Sensitizing Concepts for Socio-Spatial Literacy in HCI

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ABSTRACT
People inherently share spaces with other people. Congenitally, interactive technologies and ubiquitous environments shape our opportunities for enacting social relations. Proxemics and Spatial Sharing have been suggested as foundations for our understanding of the socio-spatial aspects of computing. By tandeming these theoretical perspectives in a set of cases in the office domain, we develop a contribution comprised of 3 key sensitizing concepts: *Proxemic Malleability, Proxemic Threshold and Proxemic Gravity* articulating socio-spatial qualities at the interplay between interactive systems, spaces, interior elements and co-located people. The sensitizing concepts qualify interaction designers in considering proxemic consequences of technology design; they serve both as analytic lenses and as generative instruments in a design process. The proposed sensitizing concepts and the theoretical work of the paper contribute to enhanced Socio-spatial literacy in HCI.

Author Keywords
Proxemics; Interaction design; Space; Spatiality, Ubiquitous computing; Socio-Spatial; Literacy; Architecture.

ACM Classification Keywords
H.5.3. Information interfaces and presentation (e.g., HCI): Group and Organization Interfaces;

INTRODUCTION
The discipline of architecture concerns itself with the understanding and design of spatial experience. Within this discipline, it is a foundational premise that people share spaces both willingly and unwillingly (see Figure 1). Interactive technologies and ubiquitous environments, inherently have agency in organizing people in spaces, and in this way influence our possibilities for spatial experiences and our opportunities for enacting social relations, whether, researchers, designers and users are aware of this or not. While ideas around space and place have been prevalent in HCI and CSCW research for decades [4, 11, 13, 21, 27, 35], much of this has been driven by the need to shift attention from geometrical notions of space to the ideas of meaning making in *place,* as the basis for thinking about computer mediated communication environments. *Space* being the opportunity and *place* being the understood reality [e.g. 21]. The arguments were originally motivated by a need to draw attention to the social practices and meaning making at play in digitally mediated collaboration. While such arguments were a necessary rhetorical device in response to the narrow conceptions of space prevalent in CSCW research at that time, the very success of these ideas has unintentionally led to an inevitable diminishing focus on the significance of spatial concerns in technological design thinking. Yet strong arguments remain in place for further articulation of architectural and spatial concerns relating to interactive technology and the ways their spatial qualities shape the opportunities for configuration of social relations [4, 14, 36, 38, 42].

To illustrate some of the concerns here, let us consider a commonplace interactive technology such as the Kinect gaming controller with a camera-based system that tracks the body of a user as a form of system input (Figure 2). When considered purely as a human machine interface, the system offers exciting potential to use body movement as a means of system control and indeed supports this well. But if, rather, we consider the device in terms of broader social-spatial context of collaborative gaming in the home, we can highlight ways in which the spatial demands of the interaction constrain the ways in which we can configure our bodies to enact socio-spatial relations with co-present others. For example, if two players are playing, the general configuration required for effective system performance is one in which the players stand side-by-side facing the camera at the right distance so that they can be seen by the

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Figure 1. Shared space in a public library allowing for a wide range of activities

camera and facing the screen so that they can see the game content. A further spatially organizing factor in the interaction mechanism is the demand that their bodies must not come together nor touch. If they do, the skeletal tracking algorithms breaks down, since the system attempts to fit a single skeleton across the pair of connected bodies, which it interprets as one (). What we see then, when we consider such an experience from the social context of gaming in the home, is that these spatial requirements of the technology unduly constrain the ways in which we can bodily configure ourselves with respects to the system and other actors – thereby limiting opportunities for particular forms of social enactment. An example of such an enactment would be a parent trying to help a small child using the game by standing behind them to support the child in moving the child's arms to effect control. The partial obscuring of a body behind a body is not something that works well with Kinect computer vision algorithms.

While such body-to-body configurations are common in other acts of parental mentoring, and enactments of parent child care and intimacy, these are curiously omitted as possibilities with conceptions of spatial performance that focus only on system input. Also not supported would be F-formations [27] in which players are able to turn and face each other as they enact, for example, a confrontational standoff, an intimate dance or even a loving embrace. The point here is not in offering a critique of the Kinect system, but to exemplify ways in which a technology, beyond its

Figure 2.Children playing a game using Kinect controller

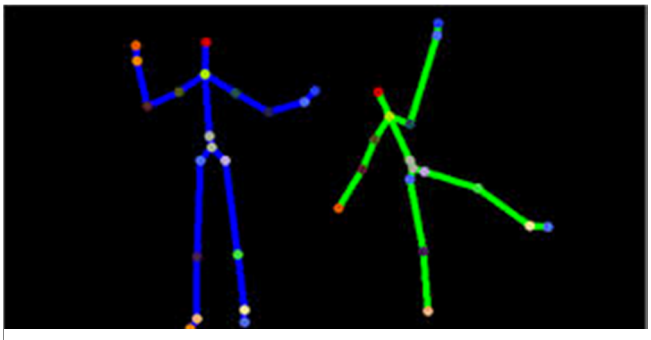

Figure 3. Kinect skeleton tracking

qualities as an interactive controller affords (or not) particular kinds of spatial relations with collocated others as a consequence of required spatial relations with the technology – and further, how this presents and shapes opportunities for our spatial enactment of social relations. In this way, the example motivates the need for improved socio-spatial literacy in HCI.

With this paper, we wish to refocus attention to how we as designers can become better at acknowledging and intentionally designing with the socio-spatial consequences of interactive systems in mind. In building our arguments, we will draw upon key notions of: (a) *proxemics* [20] – the idea that spatial relations between people is a device in the conduct of human relations; (b) *interaction proxemics* (as distinct from proxemic interactions) [36] – how the spatial properties of human-machine interactions shape spatial relations with other actors; and (c) *spatial sharing* [14] - an architectural perspective on the design of computational artefacts respecting bodily experience and awareness of other people's co-presence when designing interactive systems for co-located people. In addition, we will draw upon the architectural notion of Spatial Agency [2]. The point here is that while indeed *space* is well acknowledged as *"the opportunity*" for social action, we still lack articulation of and focus on the specific ways socio-spatial opportunities and transitions are made present through material characteristics of interactive technologies.

Important in the development of a deeper socio-spatial literacy in HCI is an acknowledgement of the continuously changing socio-spatial relations between people, technology and physical spatial elements. Such dynamic qualities and transitions are not dealt with well in the kinds of frame-based scenario tools common in interaction design. These frames based approaches can no doubt be powerful, they also tend to focus on static glimpses of the world in stable (ideal) situations (frames in a scenario) rather than how change between situations is facilitated and happening. As such, we want to include ways of discussing and articulating the more dynamic and changing elements of proxemic configurations in action (the complex of people, interactive technology, physical spatial elements and their mutual relationships) and the opportunities for transition between them. To help us here, we further introduce 3 sensitizing concepts, that provide grounds for discussing change, what initiates and influences change, how stable the change might be, and in this way encourage a level of granularity beyond the frames in scenarios (see [19] for a more detail on proxemic transitions):

1. *Proxemic Malleability* – the range of socio-spatial configurations that design decisions will encourage and enable spanning different distances, orientations and facing formations in intimate, personal, social and public encounters.

2. *Proxemic Threshold* – the difficulty with which the design of interactive technology allows for socio-spatial configurations to be changed.
3. *Proxemic Gravity* – the tendency of a setting to over time gravitate towards a default socio-spatial configuration.

In line with Zimmerman et al's analysis of Research through Design [52], the proposed sensitizing concepts serve as *Theory for Design* when applied generatively and as perspectives when deployed analytically.

In order to position the perspective presented above, we start out by a more detailed look at the notions of proxemics and interaction proxemics and review related work. On the basis of this, the theoretical position of the paper is presented. The empirical work of the argument is comprised of a description of a work situation (videoconferencing); two proposals for re-design of the interactive resources in such a situation and finally a workplace study carried out in an environment designed to invite for ad-hoc meetings. Through these 4 cases we flesh out the characteristics of the suggested sensitizing concepts articulating socio-spatial qualities. In the subsequent section we wrap and put the sensitizing concepts and related socio-spatial qualities in perspective. Finally, we point to future work and present our conclusion.

RELATED WORK

Key to our concerns is the concept of proxemics [20] that refers the use of space as a special and powerful feature of culture; our spatial relations with each other and with artefacts in the environment being key components in the unfolding organisation of social action and interpersonal relations. Perhaps the most well-known instantiation of proxemics can be found in Hall's ideas about interpersonal distance whereby that people maintain different degrees of physical closeness to one another depending on the type of relationship they are in: *intimate* distance allows touch, embrace and whisper, *personal* distance sensorially provide access to the odor of another, while *social* distance allows a gaze that catches the eye of the other, and *public* is the distance you would find in public speaking.

The key essence of Hall's ideas then was a linking of spatial relationships to action, the action of bodies to the moral compass of the mind, in highlighting how the delicate management of space affords certain actions and operations, which in turn provides the bedrock for social organization, for culture. So, for example, to be close to another allows touch or be touched, which can be enabling of intimacy but also leaving one vulnerable to more violent acts – it is easy to be hit and hurt when someone is right beside you. In Hall's view, then, physical closeness is an act of faith. To allow oneself to be the subject of gaze allows judgments of trust to be made, it enables others to see whether they can act with you together, corporately, as a moral unit.

While ideas of interpersonal distances and zones have come to dominate interpretations of proxemics theory, the core ideas of proxemics apply more generally than concerns just with just interpersonal distance. Indeed, Hall's arguments relate to a broader set of spatial relations that we might have with particular arrangements of people and objects in our environment, in co-located as well as in remote environments [38]. Such arrangements present us with constraints and possibilities for how we orient to [27], manipulate and attend to particular actors and features in our environment in the organisation of our social and cultural practices and the construction of meaning constitutive of such practices. The key issue here is that coordinated action, meaning making and intersubjective understanding in human relations are continuously realised, through our embodied actions in space and the availability of these actions to others and the availability of others' actions to ourselves. For example, in the way we move, point, touch and gesture in relation to objects and other people in that physical space [cf. 10, 11, 12, 13, 14, 21, 23, 24, 25, 26, 36, 41, 42].

These notions of proxemics have achieved widespread influence in certain design fields such as architecture. This is perhaps unsurprising given architecture's central concern with the ways that the built environment bears on the configuring of spatial relations among people and things, which, in McCullough's [35] terms, frame and instrumentalise social orientation and the interplay of embodied behaviours. This applies both to *fixed* and *semi-fixed* features of a building; its scale, and its boundaries as well as the configurations of furniture and artefacts that comprise the interior design. Sommer's [45, 46] work, for example, points to ways in which tables of different sizes and shapes (which can positon people at different orientations, distances and adjacencies) come to frame influence the social interactions, conversations and relations that play out in particular configurations around the table [46].

Such architectural concerns with proxemics are finding new form as new pervasive technologies permeate evermore aspects of our everyday world. In McCullough's [35] view, for example, networked, mobile and embedded digital technologies will allow the seams that separate people from architected things to blur and become changeable; networked connectivity particularly will bind space and people in new ways: through and across walls and buildings. In these ways, the patterned flow of bodies through architectural space is being reimagined. Proxemics and man's cultural use of space then has become an increasingly technological concern. Indeed, this has been recognised for some time, most notably in some of the foundational work with media spaces. Such technologies were of interest not just in the ability to transcend distances between physically separated spaces, but also in the ways that different camera, and display set-ups could reconfigure spatial relationships between actors and artefacts [e.g. 4, 17,

24, 39, 44, 51]. As well as being informed by key ideas within Hall's theory of proxemics, these media spaces became a vehicle for further understanding the shifting cultural and behavioral orientations in our spatial relations with other people and artefacts.

Proxemic Interactions

More recently, we have witnessed a certain resurgence in Hall's influence in the context of technology innovation. This has been driven as a more sophisticated computational ability to sense and interpret our environment allowing technologies to be more sentient of what is around and to establish proximal relations between ourselves, people and objects [e.g. 9, 18, 32, 33, 34, 41, 47, 50]. In particular Greenberg et al.'s [18] exposition of *proxemic interactions* has done much to influence this recent thinking around proxemics in HCI and ubiquitous computing research. Predominant within this paradigm of proxemic interactions is a concern with inter-entity distance, orientation, identity, location and movement. Entities here can refer to a mix of people, digital devices, and non-digital artefacts. The idea here is to operationalize such spatial relations to achieve particular system responses that react adaptively to the context defined by measured inter-entity relations. That is the system can respond in various ways to the fact that another entity is approaching it, close to it, orienting to or away from it and so on and so forth. These systems, then, are about using sensible properties of spatial relations as new forms of computational input.

There is no denying that such interaction possibilities offer huge potential and intrigue in terms of opportunities for action. However, as Greenberg and colleagues acknowledge, their *proxemics-as-input* characterization operationalizes the ideas of proxemics in a very particular way for a set of context aware technologies. Arguably this may have obscured the potential for a wider application of proxemics thinking in relation to how we understand a broader set of technologies in practice.

What we want to argue here is that such a perspective conceptualizes proxemics in HCI and Ubicomp in reasonably classic terms. In this respect, the analytic attention and design orientations are focused "*inwards"* to the interface between person and machine rather than "*outwards*" to ways that particular technologies alter the relations between bodies and their environment in socially meaningful ways. We do not want to argue that proxemic interactions do not consider the relation between other people and other objects. Indeed, they would explicitly do so. However, what we do argue is that their consideration of such relations is still primarily an inwards focused orientation that treats such relations as an interface between person and machine. Re-conceptualisations of the computer interface by authors such as Manovich [31], Gane and Beer [15] and de Souza and Frith [8], among several others, move us beyond notions of the interface simply as the mediator between man and machine to one which conceives of interfaces as mediators of our everyday experiences in social and physical space transforming relations between bodies, artefacts and environment in social practices.

Interaction Proxemics and Spatial Sharing

Such re-conceptualisations begin to point to alternative ways in which we might conceive the ideas of proxemics within the realms of Human-Computer Interaction and Ubiquitous Computing. Moving beyond the ideas of proxemics as input, we will consider the wider impact in terms of the socio-spatial qualities that the design of interactive technology may support or suppress, i.e. we wish to focus attention "outwards" at how the design of interactive technologies may change, support and or/ inhibit socio-spatial experiences. This understanding can also be found in the ideas of Fogtmann et al.'s [14] notion of *spatial sharing.* Caricatures, as presented in spatial sharing [14] also point to the strong legacy in HCI to design computers for single person use. Spatial sharing concerns itself not with the ways that we interact with artefacts as a primary concern but with the ways that this has a bearing on how we interact with others who are around. An example they use to illustrate this shift in perspective can be found in the form of a soccer game. By focusing primarily on an individual player's interaction with the ball, we ignore the relationship with all the other players on the field and the relationship with other objects (e.g. lines on the pitch, goal posts and so on). In focusing on the spatial and interactional relationship to the ball in and of itself we may as well give each player his or her own ball to play with. The spatial sharing approach, by contrast looks at how we can approach the understanding and designing of computational artefacts in the same way, as we might understand the qualities of the shared ball in a soccer game. In such a game, the action of those co-present is collectively configured in relation to the ball and environment – in the ways that participants "negotiate, fight, communicate and relate to one another" in the use of the artefact, space and environment. Here then the concerns are with how particular properties of interactive technologies are implicated in the configuration of our proxemic relations with co-present others.

Important in these arguments is a concern too with the way that interactive characteristics enable technologies to sit in particular relation to other artefacts in the environment. The possibilities for configuring these larger artefact ensembles in turn offer opportunities through which our proxemic relations with others can be configured and understood. To illustrate let us consider the simple scenario of sitting on the sofa with family, snuggled under a blanket, watching a film on a laptop that is placed on the coffee table in front of the sofa. That the laptop is stable on the table and large enough to be visible from a particular distance/angle enables characteristics of the sofa and table to express more agency in the configuring of our proxemic relations with others. A tablet device, even with the same

size display, would not facilitate such an arrangement. It would need to be held and supported at arm's length by an individual on the sofa while others leant in towards the display to achieve visibility.

There are some parallels drawn here with Kinch's [28] notion of *middleground* and McCullough's [35] ideas around "embodied predispositions" in which we design interactive technologies from the perspective of framing our bodily interactions with the broader socio-spatial world. Kinch [28] argues that notions of foreground and background in HCI are insufficient to deal with certain relations in design. In Kinch's terms, designing for the foreground activity of watching the film does not sufficiently articulate the full spectrum of design concerns here. By articulating further aspects of the middleground and proxemics the embodied relations between other bodies and artefacts in the situation. The middleground would comprise the sofa, the family and their seating positions on the sofa, the blanket, the coffee table, and laptop hardware. Our proxemic relations are configured, expressed and understood in relation to all of these components in space.

Critical in these arguments, and where these arguments build upon Hall's work while advancing it in the context of HCI is the idea that particular interactive artefacts, through their various interactive properties, dimensions and form factors have an influence on proxemics with respect to the artefacts – and in consequence, the opportunities for how we configure ourselves with respect to other actors and artefacts in the environment. The spatial opportunities and interdictions arising from these particular interactive properties are what O'Hara et al [36] term *interaction proxemics*. This is in contrast to the idea of *proxemic interactions* – and is an acknowledgement of the impact of technology on proxemics [36] rather than the impact of proxemics on technology [18]. In the following, we will emphasize how this conception of Hall's work opens up new opportunities for how we can use his work in HCI and design.

EMERGING SENSITIZING CONCEPTS

Even though proxemics is sometimes operationalized in terms of measurable distances, according to Hall [20] one should understand proxemics as inherently dynamic: Hall describes "…*man as surrounded by a number of expanding and contracting fields which provide information of many kinds…*" This dynamism is emphasized by Hall's noting that the fields do not start or end at the skin of man. E.g. the experience of *intimate proxemics* can be both larger and smaller than the boundary of the skin dependent on context, culture and role.

So, the proxemic fields are themselves dynamic, however the study of the empirical work presented later in this section made us realize that properties of socio-spatial configurations also differ in the way they allow people to engage across the range of proxemic fields – what we term *proxemic malleability*. In further discussing this, we draw upon Dunne and Raby [12]. Dunne and Raby also reference Hall [20] in developing the concepts of fields and *thresholds*. Their vision is to fuse physical and digital space, where "the interface gets off the screen and surfaces of ultra-generic products to become spatial and architectural tools allowing us to bring some of the subtle complexities of our social skills into the world of telecommunications" [12, p. 64]. The empirical material presented and referenced in this paper enable us to deepen the concept of *thresholds* through articulating how the particular properties of specific technology designs have agency in terms of raising or lowering the difficulty with which socio-spatial configurations can be changed. Furthermore, we show that some socio-spatial configurations though dynamically changing may have a tendency to *gravitate* towards a dominant configuration. In the following we describe in greater detail how the 3 sensitizing concepts *Proxemic Malleability, Proxemic Threshold and Proxemic Gravity*, have emerged from complementing theoretical reflections with analyses of cases from the office domain.

Case 1: Planned Meeting Using Video Conferencing

In this example, we want to consider a common scenario in the workplace, namely having a planned meeting using video conferencing in a standard conference room. Video conferencing provides a useful means through which we can explicate our arguments in part because it has often been used elsewhere to enable discussions around spatial and proxemic features of technology [e.g. 5, 17, 21]. This can help highlight some of the distinctive element of our particular version of these arguments.

Figure 4 A typical video conferencing setup

Figure 5 Different ways of pointing at shared materials

If we consider the above illustrative example of a work based video-conference, see Figure 4, a typical set up involves a large display arrangement at the front of a room with a camera pointing out at the room. These screens are used to display some combination of remote video feeds or data based screen shares. Many local participants are arranged around the table and may have some combination of paper documents and digital devices such as laptops smartphones and tablets arranged in the personal space in front of each of them. The first thing to note in this scenario is the ways in which the local participants configure themselves. The *scale* of the display first off all makes it visible from a particular distance and orientation meaning that all the local participants can be comfortably spaced apart from each other and from the screen; and meaning that they have a certain flexibility to orient themselves around the table. In this regard the shape and dimensions of the table becomes an expressive resource in the spatial configuration of the local participants. Having such a surface allows them also to arrange their various information artefacts in front of them. What is of particular note, though, is how having the display at the front of the room impacts on the bodily configuration of the local participants with respect to each other. In order to view the screen and in order to orient themselves within the field of view of the camera, the participants *orient* themselves towards the camera and display at the expense of facing those people with whom they are gathered. As the video screen is made the object of attention there is a constraint on the ability to direct attention to those around the table. This can be understood in terms of *proxemic malleability*. In terms of Halls proxemic zones (public, social, personal and intimate), this design centers on the social field where there is a speaker speaking out to the remote meeting participants. As discussion takes place potentially also between co-located meeting participants, this shifts more towards the personal field, but the design does not support this very well as it also enforces a specific spatial distance between co-located meeting participants for them to be visible to the camera. Thus, there is rather little flexibility in the possible ways of enacting social relationships in this setting.

Let us further consider a usual feature of video conferencing namely the sharing of digital documents and data, which is visible to both local and remote participants via their respective large displays on the front wall of their respective rooms, see Figure 5. Such visual resources play an important part in conversation, providing a common frame of reference that can be gestured, pointed at, manipulated and attended to in the production of talk [e.g. 16, 22, 23, 24]. Pointing to features of these shared visual representations in conjunction with talk is part of the repertoire of actions that we use to participate in collaborative action, see Figure 5. So for example, the act of displaying something might be used as a means to take the floor in the conversation. Likewise, we might point to a particular detail of the resource to help formulate an utterance. The extent to which these resources are to hand and accessible to all parties, then, can impact on the ability to participate. We term this *proxemic threshold.* Proxemic Threshold articulates the ease or difficulty by which the socio-spatial situation may be changed. High proxemic thresholds create stable socio-spatial configurations and low proxemic threshold invites for dynamic even rapid changes. To deepen this in relation to a classical video conference set-up as presented here we may look into available and deployable resources for participants in mobilising the shared visual display in conversations and in this way lowering the proxemic threshold?

We can begin at the most basic level of resource, which would be for a participant at the table to simply point and gesture from their seating position. While such action would enable some level of deixis, the level of precision limits its possibilities that such arm-based gesture can achieve at that distance while sitting at the table. So utterances and gesture would be added in attempt to overcome this. To take advantage of more gestural precision with respect to the shared visual representation on the display, a participant would need to get up from their seat and move close enough to the screen to delineate features of a certain scale with the desired precision.

The argument here is that such a transition from table to the required adjacency next to the whiteboard is imbued with social significance and comes at a high transition cost. The physical transition to the front of the room is a grand gesture in the ways of taking the floor in conversation. The interactive requirement of adjacency to the display at the front of the room also positions the actor in a particular proxemic relation with respect to the others in the room. By virtue of this positioning, the actor assumes a certain display of control and power [cf. 37, 43, 48, 51]. Such a spatial enactment of social power and control in the collaboration demands a big idea and contribution to justify it. Indeed, this may be the desired effect of such a socio-spatial enactment – an intended high proxemic threshold.

One can take this further and look to ways that such spatial transition from table to screen incurs additional consequences of spatial configuration with respect to other artefacts. Let us consider that the same actor had an arrangement of various artefacts on the table where they are seated, including various paper documents and laptop and a phone. Such personal information resources may contain important supporting materials for reference in the context of utterance preparation of in the context of utterance execution. Being physically separated from this ensemble, removes them as a supporting resource for the continued interaction at the display. Such organization of resources may incline a quick return to the original socio-spatial configuration. We term this strong *proxemic gravity*.

The significance of this lies not just in the use of personal resources as a point of reference in the formulation of

utterances in conversation. It also has a bearing on other opportunities for the deployment of visual resources in the unfolding collaborative scenario. Such opportunities relate to how personal resources, both physical documents and digital materials from the various personal devices that are assembled on the table. The use of the single host PC again plays out in significant ways here with access limited by the positioning of the device, its interaction mechanisms (keyboard and mouse in front of meeting host) and any supporting cabling constraints such as the length of HDMI cable. In order to display materials from their laptop the participant would have to get up from their seating position around the table to gain access to the mechanisms available for sharing personal information to the large display. So again, we see how particular interactive properties of a system involve certain spatial configurations and transitions in the performance of particular behaviors. When describing the above classical video conference setting with the sensitizing concepts suggested here we would characterize the set-up as being designed to exhibit: 1) a proxemic malleability ranging from personal to social 2) high proxemic threshold to take turns in taking the floor using supporting materials 3) high proxemic gravity stabilizing the socio-spatial configuration with a presenter in command and an audience.

As we illustrate here, the spatial properties of the system are significant elements in the opportunities for configuring in socio-spatial ways with respect to co-workers. This is not to make a normative judgment about whether this is good or bad. The point here is literacy; i.e. that the potential proxemic consequences of technology design is understood by designers. To further aid our discussion of these concerns and their significance in both analytic and generative terms let us consider a class of technological groupware interventions that look to shift these socio-spatial relations in intriguing ways.

Case 2: Planned Meeting with Democratic Control

As part of an initiative to increase audience engagement in planned meetings, Chattopadhyay et al.'s [7] Office Social was developed and tested in a longitudinal study. Office

Figure 7 Chattopadhyay's collaborative remote application allows participants to control navigation and point on the shared display from their mobile device.

Figure 6 Sorensen's Beamer application allows for wireless screen sharing [48]

Social is a PowerPoint plugin and companion smartphone app giving meeting participants access to slides from their mobile device for personal review and, when given permission by the presenter, also public control over slide navigation (see Figure 6). In this way all participants can navigate through the slides of the presenter and use a virtual pointer controlled from their own mobile device. Rich description of trial uses of the system [ibid] highlights how meeting participants engage in taking responsibility for displaying relevant contents during discussion, and also how discussions, unfold in an ad-hoc fashion in smaller groups, collectively viewing contents of the presentation on smartphones. The ad-hoc discussions being short-lived and the situation gravitating back to the classic presentation formation. Thus, compared to the first case, Office Social seems to offer *proxemic malleability* with a more equal balance between social and personal fields, as the situation shifts between presentation and discussions in smaller groups. In addition, we see a lower *threshold*, as the smaller groups seems to form more naturally in this context. However, the overall situation is still *gravitating* towards the presentation situation and the social field.

Case 3: Planned Meeting – Democratizing Contents in Video Calls

In classic video calls, contents sharing is often restricted to the contents of the person driving the host computer. Sorensen et al.'s [48] Beamer application was designed to democratize contents through allow any of the local meeting participants to wirelessly share the screen on their mobile device into an ongoing video call being hosted on a single PC that is connected to a public display at the front of the room (Figure 6). This then provides the participants with the ability to influence the shared visual resources of the public display from wherever. They can do this by sharing documents from the device. In addition, through sharing the camera feed of the mobile they can also share physical documents from wherever they have been

assembled. During trial uses of this system, it was observed how the system allowed for rather fluid switching of floor control in the meeting and for flexibility in how the mobile devices was used to capture contents both outside the room as well as live capture of contents generated on site such as whiteboard notes.

Articulating these qualities in terms of the sensitizing concepts, we argue that similar to case 2, this case also has a more equal balance between social and personal fields. Indeed, the *proxemic threshold* is lower here in the ways that situations continuously shifted between individual and shared working and the fluid interleaving between these activities as shifting participants took the floor. Compared to Case 2, this design seems to gravitate much less towards the classic presenter setup.

While the exact functionalities of case 2 and 3 may differ to some extent, what is common to them both is the ability to access and interact with shared visual resources within a conference room from their own personal mobile device from wherever they are seated. From the perspective of the sensitizing concepts forwarded here the 1) proxemic malleability stays the same, however, 2) the proxemic threshold is lowered as each participant can with little social cost intervene as each has be granted the power by device to do so and 3) the proxemic gravity is low in case 3 as the socio-spatial configuration may easily change into a shared discussion mode leaving the socio-spatial presenter/audience configuration. Had the system been designed with e.g. a time limit for participant's interruption or time limit for persistence of notes added to the slides the socio-spatial configuration would have gravitated more towards a presenter/ audience configuration.

What can be read from the above example is that interactive technologies change the signs, resources spatial experiences and human gestures of socio-spatial configurations. As will be further explored in the following example we claim that the sensitizing concepts brought forward in this paper in this way contributes to spatial literacy in HCI.

Case 4: Informal Meetings in Open-office Environment

As a final case, we bring to the fore common scenarios observed in an open-office environment designed intentionally to support informal meetings amongst co-located software developers, working on the same projects. In order to understand the nature of how both the physical interior as well as the technologies and infrastructure support collaboration during informal meetings, we conducted observations in a software development company with 50 employees. It is a Scandinavian company with a flat hierarchy with strong emphasis on democratic values. They had just been through a process of re-structuring the physical setup of the workplace. with high employee involvement. As a result, everyone, including the managers, work in an open-office environment. Collaboration in the form of informal meetings is highly valued, thus if people wish to focus on individual work for an extended period, they book a meeting room. Two of the authors spent a total of 20 hours observing the work practices and conducting 4 open-ended interviews with employees. During observations, socio-spatial transitions were captured using a snapshot notation, as can be seen in figure 9. This notation was appropriated from [3, 49] drawing upon space syntax (Figure 10). As can be seen in Figure 8, in this environment, each person has a height-adjustable desktop with double screens, mouse and keyboard at an individual workstation. The environment is further well equipped with orange guest chairs, which can be grabbed for informal conversation. The two researchers conducting the observations analysed the snapshots and identified a range of patterns, which were frequently observed. One such pattern is illustrated in Figure 9. These patterns form the basis of the discussion in the following.

Figure 8 Open office space with personal workstations and orange "guest" chairs.

What is striking from the observations are the recurring bodily enactments of sustained collaboration, where re-configurations of body posture and furniture serve to enact the collaboration around the common project. An example of a common scenario (as illustrated in Figure 9) is when two people work initially, individually besides each other at their shared desk, when one person asks the co-worker to consider an aspect of her work. The co-worker first turns his head only to glance at the problem of his colleague. A little later, he rolls his office chair towards his colleague to engage more deeply into the problem, and oftentimes, a third person approaches to engage in the discussions. Another recurring scenario involves the two people in the first configuration turn towards each other for a prolonged discussion, where no immediate visual reference is needed (Figure 9left-side top and bottom pictures).

In this environment we see how proxemic malleability is centered on social and personal fields, where the flexibility of the physical environment in particular serve to support easy transitions between individual work and awareness of colleagues in the environment, to shift focus and orientation

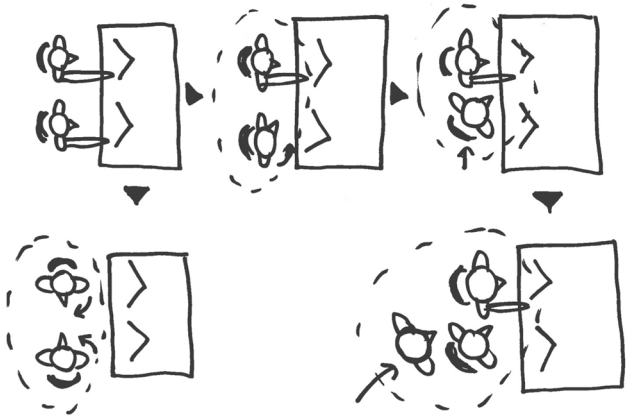

Figure 9 illustration of common scenarios observed in the open office noted using the snapshots notation.

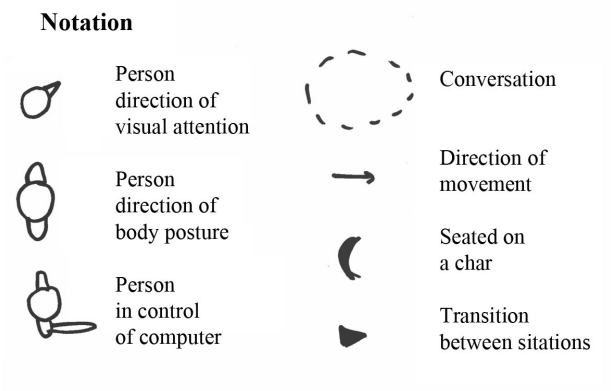

Figure 10 Snapshot notation, as developed further from [3]

and engage in discussions entering personal fields reconfiguring body position, body posture and gestures. Thus, the low proxemic threshold is very much due to the qualities of the physical environment, and the setup of the screens. In contrast, the proxemic threshold is high for modification of the digital material, as the owner retains control over the digital contents of the screen through his mouse and keyboard, as can be seen in Figure 9. Only through taking over these devices, others can obtain control, and only one person at a time. Only once did we observe that someone else took over mouse and keyboard, and the owner shifted to engage in discussions and observe the interaction. Thus, the proxemic threshold is low in terms of the physical configuration, but high in terms of the digital means of supporting proxemic transitions. Reflecting further on the properties of the physical environment, the guest chairs invite for equal foot regarding deixis and perceptual proxemics [36]. However, this only scales up to a group size of two people. As can be seen in Figure 9, we often saw how a third person would stand in the periphery of the discussion looking over the shoulders of two collaborators. Even though we observed a very dynamic environment with continuous reconfigurations around the office and conversations over and across tables, the work situation always tended to *gravitate* towards the individual working at his workstation at his desk. Based on this analysis, we envision a future design space supporting informal meetings in an open office and having a low proxemic threshold regarding both physical and digital contents. This could be in the form of a shape-changing surface, as envisioned in [19], a flexible desktop surface, which allows for both physical and digital transformations in its ability to scale up and down digital contents, as well as reconfigure scale and orientation of the physical surface.

DISCUSSION

Our aim in the paper has been to highlight further need for an increased socio-spatial literacy within HCI. Drawing on Hall's notion of proxemics, we want to offer an alternative perspective for how such ideas can be usefully deployed within HCI design thinking over and above the recent interest in using spatial properties between human and machine as a form of system input. While our interests are also bound to the particular spatial demands between humans and interactive technologies (in terms of things such as distance, orientation, mobility etc.), our primary concern is with how these demands come to bear on opportunities for our proxemic configurations with other nearby actors. Much in the way a table of particular size and shape presents opportunities and constraints for physically arranging ourselves (adjacent, facing across width, facing across length, across corner etc.) with respect to others with whom we have certain social relationships, so too do interactive technologies. From where these technologies can be seen and heard, from where can things be sensed, and from where things can be effected will all offer different opportunities and constraints for the ways that we dynamically enact our socio-spatial relations. As a simple illustration, increasing the size of a display will allow it to be viewed from further away, but there will still be requirements to face in a particular orientation (viewing angle dependent) in order to view it. Similarly turning the volume up or down will affect how near or far one has to be to the device in order to hear it but not necessarily demand a particular orientation to the device. The point then is to consider the implications of these properties in light of other social actors who around. So for example, if one has to be close to a screen and face it what does it mean for how that person may enact social relations with someone behind who is 5m away.

Our aim in developing this perspective was also to recognise the dynamics of these unfolding socio spatial relations. The 3 sensitizing concepts are important in our literacy here in that they draw our analytic attention away from the idea of spatial configuration as a static frame and raise awareness of our ability to adaptively transition to different socio-spatial configurations. The opportunities for transition are as important to consider in our design thinking as the static spatial frames in themselves. In this respect understanding the extent to which interactive contexts are *malleable* in terms of their proxemic

opportunities or understanding how and why there may be certain thresholds to change is key to how socio-spatial relations may unfold.

What is exciting about this perspective and what we hope to have illustrated in our various examples is that this alternative framing of proxemics within HCI provides both analytic and generative value. That is, not only does it offer an intriguing analytic framing within which to consider our social and collaborative use of technology, it can also serve as a generative resource in our design. As we have seen in some of the examples, design interventions can be made to deliberately shift spatial relations with technology and in doing so offer new opportunities for the proxemic configuration of action. The intention here is not to be prescriptive in terms of suggesting fixed guidelines and nor does it make sense to be so. It is not for us to be making judgements here on what the appropriate dynamics are or whether a high or low threshold is important, for example. The aim rather is to sensitize us to this set of concerns and start to develop our social-spatial literacy such that we can more deliberately design with this concerns and social dynamics in mind.

Importantly, such sensibilities are not simply limited to the office environment. The examples presented here merely offer a coherent set of scenarios and interventions through which to illustrate the concepts and help us start thinking along these lines. The Kinect example at the beginning of the paper provides some indication of the relevance in other domains. But we can imagine other examples here. Consider the difference between siblings watching a film at home either on a large screen TV or on a mini tablet. With the larger TV, there is sufficient malleability for the siblings to position themselves around the living room according to how well they are getting on at the time – close if they wish to be and far if that is more appropriate. By contrast, watching the same film on a tablet with smaller screen and lower volume would require them to huddle around the display in very close proximity – on the one hand a socio-spatial enactment of a close bond, on the other a restricted opportunity to transition to a more personal distance if necessary.

FUTURE WORK

In alignment with the above we recognize that there is no 1:1 mapping between the identified sensitizing concepts and socio-spatial experiences. The spaces explored in depth in this paper are all designed for collaboration and the identified sensitizing concepts are derived on this basis. An important part in future work is to carry out 1) experiments in "non-collaborative" situations, 2) secondly it is important to scrutinize the socio-spatial qualities in contested situations both in terms of convergent, mitigating and diverging design strategies.

There are numerous intriguing proxemic configurations in which collaboration is not pursued however infused with interactive technology co-producing the socio-spatial experience. This includes waiting at a bus stop, sitting on a park bench, co-riding in a car, bus, or train, in transit in airports, simultaneous but divergent use of urban spaces, etc. Many of these situations include both personal and contextual computing and interactive resource. What are the socio-spatial characteristics of these situations? How does interactive technologies and physical spatial attributes co-produce or counter-act socio-spatial qualities and experiences? How may we design interactive technologies for socio-spatial configurations beyond alignment, mitigating, accepting and/or co-opting socio-spatial divergence? Further research may identify other sensitizing concepts and details of socio-spatial configurations and experiences beyond what is presented here.

CONCLUSION

There are many aspects that influence social experiences: rules, power, habits etc. However, in this paper we focus on how socio-spatial experiences are configured by technology, physical spatial properties and people. For this the concept of proxemics as originally developed by Hall [20] has been helpful. In the perspective of interaction proxemics and spatial sharing we argue that every technology design has spatial agency and can be viewed as influencing possible socio-spatial configurations. We present three sensitizing concepts *Proxemic Malleability, Proxemic Threshold and Proxemic Gravity* as a contribution in this direction, showing how we may build enhanced socio-spatial literacy in HCI. Whereas the sensitizing concepts have been derived from workplace design and studies characterized as collaboration-based settings, we also apply the concepts for description and discussion of socio-spatial qualities in other interactive developments to illustrate their explanatory strength and their relevance for building socio-spatial literacy in HCI. The findings presented here invite for further investigations into how the how one might better design for stable and/or volatile socio-spatial configurations. We consider the research presented here as a step further towards understanding the spatial significance of interactive systems and devices, presenting concepts that will help interaction designers develop socio-spatial literacy.

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