Physicality and Cooperative Design

Dhaval Vyas, Dirk Heylen and Anton Nijholt

Human Media Interaction Group, Dept. of Computer Science, University of Twente,
PO Box 217, 7500 AE Enschede, the Netherlands

d.m.vyas@ewi.utwente.nl

Abstract. CSCW researchers have increasingly come to realize that material work setting and its population of artefacts play a crucial part in coordination of distributed or co-located work. This paper uses the notion of physicality as a basis to understand cooperative work. Using examples from an ongoing fieldwork on cooperative design practices, it provides a conceptual understanding of physicality and shows that material settings and co-worker's working practices play an important role in understanding physicality of cooperative design.

Keywords: Physicality, Cooperative Design, Artefacts, CSCW.

1 Introduction

Amongst its several definitions, the term *physical*[1] means something that has "material existence" or a thing that is "perceivable through senses" and "subject to the laws of nature". And the term *physicality* can be seen as an attribute or characteristic of a physical nature. The basis of human physicality (embodiment) allows us to see, talk and perform collaborative activities when we are in a shared physical space. In this case, human physicality makes the perceptual resources (visibility, sound, touch, smell or taste – any of the applicable) available to form the basis of human-to-human interaction. However, when humans do not share a physical space, it is necessary to have some technological means to support and mediate human interaction by utilizing these perceptual cues.

People use a certain language when they are involved in group activities. In fact, from the historical and evolutionary point of view, languages have emerged from joint activities of individuals working in small groups [4]. However, Clark [3] suggests that in everyday group activities, our coordination acts are not limited only to the linguistic signals but also the 'material' signals – signals in which we communicate through material artefacts, locations and our embodied actions. Keeping Clark's argument as a central theme, this paper explores the importance of physicality in the field of computer supported cooperative work (CSCW). Using examples from

1. Merriam-Webster Collegiate Dictionary. HarperCollins; 11th Edition.

naturalistic cooperative design practices, we show that both the material settings and co-worker's working practices play an important role in understanding physicality in work environments.

Despite its importance, the role of physicality in cooperative work has been under explored within the HCI and CSCW communities. Often, CSCW studies have shown a certain analytic primacy to verbal languages and linguistic conversations in collaboration. Despite the rich ethnographic tradition within CSCW and interest in analyzing technology-in-practice [15], the ways in which material artefacts are used remains surprisingly neglected [26]. We believe that an analysis of seemingly simple activities with artefacts may have important implications for our understanding of collaborative work. This is even more relevant when teams are from domain such as design, engineering and architecture – teams that use a variety of tools, objects and artefacts to support their 'simultaneous' work. The skilled and timely use of these artefacts, their availability, exchange and manipulation, is an integral feature of the accomplishment of complex collaborative activities that these domains represent.

The interest in understanding and designing for physicality has grown in recent time [5]. A handful of studies have indeed shown that material aspects play an important role in coordinating co-located and distributed activities. Several CSCW and design studies have approached materiality as supporting accountability [7], affordances [23] and coordination [10]. Others have argued that in specific cases, as in architectural practices [22], medical hospitals [2] and meeting rooms [19], a considerable part of work is coordinated through material artefacts, like paper documents, notice boards, architecture plans and drawings. In a recent work, it is shown that materiality can play performative, persuasive and experiential roles in coordinating collaborative design work [13].

Within AMIDA project, we have been focusing on understanding the role of physicality in meeting practices [28] and designing new ways to support remote collaboration. In this paper, we aim to provide a conceptual understanding of physicality, showing how 1) the materiality of work settings and 2) co-workers' working practices can contribute towards the collaboration of teams involved in co-located design practices. We illustrate this, using examples from our ongoing fieldwork of naturalistic design practices. We believe that a thoughtful consideration of these two aspects can contribute to the design of new technological tools for collaborative work without impoverishing what individuals do in their day to day working lives.

In the following sections we first describe the reason for our take on physicality. We then describe the conceptual understanding of physicality for supporting collaborative work. In the end we discuss the usefulness of the physicality approach.

2 Why Turn to Physicality

We describe several aspects that motivated us to look at physicality for understanding cooperative work of designers.

Utilizing materiality. Materiality of artefacts have a wide range of physical properties such as texture (roughness or smoothness, details), spatial (size, shape,

proportion, location in space), material (weight, rigidity, plasticity), energy (temperature, moisture), as well as other dynamic properties. The role of materiality in coordinating team work has been echoed by several researchers in HCI and CSCW [7, 10, 23]. Several field studies of collaborative work have shown that materiality expands communicative and collaborative resources, e.g. the study of paper use in large organizations [23]. Additionally, materiality of a physical object supports wider resources for actions compared to what current desktop metaphors support [9]. Material artefacts also have evocative, referential and peripheral functions that allow direct and bodily engagement with materiality [12]. Moreover, there is a lack of understanding about how to utilize material and physical aspects for design purposes within CSCW. Schmidt and Wagner [22] argue that conceptual frameworks of understanding contexts (such as distributed cognition, activity theory and actor-network theory) do not adequately address the usefulness of materiality. For example, within the framework of Distributed Cognition (DCog), Hutchins [10] shows that information migrates from the minds of actors to artefacts and back to mind without any 'change', maintaining unity and integrity across several instances of physicality, minds and time. The DCog framework does not address how the materiality of artefacts may affect the affordances of the actors. (Read [22] for a detailed discussion)

The design domain. Several CSCW studies have focused on designing systems with a view to support the cooperative work practices of specialized knowledge workers like designers, architects, engineers and doctors [16, 17, 19, 22, 25, 26]. Because of the nature of design practices, the interest in physicality in design work is pretty obvious. Designers, whose intention is to produce tangible products, communicate through a varied set of design representations often involving different materials, modalities and scale. To an extent, the whole design practice progresses through the use and manipulations of these representations and iterative refinements of both the conceptual and physical designs of products to be designed. Jacucci and Wegner [12] look at the creative and experiential side of physicality. In their work on understanding the design practices of students, they suggest that physicality spur designers' thinking, help them communicate ideas that would be difficult to communicate through words alone. Schön's [20] work on *the reflective practitioners* also emphasizes the 'conversational relationship' of designers with the medium they are interacting with.

Awareness and coordination. Understanding how material artefacts within a work environment are organized, configured, manipulated and handled could enhance the awareness of co-workers' activities and coordination of work. Awareness has been an important issue in supporting cooperative work. Taking a phenomenological stance, Robertson [18] has shown that physicality sheds light on establishing an understanding of awareness as a continuous and lived phenomenon. She suggests that if the participants in a cooperative process can be aware of what other people are doing, or have done, then the agency for structuring interaction and cooperative processes in the workplace can be claimed and practiced by the people using the technology [17]. In the case of design practice, the arrangement or configuration of material artefacts used in design process provide some useful perceptual resources that could allow participants to anticipate and structure a set of action.

Ubiquitous applications. Our particular interest in physicality is intended towards augmenting artefacts with computing capabilities taking into account co-workers

natural practices. We believe that in order to develop efficient and effective ubiquitous technologies [29] we need to have a wide range of understandings of the ways in which the mundane artefacts are used within the everyday practical design activities. A large part of the CSCW research has focused on the mediaspaces applications – supporting remote communication through audio-video links [1]. It has been argued that because of the impoverished understanding of 'collaborative work' [8, 21], researchers could not achieve efficient and seamless coordination between distributed teams. New approaches like tangible interfaces [27] have emerged within this theme but they are mainly for 'one' user and do not support much collaboration [9]. In some cases when these applications support collaboration, they are mainly for supporting the co-located activities, using, for example, tabletop interfaces [e.g. 24]. Ishii's work on TeamWorkStations allows a shared drawing space for distant participants to coordinate their work [11]. However, the use of work practice studies to inform the design of ubiquitous applications is still lacking in the current research.

3 Physicality and Cooperative Work

Cooperative work is about supporting communication between two or more actors by establishing mutual understanding ("common ground") about the subject of conversation [6]. This mutual or shared understanding is not a precondition of cooperative work but it is obtained and maintained only as a result of articulation efforts. The distributed activities of the actors in a cooperative situation are *interdependent* in the sense that they contribute to the overall process of a shared practice of work. In order to contribute purposefully to the cooperative effort, each actor needs access to information pertaining to the state of the work: what is the situation, what has happened, what is happening currently, what might happen, and so on. We consider successful coordination in co-located and distributed teams as the situation where all participants can monitor, notify, share, allocate, mesh, or interrelate each other's distributed individual activities in an effective manner. As an example from a non-computing domain, Dix [6] discusses, in his framework of CSCW, how two actors trying to move a piano coordinate their activities. Even though the two actors cannot see each other very well the feedback that they receive from each other's activities – mediated through the material properties of the piano – help them make sense of each other's moving process. In the case of computer mediated communication the same process occurs. Actors who cannot see each other can be aware of each other's actions as mediated in different ways.

We discuss physicality at two levels: the materiality of the work setting and the social practices of the co-workers involved in the interaction. What seems to make an artefact meaningful to an actor is the interplay of its materiality and the practice within which the artefact is used or developed. Figure 1 provides our initial understanding of physicality as a lens to understand cooperative work. In order to support effective coordination (C), we need to understand both the materiality (A) of the overall work setting and the practice within which this materiality is utilized (B). Here (A) and (B) are mutually dependent: sometimes facilitating and sometimes constraining each other.

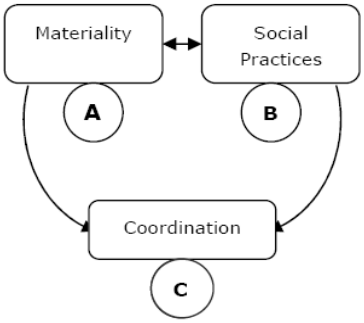


Fig 1. A conceptual understanding of physicality for understanding cooperative work. The interplay between the materiality of the work setting and social practices of the co-workers could support coordination of work.

In the following sub-sections, we will discuss issues related to the materiality of work environments and the social practices of co-workers and how both contribute towards the collaborative work. We also provide examples from our ongoing fieldwork of co-located design practices to support our discussion.

3.1 Materiality of Work Setting

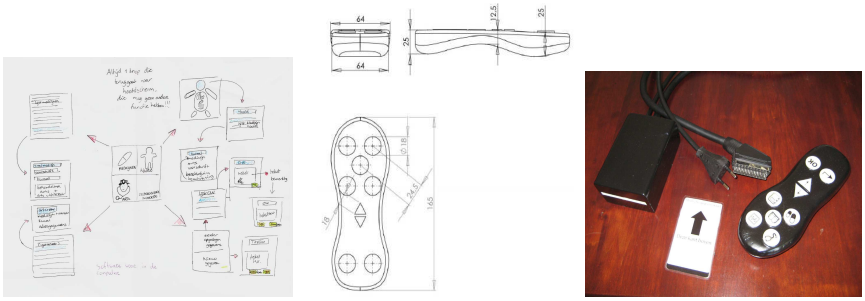
Design practitioners use a plethora of material artefacts to support their work. In order to understand designers' collaborative work practices one needs to take into account how these artefacts play a role in their work. As such, the use and manipulation of these artefacts is not a given, neither these artefacts exist objectively in designers' everyday practices, but they are constructed in and through the process of design. Additionally, the materiality of artefacts can be seen in two different ways: materiality as a tool to support work and, materiality as representations of work. Artefacts such as drawing board, scale, pencil and others are used as tools to support designers' work. Whereas artefacts such as design sketch, clay or 3D model can be considered as representations of design process. In the following, we provide several characteristics of materiality of a cooperative design setting, supported by some examples from our own fieldwork with designers.

We use a specific case in our discussion, where student designers were involved in designing a health-care system for supporting everyday medical care of the elderly. They developed an interface for a set-top box attached to a television that can be operated through a specialized remote control. We captured their complete design cycle and analyze the role of artefacts in the design process.

Representational. Material artefacts often used and produced during design practices such as paper drawings, physical or graphical models can serve as representations of a cooperative work. In Bruno Latour's [14] terms, these representations have the characteristics of immutability and mobility. I.e. these artefacts can work as a persistent form of information as well as a carrier for information that can be moved in our out of the work space in order to support

efficient collaboration amongst different co-workers. For example, Sellen and Harper [23] have utilized the concept of affordances of papers. They show that the physical properties of paper (its being thin, light, porous, opaque, flexible, and so on) afford many different human actions, such as grasping, carrying, manipulating, folding, and in combination with a marking tool, writing on. Central to their notion of affordance is the materiality of artefacts. The immutability and mobility of artefacts, designed or used during a design process, allow co-workers to collaborate and coordinate work amongst themselves.

From our fieldwork we observed several examples of design representations depicting different stages of design (figure 2). These representations, in the form of a design sketch or a detailed design carry a great number of conventions, notations and layers that can be very useful when designers collaborate with each other and allow them to extract information they need. They can also extract the details of notation, format, and syntax underlying their form and use, such as the specific techniques involved in working with maps, charts or matrices. The important issue here is that the materiality of different design representations can afford and trigger different collaborative actions in the design team.



(a) **(b)** **(c)**

Fig 2. Examples of different levels of design representations: (a) Information architecture of the health-care system, (b) Detailed design of the remote control and (c) Final product.

Multi-modality. The multi-modality supported by material artefacts can provide a better understanding of a design practice as opposed to the sequential text or speech. Considering different stages of any design process, designers produce different models of the product they are trying to build. This could range from a conceptual stage in a sketch, to a card-board model, to a full prototype. Figure 3 shows some examples from our fieldwork that provides indication about different levels of multi-modality of the design artefacts. As can be seen in the figure, the multi-modality of these artefacts involves two dimensional hand-made drawing (3a), to three-dimensional physical object (3b) to a software-based representation (3c). It is important to note that these variations influence the properties of a representation and suggest or enable different usages, interaction styles and variations in meaning, even if they represent the same object, idea or concept. Each of these models can be seen as having a specific 'mode' of expression, when put together forms a multi-modal representation of the design concept. The materiality of these artefacts connote a variety of qualities that are connected to the designers' senses (vision, sound, smell or

touch) and vary with parameters such as weight, thickness, transparency, and so on. It is this multi-modality that turns the materiality of an artefact into a source of multiple channels of interactions that could lead to rich experiences.

(a) **(b)** **(c)**

Fig 3. Examples of different design modalities: (a) A drawing of design scenario, (b) Physical remote control created in the studio and (c) Software interface of the final product.

Temporality. The temporality of different material artefacts could help establishing an understanding of the process that is used in the cooperative design work. Figure 4 shows three different stages of the design of the remote control used to operate the set-top box of the elderly-care system. Because of the iterative nature of the design process, temporality becomes especially relevant since there will be a need to understand, explain and mediate the design activities involved in it. The temporal dimension of the materiality of artefacts points to different time frames too.

Fig 4. Different stages of the design of remote control.

Additionally, designers produce different models and representations throughout the different stages of design such as, text, diagrams, comics, and video clips to sketch models, virtual models, and physical prototypes. The materiality of these representational artefacts could provide a great deal of information about the way they are created, used and manipulated, conveying the process that is applied in designing. Importantly, the temporality here server not only as indicative of different stages of design it also serves for accountability (planning, managing, budgeting, and so on) of the design work. A thorough insight into different artefacts produced during a design process could lead to some indication about change of plan, change of methods or any other deviations during the cooperative work. Especially in the collaborative design processes, these artefacts provide cues and signals for the co-workers to appreciate the intention of colleagues and the challenges and problems that are faced by the others. The temporality is indicative of the design-in-progress which is of paramount

importance in cooperative work.

Spatiality. The use and design of artefacts is often connected to their specific physical form and positioning in an environment. In addition the way a set of artefacts are organized could provide useful information about their relevance in the design process. Spatiality is not only a practical property of an artefact but it supports interactions and communications amongst several co-workers and is often used as a thinking tool. For example, in a brain storming session (normally, early in the design process) designers collect their ideas in sticky-notes and position them and group them in a certain way that allows co-workers to articulate the current understanding of a design project and generate new ideas for design. In this case, the spatiality of material artefacts such as sticky notes plays a role in explaining the order, relationship and overview of different activities of designers. In addition, the spatiality of artefacts also serves as a source of inspiration, especially in the case of designers.

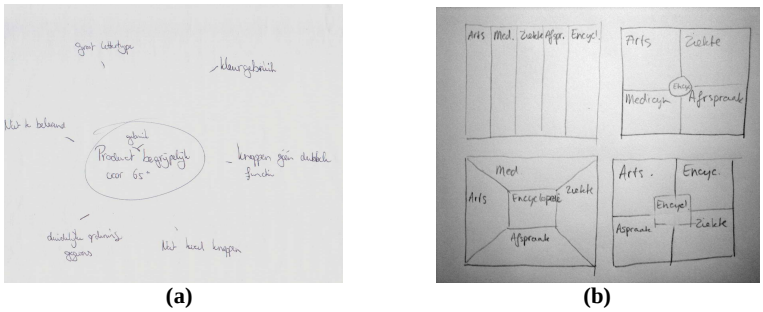
3.2 Social Practices

In addition to the material aspects within the work environment, the social practices that are applied to support cooperative design is also an important aspect to understand physicality of design work. These two aspects of physicality: materiality of work environments and co-workers' social practices are dependant on each other and co-evolve over time. This has also been proven by the work of Sellen and Harper [23] on understanding the use of paper documents in organizations. They show that some specific use of papers is not replaceable by other means (e.g. organizational policies and changes), as papers have become so integral to organization's work practices.

Fig 5. Two different sessions of design meetings.

Our fieldwork of design practices was limited to co-located design meetings. Figure 5 shows two different sessions of design meetings. In co-located design environment the perceptual resources (visibility, sound, touch, smell or taste – any of the applicable) are readily available. During design processes, designers accomplish activities and tasks utilizing not only their internal cognitive processes but via the combination of different cooperative 'embodied' actions [17]. The public availability of embodied actions of one designer enables others to organize their own actions

accordingly, to support a cooperative activity in design. Cooperation is achieved by the mutual perception of these actions as the basis for the ongoing creation of shared meaning. Designers align and integrate their activities with those of their colleagues in a seamless manner by asking, suggesting, requesting, ordering or reminding others of some specific activities. From our fieldwork, we found several examples (figure 6) of designers' brainstorming process that provides indications about how designer collected ideas amongst themselves at different stages of design. Figure 6b is an indication of different interface design mockups that these designers considered by discussing issues amongst themselves.



(a) **(b)**

Fig 6. Brainstorming processed used in the design team at different stages of their design project. (a) At concept development stage and (b) During interface design stage.

One of the important issues to take into account when understanding physicality is that the role of physicality is not limited to providing the external tool support (specialized tools used to design products) or the material itself that is used for designing the product, but physicality is both what is produced and the process that is used in producing it.

Public availability, central to many CSCW studies [7, 18, 21], of actions and material artefacts allow co-workers to appropriate their own actions. In other words, while carrying out the individual part of a cooperative work, actors typically modulate their own actions such that their colleagues are provided with cues and other kinds of perceptual resource pertinent to their monitoring these activities. This calls for a consideration not just of human perception but also an understanding of how human perception relates to the way in which the significance of artefacts and actions is negotiated and conveyed in practice.

The communicative function of actions and artefacts is of particular importance here, as it goes beyond perceptions. People can only shape their own actions so that they are meaningful in relation to those of others if the ongoing activity is publicly available to each of the participants; that is to say, if they can be aware of it. Moreover, the significance of the same artefacts and actions is negotiated in different ways for different people embodied within the same workplace. As Schmidt [21] suggests that 'awareness' of x may or may not entail the same practices as 'awareness' of y.

6. Discussion: Physicality – Beyond Communication

What has been presented here is our conceptual understanding of physicality that is used as a lens to view cooperative work. However, there are some important issues that could be useful for consideration when designing new technologies to support cooperative work. In this section we discuss the benefits of taking a physicality approach to understand cooperative work.

In cooperative work, establishing shared perspective or common ground between the co-workers is the most important aspect. A recent review [31] shows that mediating visual information about work related artefacts is more efficient to support coordination than information about the participants involved in a cooperative work. This means that the artefacts – used or designed during a cooperative work are a source of supporting and mediating interactions amongst the distributed or co-located workers. The physicality of these artefacts could support rich understandings of cooperation between co-workers.

Directness. The physicality of artefacts allows direct engagement with the artefacts and provides direct feedback, which in tern leads to shred resources for coordination and expression. Since the designers are in the direct touch with their artefacts, the engaging nature of these artefacts can support better ways of collaboration. The issue of directness has been utilized by the research theme of Tangible Interaction [27]. Hornecker [9] has utilized this aspect and provided several guidelines to design new technology for supporting collaborative work. For example, she suggests utilizing physical constraints to facilitate the distribution of work and help co-work in coordinating each other's actions.

Affordance. The physicality of a material artefact allows a rich set of possibilities of actions. For example, Sellen and Harper [23] show that paper documents, because of their material properties, allow an array of collaborative practices amongst co-workers, such as: providing a flexible medium for the display of real-time information, a mechanism for team coordination, providing support for face-to-face interactions, and so on. Designers can think about new systems that allow multiple points of interaction, providing simultaneous access or establishing access control within the design of these systems.

Configurability. The spatial flexibility supported by physicality of an artefact allows co-workers to configure the artefacts and importantly the inherent signals that are conveyed by the positioning of these artefacts. For example, in a meeting room, papers can be positioned in such a way that can make them 'public' or 'private'. Additionally, the spatiality of material artefacts has a specific design narrative. The way different artefacts are positioned, along with their multi-modal expressions and behaviors could inform us about the design process and activities that are applied to it.

Experiential aspects. Again, the multi-modality and ability to support and convey information through all senses, makes the use of an artefact experientially rich. In the case of joint design activities, co-workers don't just interact with these artefacts when they are designing, they actually get the feeling and experience each other's activities through these artefacts. This really helps in the process of collaborative design in which the designers are always in search of new, creative and inspirational ideas. The communication channels that are established by these multi-modal artefacts go beyond facilitating and satisfying the basic task-oriented activities.

Conclusions

We highlight that the issues that are presented here are conceptual and are used here mainly to generate awareness about the issues related to physicality. However, these issues adequately point to the importance of physicality in understanding cooperative work – a perspective different from other face-to-face or linguistically oriented approaches. We believe that in future a take on physicality is inevitable as the ubiquitous technologies are immerging. At the current stage, a thorough insight into the notion of physicality could help us foresee the future trends of ubiquitous technologies.

What has been discussed in this paper, in a nutshell, shows that in order to support efficient coordination amongst different co-workers we have to understand the real – material world and the world that we have created with our social and cultural practices. They are both the product as well as the mediator of each other. These aspects related to physicality are important to understand how co-workers make sense of each other's collaborative activities.

Overall, physicality is an important notion to understand cooperative design practices. It captures several important aspects that may not be easily extracted through other means, such as speech.

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