2 Designing Blended Spaces for Collaboration

Abstract: In this paper, we reflect on our experiences of designing, developing, implementing and using a real world, functional multi-touch enabled interactive collaborative environment (ICE). The paper provides some background theory on blended spaces derived from work on blending theory, or conceptual integration. This is applied to the ICE and results in a focus on how to deal with the conceptualization that people have of new collaborative spaces such as the ICE. Five key themes have emerged from an analysis of two years of observations of the ICE is use. These provide a framework, TACIT, that focuses on Territoriality, Awareness, Control, Interaction and Transitions in ICE type environments. The paper concludes by bringing together the TACIT framework with the principles of blended spaces to highlight key areas for design so that people can conceptualize the opportunities for creative collaboration that the next generation of interactive blended spaces provide.

Keywords: Interaction Design, Collaboration, Multi-touch, Multi-surface Environment, Interactive Environments, Blended Spaces

2.1 Introduction

Blended spaces are spaces where a physical space is deliberately integrated in a close-knit way with a digital space. Blended spaces go beyond mixed reality (Milgram & Kishino, 1994) and conceptually are much closer to tangible interactions (Ishii & Ullmer, 1997) where the physical and digital are completely coupled. The concept of blending has been in existence for many years in the field of blended learning where the aim is to design a learning experience for students that blends the benefits of classroom learning with the benefits of distance, on-line learning, but more recently the concept of blending has been applied to spaces and to interaction.

O’Hara, Kjelsko and Paay (O’hara, Kjeldskov, & Paay, 2011) refer to the distributed spaces linked by very high quality video-conferencing systems such as Halo as blended spaces because of the apparently seamless joining of remote sites. In systems such as Halo, great attention is paid to the design of the physical conference rooms and to the angle and geometry of the video technologies in order to give the impression that two distant rooms are collocated. High-end video conferencing supports the collaborative activity of business discussions, but it does not deal well with shared information resources. O’Hara, et al. (O’hara et al., 2011) use the term blended interaction spaces for ‘blended spaces in which the interactive groupware is incorporated in ways spatially consistent with the physical geometries of the video-mediated set-up’. Their paper explores the design of a blended interaction space that highlights the
importance of the design of the physical space in terms of human spaces and the different proxemics (Hall, 1969) of personal spaces, intimate spaces and so on. They also draw on a theory of spaces proposed by Kendal (1990) that describes the interactional spaces that participants in collaborative activity share.

Jetter, Geyer, Schwarz and Reiterer (Jetter et al., 2012) also discuss blended interaction. They develop a framework for looking at the personal, social, workflow and collaborative aspects of blended interaction. Benyon and Mival (Benyon & Mival 2013, 2012) describe the design of their interactive collaborative environment (ICE, discussed later in this chapter) focusing on the close integration of hardware, software and room design to create new interactive spaces for creativity. A workshop at AVI 2012 conference on collaborative interactive spaces has led to a special issue of the journal Personal and Ubiquitous Computing and another workshop at the CHI2013 conference on blended interaction. In these meetings researchers are developing theories and examples of blended spaces and blended interactions in a variety of settings.

In addition to these examples of blended spaces and interaction in room environments, the idea of blended spaces has been applied to the domain of digital tourism (Benyon, Mival and Ayan, 2012). Here the emphasis is on providing appropriate digital content at appropriate physical places in order to provide a good user experience (UX) for tourists. The concept of blending has also been used for the design of ambient assisted living environments for older people (Hoshi, Öhberg, & Nyberg, 2011) and for the design of products including a blood taking machine (Markussen, 2007) and a table lamp (Wang, 2014).

A central feature about these latter examples is that they take as their theoretical basis the work of Fauconnier and Turner (Fauconnier, 1997; Fauconnier & Turner, 2002) on blending theory (BT), or conceptual integration. Originally developed as a theory of linguistics and language understanding, BT has been applied to a huge range of subject areas from mathematics to history to creativity (Turner, 2014) making it more a general theory of creativity than just a theory of language construction. BT is concerned with how people conceptualise new experiences and new ideas in terms of their prior knowledge. Imaz and Benyon (Imaz & Benyon, 2007) originally applied BT to Human-Computer Interaction (HCI) and Software Engineering (SE) looking at how the metaphors in HCI and SE have changed over the years and how this effects how these disciplines are perceived. In their book they analyse many examples of user interfaces and interactive systems and suggest how BT could be used to design interfaces and interactions.

The aim of this chapter is to develop the concept of blended spaces, in the context of multi-user, multi-device, collaborative environments and to see the contribution that BT can make to the design of multi-device collaborative spaces. We see the concept of a blended space as a clear example of human-computer confluence (HCC). Benyon (Benyon, 2014) discusses how blended spaces provide a new medium that enables new ways of doing things and of conceptualizing activities. He talks about the new sense of presence that comes from blended spaces (Benyon, 2012). Our view
is that, in the days of blended spaces, designers need to design for interactions that exploit the synergy between the digital and the physical space.

The particular space that is the focus of this work is known as the Interactive Collaborative Environment (ICE). The concept of the ICE took shape through an interdisciplinary university project where the aim was to look at how the next generation of technologies would change people’s ways of working. We envisaged a ‘future meeting room’ that would contain the latest multi-touch screens and surfaces, novel software and work with mobile and tangible technologies to create a new environment for meetings of all types including management meetings, research meetings, collaborative compositing for magazines, video-conferencing and creative brainstorming meetings. We negotiated a physical space for the meeting room and within a limited budget commissioned a multi-touch boardroom table and installed five multi-touch screens on three of the walls to produce a meeting room with an interactive boardroom table that can seat 10 people, interactive whiteboard walls and five wall mounted multi-touch screens (Figure 2.1).

During the last two years the ICE has been used for meetings of all kinds by people from all manner of disciplinary backgrounds. This activity has been observed and analyzed in a variety of different ways, resulting in a set of five generic themes that designers of such environments need to consider. These provide our framework for describing the design issues in ICE environments, TACIT, that stands for territoriality, awareness, control, interaction and transitions.

The chapter is organized as follows. Section 2 provides a background to the work on conceptual integration, or blending theory. Section 3 describes the design rationale for the ICE in the context of the design of the physical space and the design of the digital space. We discuss how physical and digital spaces are blended to create a new space with its own emergent properties. It is within this blended space that people must develop their conceptual understanding about the opportunities afforded by the blended space and how this can alter their ways of working. Section 4 provides an analysis of the ICE in use, drawing upon observations over a period of two years, a controlled study of the room being used and interviews with users of the ICE. This analysis highlights five key characteristics of cooperative spaces such as the ICE that reflect our own experiences and many of the issues raised elsewhere in the literature. In section 5 we see how these characteristics are reflected in the physical, digital and conceptual spaces that make up the blended space. Section 6 provides some conclusions for designing blended spaces such as the ICE.
2.2 Blending Theory

Fauconnier and Turner’s book *The Way We Think* (Fauconnier & Turner, 2002) introduced their ideas on a creative process that they called conceptual integration or blending. They argued that cognition could be seen in terms of mental spaces, or domains. Cognition involves the projection of concepts from domains and their integration into new domains. Blending Theory (BT) develops and extends the ideas of Lakoff and Johnson on the importance of metaphor to thought (Lakoff & Johnson, 1980), (Lakoff & Johnson, 1999). Where metaphor is seen as a mapping between two domains, Fauconnier and Turner see blending in terms of four domains. They explain the simple but powerful process as follows (see Figure 2.2). Two input spaces (or domains) have something in common with a more generic space. Blending is an operation that is applied to these two input mental spaces which results in a new, blended space. The blend receives a partial structure from both input spaces but has an emergent structure of its own.

In linguistics blending theory is used to understand various constructs such as counterfactual statements, metaphors and how different concepts arise (Fauconnier, 1997). For example blending theory can be used to understand the difference between houseboat and boathouse by looking at the different ways in which the concepts of house and boat can be combined. There is now extensive work on blending theory applied to all manner of subjects that offer different insights into the way we think. Mark Turner’s web site is a good starting place (Turner, 2014).

The main principles of blending are that the projections from the input spaces create new relationships in the blend that did not exist in the original inputs, and that our background knowledge in the form of cognitive and cultural models allow the composite structure to be experienced in a new way. The blend has its own emergent logic and this can be elaborated to produce new ideas and insights. This blended space may then go on to be blended with other mental spaces.
Fauconnier and Turner (Fauconnier & Turner, 2002) discuss different types of blend and provide guidance on what makes a good blend. Four types of blend are identified based on the way in which concepts from the input spaces are projected into the blended space, from simple one-to-one mappings to more complex ‘double scope’ blends that creatively merge concepts from the input domains to produce a new experience. Fauconnier and Turner see the process of blending as consisting of three main processes. Composition is the process of understanding the structure of the domains, completion is the process of bringing relevant background knowledge to the process and elaboration is the process of making inferences and gaining insight based on these relationships. They propose six guiding principles to support the development of blends. The first three, integration, web and unpacking, concern getting a blend that is coherent and in a form that people can understand where the blend has come from. The fourth, topology, concerns the correspondences between the input spaces. The fifth, ‘good reason’, captures the generic design principle that things should only be in the blend if there is a good reason for them to be there and the sixth, metonymic tightening, concerns achieving a blend that does not have superfluous items in it.

Imaz and Benyon (2007) have applied the ideas of conceptual blending to analyze developments in HCI and software engineering. They analyze a number of well-known examples of user interfaces, including the trash can icon and the device eject function in Mac OS and critical HCI concepts such as scenarios and use cases. One example they consider is the concept of a window in a computer operating system. This is a blend of one mental space – the concept of a window in a house – and another mental space, the concept of collecting some computer operations together. The generic space is the idea of being able to see a part of a large object; a window on the world if you like. The process of bringing these spaces together results in a new concept of ‘window’ that now includes things such as a scroll bar, a minimize button and so on that you would not associate with a window in a house. The blended space
of a computer window has inherited some shared characteristics from the generic space of ‘looking onto something’, but now has its own characteristics and emergent properties. This can be illustrated as in Figure 2.3.

Imaz and Benyon argue that in interaction design, designers need to reflect and think hard about the concepts that they are using and how these concepts affect their designs. They emphasize the physical grounding of thought by arguing that designers need to find solutions to problems that are ‘at a human scale’. Drawing upon the principles of blends suggested by Fauconnier and Turner they present a number of HCI design principles. When creating a new interface object, or new interactive product designers will often create a blend from existing designs. Designers should aim to preserve an appropriate topology for the blend, allowing people to unpack the blend so that they can understand where the new conceptual space has come from. There are principles for compressing the input spaces into the blend, aiming for a complete structure that can be understood as a whole (the integration principle) and for keeping the blend relevant and at a human scale.

They go on to present an abstract design method that shows how conceptual blending can be used during the analysis phase of systems development to understand the issues of a particular situation and how it can be used during the design stage to produce and critique design solutions. For example, they discuss the existence of the trashcan on the Windows desktop. Here the designers have chosen not to enforce the topology principle (which would suggest in this case that since trash cans normally go underneath a desk the trash can should not be on the desk top). Instead the designers have promoted the integration principle, keeping the main functions of the interface together in a ‘desk top’ metaphor.

The danger in presenting blending theory in such a short section is that it can seem trivial, when in fact it is a very powerful idea. Underlying BT are ideas about embodied
cognition that go back to the roots of how human cognition starts with the bodily experiences that we have as human babies growing up in a three dimensional world. Lakoff and Johnson (1999) develop this ‘philosophy of the flesh’ from a conceptual perspective and Rohrer (2010) develops related ideas from a cognitive science and neurological perspective. People think the way they do because of their inherent physical and perceptual schemata that are blended to produce new concepts that in their turn are blended to form new concepts. Understanding this background helps designers to create experiences ‘at a human scale’.

### 2.3 Blended Spaces

In looking at the sense of presence in mixed reality spaces, Benyon (Benyon, 2012) develops a view of digital and physical spaces in terms of four characteristics: ontology, topology, volatility and agency. These constitute the generic space structure that both physical and digital spaces share. Bringing blending theory together with the idea of physical and digital spaces leads to the position illustrated in Figure 2.4. He argues that for the purpose of designing mixed reality experiences, physical and digital space can be usefully conceptualized in terms of these four key characteristics.

The ontology of the spaces concerns the objects in the spaces. The topology of the spaces concerns how those objects are related to one another. The dynamics or volatility of the spaces concerns how elements in the spaces change over time. The agency in the spaces concerns the people in the spaces, the artificial agents and the opportunities for action in the spaces. By understanding these characteristics and looking at the correspondences between the physical and the digital spaces, designers will produce new blended spaces that have emergent properties. In these spaces, people will not be in a physical space with some digital content bolted on. People will be present in a blended space and this will give rise to new experiences and new ways of engaging with the world.

The conceptualization of blended spaces illustrated in Figure 2.4 relies on a generic way of talking about spaces – ontology, topology, volatility and agency. This is the generic space of spaces and places that is projected onto both the physical and the digital spaces. The correspondences between the physical and the digital are exploited in the design of the blended space. The job of the designer is to bring the spaces together in a natural, intuitive way to create a good user experience. The designer should design the blended space according to the principles of designing with blends such as drawing out the correspondences between the topology of the physical and digital spaces, using the integration principle to deliver a whole experience and designing at a human scale.
Another consideration that is important in the design of blended spaces is that the physical and the digital spaces rarely co-exist. There are anchors, or touch points, where the physical is linked to the digital, but there are many places where the physical and the digital remain separate. QR codes or GPS are examples of anchor technologies that bring the physical and the digital together. In the context of an ICE type environment people will be collaborating through some physical activity such as talking to each other, but then may access the digital space to bring up some media to illustrate what they are saying. The conversation may then continue with shared access to the digital content. In the context of digital tourism we may observe someone walking through a physical space, accessing some digital content on an iPad and then continuing his or her physical movement. Thus, in blended spaces, people move between the physical, the digital and the blended spaces. This movement through and between spaces is an important part of the blended space concept and leads on to issues of navigation in physical, digital and blended spaces. It appears in Benford’s work on spectator interfaces as the idea of a hybrid trajectory (Benford, Giannachi, Koleva, & Rodden, 2009). Related ideas from Yvonne Rogers on access points, or entry points are discussed later.

The blended space encompasses a conceptual space of understanding and making meaning and this is where the principles of designing with blends are so important. People need to be aware of both the physical and the digital spaces, what they contain and how they are linked together. People need to understand the opportunities afforded by the blended space and to be able to unpack the blend to see how and why the spaces are blended in a particular way. People need to be aware of the structure of the physical and the digital, so that there is a harmony; the correspondences between
the objects in the spaces. The overall aim of blended spaces is to design for a great UX, at a human scale.

2.4 Designing the ICE

The aim of the project to develop the ICE was to provide a great experience for people and to give them an insight on what leading edge meeting spaces can be like. The aim is to generate enthusiasm and to get people to see how new spaces could be used by domain experts in very different areas and the impact that these spaces will have on their working practices.

As with all real-world projects, the ICE had to comply with a number of constraints such as the existence of a room and a budget. It was also to be a ‘bring your own device’ (BYOD) environment. The philosophy underlying the design focused on providing an environment that would help people within it fulfill their activities and do so in pleasurable intuitive ways. Wherever possible the aim is to remove function from the content of devices (screens, laptops, mobile devices) and instead consider these devices as portals onto function and content that is resident in a shared space. This should enable and facilitate real time, concurrent, remote collaboration. Another key aim is to enable the seamless mixing of digital and analogue media. People bring notebooks, pens and paper to meetings and we are keen that such analogue media should co-exist happily alongside the digital spaces.

2.4.1 The physical Space

The physical space that was available for the ICE was an empty office, so the design started with a room, a vision and a budget of €150,000 about a third of which went on technologies for the digital space, a third on room alterations and a third on necessary infrastructure. After extensive research into the options available we settled on the following technologies. A 46” n-point HD (1080p) multi touch LCD screen mounted on the end wall of the room. This screen uses the diffused illumination (DI) method for detecting multi-touch and is capable of detecting finger and hand orientation as well as distinguishing between different users’ hands. A 108” n-point multi-touch rear projection boardroom table, also using DI is the centrepiece of the room. The table can recognize and interact with objects placed on its surface such as mobile phones, laptops or books using infrared fiducial markers. It has 2 patch panels on either side allowing the connection of USB peripherals and storage devices as well as any external DVI or VGA video source, such as a laptop or tablet, to any of the surfaces.

The table was designed specifically for the space available, which determined its dimensions and technical specification. Due to the requirement of using the table both when sitting and standing the surface is 900mm from the floor, the standard
ergonomic height for worktops. Four 42" HD (1080p) dual point multi-touch LCD screens utilizing infrared overlays are mounted on the room's side walls. Each screen is driven by a dedicated Apple Mac Pro, which can triple boot into Mac OSX, Windows 7 and Linux. The room has 8-channel wireless audio recording for 8 wearable microphones as well as 2-channel recording for 2 room microphones. Each audio channel can be sent individually to any chosen destination (either a computer in the ICE or to an external storage via IP) or combined into a single audio stream. A webcam allows for high definition video (1080p) to be recorded locally or streamed over IP. The recording facility is used both as a means of archiving meetings (for example, each audio channel can record an individual participant) or for tele- and video conferencing activities. Any recordings made can be stored both locally and on an external cloud storage facility for remote access.

The walls are augmented with the Mimio™ system to serve as digital whiteboards, thus when something is written on the whiteboard it is automatically digitally captured. Importantly no application needs to be launched before capture begins, the process of contact between the pen and the wall initiates the digital capture.

2.4.2 The Digital Space

The ICE hardware has been selected to offer the widest range of development and design opportunities and as such we have remained platform agnostic. To achieve this, all the hardware runs on multiple operating systems (Mac OS X, Windows 7 & 8, Linux). Alongside the standard development environments are the emerging options for multi-touch, central to which is the Tangible User Interface Objects (TUIO) protocol, an open framework that defines a common protocol and API for tangible multi-touch surfaces. TUIO enables the transmission of an abstract description of interactive surfaces, touch events and tangible object states from a tracker application and sends it to a client application. All the hardware in the room is TUIO compliant. The TUIO streams generated by the screens and table in the ICE are passed to the computers via IP thus enabling the possibility for more extensive remote screen sharing. Indeed, if a remote participant has the capacity to generate a TUIO stream of their own, as is the capability with many modern laptop track-pads, they can collaborate with the ICE surfaces both through traditional point and click methods but also multi-touch gestures.

A key design issue for the software is that there is no complex software architecture required. All applications are available at the top level; the TUIO protocol means that any device running it can interact with other devices running it. This allows for easy integration of mobile devices into the room and sharing control across devices. Since everything in the room is interconnected through the Internet, the room demonstrates how such sharing of content and manipulation of content could be physically distributed.
In terms of software, the ICE makes extensive use of freely available applications such as Evernote™, Skype™, etc. A key design decision for the ICE is to keep it simple and leverage the power of robust 3rd party services. People need to be able to come into the room and understand it and to conceptualize the opportunities it offers for new ways of working. It is little use having applications buried away in a hierarchical menu system where they will not be found. Hence the design approach is to make the applications all available at the top level. One particularly important application is Dropbox™, which is used to enable the sharing of content across devices. Since the Dropbox™ service is available across most devices; any content put into one device is almost immediately available on another. For example, take a photo on an iPhone or Android Phone and it is immediately available on the table and wall screens. Essentially Dropbox™ works as the synching bridge across all the separate computers driving each surface, which enables a seamless “shared repository” experience for users. Any file they utilize on one surface is also available on any other, as well as remotely should the user have the appropriate access authority.

Of course things are constantly changing, but the aim is to keep this philosophy stable.

2.4.3 The Conceptual Space

The conceptual space concerns how people understand what the novel blend of physical and digital spaces allows them to do and how they frame their activities in the context of that understanding. There are a lot of novel concepts to be understood. For example, people need to understand that the screens on the walls are not computers, but are windows onto data content in the cloud. They will recognise the Internet Explorer icon on a screen and rightly conceptualise that this gives them Internet access, but they may not realise that they can save files to a shared Dropbox™ folder and hence enable files to be viewed through different screens. They need to conceptualise the wall screens as input and output zones that can show different views at different times. People who have used the ICE a few times come to understand that they can see an overview of some data set on one screen and the detail on another and that this is useful for particular activities. The wall screens can be easily configured to mirror each other, or to show separate content. The challenge for spaces such as the ICE is that people do not have a mental model, a conceptualization, of the space when they first arrive. It is up to the designers to present an informative, coherent image of the system that enables people to develop an appropriate conceptual understanding of the opportunities. For example we developed a control room map to help people conceptualise the interaction between the different screens and how any screen could be the source of an image displayed on any number of other screens. This is one example of an attempt to provide a way into the conceptual space. Restricting
the functionality of the digital space and providing this through a few familiar icons is another.

2.4.4 The Blended Space

We can summarise the ICE through the lens of conceptual blending as illustrated in Figure 2.5.

2.5 The TACIT Framework

We have now had the opportunity to observe many meetings in the ICE. It is a space that encourages people to get up and move to one of the screens to demonstrate something, or use the whiteboard capabilities of the wall surface to illustrate ideas. The room is highly flexible in terms of lighting, audio and the use of the blinds. Thus the atmosphere can be quickly changed as required. The ability of people to easily join in the room using internet-based video-conferencing has proved an important feature.

The room certainly encourages collaboration and participation. With five screens it is very natural to have documents displayed on one or two, web searches on another and perhaps YouTube videos on another. However, it is also true that many people find it difficult to conceptualize what the room can do and how they can make it do things. This serious challenge for interaction design – how to get people to understand the opportunities afforded by novel interactive spaces – remains stubbornly difficult to solve.

Figure 2.5: The ICE as a blended space
The meetings that we have observed have included conference organisation meetings, preparing research grant proposals, publicity preparation, teaching interaction design, remote viva voce examinations and numerous general business meetings. A controlled study of the ICE has been completed that included a grounded approach to analyzing video, interview and questionnaire data and a survey of user attitudes to the ICE has been completed. The results of this analysis of video, the interviews and the real-time observation have provided a rich picture of collaboration in the ICE.

Classic issues of computer supported cooperative work have been identified and described over the years (Ackerman, 2000). Against this background five themes have emerged from our analysis of the ICE in use that provide a way of structuring the issues that have arisen and that designers of room environments need to deal with. These reflect the main concerns identified in previous literature on collaborative environments. We discuss the issues in terms of territoriality, awareness, control, interaction and transitions between spaces: the TACIT framework.

2.5.1 Territoriality

Territoriality concerns spaces and the relationships between people and spaces. Scott and Carpendale (Scott & Carpendale, 2010) see territoriality as a key issue in the use of tabletops (both traditional and interactive) for cooperative work. They identify personal spaces, group spaces and storage spaces. They also point to the importance of orientation, positioning and proximity in addition to the partitioning of spaces into different regions. These all contribute to people’s sense of territory and their relationships with their space. Territory is also important on large multiuser displays (Peltonen et al., 2008). There are many social and psychological characteristics of territories that designers need to consider such as proxemics (Hall, 1969), (Greenberg, Marquardt, Ballendat, Diaz-Marino, & Wang, 2011) and how comfortable people feel when they are physically close to others.

Issues of territoriality are central to working in the ICE and we have witnessed many examples of groups configuring and reconfiguring their spatial relations depending on the task. We have observed incidents where people cluster around a wall screen watching one person working and commenting on what is going on before going back to work individually. People have commented that being able to work in different places in the room helps collaboration and moving around in the room makes collaboration easier.

We have seen a number of incidents where the assignment of roles and tasks is influenced by location and proximity to a particular piece of technology. The role of penholder in brainstorming tasks may be assigned to the person sitting nearest to the whiteboard. Participants tend to use the wall-screen nearest to them and the person interacting with the tabletop applications at the table was the person sitting nearest the controls at the bottom edge of the screen. There is often a close connection
between the control of physical space in the environment and the control of screen workspace, which in turn affects the assignment of roles and tasks.

The tabletop can be configured in different ways and there is one setting that has six individual places each with a digital keyboard and media browser. This allows people to have their personal space and then to move work into a public sphere when they are ready. Haller, et al., (2010) emphasise the importance of these different spaces in their NiCE environment. Personal spaces are provided through individual PCs and through personal sketching spaces. These can be shared with the group through a large wall display. In earlier contributions to collaborative spaces, Buxton (2009) describes media space in terms of the person space, task space and reference space and provides a number of design guidelines for ensuring quality spaces. It is the intersection of these and the ease of moving between them that is important.

2.5.2 Awareness

The issue of awareness is a common central theme running through the literature on cooperative work (e.g. (Tang, 1991)) and is a central issue for the ICE. The concept of awareness hides a large amount of complexity. Schmidt (Schmidt, 2002) lists seven common adjectives often attached to the word ‘awareness’ such as peripheral, background, passive, reciprocal and so on. He goes on to explore the concept in detail, finally arguing that “the term ‘awareness’ is being used to denote those practices through which actors tacitly and seamlessly align and integrate their distributed and yet interdependent activities”. Awareness includes aspects of attention and focus, so explicit awareness of what others have done is also an important aspect. Awareness is much more than simple information, however. It is to do with the social aspects of how people align and integrate their activities. Awareness is an attribute of an activity that relates to many of the characteristics of a situation. Rogers and Rodden (Rogers & Rodden, 2003) also emphasise the importance of dealing with different types of awareness and with the transitions between them (see below).

In the ICE, different tasks invite different degrees of awareness. For example, brainstorming tasks require shared attention whereas an individual searching the web on a wall screen does not. Tasks that can be undertaken in parallel may need support to keep others aware of progress and when the task is completed. Several people have commented that a shared Dropbox™ folder is useful for maintaining awareness as it gives real time information on the progress of the work of the other participants; images dragged into Dropbox™ on a screen soon appear in Dropbox™ on the table.

Even during individual tasks there are frequent shifts between shared and divided attention with people participating in discussions in a group across the room and then turning their backs to individually search for images and information on the wall screens.
When collaborating in a shared physical environment like the ICE participants become aware of each other’s activity through direct perception. People are able to see and hear each other as they work at the surfaces, moving around the room or talking to other participants. Writing on the whiteboards enhances awareness and collaboration and allows people to use gestures to refer to specific objects or the organisation of objects on the surfaces.

The various surfaces support collaboration through awareness differently. There have been instances where participants grew silent while working on the wall screens and focused on their own tasks loosing awareness of what was going on in the room behind them. Working around the table creates a higher degree of shared awareness; one of the advantages of table displays with respect to collaboration.

2.5.3 Control

Control refers both to the control of the software systems and to social control of the collaborative activity. Yuill and Rogers (Yuill & Rogers, 2012) highlight the importance of control in their discussion of collaborative systems. This is related to the concepts of access points (see below). Rogers and Lindley (Rogers & Lindley, 2004) also identify control as one of their factors describing collaborative environments along with awareness, interaction, resources, experience, progression, team and coordination.

In the ICE we have observed people taking turns to interact with the table with only one person touching it at a time in order to maintain control. However, some of the software on the table has a lack of support for multi user interaction and this creates issues with conflict of control. It is easy for one person to enlarge a display (often accidentally) so that it covers the whole of the tabletop and the whole workspace and all the objects on it are covered over. People have adapted to this by taking turns interacting with the table.

A common configuration of the input and output structure is to have two screens mirroring each other on opposite sides of the table. However, whilst this helps awareness, it can negatively impact control. One person may have started interacting with a screen without realising that another person was using the mirrored screen and hence takes over control of the pair of mirrored screens.

Often people sitting at the “bottom side” of the interface near the controls were also the ones who controlled and interacted with the application. However we also observed incidents where people are working at the table from both sides without regard to the orientation of the application. The location of the controls on the bottom edge at the lower left and right side of the screen demonstrated a “short arm problem”. Due to the size of the table’s screen, it is impossible for someone standing at the centre of an edge of the screen to reach the corners without actually moving his or her body to the left or right. This also gives rise to a mode of collaboration where the participant standing near to the controls would press buttons at appropriate times.
Control is a key component of Yuill and Rogers framework for collaboration. The locus of control is closely related to the access points provided by the technology. Their main focus is on aiming for equitable control in a collaborative setting and they emphasise that the location of access points and how people move between access points is critical.

Control, and people’s understanding of what they can control is key to ideas of appropriation and ‘tailoring culture’. People need to be encouraged to understand that tailoring is possible in an ICE organizationally, technically and socially. This tailoring, or customization is an essential part of the appropriation of technology and of spaces. People need to adapt, and shape the environment, the interactions, the content and the computational functions that are available to suit their ways of working. However, this is easier said than done. People have to be confident and capable to appropriate their technological spaces. They need a conceptual understanding of the digital and physical spaces so that they can change their ways of working, and designers need to design to support appropriation and the formation of an appropriate conceptualization of the space.

2.5.4 Interaction

This theme concerns how people interact with each other and how they interact with the activities they are undertaking. In collaborative tasks, articulation is concerned with how work is divided up and tasks are allocated between members of a group. How this happens is quite different with respect to how the surfaces of the room are used for the different tasks. The users’ familiarity with the room, their experience with working on touch screens, their prior knowledge of each other and experience in working together are all factors in producing the different conceptualizations of the ICE and hence the best ways to interact. People do things in different ways and the variation in the use of the room and its facilities indicates that the environment effectively supports this variety.

The ICE supports articulation as it affords the distribution and execution of sub-tasks. The physical layout of the room gives easy access to workspace and this makes coordinating tasks easy. We have also seen numerous and at times very rapid shifts in the social organisation of work. For example, people will shift between working individually at the wall screens and turning around to communicate across the room as a group. Shifts also occur when people go to the wall screens to search web for information during a discussion or the execution of a task only to return to the group when information is found. Also while working at the table there is a variety of ways to organise the work. The parallel tasks of searching and sorting can be accelerated if the group divides itself into subgroups. This may be contrasted with serial tasks such as putting collaborative projects together.
We have observed tasks being distributed by negotiation through verbal communication, but also seen people spontaneously go to a surface and start doing a task. We also observed how roles and tasks were handed over simply by turning around workspace on the table surface.

Interaction is one of the four components in the model of collaboration discussed by O’Hara et al. (O’Hara et al., 2011) along with work, communication and service. They emphasise the importance of getting the granularity of the space right. The interplay between the spatial configuration, the social organisation and interaction is critical. O’Hara, et al. discuss their blended interaction space (BISi) as an example of workplace design, once again emphasising proxemics in design and the control and set up of work tools as an essential part of the interaction.

Hurtienne and Israel (2013) offer sound design advice for designing ICE type environments with their PIBA-DIBA technique. PIBA-DIBA stands for ‘physical is best at – digital is best at’. The aim is to identify where designers should allocate parts of the interaction to physical objects and where they should be allocated to digital objects. For example physical objects are perceived in 3D and are graspable whereas digital objects are easy to transfer and transform into other representations. The aim of PIBA-DIBA is to sensitize designers to the qualities of the different media in order to design for better interaction in blended spaces.

### 2.5.5 Transitions

Blended spaces are rarely completely integrated. Instead there are touch points where the digital and physical are brought together and where people transition from the digital to the physical or vice versa. In the context of digital tourism, for example, the global positioning system (GPS) is often used to link the physical world of a tourist location with some digital content that is relevant to that location. Quick Response (QR) codes also serve this purpose. In the context of blended spaces such as the ICE people transit from the physical to the digital and back again as they use personal and shared devices to access digital content and bring this into the physical world of displays and discussion.

Discussions with users of the ICE indicate that the physical layout of the room gives easy access to different workspaces. It seems to be less clear whether the individual platforms (whiteboard, wall screens or table) were easily accessible for all people. For example, the placement of the whiteboards at the corners of the room has been suggested as a problem limiting the physical access to the board, and others have argued that seeing objects from different perspectives when working at the table is a problem.

Transitions between spaces and between the physical and the digital are identified by Scott, Grant and Mandryk (Scott, Grant, & Mandryk, 2003) as a significant feature of tabletop interaction. Yvonne Rogers and her colleagues in a number of
publications describe these transitions in terms of access points, or entry points. They find that people are excluded from equitable participation in collaborative activities because of difficulties in gaining access to the physical environment, or the digital environment or both, or in moving between the physical and the digital. In the Shared Information Space framework they offer advice on removing barriers to access and enabling entry points that provide a good overview of the space and the opportunities to move between locations in the spaces.

2.6 Discussion

People are aware of each other’s actions because they can see and hear each other and they can sense what is going on in the room. People are able to move about and interact with physical and virtual objects and information in the room and on the surfaces. They are aware of each other as human beings and react to each other and the physical environment according to norms and habits they find appropriate for the situation. The physical and social interactions are intricately intertwined.

Visibility of information and objects in the environment — often referred to as the information and interaction resources — is another key finding. Different surfaces offer different opportunities for reference. People check notes on the whiteboards or use file browser windows to follow the progress of work or to recapture information needed for the work being done. These notes and traces of work were important tools in the collaborative work as they serve as external memory and a representation of common ground (Monk, 2003).

The shifts in social organisation of work are important. We have observed constant fluctuations of groups of participants being formed and broken up to work on tasks, communicate or just to observe the progress of a task. There are shifts between working collaboratively in groups and working alone on subtasks. The fluency in the social organisation of work reflects the way participants move around in the physical environment and take control of physical and interactional resources.

2.6.1 Designing the Physical Space

The design of physical space draws upon the disciplines of architecture and interior design and an understanding of social psychology. The physical space comes with the social expectations of people concerning behaviours and at the same time the physical space will help to shape those behaviours. The physical space allows for interaction between people through touch, proximity, hearing and visual perception. The physical space influences many aspects of the interaction such as territory, position, control, and orientation. Orientation is an issue on flat surfaces and occlusion needs to be avoided.
2.6.2 Designing the Digital Space

The digital space concerns data and how it is structured and stored. It concerns the content that is available and the software that is available to manipulate the content. The digital space is the medium through which people engage with content. Digital tools need to be appropriate for the physical space and for the characteristics of the devices that interface with the digital space. Gestures, touch and other forms of physical interaction provide a direct engagement between the physical and the digital. With no standards for gestures on multi-touch surfaces, designers need to attend to facilitating learning and minimizing mistakes.

2.6.3 Designing the Conceptual Space

In a blended space such as the ICE, designers bring together the digital and the physical to produce a new space. In the case of the ICE the aim was to create a space that would support collaborative activities such as meetings of various sorts. The conceptual space is where people produce meanings and understand where they can go and what they can do. People need to understand the relationships between the physical and digital spaces, their organization and structure, so that they can navigate these spaces. Conceptually these spaces are not easy to understand. It is through, or in, the conceptual space that people work out roles, task allocation and the social organisation of their work. This is where they figure out what they need to do and how best to do it conceptualizing the opportunities and reacting to the physical and digital constraints.

2.6.4 Designing the Blended Space

By thinking about the three spaces – conceptual, physical and digital – that make up the spaces of interaction, and the five themes that emerged from our reflections, we can sensitize designers to the bigger issues. Interaction designers need to design for space and movement as well as interaction with technology. They need to consider the devices that people will bring with them and how these can be integrated into the whole experience of being in, and working in rooms and other interactive spaces. They need to consider how to keep people connected to their personal digital spaces whilst working and collaborating in shared spaces.

Analogue and digital media are mixed in different ways and need to be managed and interchanged. There are multiple digital territories and physical spaces to manage. There are public, private and shared spaces, storage spaces, historical spaces and different types of content that exist in those spaces. Moving content between them, easily and naturally, is critical to providing the seamless experience of sharing. The
physical space, seating, lighting and general ambience need to be well designed to enhance the quality of experience.

There is also a lot of design needed to deal with meta-level, conceptual issues in these new collaborative spaces. People need to know what the space can do, what applications there are and what they do. The design principle of consistency is not possible in an environment that exploits cloud-based applications from different providers, so designers need to provide guidance on how to transfer content from one view to another, how to link views and how to switch media.

Designing blended spaces for collaboration means thinking about the five themes and how the proposed blend of physical and digital spaces have new properties providing new opportunities. Design to support the different territories of interaction, both physical and digital. Design for physical and digital awareness of what others are doing and what they have done. Design for equitable control of spaces and resources. Design for flexible task allocation and execution and interaction. Design for transitions in the physical and digital and between the physical and digital.

2.7 Conclusions

Conceptual blending as extended here into ideas of blended spaces for collaborative interaction provides designers with a way of thinking about design issues involved in the design of room environments. The TACIT framework – derived from our own experiences and those of other researchers and designers – orientates designers to the key issues that need to be considered in ICEs; territoriality, awareness, control, interaction and transitions.

Our own design methodology (Mival & Benyon, 2013) reflects the fact that every use case for an ICE is different. One reason for applying blending theory and the TACIT framework to the design of ICEs is to help designers deal with the variety of physical and digital spaces that they will be dealing with. Five general steps are needed: identify and understand the purpose of the ICE; examine the current practice; determine the project constraints; determine appropriate technologies for the space (the digital space); model and map the physical space including layout, furniture and lighting and environment control. Understand the main objects in the spaces (the ontology) and how they are to be related to one another (the topology). Understand how things change within the spaces (the volatility) and understand what people need to do (the agency). Develop the space utilizing the concepts in designing with blends, aiming for an integrated blended space that deals with the known issues of collaborative environments of territories, awareness, control, interactions and transitions (TACIT). Recognize that your users will use conceptual blending when they come to use the ICE, bringing their background knowledge of computers, multi-touch domestic devices, domestic media players and naïve networking knowledge. Provide information in the
conceptual space to help people understand the opportunities afforded by the new blended space.

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**References**


