

# Cooperative Work and Lived Cognition: A Taxonomy of Embodied Actions

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Based on a field study of cooperative design in a distributed company, this paper identifies and defines the embodied actions of the designers that enabled a cooperative design process. These actions are considered as classes of cognitive practices that are simultaneously available to the actor and others in a shared physical workspace. The public availability of these actions to the perceptions of the participants in a cooperative process enables their communicative functions. A taxonomy of embodied actions is developed as a bridging structure between the field study of cooperative work and the design of technology that might support that work over distance.

Boundaries are drawn by mapping practices; "objects" do not pre-exist as such. Objects are boundary projects. But boundaries shift from within; boundaries are very tricky. What boundaries provisionally contain remains generative, productive of meanings and bodies. Sighting (sighting) boundaries is a risky practice

Donna Haraway, *Situated Knowledges*, 1991, p. 200.

## Introduction

When people do not share a physical space, they are unable to see each other, hear each other speak, handle or look at the same thing, or perceive anything about the place where others are or what they are doing. This is a fact of human embodiment. Interaction just cannot happen when people are apart because there are no perceptual resources explicitly available and shared between them to form its basis. Unless, of course, they use some kind of technology to support, mediate, or even enable their interaction by providing some common basis for the creation

of shared meaning. Because CSCW technology can convey various kinds of information between arbitrary points, it can be used to support remote collaboration (Gaver, 1992). Exactly what information is needed, however, is by no means a foregone conclusion. This paper recognises the active and perceiving body as the essential basis of all human action and interaction. My starting premise is that the defining constraint in the design of technology to support interaction between people working in different places is the essential corporeality of human cognition. While many studies of the use of CSCW technology have recognised the implications of the corporeality of the users of technology, this paper focuses directly on the embodied actions of the participants in a cooperative process.

The empirical basis of this paper is a longitudinal field study of a small distributed company that designs computer based training and educational software products. This paper is not a descriptive account of the empirical research that inspired it (interested readers can find such accounts in Robertson, 1996a, 1996b). Instead, it attempts to structure the results of a field study of cooperative design in a way that might bridge the gap between the description of the work and the design of technology to support that work. A taxonomy is presented that identifies and defines the embodied actions of the designers that were observed in video tapes of cooperative design work within a shared physical space. The term "embodied action" is used here to name the publicly available, meaningful actions that people rely on to interact with others and their environment. Embodied actions are considered as classes of cognitive practices that are publicly and simultaneously available to the perception of the actor and others in a shared physical space. These include actions like talking, touching, drawing, looking and moving around in the environment, in order to accomplish whatever the person acting wants to do. It is the public availability of these actions that enables their communicative functions. It is these actions that need to be considered for technical support if the designers, in the field study, were to increase their options for robust and flexible communication while they are working apart.

## Bodies, Spaces and Objects in the CSCW Literature

Interestingly, it is recent work on user embodiment in virtual spaces that has called for a greater understanding of the social and interactional role of actual bodies (Benford et al., 1995; Bowers et al., 1996a, 1996b). Benford et al. (1995) commented that in cooperative systems "embodiment often seems to be a neglected issue (It appears that many collaborative systems still view users as people on the outside looking in)" (p. 242). They identified some of the design issues involved in implementing virtual embodiment in two prototype systems, DIVE and MASSIVE. Bowers et al. (1996a) applied empirical techniques from interaction analysis and conversation analysis to the study of a meeting supported

by the MASSIVE system. They found that the virtual embodiments seemed to have some social interactional role (p. 63). In a more recent paper, Bowers et al. (1996b) considered how action and interaction in the virtual and physical world inter-relate. Their analysis articulated the work that embodied subjects have to do within their local physical environment in order to manage their virtual body in its virtual environment.

Studies of the use of media spaces have revealed the interactional asymmetries between shared physical space and virtual space (Heath and Luff, 1991; Heath et al., 1995) as well as the effect on these interactions of the physical medium in which they occur (Gaver 1992; Gaver et al., 1995). Heath and Luff (1991) used ethnomethodology to analyse how technology transforms verbal and non-verbal conduct, particularly on the ways individuals used gestures and other forms of visual conduct to establish and preserve mutual involvement and to coordinate work tasks and activities. In a later paper, Heath et al. (1995) argued that the focus in media space research on supporting face-to-face communication does not allow participants the flexibility to align towards the focal area of their collaborative activity, for example a document, where coordination is achieved through peripheral monitoring of other people's involvement in the activity at hand. The taxonomy that is developed here encompasses the whole range of actions observed within the shared physical workspace during cooperative work. Gaver's (1992) extension of Gibson's (1979) notion of affordances to media spaces highlighted the centrality of active perception to technology-mediated interaction. He argued that if social activities are situated in their environment (Suchman, 1987), then collaboration depends both on complex social relations as well as the physical medium in which these relations can work (Gaver, 1992, p. 17). More recent work investigated the constraints that media spaces placed on participants' ability to move through the environment (Gaver et al., 1995).

Studies of the use of physical objects in cooperative design have identified their role in design conversation (Harrison and Minneman, 1994, 1995). Harrison and Minneman (1994) found that interaction with 3-D objects in the design process objects "provides a rich source of information for the designer, is an integral part of the communications, alters the dynamics in multi-designer settings, and forms part of the pool of representations that are drawn on by designers" (p. 205). In a later paper reflecting on a range of studies of architects designing together in distributed workplaces, Harrison and Minneman (1995) argued that the use of representations and other objects involved in design work is dictated by and managed through the ongoing conversation of the designers.

## Background to the Taxonomy

The field study that forms the empirical basis of this paper followed the design of a educational computer game from initial discussions through to the development of

a prototype. The company studied is very small and the designers are professionals doing their normal work, within their usual work environment, over its actual time frame. The work environment included geographically separate workplaces, in fact the designers' homes, and a weekly gathering in a shared physical space. The designers used computer systems and communication technology, as well as highly developed communication skills and procedures, to enable them to work together despite being separated most of the time. My central conclusion from the field study was that the cooperative design of a software product was enabled and achieved by the work the designers did communicating with each other. Communication is used here in its widest and most active sense; where people interact to create, negotiate, maintain, share and review meaning, understanding and knowledge, to enable cooperation, to build and maintain relationships, and use whatever options for achieving this that they can. When the designers shared a physical space, the space itself enabled communication by supporting the mutual perception of their embodied actions, as they talked together and made and used various artefacts within the shared physical workplace. When they were apart, communication had to be supported by the interplay of specifically evolved work practices, with whatever communication technologies were available.

The taxonomy presented in this paper was developed as a possible bridging structure between the field study of cooperative work in practice and the design of technology that might support that work over distance. By definition, the design of any technology requires formalisation that, in turn, relies on categorisation and the setting of boundaries. Also by definition, formalisation distances the analysis from its basis in the lived corporeal world. This distancing is the source of the power of formalisation to structure that world. As Haraway (1991) observed "Siting (sighting) boundaries is a risky practice" (p. 200). For those seeking to design technology based on the lived experience of those who will use it, formalisation is always approached with caution. The taxonomy developed here is not concerned with any specific stage of the design process. Instead, in an attempt to tie it explicitly to the lived experience of the designers, the categories of embodied action are derived from the observation and analysis of the actions of the designers themselves. I should emphasise that this taxonomy defines categories that remain totally open and flexible in how and when people achieve and combine them in practice. This is an important point because it leaves open the possibility that people will evolve different ways to perform these actions; perhaps including ways to perform them in virtual spaces. The categories are definitely *not* suitable for implementation as explicit menu options. The following sections ground the taxonomy in the conditions of its development by accounting for its theoretical commitments and clearly stating its limits. In the remainder of the paper, categories of embodied action, for both individual actions and group activity are identified and defined.

## Cognition as Embodied Action

Embodied actions are the actions of an active and perceiving embodied subject. The consideration of embodied actions as classes of cognitive practices recognises that human cognition depends on the "kinds of experiences that come from having a body with specific sensorimotor capacities" (Varela et al., 1991, pp. 172-173). These experiences are, in turn, always embedded within a specific social, historical and cultural context. Moreover, embodied sensory and motor processes, perception and action, are fundamentally inseparable in lived cognition and have evolved together over the lifetime of any particular individual (ibid). Perception and action are inseparable in this taxonomy because perception, as an active process, is achieved by motor actions at the same time that motor actions, as purposeful actions, are achieved by perception. The embodied actions identified and defined here are always, at the same time, both sensory and motor actions.

### Perception as Lived Cognition

Merleau-Ponty (1962, 1968) provided an explanation of how our embodied actions enable us to create and maintain shared meaning between people. He recognised that our bodies are our sole means of communication with the world. Perception, as an active and interpretive, embodied process, immerses the human body in its lived world. For Merleau-Ponty perception is active, embodied and always generative of meaning. As such it belongs to neither body or mind but is constitutive of both. Over time, as it is lived by an embodied subject, the meanings generated during perception are continually shaped by what has been lived before. Central to Merleau-Ponty's (1962) account of perception is his insistence that bodies are both physical structures in the world at the same time as they are lived by the embodied subject. He called these two aspects of embodiment the phenomenological body and the objective body, "my body for me and my body for others" (p. 106). These two aspects of embodiment are continually interlinked by the fact that our objective body is perceivable by ourselves and, most importantly, by others. It is our phenomenological body, as a lived, experiential body that, through our awareness and control of our objective body, is able to act.

### The Reversibility of Perception

Merleau-Ponty used the term "reversibility" to name the body's presence to itself as both perceiving and perceived (1968). Reversibility is the complex, reciprocal insertion and intertwining of the sensed and the sensing, that is the essential condition of our interaction with the world and with others. In a shared physical space a lived body can simultaneously see and be seen, touch and be touched, make sounds and be heard, move and reorient its perspective and cross over these sensory modes; that is, see *both* itself *and* others being touched or touching, moving, making sounds etc. The fact that we are able to perceive our own bodily

surfaces at the same time as we live our acting bodies enables us to organise our actions (ibid). The public availability of these actions to the perceptions of others enables them to organise their own actions in relation to ours. In this way group activity is achieved that, in the field study, enabled a cooperative design process (Robertson, 1996a). Whatever the designers did was accomplished not just by internal cognitive processes, but by different combinations of their purposeful, embodied actions. Cooperation was achieved by the mutual perception, by the actor *and* others, of these actions as the basis for the ongoing creation of shared meaning.

The taxonomy of embodied action developed here assumes the reversibility of perception. It recognises that reversibility holds both reflexively to a single body (I can perceive at least some of my own body as the same time as I perceive with my body) and between bodies in a shared space (I can perceive others' embodied actions and they can perceive mine). This point is important when considering work that needs to be done in a shared space, whether physical or virtual, and work that does not. It also recognises that individual actions can be done when the actor is alone or when they are in shared space, where the availability of the action for others' perception may or may not contribute to the creation and maintenance of shared meaning. For this reason I have made a fundamental distinction between the embodied actions of an individual interacting primarily with physical objects, other bodies, or the workspace, and the activity of the group as a whole. The distinction recognises that the individual actions of group members enabled the activity of the group. But the activity of the group is something different from these actions and needs its own categories. This distinction becomes crucial in the design of CSCW technology to support work over distance. Individual participants in a cooperative process will always be acting in their local physical space. Some actions may be enabled by the technology, others will occur within their immediate physical environment. But all would need to be incorporated into the technologically-enabled, shared workspace if they were to be available to contribute to group activity.

## Inclusion and Exclusion

I make no claim that the actions defined here are "natural", in the sense that they correspond to anything that is not culturally and socially produced. But any process of abstraction, by definition, excludes what is not explicitly included. My judgements about what is included and excluded by the categorisation, as well as how the taxonomy is structured, have been shaped by my perspective as a CSCW researcher concerned with designing systems that support remote collaboration. My aim is to identify those embodied actions, constitutive of shared meaning, that must be considered in any attempt to provide this support.

The categories emerged from an iterative process of viewing videotapes of group design work, identifying and then grouping the embodied actions of the participants. These were checked against further viewings and redefined. There were many iterations of this process until eventually the categories stabilised into those defined here. Some of these categories are already established in various disciplines that study different forms of interaction, including CSCW. I have identified other work I am familiar with, that is relevant to a category, or group of categories when I define the category.

These are not mutually exclusive categories in either the temporal or spatial dimensions. Individuals, or the group, were usually doing more than one of them at any one time. People talked at the same time as they looked at something or moved around the workspace. The actions are categorised separately because they are identifiably separate actions that would require different technological solutions if they were to be mutually perceivable over distance. The categories of group activity all require a range of individual actions occurring simultaneously. In this sense, they are another way of dividing the same analytic space as that of individual actions. While I would argue that the taxonomy accounts for the individual actions and activity of the group in this study, additional categories may be required in other contexts.

## The Taxonomy of Embodied Actions

The major divisions in this taxonomy are

- individual embodied actions
  - in relation to physical objects
  - in relation to other bodies
  - in relation to the physical workspace
- group activities constituted by individual embodied actions

### Individual Embodied Actions

These have been divided into individual actions performed in relation to objects, other bodies and the workspace. The "in relation to" recognises the indexicality of all embodied actions. Indexicality, in this context, is not used in a narrow linguistic sense, but in the ethnomethodological sense that all actions need to be interpreted within the context they occur (Garfinkel, 1967, pp. 4-7). This is the basis of ethnomethodology's focus on accounting for the "demonstrably rational properties of indexical expressions and indexical actions [that] is an ongoing achievement of the organised achievements of everyday life" (p. 34). I should also emphasise that actions defined in relation to objects and other bodies, have an implicit "in relation to" the physical space in which they occur.

## Embodied Actions in Relation to Physical Objects

In their study of the role of 3-D objects in the design process, Harrison and Minneman (1994) argued that "a common thread that runs through all of the ways that objects were used is the relation of hand and eye" (p. 207). The actions in this section are defined from the "other side" of the relationship to the perspective of these studies. The focus here is the embodied actions of designers in relation to objects during that process.

### 1. *Moving physical objects*

Actions within this category make it possible for the designers to take advantage of the motility and immutability of physical objects (Seeley Brown and Duguid, 1994, pp. 21-22). Physical objects, including books, pieces of paper and computer disks are essential resources that the designers can move from place to place, as required by the specific unfolding of the design process.

- Moving a physical object into or out of the shared space
- Moving objects within individual workspace (within bodily reach)
- Making a physical object explicitly available, as a generator of meaning, during the current activity, e.g. passing it to someone else, holding it up or putting it somewhere so that it is available

### 2. *Producing a private physical representation*

These representations may or may not be available for the perception of others during production. Depending on how the work unfolds, they may or may not be made available during or after production via other actions.

- Drawing - usually on paper
- Writing - usually on paper

### 3. *Highlighting some aspect of an object*

Goodwin (1994) defined highlighting as those "methods used to divide a domain of scrutiny into a figure or ground, so that events relevant to the activity of the moment stand out" (pp. 609-610). In this way highlighting shapes "not only one's own perception but also that of others" (ibid). In highlighting, embodied actions are used to tailor the object, by framing, in some way, some part of it. In the study highlighting was done in relation to representations including those on the whiteboard, in books, on sheets of paper and on computer screens.

- Drawing a line around some part of an object with a pen, e.g. annotation, or by gesture alone
- Masking background of representation, or part of object, with one or more of: hand, arm, paper or other object

### 4. *Personal use of a physical object*

This action (like 2) may or may not lead into shared use of the object. It can also be a source of information that is then shared with the group

- Browsing through a book

- Working on a computer
- Reading
- Looking at a picture
- Holding object for some, not necessarily obvious, reason
- Touching (including when pointing) to some part of an object

### Embodied Actions in Relation to Other Bodies

Kendon (1990) argued that "all aspects of behaviour in a situation must be seen at least, potentially, to have a role in the communication process" (p. 27). He observed that participants in interaction do not attend to all aspects of each others' behaviour in the same way, and do not place the same significance on every action. These distinctions make it possible for people to organise their actions in relation to others without having to explicitly do so. The mutual perception of these actions functions as a way of providing advance information that any one proposing to interact with another has to have (p. 262). Some of these actions are defined within other sections. But those defined here are central to the creation of shared meaning in that they enable the designers' conversation.

#### *1. Emitting signs and monitoring signs*

The embodied actions included within this category are those that enable individuals to monitor others' reactions to whatever is happening, as well as the actions that individuals make that indicate their own. These actions are continually performed by each individual. Their availability for mutual perception is an essential condition for the group activity of conversing.

- Visual indicators of individual involvement, attention and attitude including changes in body posture, changing facial expressions, changes in direction and intensity of gaze and other communicative movements like nodding, rolling eyes, gestures
- Oral/aural indicators of individual involvement, attention and attitude including speech and other sounds

#### *2. Pretending to be another body*

This category is defined to account for enactment that has been identified as a crucial activity in design (Tang, 1989; Robertson, 1996a). It is defined here as an action where an individual acts out the behaviour of someone else or animates the behaviour of an object. Enactment enables the individual to make and live within a temporal representation of some process or activity. A person, pretending to be another, makes various changes in their usual embodied actions. In a shared space, these changes shape the perceptions of others so that they are able to interpret the action as enactment and participate in it. As enactment is done through time, only a small part of the enacted process needs to be directly considered at any moment enabling the immersion of the participants in the process. This action was often done at the same time as actions in relation to objects.

- Pretending to be the user
- Pretending to be a character in the game
- Animating the behaviour of some inanimate object or process

### Embodied Actions in Relation to the Workspace

The workspace includes not just the permanent physical features, such as doors and furniture, but the changing positions of other objects within it (including the bodies of others). These have been considered in previous categories. But the workspace also includes the physical medium through which actions can be performed and perceived - in this case air. The reversibility of perception (Merleau-Ponty, 1968) depends on air as the medium through which bodies intertwine perception and action. The communicative functions of all of the categories defined here depend on the physical properties of the space where the actions are done. Those in this section are defined specifically in relation to the properties of air that enable the embodied actions of moving through and looking through. Gaver (1992) analysed the differences between the affordances (Gibson, 1979) offered by media spaces for collaboration, with those of air. My concern here is the embodied actions of designers in relation to air, as a medium, during the design process.

#### 1. *Moving around*

Gaver (1992) identified the ability of media spaces to support only static perception as a major interactional constraint. Our perception is seldom static. He argued "Successful systems must *afford* movement" (p. 21).

- To get a better view
- To change bodily alignment to something
- To get an object or put an object somewhere out of immediate reach

#### 2. *Pointing at something*

The interpretation of what is being pointed at is dependent not just on the act of pointing but on other people being able to perceive what is being pointed at. Pointing is the classic example of an action used to maintain indexicality.

- At an object (including other bodies) somewhere in the workspace, e.g. "have a look in there"
- At something outside the workspace but perceivable from within it, e.g. "the green of that tree"
- As an indicator of direction, e.g. "they live over there"

#### 3. *Shifting direction of gaze*

Gaver (1992) observed that air is isotropic with respect to light. Isotropism is a term from physics that refers to a material that has characteristics that are the same when measured along any axis (p. 22). Air is the medium through which we look, irrespective of the object or direction of the gaze. The gazer needs to be able to

gaze at something and others have to be able to perceive what it is, or that the gazer is just gazing into space which is an indicator of action in itself.

- To look at the current speaker (in order to follow a conversation)
- To look at an object (including other bodies) for some reason
- To look at nothing in particular

#### *4. Moving in or out of the shared space*

Individuals would, for a range of reasons, temporarily leave the shared workspace. This category is defined separately to moving around within the workspace because absence from the workspace meant that the individual could not participate in the current group activity, whereas moving round within the workspace contributed to the current group activity. Temporary absences were perceivable, by others, as temporary and the individual's return was assumed.

- To prepare the group lunch
- To meet with a client in another room
- To attend to other responsibilities, including domestic responsibilities
- For no obvious reason

### Group Activities Constituted by Individual Embodied Actions

These actions define shared activity in a shared physical space. All rely on the predictable availability of the individual actions of the designers for the perception of the other group members. They identify the different group activities that these individual actions made possible. Technology to support remote design collaboration needs to support these activities across the individual workspaces of the participants. In remote collaboration, the shared workspace is not a shared physical space, but one made possible by computer systems and communication technology. This space does not support the reversibility of perception, but mediates how the embodied actions of the participants are perceived by them.

#### *1. Conversing*

The literature devoted to the organisation of conversation is huge (e.g. Garfinkel, 1967; Goodwin, 1981; Suchman, 1987, pp. 68-97; Kendon, 1990). Conversational analysis, a branch of ethnomethodology, has examined the local organisation of human-human conversations in a variety of settings (Heritage, 1984). A number of principles governing the local sequencing of talk have been proposed including turn taking (Sacks et al., 1974) and repair (Schegloff, 1992). Interaction analysis (Jordan and Henderson, 1994) draws on these traditions among others. As would be expected, the organisation of conversation has been an important concern in CSCW research and product development (e.g. Heath and Luff, 1991; Heath et al. 1995; Bowers et al., 1996a). Harrison and Minneman (1995) argued that all the different elements of the design process are "held together by the conversation of the designers". Whatever work the designers did in meetings was accomplished by

them talking together. Conversing is the major and essential category in this taxonomy of group activity.

- Maintaining a single conversation involving the whole group
- Maintaining more than one conversation involving different subsets of the group within the same space (individual involvement can vary over time)

## 2. *Looking at the same thing at the same time*

This activity made the design conversation more robust by enabling the inclusion in the conversation of some aspect of what was being looked at. Company members identified support for this activity, while working apart, as the most urgent requirement for CSCW support.

- Looking at a single shared representation, e.g. whiteboard, book, screen
- Looking at a series of shared representations one at a time
- Looking at a number of shared representations at the same time
- Looking at something in, or perceivable from, the shared workspace

## 3. *Organising shared communication resources*

These are actions that alter some physical aspect of the workspace in order to make communicative resources available to be the shared focus of group activity. This was done most frequently when the group needed to look at something on a computer and to organise the sequential viewing of files.

- Changing what the group is looking at
- Installing graphic files on the computer
- Installing software to enable group viewing

## 4. *Creating a shared representation*

Representations may be physical, or temporal/spatial representation. Bly (1988) suggested the importance of drawing activities are as important to collaborative design as the resulting artefacts (see also Tang, 1989). The creation of shared representations was used to express ideas, add meaning to the accompanying talk and to summarise work as it was done.

- Drawing - in the air, using the actor's body as the background, on paper or the whiteboard using a drawing tool
- Writing - using a writing tool, on paper or the whiteboard

## 5. *Shared physical use of an object*

This activity is distinguished from the others involving various kinds of sharing of objects because more than one individual is in physical contact with the same object in some way at the same time. The shared use of objects became more central to shared design work as the work progressed. This activity is severely compromised, if not impossible, in shared drawing systems that impose separate layers for each participant or those that impose locking systems to prevent or place conditions on shared use.

- Performing the same action, e.g. drawing

- Performing different actions, e.g. one person highlighting at the same time as another is drawing

#### 6. *Focusing group attention*

This is usually initiated by one person's actions. But the group, as a group, perceives the action and reorients its attention. This category enables changes in group focus and is used as a way of structuring the conversation.

- Focusing on a shared object or representation
- Focusing on a speaker
- Focusing on a specific group activity

#### 7. *Breaking into smaller groups and reforming*

When some aspect of the design work required it, people moved themselves and various objects in the workspace to form into smaller groups. The larger group would reform when this stage of the work was completed. People in different subgroups were peripherally aware of the activities of the other group/s and could participate in these at will. Interaction and movement between groups occurred with minimal overhead.

- To enable smaller groups to work on specific parts of the developing design, e.g. graphics, coding or planning
- To enable a smaller group to work on one project while monitoring the progress of another group

#### 8. *Seizing the moment*

Group members took advantage of lulls in the group activity for the opportunistic use of time they were together to do something unplanned. The unplanned activity could include the whole group but was often done when one or more of the others was attending to an interruption, or to other work. At these times the main activity of the group was interrupted, providing opportunities for this activity.

- Asking a question about something else to do with work, e.g. technical information
- Used for explicit social interaction, e.g. to discuss movies, tell jokes

#### 9. *Doing something else*

Individuals occasionally did something other than the group activity, while remaining in the same physical space. Those doing other work are aware of group activity, usually by listening, even if they are not actively participating. Should they wish to participate at any time, they can do so by changing their spatial position and orientation. Perceptual clues for this category include positioning the body to face away from the group and prolonged personal use of a physical object.

- Doing other work, e.g. meeting deadlines on other products
- Disinterest in current group activity
- Personal preference

## Discussion

Mapping the actions defined in the taxonomy back onto the videotapes of cooperative design work revealed that irrespective of the stage in the development of the product, the same actions were used to achieve whatever specific work was being done. As would be expected, the spread, frequency and combination of the different actions varied, depending on what the specific work was. There were no occasions when the embodied actions of the designers were performed in any predetermined sequence. Nor were there any occasions when designers were performing individual actions in unison, even though they were participating in the same group activities. This is not to say that there were no patterns of interaction. Certain actions frequently occurred together, though not necessarily in any fixed sequence. For example, someone may leaf through a book to find a picture. When they find it they hold it up for the others to see, frequently highlighting some part of the picture. Other people move to get a better view and may point to the picture while discussing it. Highlighting connected physical objects with the design conversation, particularly when the group were looking at the same thing at the same time. These actions were performed purposefully and opportunistically by the designers as they worked to create and maintain shared meaning. Nevertheless they constituted the work of cooperative design at the same time as they enabled it to continue.

But the fact that these actions occurred throughout the cooperative design process, from early discussions through to the building of a prototype, demonstrates that people's embodied actions are not tied to specific functional stages of the design process, nor to any explicitly defined design procedure. This would suggest that technology, designed to support cooperative design over distance, might be more effectively directed to supporting the negotiation of shared meaning by the designers rather than attempting to structure the design process according to any functional categorisations of design work. The basic argument of this paper is that what needs to be supported, mediated and enabled by CSCW technology used to support design communication over distance is the mutual perception, for the actor and others, of the embodied actions of the participants in the process. All the categories of embodied action, defined in the taxonomy, function as communicative actions in shared physical space because physical space enables the reversibility of perception (Merleau-Ponty, 1968). Yet the reversibility of perception, a fact of human embodiment in physical space, is not a fact of virtual spaces.

In shared physical space we can predict how our actions are perceived by others because we can perceive them ourselves as we live them. In technology-mediated communication individual participants will always be acting in their local physical space at the same time as they act in virtual space. Self-perception, then, will require not just the assumed resources of the local physical space but the

development of perceptual skills and the provision of perceptual resources to enable each individual to perceive their own actions as they appear to other participants. Put another way, a basic principle in the design of CSCW technology to support cooperative work over distance is that the perception by others of any individual's actions needs to be explicitly regarded as part of the same process, or act of perception, as that individual's perception of their own actions. I am perfectly aware of what a "big ask" this is. Developing technology to support the reversibility of perception of even one of these actions, with the finesse and flexibility of selection and combination available to embodied users in shared physical space, would be a major achievement in itself. But this does not mean that the provision of perceptual resources people need to organise their own actions in relation to others' actions ought not to be a central focus of technology design.

The taxonomy presented here is intended to structure the results of a field study of cooperative work in a way that might bridge the gap between the work itself and the design of technology to support that work if it were to be done over distance. Its immediate value may lie in enabling us, as researchers and designers of CSCW systems, to recognise the actions that our systems do not support and perhaps cannot support. On one level, this recognition may enable a clearer understanding of what our systems do, in fact, support in practice. On another it may lead to the development of perceptual resources in virtual space that are compensatory or even analogous to those provided by physical space.

## Acknowledgements

My thanks, again, to the people whose work I have discussed in this paper. This research was partly financed by an Internal Research Grant from the University of Technology, Sydney and by the Telstra Fund for Social and Policy Research in Telecommunications.

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