ORIGINAL ARTICLE

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Knowledge in co-action: social intelligence in collaborative design activity

Abstract Skilled cooperative action means being able to understand the communicative situation and know how and when to respond appropriately for the purpose at hand. This skill is of the performance of knowledge in co-action and is a form of social intelligence for sustainable interaction. Social intelligence, here, denotes the ability of actors and agents to manage their relationships with each other. Within an environment we have people, tools, artefacts and technologies that we engage with. Let us consider all of these as dynamic representations of knowledge. When this knowledge becomes enacted, i.e., when we understand how to use it to communicate effectively, such that it becomes invisible to us, it becomes knowledge in co-action. A challenge of social intelligence design is to create mediating interfaces that can become invisible to us, i.e., as an extension of ourselves. In this paper, we present a study of the way people use surfaces that afford graphical interaction, in collaborative design tasks, in order to inform the design of intelligent user interfaces. This is a descriptive study rather than a usability study, to explore how size, orientation and horizontal and vertical positioning, influences the functionality of the surface in a collaborative setting.

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1 Introduction: knowledge in co-action

In this paper we focus our analysis on how we engage with the representations of another's actions and move with these representations when interacting in a joint design activity using various types of surfaces. Particular emphasis is on the rhythmic patterns in this coordination, and observations of how the use of artefacts can influence these. The motivation behind this focus is to understand the formation and transformation of knowledge in communication. It is located within a framework that sees cognition as a dynamic system that co-evolves and emerges through the interaction of mind, body and environment. This co-evolution includes body moves (kinesics and kinaesthetics) that give the cognitive dynamic system meaning. Previous work on the metacommunicative[1] body dynamics of the engagement space (Gill, Kawamori, Katagiri, Shimojima 2000) showed that composite dialogue acts, of gesture, speech and silence (body moves), play an important role in the flow of information in interaction. Body moves are forms of behavioural alignments.

Skilled cooperative action seems to depend on specific types of behavioural alignments between actors in an environment. These alignments allow for a degree of coordination or resonance between actors that constitutes the knowledge they have available to them, both explicitly and implicitly. Knowledge is seen here as a process that is dynamically represented in actors' behaviours and the tools, technologies and other artefacts within an environment. These behaviours involve the sense of touch, sound, smell and vision. We will focus on touch, sound and vision in this study. Coordinated structures of these behaviours and artefacts—structures which can be extended and transformed through technology—form the interactional space in which the process of knowledge creation through co-action takes place. This analysis of coordinated structures in skilled cooperative action involves understanding what constitutes the socially intelligent behaviour that we takes so much for granted in our everyday behaviour. As a framework, the idea of social intelligence has been defined[2] as the ability of a collection of actors/agents to learn and to solve problems as a function of social structure, and to manage their relationships with each other through intelligent actions. Our study of such intelligent action is presented in this paper, through a study of body moves of designers collaborating and negotiating. It lies within the scope of social intelligence design that involves the detailed understanding of interpersonal actions exhibited during the course of computer-mediated or conventional communication environments in search for better design of communication media.

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[1] Scheflen (1975) on the relation between kinesics (movements) and language: the former can "qualify or give instructions" about the latter in a relation that Bateson (1955) called metacommunicative, whereby the "movement of the body helps in clarifying meaning by supplementing features of the structure of language. Body moves do just this, and contribute further to the idea that the structure of language lies in its performance.

[2] Toyoaki Nishida's summary of the idea of social intelligence in his paper at the close of the Social Intelligence Design Conference, at the Royal Holloway, London, 2003.

Fig. 1 Physical contact
enabled at surfaces

In the analysis that follows, we have found that certain behavioural align-ments (e.g., the body move showing acknowledgement,[3] and suggestions (Fig. 1) operate upon the surface of the interfaces, e.g., by touching, pointing actions and suggest that touch influences the implicit formation of ideas. This haptic dimension of knowledge is part of the body move and other salient behavioural alignments that we will present here. The relation between touch and implicit knowledge has been investigated by Reiner (2003, 1999). She studies, for example, how the touch language learnt by surgeons who acquire this through experience, linking patterns of touch with interpretations in a non-symbolic manner. Related to this, she also studies how gestures are part of physics learning.

Our research also shows that design activities take place in zones of interac-tion within the configurations of the space of engagement around the surface(s), to reflect, negotiate and act. We note how these zones are blurred when physical contact is enabled at surfaces (as in Fig. 1), but demarcated when they are not enabled. This is not always evident in speech, but is visible in the spatial and movement orientation around the surface(s) and between participants.

2 The studies

The analysis in this paper is taken from an experiment and an observation study, to explore how people coordinate their interaction in a shared task. Students in pairs (dyads) and groups were asked to undertake collaborative conceptual drawing tasks, and student design projects, using the following affordances:

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[3] "Acknowledge (Ack). The acknowledge move gives an idea of the attitude of the response, i.e., how the person hears and understands and perceives, what is being discussed. It shows continued attention. In the discourse act (DA) "acknowledge", this aspect of acknowledge, which was raised by Clark and Schaefer (1989), has not been included because it leaves no trace in a dialogue transcript to be coded. However, it is a part of the body move. The hearer or listener demonstrates, with his gesture, how he is acknowledging the other's proposal or request for agreement. The body move occurs in response to the other's verbal information reference or suggestion, and their body release-turn or bodily placeholder. Its associated DA is the speech act "ack" or "accept. The movement creates a change in the *degree* of contact which indicates the nature of the acknowledgement or acceptance." (Gill, Kawamori, Katagiri and Shimojima 2000)

a) paper and pens b) a shared white board c) SmartBoards (electronic white-boards for Web browsing, typing up session notes, drawing mock-ups, and viewing their work). In the student projects using the multiple SmartBoards a range of activities were recorded and some salient categories identified as fol-lows: device interface, interaction dance, attention control, team communication and personal work.[4] We have sought to capture the management of both the body and speech spaces within a task where you need to produce something together and agree upon it, i.e., in the performance of knowledge in co-action.

The experiment involved two drawing surfaces, used by different sets of subjects, a whiteboard and a SmartBoard. This is a large-scale computer-based graphical user interface, and is touch-sensitive (an electronic whiteboard). "Smart" technology does not permit two people to touch the screen at the same time. The contrast between drawing at the "smart" and the whiteboard was expected to reveal whether or not there are particular differences in body moves and gesture and speech coordination at these interfaces. Preliminary analyses[5] reveal that the participants' commitment, politeness and attention to each other becomes reduced at a single SmartBoard, showing behaviours that are in marked contrast to those of users at a whiteboard. Furthermore, the quality of the resulting design is lower when using the SmartBoard.[6]

Acting in parallel, e.g., drawing on the surface at the same time, involves a degree of autonomy that is coordinated, i.e., where the designers are aware of where and how they are in relation to the other. *The management of coordinated autonomy is culturally determined.* In our study we observe patterns of move-ment from sequential (e.g., turn taking) to parallel actions, as part of this design activity, and suggest that *coordinated autonomous action is part of sustainable collaborative activity*.[7] The role of autonomy within collaboration is an idea that lies at the heart of this research and has implications for any kind of collabo-rative activity, including cross-cultural collaboration. For instance, in the study, when a group of four users has three SmartBoards available to them, there appears to be a transposition of the patterns of autonomy and cooperation that one finds between a pair of users working on a whiteboard.

The focus of our analysis is of the gestures participants use to manage their interactions with each other and the interface during collaborative activity. This activity takes place in the "iRoom", which is the laboratory of the Stanford Interactive Workspaces project[8] (Guimbretiere, Stone and Winograd 2001). The study will raise issues for designing mediating interfaces that could support collaborative human activities to involve sustainable and committed engage-ment of the self and the interpersonal self.

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[4] Some examples of behaviours are: device interface: right clicking, marker fixing, dragging, reaching, tapping, comparing, referring to paper, erasing; interaction dance: side stepping, pacing, stepping back, hand waving, cutting in, waiting, bumping, peeking, touching (others); attention control: pointing, asking permission, directing, teaching, concurrent control, pos-turing, calling out; team communication: reading aloud, catching up, filling in, talking, swag-gering, sharing, taking turns, role-playing; personal work: reading, note-taking, scanning, browsing, watching, concentrating, viewing, drawing and pointing.

[5] For a preliminary discussion of this research, see: Borchers, Gill and To (2002).

[6] This could in part be due to the awkwardness of the interface for producing smooth drawings.

[7] The relationship between autonomy and sustainable collaboration is being developed in a forthcoming paper by the author.

[8] http://graphics.stanford.edu/projects/iwork/

3 Parallel coordinated moves and collaborative activity

In 2001, whilst exploring the affordances of SmartBoard technology, we found that a SmartBoard's inability to allow for parallel action at the surface of the task being undertaken by participants, made for a useful case bed of data to analyse how such action affords collaborative activity. In the process of our observations, we also discovered that the use of multiple SmartBoards produced similar patterns of behavioural alignments of body moves and parallel actions (see Borchers, Gill and To 2002), but in a very different form, to those undertaken at a whiteboard or over a sheet of paper on a horizontal surface (table). When one has to wait one's turn to act at the surface, it may (a) take longer to build up the experiential knowledge of that surface than if one could move onto it when one needs to, and (b) there is a time lag for the other person working with you to experience with you, in a manner of speaking, your experience of the situation, i.e., there is an awareness lag. The former and the latter difficulties are, we suggest, linked because of this experiential dimension of tacit or implicit knowledge. With multiple boards in parallel use, awareness of the experience seemed more fluid than that of a dyad at the one board, evident in the movements around the boards to gather and disperse where rhythms in behavioural alignment were halted.

The interest in parallel coordinated action first arose during a study of landscape architects working on a conceptual design plan. The study focused on analysing the metacommunicative dynamics of body and speech coordination, and identified various body moves (Gill, Kawamori, Katagiri and Shimojima 2000). These are a kind of interactional synchrony (Birdwhistle 1970). One of these body moves was coded as the parallel coordinated move (PCM). This contrasts in rhythm to the other body moves whose action-reaction rhythms maintain the flow of information in the communication situation by participants. It was further analysed (Gill 2002) to understand its quality. During a five-minute video excerpt of architects working on a conceptual design plan, this PCM occurred only once and lasted 1.5 seconds. It was salient because it was the first time in that session that the disagreement between two architects was able to find a resolution, and it involved both their bodies acting on the surface at the same time, even whilst presenting alternative design plans. One of them was silent and the other speaking. It enabled the grounding in the communication to come into being (see Gill 2002 for a deeper analysis of the PCM) by enabling an open space for the negotiation of differences and possibilities for creative co-construction. The opening and closure of the PCM is by action-response body moves. For example, the "focus" move involves a movement of the body towards the area the "speaker" or "actor" is attending to, i.e., space of bodily attention, and in response causes the listener or other party to move his or her body towards the same focus.

In order to understand the PCM further, and to gather more examples for analysis, a number of configurations for a similar task were set up to collect further video data. These are the studies reported here. One task set was for dyads of students to design shared dorm living spaces. We also collected data and made a preliminary analysis of group activity where students are using multiple large-scale surfaces, i.e., SmartBoards (Borchers, Gill and To 2002).

The PCM is explored as a category of body move that has its own set of variable configurations, where the basic common defining feature is that participants act at the same time. In this paper, we concentrate on such actions taking place upon the surface of the interface, and the contexts within which these occur. Such actions, for example, can be to indicate ideas or proposals with a pen or finger or hand. We also consider the cases where only one participant has physical contact with the surface in order to glean some understanding of what the function of touching is, and reflect on that back to the case of parallel action.

4 Examples from the case studies

We will consider examples from two settings: a) using felt pens and standing at a whiteboard, b) using electronic pens, fingers and hands (tools that can produce representations on the surface) and standing at a SmartBoard, and marginally draw upon two other settings for reflection, namely: c) using paper and pen, and seated at a table; d) using paper and pen, and standing at a table. Using these examples, we will compare alignments and indicate salient phenomena that need deeper exploration for an understanding of how the configuration and affordances of surfaces influences collaborative activity.

4.1 The haptic connection

There is something about the contact that is made when standing at a horizontal surface that may alter the possible modes of configuration to communicate information, from the situation of standing at a vertical surface. When standing at a horizontal surface, the eye contact between participants is available without departing from the particulars in the locus of the surface. In the following examples (Figs. 2, 3, 4), we consider a case where one person is looking at the other. In Fig. 2 the person at the whiteboard (A) has to turn his head from the surface to see the person (B) who is standing back from it. There is neither a haptic connection via the artefact nor is the representation visually available to him, at that moment. (A) is discussing the location of a fireplace in the design of a room, which he has touched with a pointing hand gesture before he turns his head away. The use of deictics and his contact with the surface, enables (A) to locate the idea both for himself and for (B) who maintains a gaze on it, such that he (A) does not need it in front of him at that moment. This pattern is repeated by other dyads at whiteboards.

In the case of the architects (Fig. 3) standing at the drawing-table, the person to the left (P) has his hand on the drawing surface and is holding a pen (in this case, he is holding a position or idea), whilst his speech acknowledges (''yeh'') what the person to his right (W) is saying). (W) is pointing to another particular place on the drawing and making a design suggestion. P is holding an idea and W proposing an idea. The contact on the surface allows for both acts simultaneously.

At the SmartBoard, pointing or touching acts at the surface, operate upon it causing marks. Hence, when such acts do occur, it is to explicitly suggest an idea by drawing it, or if it is not intended as an operation the result is an unintended

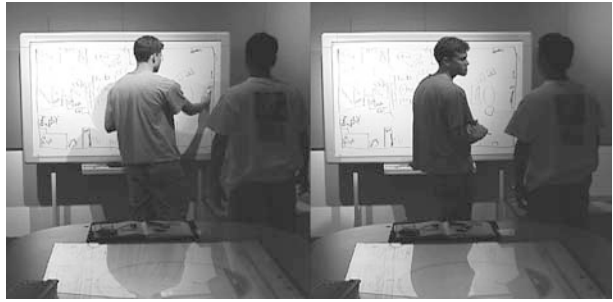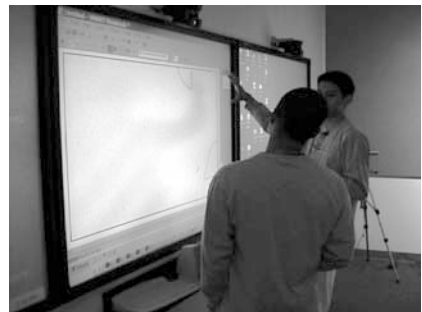**Fig. 2** A touches the surface, then turns his head to see **B**

Fig. 3 Surface contacts allowing for simultaneous acts

Fig. 4 Pointing over the surface combined with looking at another to communicate an idea

mark or two.[9] Acting on the surface seems to be to make things clear, e.g., in seeking confirmation or to emphasise a position. In this case, we find that instead of pointing directly on the surface, pointing combined with looking at the other person to whom one is communicating an idea, is done by keeping the hand hovered over the place one is referring to (as in Fig. 4).

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[9] Work at Berkeley on Transient Ink is a potential solution, leaving marks that disappear after a while (Everitt, Klemmer, Lee, and Landay, 2003)

The haptic dimension in these examples seems to be important in its combination with vision, for touch surfaces that permit non-operational contact. Compensation for not being able to use the surface of the SmartBoard is to hold one's hand over the specific point or idea being proposed for a specific location. We do know from work by Gregory (1963) on touch and creativity, that there is a direct relation to being able to create conceptual designs and having the ability to tactilely feel our world. Although that work primarily concerns the individual's experience, it bears upon the collaborative experience in these design tasks given the physical role of the body, and where physical autonomy within coordinated parallel action constitutes a form of joint action. This cohesion between the virtual or imaginary, the tactile and the physical connection of coordinated movement involves social intelligence, i.e., it requires us to be able to use our bodies in rhythmic coordination with speech to share and co-create knowledge.

So far, in Figs. 2, 3, 4 we have considered three surfaces, all involving standing positions, and the making or holding of a specific design idea by a designer(s) at a specific location on a conceptual design plan. We made observations about how looking at another person and away from the surface, whilst touching it (the drawing-table), and after touching it (the whiteboard), involves certain kinds of behavioural alignments that differ from the use of pointing gestures held above the surface during the period of looking away from it (the SmartBoard).

4.2 Narrative and virtual space

Let us consider the case of zones, which were introduced earlier in the paper. In Fig. 3 (the drawing-table) one architect is acting on the surface and the other reflecting on the surface. *The narrative space lies in between the bodies and the surface, where the surface provides a mediating point of contact within it.*[10] In Fig. 2, neither are acting upon the surface of the whiteboard, but are negotiating and reflecting. The *narrative space lies in a virtual space between the bodies*, and the point on the surface that is being discussed, has been identified with a prior touch. The person to whom it was indicated (B) can look at it and at the proposer (A). In the case of the SmartBoard (Fig. 4), neither are acting on its surface, but are negotiating and reflecting with a hand held over the part on the surface being discussed. The hand position is needed whilst the idea is clarified in the mind of the person proposing it,[11] and they do not move into a virtual narrative space away from the surface until the idea becomes clear enough for such discussion.[12]

4.3 Engagement space

At this juncture, it may be helpful to situate this discussion about zones, and the use of hands and eyes to make contact, in the context of the engagement space (Gill et al. 2000; Gill 2002). The engagement space has been defined as the arena within which coordinated body movements take place in interactive settings.

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[10] This is work in progress in a forthcoming paper by Satinder Gill.
[11] This could be another category of body move.
[12] This is a hypothesis and not a statement of fact, but is under analysis.

These movements take place within shifting spaces of engagement. An *engagement space* may be defined as the aggregate of the participants' body fields of engagement. An engagement field is based on some commitment in being bodily together. Hence we can call the engagement space, the *body field of engagement*. In defining this space, it was most useful to draw upon Allwood et al.'s theory of communicative acts (1991) where they speak of participants signalling and indicating their orientation to each other.[13] In so doing they can increase commitment by increasing contact.

The body field of engagement is set as the communication opens and the bodies indicate and signal a willingness to co-operate. The body field of engagement is a variable field and changes depending on the participants being comfortable or uncomfortable with each other. For instance, in the case where one person moves their hand over into the other's space, and that person withdraws their hand, this indicates that the 'contact' between these persons is disturbed. The degree of contact and the nature of distance are expressed in terms of commitment and attitude. Hence an *immediate* space of engagement involves a high degree of contact and commitment to the communication situation, whereas a *passive distance* is less involved and committed, *disagreement*, is very distanced and commitment is withheld.

Disagreement or discrepancy can necessitate a *reconfiguration* of the body field of engagement due to a disturbance in the relationship between the speakers, so that a feeling of sharing an engagement space is re-established. This reconfiguration is a rhythmic bodily reshaping of the field of engagement. This category of action occurs because there is a problem in the overlap in one body's field of engagement with the other body's field. Note that if there is no problem in the overlap of their respective fields, the participants can undertake parallel co-ordinated moves.

4.4 Engagement space and zones of interaction

The spatial fluidity of the zones (reflection, negotiation and action) of interaction makes it challenging to provide a definitive demarcation of their boundaries in terms of simply physical space, as such a demarcation does not help to explain how the zones work together when the designers are in more than one zone at the same time. Further, we need a framework to understand the movements from one zone to another. The zones were initially observed as being in distinct physical areas as depicted in Fig. 5: from left to right—reflection, negotiation, and action:[14]

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[13] Allwood, Nivre and Ahlsen (1991) pay special attention to the context sensitivity of feedback. Aspects of their theory were adapted for the body situation, such as 'contact'. The four basic communicative functions are: 1) *Contact*; 2) *Perception*, 3) *Understanding*; 4)*Attitudinal reactions*. Winograd and Flores (1986)emphasise 'the need for continued mutual recognition of commitment' (p.63) that we find expressed in the maintenance of the 'engagement space' and they speak of communication as 'dance', a metaphor suited for Body Moves. Further, their argument for 'sufficient coupling' to ensure freguent breakdowns and a standing commitment by [participants] to enter into dialogue in the face of breakdown, is helpful for understanding the role of parallel coordinated motion for sustaining collaborative activity.

[14] This emerged when reflecting out loud with Renate Fruchter, Stanford University, in the Spring of 2002, about Donald Schon's work, in relation to this study.

Fig. 5 Reflection, negotiation and action

1. Reflection zone: if one person is acting at the surface, and the other person is standing further back and silently observing this action then he or she is reflecting. If both are standing back and looking at the surface, then both are reflecting. This state does not involve any immediate intent to act.
2. Negotiation zone: If both are engaging about an idea and there is some movement or indication to access the surface, then this occurs in the negotiation zone.
3. Action zone: this takes place upon the surface and involves direct physical contact with it.

The categorisation of zones does, however, provide a helpful description of a base level pragmatic activity above that of the metacommunicative (e.g., body moves) and we can see how the latter work in relation to them. By drawing upon the framework of the engagement space, we can see how the metacommunicative level of communication carries the fluidity of the zones, as it operates within movement, time, and space.

In Figs. 2, 3, 4, when looking away from the surface, the engagement space alters and bodily contact increases with the act of (A) opening the frontal part of his body and eye contact to the other person (B). In the case of the whiteboard, engaging (B) involves two steps on (A)'s part; first to touch the surface to indicate the idea and to hold its location for himself, and then turning to look at (B) and engage him in a discussion about it. In the case of the drawing-table, the (P) increases contact in two steps. He enters the floor space of the drawing by placing one hand down upon it, holding a pen, with his gaze on the place he has an idea about. His fingers and pen are moving in his hand in rhythm with the speech and motion of the other architect (W), but his hand is in a fixed position. After touching the surface, (P) looks at (W) to acknowledge his action and gauge it. The increase in contact using the SmartBoard, involves two steps. First, the designer (C) locates the idea with his hand gesture, and then opens his frontal body and eye contact to the other designer (D) whilst holding his hand gesture.

All three examples indicate or invite increased commitment in the engagement space, and make for increased contact. The body fields of the designers are not overlapping.

When a designer is making contact with the surface to act upon it, whilst the other person is doing so too, there is an attempt to engage with the body field of the other person, as in the case of the architects. It also happens in the example that Fig. 1 is taken from. In Fig. 6 the designer on the right side, close to us (E),

Fig. 6 E enters the body field of F

enters the body field of the other one (F) who is currently drawing (the action zone), and uses his index finger to trace out a shape that denotes a bed. He is proposing this idea to (F) who is drawing and getting his opinion (the negotiation zone). Both zones are operating at the surface.

The body field of the person drawing (F) is not disturbed, and as we know from the discussion of the engagement space, this indicates a high degree of contact and is identifiable as a PCM.

(F) acknowledges (E)'s proposal, after tracing the proposed idea above the surface of the board with his pen whilst (E) taps a position of one bed with the back of his hand on the surface. After tracing (E) continues to draw, and his pen touches the surface at the same time as (E) begins to lift his hand away. There is no break in the fluidity of the rhythm of the coordination between them (of body and speech).

4.5 Parallel coordinated actions

The following examples are of more parallel coordinated actions. During the studies, we note many instances of parallel actions taking place at the surfaces of the table and whiteboard, and attempts to do so at the SmartBoard when only one such board is available.
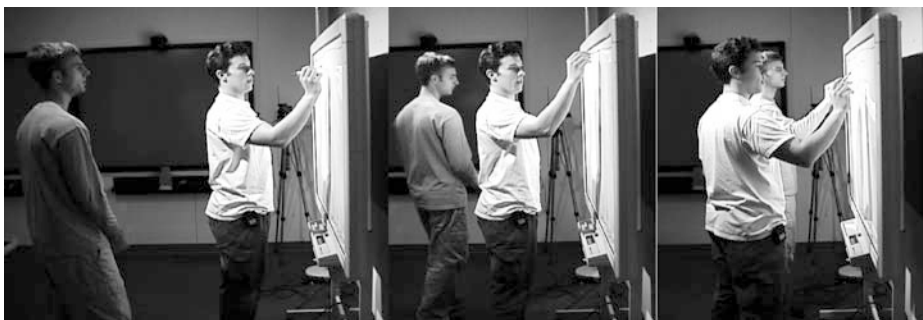
Fig. 7 A silent parallel shift

Fig. 8 Waiting for D to end his turn

In Fig. 7, (E) is standing back, watching and talking, and (F) is drawing on the whiteboard. (F) has his body positioned to accommodate (E) by slightly opening it, slanted to the right, to share the engagement space with (E). At some point, (E) looks to the left of (F) to an area on the whiteboard and moves towards it. He picks up another felt pen and begins to draw as well. As (E) touches the surface, (F) shifts his body and alters his posture so that it is now open slanted to the left, and increases contact with (E). Both are now acting in parallel. This shift occurs in silence.

At the SmartBoard (Fig. 8), C is standing back whilst D is drawing. He looks and moves to a position to the right of D, on the SmartBoard. He leans into the surface but cannot draw because he has to first wait for D to end his turn.

D, without looking up, speaks, and his utterance causes C to turn his body back to look at him. As he cannot yet act, C moves back from the surface and waits, and as he is doing so, he breathes in deeply in frustration. C notices him, pauses his drawing, turns to look at him and moves back from the zone of action, allowing D to move into it (Fig. 9).

Once C is acting, i.e., drawing, D continues with his drawing on the SmartBoard (Fig. 10). The result is a disturbance on the board, and a jagged line cuts across from D's touch point to C's, causing them both surprise and laughter (Fig. 10). D momentarily forgot that you cannot touch the surface at the same time. The need to act whilst another is acting is not a conscious one. This autonomy in co-action seems to be part of the coordinated collaborative process but at a metacommunicative level.

In Figs. 8 and 9 we see an attempt to act, causing frustration until the need to act is noticed, at which point the turn to act is offered to C by D. It is significant

Fig. 9 Allowing D to move into the zone of action

Fig. 10 A disturbance on the board

that they recognise each other's need to act, and signal this need (moving body away, distancing) and respond to it (speech and body), and further, that they forget the limitations of the surface to afford them this need. In contrast, the whiteboard permitted (Fig. 5) a more fluid movement around the surface, as there was no enforced pause by the surface, and no turn-taking required on one designer's part to permit the other person to act.

These examples are of parallel coordinated actions that involve autonomy, where *autonomy involves awareness of and attendance to the state of engagement in the space between participants and the surface(s)*. When a designer at the SmartBoard does not easily give the turn to the other one, we see various strategies to force it. These include, moving close to the board and inside the visual locus of the drawing space in a quick motion, or moving back and forth, or reaching for a pen, or looking at the pen, or simply reaching out and asking for the pen the other person is currently using, or just moving right in front of the body of the person currently drawing, thereby forcing them back, and taking a pen from the pen holder. As either person can act at the whiteboard, there is no need for such strategies.

In contrast to the SmartBoard, at the whiteboard an autonomous performance by one person that is not occurring in co-action can bring a reaction to regain co-action. In an example below, (Fig. 11) (E) looks up and stands to draw something higher up on the board, just after (F) has knelt down to draw beside him. (E) altered his position such that the contact within the engagement space became too low for (F) to be aligned with him in order to act.

(F) attempts to regain contact so that he can work with (E), first by speech and when that fails, by using body moves to *attempt contact* and *focus* (Gill et al. 2000).

Fig. 11 An autonomous performance by one person that is not occurring in co-action bringing a reaction to regain co-action

5 Discussion

The ability to engage at the surface results in strategies for managing autonomous behaviour through various body moves. These strategies differ when using the SmartBoard and the whiteboard. At the former surface, for example, body moves such as take-turn are used, where the body field of the person acting is disturbed by the other one's entering it, and a reconfiguration of the engagement space is required. At the whiteboard, body moves such as attempt contact and focus are used, to increase contact.

In all the dyads working at the SmartBoard we observed moments where one person stands back in silence waiting (in contrast to the whiteboard where the person standing back sometimes speaks); or turning away to look at other parts of the surface and looking back at the person drawing because they cannot act; looking at the pens indicating an interest to act; or moving around the person drawing, and using the body field disturbance strategies listed above to intercept and take the turn or force it. If the SmartBoard were a horizontal surface there would be further inhibitors to natural actions such as that of bringing one's hands into the drawing space to increase contact, as in the example of the landscape architects (Fig. 3).

The SmartBoard makes those actions that are invisible, or are extensions of ourselves, when acting at a whiteboard, visible. Winograd and Flores (1986) speak of how 'structure' in communication 'becomes visible only when there is some kind of breakdown' (p.68). For instance, acts of rubbing something out whilst another is drawing, checking something by pointing on it, or touching the surface with a finger or hand to think about an idea, etc. When all these aspects are inhibited or have to be negotiated, the fluidity of sharing an engagement

space in an interactive drawing task becomes altered by the kinds of communication strategies available to participants to achieve collaborative activity.[15]

The simultaneous synchrony of PCM in drawing or being able to touch the surface together provides for a certain kind of awareness of states of contact within an engagement space. This synchrony allows for the multi-dimensional expression of ideas in combinations of zones of activity using a pen, hand or finger, to sketch ideas.

These ideas can be rubbed out, located in one's self and made clear for the other person. Contact with each other's ideas can be made with gestures as well as speech. This is tacit bodily knowledge of self and intra-self.

We have noticed that in group activity using multiple SmartBoards, the patterns of rhythmic coordination of sequential movements and parallel coordinated actions, bear similarity to those in using a single whiteboard, with additional characteristics due to the increased complexity of the task, the larger numbers of participants and more surfaces. The locus of action in our study takes place around three SmartBoards, seen in the figures, and around the table in the centre of the room. A common pattern of motion activity between the boards is to have all three in use, or two boards in use, with one or two persons at each. When problems are noticed, either by pauses in body action at a surface, or by someone saying something, the other group members migrate towards the problem space, and try to help resolve it. As they cluster around a board, they frequently take turns by moving in and out of the problem focal spot to the outer rim, and once the problem is solved, they disperse to the separate boards.

This interactional dance happens when all the participants are at the boards, as this enables an awareness that allows them the fluidity of movement within each other's problem spaces. The fact that there are four students to three boards, may help this fluidity as one person will, at any time, not be acting on the surface, and hence have a sense of actions occurring elsewhere. However, other patterns occur in this configured room. Take Fig. 12, where two students at the centre SmartBoard are having some difficulty in erasing something they have drawn over the photographic image that they are working on by using Photoshop.

The student to the left of the centre SmartBoard has asked his partner to try to "take it (the pen stroke) away" using the rubber. He is overheard by another student who is standing at the table. (facing us in the picture). She breaks off her communication, stands straight and turns to look at the dyad, observes and asks them if they are having problems "deleting from the image". The dyad attempt to open the image from another board but that proves temporarily unfruitful. The "research observers", who are standing in the background behind the camera, hint to the student who is watching the pair at the board, to try using the third SmartBoard on the right. This hint is acted upon when she is gestured at with a pointing arm directed at it. All three SmartBoards are then used.

This is a different dynamic to the sequential-parallel movement transitions as the participants undertake different activities in spaces that separate them. Hence there is a lag in awareness. In the case above the observer has intervened

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[15] The whiteboard is slightly unsteady if one person moves heavily upon its surface, but that is well handled and managed by the participants. In the example, where E taps the surface with the back of his hand, F has to momentarily lift his pen, yet the rhythmic coordination between them is maintained.

Fig. 12 A different dynamic to the sequential-parallel movement transitions: the overhearer and the mediator

to help because of difficulties in using the surface functionalities. We have discussed the limitations of the desktop metaphor for such design surfaces and design activity in Borchers, Gill and To (2002). The proximity of participants to each other within the space facilitates overhearing,[16] which is significant in helping the awareness and maintenance of the engagement space of the group.

The analysis being undertaken in this paper is work in progress. As part of a design effort to better understand how providing more contact affordances at the surface can improve collaboration in joint activity, we have been designing the software to permit the simultaneous operation of multiple functions at the surface.

6 Conclusions

Collaboration and cooperation in joint activities is analysed as having three basic elements: the skill to grasp and respond to the representations of the tacit dimension of our actions (e.g., in body moves, gestures, sounds), the ability to coordinate this grasping and responding in a rhythmic synchrony of sequential

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[16] The SANE Project at Royal Holloway, London, shows that people who overhear others talking in work environments are participants of a kind within that space and constitute part of the organisational knowledge.

and parallel actions and coordinated autonomy that occurs within parallel coordinated movements, and involves awareness and attendance to the state of engagement in the space between us and interfaces.

The analysis of PCMs shows the importance of coordinated autonomous behaviour for sustainable collaborative activity, as it facilitates cooperative behaviour. Without it, the designers use disturbance strategies or behaviours. These ensure that the design task is completed, but with less engagement at the conceptual level.

The disruption of parallel coordinated action makes it problematic for participants to achieve a tacit awareness of their state of contact within the engagement space at the surface of the board. The fluid coordination of their rhythmic synchrony of body and speech, that would normally be invisible, i.e., not something they are consciously aware of doing, is made visible to them and they have difficulty in getting it back.

Parallel coordinated actions occurring at the surface have a physical touch dimension. There is an additional value to being able to touch the surface. We have found that touch enables the designers to create narrative spaces between their bodies and the surface of the interface, where the surface becomes a mediating point of contact within that space as virtual and imaginary. Where we cannot touch the surface to indicate an idea that we are talking about, for example, deciding on the location of a fireplace in the room we are drawing, we use our hands and arms to hold that place, above the surface, until we are ready to shift away from the surface to the virtual narrative space.

This study of the complexity of body moves of pairs and groups of designers collaborating and cooperating on design tasks shows how they learn and solve problems as a function of communicative and social structure, and manage their relationships with each other through intelligent actions. By intelligence, we mean the skill of grasping and responding to the representations of the tacit dimension of our actions and knowledge, appropriately for the purpose at hand. We call this the performance of knowledge in co-action. A challenge for designing mediating interfaces is for them to afford us our human skills of engaging with each other, communicating information and forming knowledge.

References

Allwood J, Nivre J and Ahlsen E (1991) On the semantics and pragmatics of linguistic feedback. Gothenburg Papers. Theoretical Linguistics, 64

Bateson G (1955) The Message. 'This is the Play'. In: B Schaffner (ed) Group Processes. Vol. II. New York: Macy

Bavelas JB (1994) Gestures as part of speech: methodological implications. Res Lang Soc Inter 27(3):201–221

Birdwhistle RL (1970) Kinesics and context. University of Pennsylvania Press, Philadelphia, PA

Borchers J, Gill S and To T (2002) Multiple large-scale displays for collocated team work: study and recommendations. Technical Report. Stanford University

Clark HH, Schaefer EF (1989) Contributing to discourse. Cog Sci 13:259–294

Everitt KM, Klemmer SR, Lee R, Landay JA (2003) Two Worlds Apart: Bridging the Gap Between Physical and Virtual Media for Distributed Design Collaboration. Proceedings of CHI 2003, ACM Conference on Human Factors in Computing Systems

Gill SP (2002) The parallel coordinated move: case of a conceptual drawing task. Published Working Paper: CKIR, Helsinki

Gill SP, Kawamori M, Katagiri Y and Shimojima A (2000). The role of body moves in dialogue. RASK 12:89–114

Gregory R (1963) Recovery from blindness. A case study. Experimental Psychology Society Monograph No 2

Guimbretiere F, Stone M, Winograd T (2001) Stick it on the wall: a metaphor for interaction with large displays. Submitted to Computer Graphics (SIGGRAPH 2001 Proceedings)

Reiner M (1999) Conceptual Construction of Fields with a Tactile Interface. Interactive Learning Environments 6 (X), 1–25

Reiner M and Gilbert J (in press) The Symbiotic Roles of Empirical Experimentation and Thought Experimentation in the Learning of Physics. International Journal of Science Education

Scheflen AE (1975) How behaviour means. Anchor Books, New York

Winograd T and Flores F (1986) Understanding Computers and Cognition. A New Foundation for Design. Norwood NJ, Ablex Corporation