artifact, has been realized, typically in applications based on online transaction processing, in a spectrum of organizational coordination systems such as production planning and control systems (MRP, ERP) workflow management systems scheduling systems; group calendar systems project management systems document management systems electronic patient records.

The challenge of developing techniques for constructing computational artifacts incorporating models of coordinative protocols that can be integrated in coordinative practices such that the models are or can be subsumed under the control of the cooperative ensemble can hardly be said to have to be met but has been addressed, tentatively, from different approaches (e.g., Agostini et al. 1993; Schmidt and Simone 1996; Simone et al. 1995) but the issue remains open.

The domain of coordinative practices is enormously varied, reflecting the diversity of the myriad techniques at work in manufacturing, metallurgy, production of microprocessor chips, transportation, administration, collection curation, health care, cooking, etc. It would be absurd to expect that one particular notation or modelling technique would fit all coordinative protocols.

Accordingly, a problem that cuts across the many strands of CSCW is that of transferring findings from one setting or type of setting to others. The problem arises on many levels. That is, what CSCW research faces is what CSCW as a research area has been facing all along, namely that of building ‘an analytic framework of some generality’, so as to be able not only to transfer findings and lessons learned from one study to the next but to do so in an accountable way. It is therefore essential that such a framework is ‘capable of retaining a sensitivity to the details and the variety of work domains’, and this in turn means that it ‘needs to be developed “from the ground up” as it were’ (Hughes et al. 1994, p.129)

Empirical studies of coordinative practices not only play an important role in CSCW; they are fundamental: not only because it is sensible to do requirements analysis before committing resources to building and implementing an application, but because the technologies to be applied are still in their infancy. CSCW is not a research area devoted to the study of particular settings but to the development of technologies that can then be applied, with a reasonable degree of confidence, to building computational artifacts for coordinative practices in particular settings. CSCW’s business is one of generalization from the bottom up.

5 CSCW Application Domains and Technologies

Because of such orientation, the starting point of CSCW as a research area is the acknowledgement that the articulation work that makes possible any cooperative activity is complex, and technologies that are appropriate to handle this complexity are needed. What enabled CSCW researchers to identify the issues that arise when any technology is applied to a cooperative work situation was not the (type of) technology itself nor the domain, but studies

bridging the gap between what technology can offer and its appropriation in specific settings (Ackerman 2000). What made these studies particularly valuable and the reason why they led to new concepts, frameworks and methods was their hybridity between socio scientific studies and design and computer science contributions ('Editorial' 1992). These studies have been conducted in numerous domains and featuring a broad range of technologies, rather than a uniquely identified type of 'groupware'. For summarizing purposes, we can categorize them in three groups.

Firstly, studies describing cooperative practices in such detail that they can be integrated into the design of future systems to support these practices. These practices can be manual or already digitized, using one system or a constellation of technologies. These studies aim either at informing the design of a particular system, or at defining design guidelines anticipating the complexity of cooperative work and of any intended intervention around these practices.

Secondly, studies following the deployment into a particular setting of a technology that was not specifically designed to support cooperative practices but that it is used thus in practice, identifying the issues faced when using systems that are not designed or deployed in a practice-centered manner, with a hope for future improvements.

Thirdly, studies following the deployment of collaborative systems designed with CSCW issues and insights in mind. This kind of work informs how the interactions between practices and technological features can take place, the factors that may support systems' adoption, and the ways in which the iterative development of systems should follow.

In other words, CSCW is addressing technology at different levels, at the same time *receptively* (i.e. observing how technologies or systems are introduced, can support cooperative practices, and are appropriated) and *proactively* (i.e. offering insights to systems designers, methodologies for practice-centered computing, and technology components) in relation to technology.

This chapter cannot describe or account for all the domains in which studies of cooperative work happened or for which systems have been observed or designed. However, we highlight select domains where significant work has been conducted that contributes significantly to the body of CSCW knowledge: control rooms, coordination centers and shop floors; large (service) organizations and public administrations; crisis response and management; healthcare; domestic work; heritage, data, and knowledge curation work; digital labor. For each, we refer to existing work corresponding to the three types of studies outlined above, and indicating why they are interesting exemplars. By doing so, we are illustrating both the diversity of CSCW domains and technologies, and the commonalities of the CSCW research agenda.

Early studies in CSCW were conducted in control rooms or coordination centers, with the idea that sociologists, or rather ethnomethodologists, would be able at the same time to finely explain how people work and what is relevant when doing their job, and to collaborate with computer scientists on the design of systems supporting work in these environments. One of

the first such ‘hybrid’ studies where ethnography and ethnomethodology were mobilized was an analysis of cooperative work in the London Underground control rooms in order to design and implement technologies in support (Heath and Luff 1991). This is historically important to CSCW and exemplary of the importance of empirical investigations of work practices and interpersonal communication to design systems, and of how the results of these investigations can be presented so that they can in turn inform design. In particular, it showed that such empirical approach enables to identify which artifacts are central for the activity and why, what kind of information is exchanged between co-workers, and in which forms, with which supporting artifacts, and which parts of the activity are routinized and which ones are regularly redefined. This identification of cooperative processes that are systematically applied in a work setting (even if they remain informal) is one of the core building blocks of CSCW knowledge, and has given rise to a number of frameworks or methods for identifying, modeling, or transferring them to design, as will be seen in the following section.

Another example, showing more concretely how to move from ethnographic inquiry of work situations to implications for design, features in one of the first issues of the CSCW Journal (Hughes, Randall, and Shapiro 1992), and reflects on interdisciplinary projects involving sociologists and computer scientists in the domain of air-traffic control. It shows again the risk of overlooking some features of cooperative work if a classical engineering approach is adopted, and, more importantly, it suggests ways to establish dialogue between social and computer scientists.

These early studies also discussed how systems that are not designed in a practice-centered way usually fail. For example, in the case of the introduction of a workflow system into the shopfloor of a print company (Bowers, Button, and Sharrock 1995), observing the technology in use highlighted how the lack of understanding of existing cooperative work practices (and supporting artifacts) causes critical problems by disrupting the usual smooth flow of work on the shopfloor. A conceptual distinction is made by the authors between workflow ‘from within’ (the methods internally defined and adopted by the organization so that the work can be properly achieved) and ‘from without’ (methods and procedures that are external to the existing practices, that establish another way of organizing the work rather than the one that exists). Tensions arise when workers have to follow a ‘workflow from without’ in order to produce accounts of their work, but this workflow does not correspond to the one from within. This study advocates that the introduction of technologies for accountability should be done in parallel with an empirical study of actual practices so that potential disruptions, new demands, and so on, can be anticipated and discussed, arguing that: ‘a naive view of cooperative work and its support has no place on the shopfloor’ (Bowers, Button, and Sharrock 1995, p. 66), which is a generalisable insight subsequently confirmed by studies of other domains. It is interesting to notice that fifteen years later, another study examined workflow systems and illuminated how workers try to make their work fit the systems, or develop workarounds, or ignore them, resonating with the findings of Bowers, Button and Sharrock. The case described in this later study (Martin et al. 2010) deals with the work of producing color prints, starting

with the fact that color management workflows were still only rarely successfully implemented in systems design. The in-depth analysis of the cooperative work to produce the prints shows that this implementation is difficult as the process itself is very complex and relies on an infrastructure characterized by different expertise types and devices that do not ‘speak the same language’. Implementing color management workflow systems would then mean adding a software layer in the existing infrastructure so that the process could be run.

Landmark CSCW studies also have been conducted in large service organizations and public administrations. In the 1990s, several attempts were made to deploy collaborative systems on a large scale, the design of which was taking into account the complexity of cooperative work. In particular, the work by (Bradner, Kellogg, and Erickson 1999) followed the deployment of Babble, a chat system, in six different groups at IBM, and analyzed the link between the technical properties of the system and the communicative practices they enable, looking at understanding how practices may influence the adoption of the chat system. This is an instance of the deployment of a system that focused on the interaction between practices and technical features, without neglecting either. Four practices that emerged while using Babble were identified (waylay, unobtrusive broadcast, staying in the loop, discussion sanctuary) and analyzed insofar as they supported or hindered the adoption of Babble in the different groups where it was introduced. This led to the development of concepts for understanding the adoption of collaborative systems, based on the interaction between the communicative practices and the features of the system: critical mass, social affordances, and interaction ecologies.

Another example relating to large service organisations is the analysis of the POLITeam system, supporting the digital transformation (although it was not called thus at that time) of administrative work in government ministries in Germany (Mark, Fuchs, and Sohlenkamp 1997). It revealed how conventions about the use of shared objects (for instance, how to name files) are established so that articulation work underpinning cooperation could occur, and how perspectives could be very different among users, which emphasizes the importance of conventions. Conventions need to be carried over from existing practices before the introduction of the system (for instance, the distinction between private and common spaces); conventions that are not easily understandable or applicable are often violated; conventions cannot always be planned top-down, and can, on the contrary, emerge with the use of a system that creates new work processes. The authors conclude that for conventions to emerge and be adopted in collaborative systems, systems have to allow a shared awareness of the use of shared objects.

Other service organizations were studied by CSCW researchers focusing on existing practices in order to design future systems. Practices of help-giving are finely described, thanks to investigations in two different work domains: a library where the help desk support people are co-located with the help seekers; and a print service that relies on remote help from a call center (Crabtree et al. 2006). These two cases allowed the identification of methods of articulation in

help seeking/giving situations: help seeking/giving starts by initial formulations of a problem, followed by a translation of vernacular descriptions, reformulations and refinements of the problem's description, and finally the use of instructions to articulate candidate solutions. A fine-grained analysis of help-giving practices is needed for designing systems in support of the articulation work between the help seeker and the help provider, and design should focus on the resources that have to be shared to articulate this work.

A domain where very significant CSCW research has been conducted over the years is healthcare. In-depth studies mainly in hospital settings in Europe and in the US, have shed light on the complexity of healthcare work, demonstrating the important role of time (Reddy et al. 2006), place (Bardram and Bossen 2005), documents (Heath and Luff 1996; Schneider and Wagner 1992), and how they are interrelated (Bjørn and Hertzum 2011; Østerlund 2008). These practices and their complexity are often not taken into account in the design of healthcare information systems (Hartwood et al. 2003). Researchers have therefore demonstrated that relying on standardized technical solutions to deal with local socio-technical problems does not lead to the benefits that are claimed by policy makers and managers in relation to introducing new systems, such as for example with the deployment of electronic medical records (Hartwood et al. 2003). Indeed, numerous studies have described the important roles (e.g. medical secretaries) and/or mechanisms (e.g. note taking) put in place by healthcare actors that are totally ignored by large standardized systems (Abraham and Reddy 2008; Bansler et al. 2016; Bossen et al. 2012). The reflexive review by (Fitzpatrick and Ellingsen 2013) on 25 years of CSCW studies in healthcare settings (published in the Jubilee issue of the CSCW Journal) consolidates the considerable body of knowledge within the discipline up to 2013.

Another kind of collaborative work examined within CSCW is the curating of data – be it scientific or cultural data - to produce or present knowledge to the public. Longitudinal ethnographic studies of this highly complex activity (one that may not be highly standardized and routinized) revealed cooperative practices the conceptualizations of which are also relevant for other domains. For example, the observation and analysis of a team of museum exhibition designers, and how do they use artifacts to coordinate their work (Lee 2007) clarified the roles of material artifacts in cooperative practices, and offered the concept of ‘boundary negotiating artifacts’ that characterizes the role of material artifacts in non-routine work, and by so doing offers a more precise concept than the one of boundary object. Indeed, boundary negotiating artifacts can be of different types: self-explanation, inclusion, compilation, structuring, and borrowing - each type being intertwined in an ensemble of practices. A more recent study of how a team of researchers prepared an astronomical catalogue (Hoeppe 2021) showed how the structure of a data set is collectively defined and refined, and how the collective knowledge created through the negotiation of how to build or fix a data set can be encoded in the catalogue itself so that so it instructs its users on how to use it.

CSCW researchers have followed the evolution of work and the environments, organisational settings and labor conditions that have emerged over the decades, and have looked at how digital platforms shape different working environments (for a literature review see (Dillahunt et al. 2017)). This work informs us on how existing platforms are structured and used (Bødker, Lewkowicz, and Boden 2020; Sutherland and Jarrahi 2017), and raises issues about the conditions in these new workplaces and types of labor (Hui et al. 2018; Martin et al. 2016). Attention has been paid to how work is done also in non-designated and non-institutional workplaces, such as in the case of transitional environments or informal locations (Ciolfi and De Carvalho 2014; Lee et al 2019). It is also important to note that CSCW researchers are looking for alternative socio-technical models, in particular how to support member-owned businesses with cooperatives (Lampinen et al. 2018), sustain local sharing initiatives (Light and Miskelly 2019), create alliances to bypass algorithms (Kinder, Jarrahi, and Sutherland 2019), or find ways to rate and even contest working conditions (Harmon and Silberman 2019).

Collaborative activities outside of paid employment, such as volunteering, have also been examined, including the labor of individuals working with a community of others remotely or fully virtually (Menking and Erickson 2015). One of the most prominently researched of these domains is crisis response and management, which involves an intensive use of social computing tools and platforms. Indeed, social computing – both globally established brands and small scale systems - increasingly feature in the cooperative work of self-organized groups and volunteer communities due to their availability and familiarity. CSCW research in this area is closely adjacent to social computing and communication studies. In (White, Palen, and Anderson 2014), for instance, we learn how large emergent groups organize themselves to engage in coordinated action when they need to be mobilized in the face of a crisis, and so to act fast and in a constrained – and often severely disrupted - environment. Cooperative work practices emerged to rescue pets after Hurricane Sandy in the USA, and a seven-month study of volunteers coordinating action via a social media page shed light on the mechanisms by which collective action in digital environments can be organized. The features of the platform that shaped the group's activities were identified, and so were the ways in which cooperative practices (in this case, matching between lost and found pets) emerged, and how the information was structured and shared so that the work was made accountable (for instance by communicating the resolution of lost pet cases). The use of social media during the European Floods of 2013 was examined by combining an observation of posts and interviews with digital volunteers (Reuter et al. 2015). This led to identify challenges for the organization of volunteer work and to suggest the design of a cross-social-media application for moderators of groups of volunteers. These moderators mediate offers of and demands for help with the use of the technical functions of the social networks. Moderators tested the application, which allowed the authors to discuss their design requirements and identify the main challenges when designing for moderators.

Another prominent place where (largely unpaid and/or voluntary) cooperative activity takes place is the home, and numerous studies have been conducted in domestic settings, documenting how the members of an household collectively build assemblage of artifacts (Crabtree and Tolmie 2016), or are involved in the bricolage of existing devices (Procter et al. 2014). Other studies have observed existing practices in order to derive design implications to support these domestic activities, being for instance do-it-yourself (Wolf, Ringland, and Hayes 2019), household administration and engagement with public services (Verne and Bratteteig 2016), or care work among family members and between families and professional carers (Christensen and Grönvall 2011).

6. Research Approaches in CSCW

Due to the variety within the bazaar that is CSCW, there is no one approach (either epistemological or methodological) that the entire field adopts. The legacy of a hybrid constitution of the field and the heterogeneity of CSCW research agendas have also meant the convergence of a number of framing and practical approaches to shape empirical work, and a correspondingly variegated and fragmented adoption. As well as the repertoire of CSCW concepts and theoretical frames having been informed by cognate fields, CSCW research also draws from other traditions in terms of applied approaches, although some indigenous ones have emerged as the field has grown and matured.

First of all, the scope of CSCW research and the range of domains studied are broad, and therefore approaches may be focusing on different research challenges: from understanding and describing (computer-supported) collaboration and aspects thereof (be it intended as behavior or as socially and/or organizationally situated practice), to designing collaborative systems and interactions covering the span from conceptual design to technical systems development, and evaluating and analyzing the features of cooperative systems in use. Due to such complexity, approaches can be described and discussed at different levels of conceptual and empirical granularity. Here we present something of both to illuminate how CSCW research is approached, also as there are often correlations between particular framing approaches to thinking about CSCW phenomena and issues, and the actual techniques that are applied to tackle CSCW problems. Naturally, more distinctions could be made in relation to even broader paradigms (such as qualitative and quantitative) and their adoption within CSCW but those are best left to research methods handbooks.

Some approaches are derived from human factors and cognitive psychology and focus on the ‘mechanics’ and ‘taxonomies’ of collaboration: ways to analyze social and collaborative behaviors and to create models that can be operationalized for analytical or implementation purposes (e.g. Grudin and Poltrock 2012; Olson & Olson 2003). For example, such models are often used for forming design specifications or for conducting evaluations of collaborative

systems. Some psychological research approaches are grounded in experimental methods, meaning lab-based studies and protocols of research design that are independent from organizational contexts, although often do consider to a certain extent cultural contexts in relation to how they influence some individual characteristics.

The sociocultural approach in psychology has influenced CSCW as well as HCI, with approaches such as Distributed Cognition and Activity Theory being adopted to conceptually and methodologically examine actors, activities, patterns of collaboration and related tools and artifacts in context (Kuutti 1996) and therefore have predicated the adoption of field-based methods. The set of CSCW approaches also draws from organizational studies, sociology of work and Science and Technology Studies (STS) to understand cooperative work more broadly in organizational contexts, and to capture organizational aspects (managerial, political, historical, and cultural) that might shape collaboration, its actors, and the artifacts involved.

Such conceptual lenses to make sense of why people and groups act in the world as they do align with a methodological stance grounded on fieldwork and field studies that, as we have seen, has been widely embraced by CSCW researchers from the inception of the field. The emphasis on field-based approaches – particularly ethnography - and the argument for their validity in relation to computer systems research is very significant in CSCW overall, and a major historical legacy of the field with wider influence and reach into HCI and human-centered computing more broadly. At the core were both the need to expand the range of socio-scientific approaches so to capture situated aspects of collaborative conduct, and the argument for a more embedded and situated approach to introducing collaborative systems into work settings and organizations based on ‘studying phenomena in their natural settings, taking a holistic view, providing a descriptive understanding, and taking a members’ perspective’ (Blomberg & Karasti 2013, p.374).

Ethnographic studies in CSCW generated considerable empirical knowledge of various work settings, such as coordination centers, and particularly of safety critical work and the systems to support it that was before then the province of human factors: from Air Traffic Control and other transportation control systems to emergency management, as discussed earlier in this chapter.

Ethnographic approaches had impact beyond expanding the CSCW repertoire of techniques, i.e. the ‘toolbox’ available for documenting phenomena and reporting accounts of them. Rather, as an ‘explanatory frame by which this account can be organized (...) ethnography provides new lenses through which to see the world (...) Ethnographic inquiries can illuminate the practices of particular peoples, but it does more; through this, it explores the generally operative principles by which these practices are shaped, shared, reproduced and transformed’ (Dourish 2006, p. 547).

From Lucy Suchman’s early study of auditors in 1983, to the exemplary studies of coordination centers discussed earlier, ethnography in CSCW has not just been a way of defining

requirements for system design, but played a fundamental role in upsetting the management and engineering-driven notion of work and practices, and driving conceptualizations of key facets of the articulation work of cooperation and coordination. Ethnomethodology and Conversation Analysis (EMCA), critical of 'classical' ethnography with roots in anthropological fieldwork, found a conducive home in CSCW for the understanding of workaday social interactions producing social order. This approach led to a strong tradition of ethnomethodological 'workplace studies': fine-grained examinations of social interactions and naturally occurring workplace activities in everyday settings. The focus is not just on accounting for practices but on the reasons why actors are doing the things they do in the way they do them, which clearly aids the process of designing systems.

Ethnographic and ethnomethodological studies of everyday collaborative interactions have since moved beyond workplaces, to include for example leisure, domestic practices, community initiatives, etc. A recent instance examines social interactions featuring systems such as conversational user interfaces and smart assistants as they are used by families in the home (Porcheron et al 2018).

The common trait across this body of field-based approaches is the focus on the materiality and sociality of collaborative activities: 'Ethnographic research has given us insights into the ways artifacts such as paper documents, computer displays, timetables, whiteboard, and maps enable people to work together, aligning their actions with those of others' (Blomberg and Karasti 2013, p. 381). Furthermore, ethnographic approaches in CSCW also extended to online ethnography (Nardi 2010). As social life unfolds more and more via global platforms, researchers have applied techniques such as observations to the online realms of social networks and gaming platforms. Communication and media studies research has been an influence on how to design and tackle fieldwork online and to make sense of online environments as field sites. Approaches shaped by social psychology that look at categorizing the characteristics of groups and their members, group tasks, the forming of shared goals, and certain contextual and situational factors influencing group dynamics have been core to Computer-Mediated Communication, closely related to some quarters of CSCW research, particularly to study remote collaboration, coordination, and cooperation (Olson and Olson 2013), and which has expanded to examine large scale online communities and the practices occurring on social computing platforms. However there has been debate on the ethics and implications of researchers doing fieldwork online, particularly in large online communities and in relation to collecting public online data (Vitak, Shilton and Ashktorab 2016; Zimmer 2010). Qualitative CSCW research on social media platforms also extensively relies on techniques such as surveys and interviews, often in combination with monitoring online behavior (Lampe et al 2010). The growth of global platforms has brought into CSCW also approaches for the study of collaborative knowledge creation and production at scale (Bruckman 2022), drawing insights and methods also from information science, data science and STS – such as, for example, trace ethnography (Geiger and Ribes 2011).

Instances of higher level framework approaches have also been adopted within CSCW in order to capture ‘the socio-technical’ in a broad sense. These include for example Actor Network Theory, sociomateriality (Orlikowski and Scott 2008), and participatory action research. In some instances, ‘big sociology’ approaches have been useful to generate models of interpersonal networks and exchanges, from social network analysis to other computational models of collaborative ties. Their adoption is increasingly linked to a big data approach to understanding cooperation at scale, particularly on large social media platforms (Starbird, Arif and Wilson 2019).

This overview is not exhaustive and only intended to delineate notable examples of approaches, which are also inevitably destined to grow. For instance, as issues to do with politics, justice, and equity become more prominent in CSCW, the field is further opening up to relevant epistemologies from other fields that have tackled these topics, also in relation to technological development (Chancellor et al 2019).

The overview also hints at the question of whether CSCW is more inclined to adopt and appropriate frameworks and methods from relevant fields, rather than to develop its own. As discussed earlier in this chapter, CSCW has long faced the challenge of building ‘an analytic framework of some generality’ but nonetheless ‘capable of retaining a sensitivity to the details and the variety of work domains’ (Hughes et al. 1994, p.129). While this question remains open as CSCW lends itself to incorporating an eclectic array of approaches, it has also produced indigenous ones. Analytic frameworks are being built mainly through a suite of synthesising concepts that have been identified ‘from the ground up’ in domain-specific studies, as we have illustrated, rather than top-down theories.

Schmidt (2018) argues for a practice-centered computing approach in CSCW by virtue of the very nature and orientation of the field, as discussed earlier. Indeed, the ‘European’ CSCW tradition has long embraced a practice-centered approach and developed programmatic frameworks and concepts on this basis, in contrast to approaches where the design of systems to support cooperative work is based on models or patterns of activity (often formed in controlled conditions) that do not refer to actual practice, its contingencies, variations, local circumstances, etc. (Schmidt 2018).

Building on such situated view of collaborative work has led to the development of ‘strong concepts’ and conceptual frameworks, often intended to critically approach systems design, although the relationship and mutual interdependency between conceptual and design approaches is not linear and thus hard to unpack.

The proposition of design ethnography emerged in CSCW from the argument for ethnographic fieldwork as directly relevant for the design of systems (Randall, Rouncefield and Harper 2007). The Locales Framework (Fitzpatrick, 2003) builds on the concepts of situated action and place to both evaluate and design collaborative systems in organisations. Sociomaterial-

Design (Bjørn and Østerlund 2014) links design research to sociomateriality as analytical lens accounting for the entangled and mutually constituting nature of materials, people, and practices. Grounded Design (Stevens et al 2018) is based on the understanding of the relationship between social practices and the design space for systems built to support them (Stevens et al 2018). The core technique of this approach is Design Case Studies that sensitively examine and capture complex social practices for contributing to the design of IT artifacts. A Design Case Study is in turn articulated into context study, design study, appropriation study: ‘because actual design practices are reflective and iterative, these activities are treated as overlapping, interleaving, and recursive’ (Wulf et al. 2011, p 7). Grounded Design also aims at building ‘sensitizing concepts’ by aggregating and comparing case studies, in a manner inspired by abductive Grounded Theory (Wulf et al. 2011).

Besides design frameworks, several design techniques have garnered considerable adoption in CSCW. A notable example is participatory approaches to design and related techniques, particularly drawing from the Scandinavian tradition of Participatory Design (PD) (Kensing and Blomberg 1998). There are affinities between CSCW and PD in terms of methodological stances and actual techniques, and a more general resonance in terms of an ethos towards people, groups and their practices, of recognition of participants’ expertise in accomplishing work and collaboration, and of the importance of representing stakeholder voices in understanding and designing for work practices. Some community-oriented CSCW research is also heavily adopting participatory approaches drawn from community-led co-design.

While providing a detailed catalogue and descriptions of specific methods goes beyond the scope of this chapter, it is worth mentioning some key examples insofar as they have been influential in shaping how design activities are planned and what they look like in CSCW research, in a manner similar to HCI. Workshops (and workshoping) are widely used as a focused design activity in CSCW projects, and a core frame for bringing together participants, stakeholders and researchers in various design and co-creation techniques. Scenario-based design has been conducive of design based on fieldwork, as it facilitates the envisioning of systems in rich contexts of practice. It is a common workshop technique, but also often used in longer-term design processes by research teams, and often with a strong focus on particular domains for design (Bardram 2000). Since their introduction, Cultural Probes (Gaver, Dunne and Pacenti 1999) have been adopted and adapted widely in CSCW as well as HCI. They have been particularly useful to facilitate design exploration and engage participants in sensitive and emotionally-resonant contexts (e.g. older populations, care settings, patient groups, etc.), and as part of longer-term partnership projects allowing for inspirational materials to be contributed across longer time spans and used to shape design together with more traditional datasets. Technology probes are a notable technique that resonates with the hybridity of CSCW as concerned with both technology and how people and teams use it in practice.

Overall, a variety of approaches have been adopted within CSCW at various levels and in various ways for understanding and designing for computer-supported collaboration. As well as embracing approaches originating from cognate fields, there has been substantial development of concepts, frameworks, and models that have been adopted, applied, expanded, and critiqued to various extent. While it is not possible to describe all of them here, we illustrated some major instances and how various traditions have been shaped by particular approaches. One overall remark worth making is about the role that CSCW played in showing the importance of in-depth studies capturing the complexities of human practices, in terms of computer-supported collaboration but more in general for the broader human-centered computing field, and not only in terms of so-called ‘implications for design’ (Dourish 2006). CSCW researchers have also engaged self-reflexively in debates about how such understanding of collaborative practices is formed and in approaching their subject matter, identifying various threads within the community (Kensing and Blomberg 1998; Müller et al 2015; Randall, Rouncefield and Tolmie 2021).

7. Summary and Future Directions

CSCW is work in progress. Bringing together, and uniting, research on the applicability of a disparate family of collaborative computing technologies to an even more heterogeneous array of domains necessarily involve the ongoing conceptual effort of identifying commonalities among requirements and technical solutions so as to build, from the bottom up, through meticulous comparative analysis, the generalizations that are necessary for researchers, designers, and users be able to design and adopt computational artifacts to relieve the complexity of coordinative practices.

This work is ongoing but has made significant progress since the first steps were taken in the nineteen eighties. As a research area, CSCW has clarified its focus. The object of research is not cooperative work *per se* but the coordinative practices that are particularly complex in typical work settings but also pose significant challenges to the orderly conduct of collaborative activities in many other walks of social life. Furthermore, the concept of practice, increasingly understood in the Wittgensteinian sense of normatively regulated contingent activities, has moved center stage over the years, and is now the concept upon which comparative analysis and generalization work in CSCW hinges. As a key part of this conceptual development, CSCW research have found extremely useful to focus on the ‘materiality’ of social interaction in general and coordinative practices in particular. There is thus close to consensus in CSCW that systematic attention to the roles played by coordinative and other material artifacts in coordinative practices is a crucial methodological precept.

Given the heterogeneity of CSCW this is no mean feat. What has made it possible is, in part, that the research has been institutionalized in the form of relatively few conference series (ACM CSCW, ACM GROUP, ECSCW and lately also the CSCW subcommittee of CHI) and

the CSCW Journal, and that these stable venues have been anchored organizationally in the formation of steering committees for the ACM conferences and of professional associations such as EUSSET. This has made it possible for the otherwise disparate research activities to be related and also to clash. These organizational frameworks serve as forums where debates occur, where new members join, and where decisions are made that shape how CSCW will develop.

The research program remains lively and timely, as witnessed by recently arrived themes such as collaborative computing for community activism, working-from-home, advanced manufacturing, and possible applications of machine learning in cooperative work and social interaction. This also goes to show that CSCW research is committed to social relevance and manages to have a lot to say about current issues.

But because the technological foundations of CSCW are shifting and evolving, CSCW is in flux. Consequently, CSCW remains what it always was, a hub where disparate efforts meet to explore possible commonalities, compare notes, as it were, and to develop generalizations from lessons learned. That is, CSCW is also, in some — significant — sense, like a railway station, a junction where researchers often arrive with a practical technical or organizational problem, explore from a CSCW perspective, and then leave with what they have learned, bringing it back to their home domain, or depart for other destinations.

Under these conditions, to prevent fragmentation and even loss of accumulated knowledge, and also to enable knowledge building (Soden et al 2021), it is crucial for CSCW to work systematically towards consolidation, for instance, by giving priority to review articles that carefully and systematically map research findings (by domain or technology or methodology). That is, for CSCW as a research area to remain progressive it is crucial that the work of generalization is undertaken in a manner that reprocess the accumulated knowledge so as to reproduce and reconsolidate it.

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