WP 4 Mediated Presence Components

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# Context

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**Dependencies**

This deliverable uses specifically the input of the deliverables D2.3 High-fidelity Mockup; D2.4 User Requirements 1.0, and D4.1 Virtual Cameras 1.0. It will be the basis for D6.2 First Pilot, D4.8 Immersive Spaces 2.0.

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**Approved by:** PMT

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## Abbreviations

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<td>COMPEIT</td>
<td>Connected Media and Presence from European Institute of Technology (this project)</td>
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<tr>
<td>EIT ICT Labs</td>
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<td>WebRTC</td>
<td>Web Real-Time Communication as defined by the W3C</td>
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<tr>
<td>Chromakey</td>
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1. Summary

COMPEIT creates a web-based system for highly interactive, personalised, shared media experiences. The new technologies will improve the feeling of being together in a shared mediated space and support interaction and collaboration between people who are separated in time or space.

Immersive spaces 1.0 is a software component for the COMPEIT presence system with a feature set that allows users to interact and perform shared actions in virtual spaces, simply using their web browser. The main features are called SharedSpace, a virtual 3D environment which users can redesign and populate by scaling and rearranging their avatar-like live videostream representations; and PixelPresence which offers a pixelated view of a livestream, thereby adding an ambient and discrete presence filter, which indicates movement and subtly prompts users to enter a mediated interaction. The presented component lets users design their own Immersive Space, which in its most basic implementation can be described as a “group video chat” or a shared video window in which participants develop a rich sense of being together in a mediated space. The easy access opens a wide range of tools that facilitate co-creation of virtual space and shared actions. These functionalities derive from an iterative design and prototyping process in T4.2 Mediated Spaces and were informed by preliminary user tests and results from D2.4 Value Sensitive requirements 1.0. Preliminary versions of components were reported in D2.3 High-fidelity Mockup, such as environmental displays (PixelPresence, Softwall) that form part of a building interior and invite users to monitor features both in their immediate physical environment as well as in online virtual spaces, in other words, to collaborate in mixed-reality space. What emerges from the on-going research in WP4 is a digital toolbox of new design materials to furnish interiors and create mixed-reality spaces. Real-time video and audio streams are combined with embedded smart devices and building components that respond to users’ presence by local action or remote interaction.

The COMPEIT presence system supports individuals and distributed groups who want to stay close with one another on a regular basis, ready to spontaneously interact in mediated and virtual space. Feedback from users and user requirements in WP2 showed that people want to be subtly aware of what others are doing, and if they are at a particular place at a given time – which, of course, is quite different to keeping a videolink open 24/7. Whether the context is professional or social, ambient forms of presence are thus called for, in order to support gradation and, perhaps more importantly, to prompt users to join a shared virtual space. The way in which immersive experiences take place in everyday communication and meetings differ greatly from that of a gaming context. One of the design efforts in WP4 has been to study this gradation of immersion, result of focus and attention between fully immersive virtual meeting spaces, composed from the audio-visual and 3-dimensional data of remote locations, and the peripheral, ambient awareness of potential for engagement, through what we tentatively call environmental displays (which in some cases can also consist of audio and video). When a space has immersive properties, it has the prerequisites to deeply involve and engage the user. An immersive space allows the user to not only consume media in an engaging way, but also manipulate, monitor and control the communication channel(s) and the remote location(s) where other users are present and where events occur that can be mediated back to the user’s own node.

The report also discusses the wider application area and potential commercial exploitation of Immersive Spaces 1.0 in light of the planned piloting in WP6 (D6.2 First Pilot Report), and for which several possible use contexts are currently investigated. While the Immersive Spaces feature set supports socialising and co-creation of virtual shared spaces for generic office contexts and for children with special needs (who can use paint and other overlay functionalities to creatively transform live videostreams and co-create 3D virtual environments etc), it may also be applied to more specific professional contexts, such as mobile journalism and broadcast settings. Finally, the report presents an online pilot study targeting web communities, the COMPEIT Fun Palace, which could be developed in conjunction with the COMPEIT Experience Lab.
2. New introduction

This is a resubmission of the short report that accompanies Deliverable D4.4 Immersive spaces 1.0 and it describes the background, functionality and role of the Immersive Spaces component in the COMPEIT system. D4.4 is delivered by T4.2 Mediated Spaces with contributions from T4.1 Virtual Cameras and work has primarily been produced by KTH and LTU, with contributions from all other partners. This introduction has been rewritten in response to comments from the Year 2 Review in January 2016 and approved by PMT date [suggestion]. Besides the introduction with an updated list of references, and a new caption for Figure 3, this resubmitted report is the version that was approved by PMT in February 2015 when work to deliver the component was completed. D4.4 was ready for submission then, however not submitted.

Early on in the design process, we discovered that the Immersive Spaces 1.0 component prototype (Figure 1) was very attractive to users and we soon labelled it SharedSpaces. During COMPEIT’s second year, and based on the preliminary positive findings from our piloting and dissemination of SharedSpaces, PMT decided that SharedSpaces henceforth will constitute the main framework for the COMPEIT system. Through iterative design and development, not least informed by the pilot studies we launched in Q1 (cf D6.2 First Pilot), and parallel work towards other deliverables, new versions of SharedSpaces were produced since February 2015. This report however documents the first version of SharedSpaces and refers to the status of the COMPEIT system at the time when the component was concluded. Work to integrate SharedSpaces to the main prototype had not yet started, but a first iteration was reported in D3.4 First Prototype in March 2015. (The above explains why WP6-7 decided to pilot component prototypes rather than integrated system prototypes, see D6.1 for further explanations).

Figure 1 SharedSpaces is a component from COMPEIT, reported in D4.4 Immersive Spaces (February 2015) and has since been identified as the main framework and interface for the system that results from the project. Cf. COMPEIT filmclips.
Now that we are rewriting this introduction in March 2016, more recent iterations of SharedSpaces prevail and we can prove the functioning of an integrated COMPEIT prototype available at: http://sprint.compeit.eu

The software is available here (contact us for login access):
https://github.com/mylikerala/compeit

User instructions for the integrated prototype are available here:
https://drive.google.com/folderview?id=0B3F7Y5C2Wd0vWE55eVlyUHlhWXc&usp=sharing

The version of SharedSpaces reported here, a.k.a D4.4 Immersive Spaces 1.0, that was ready in February 2015, is still available and can be tried out here: https://smartspaces.r1.kth.se:8022, (a recreated version of http://compeit.eu/sharespaces, as it was available in February 2015). The delivered software is found here (contact us for login access): https://github.com/mylikerala/compeit.

More recently, a SharedSpaces prototype with similar functionality and that incorporates additional features developed in Year 2 (linked to work towards D4.3, D4.5, and D4.6) can be found here: https://compeit-enjoy.herokuapp.com/someRoomName (The software is available here (contact us for login access): https://github.com/jimnys-8/compeit).

The following earlier versions of SharedSpaces provide slightly different functionality and are also maintained for dissemination and piloting purposes: https://r1.kth.se/smartspaces/fun, https://r1.kth.se/smartspaces/ericsson (The software is available here (contact us for login access): https://github.com/mylikerala/compeit).

That the above component prototypes have been working in parallel proved very fruitful for various contexts (distributed work, socialising and fun, mobile journalism) and have also served our numerous dissemination activities in Year 2 (see SharedSpaces filmclips and dissemination, in List of references).

In spite of its name, this report is not a study on immersion in video-mediated environments; it documents a software component in which, following DoW, the "local space and the spaces where live media streams originate are one and the same. This is achieved with augmented video streams that use chroma keying and virtual camera techniques. This represents the first result from T4.2, with contributions from T4.1."

D4.4 accounts for precisely this; it is a software component for the COMPEIT system with a feature set that helps to create an illusion that the local space and the spaces where live media streams originate are one and the same. It employs established chromakey technique through a web-based service, without any additional software or plug-ins, hereby making it accessible to users in different contexts, not least for the integration of video effects and virtual camera techniques. Shared Spaces/Immersive spaces 1.0 is the fourth software component to come out of WP4 "Mediating Presence Components". SharedSpaces brings people together: although you are in different locations, you appear side by side in front of a chosen backdrop, and you can draw together in a virtual space.

What this report also lays the foundation for, is the possibility that SharedSpaces can be developed to support the creation of instantly shared virtual spaces, in which backdrops are swiftly replaced by (a)synchronous video feeds and/or 3D models, and into which objects from real spaces (or sensor-data) can be added, stored, and shared and monitored among recognised users (notifications in a dedicated user group), in short: a web-based tool for spatial and social connectedness. This is in line with an over-arching research interest within WP4 Mediating Presence Components that has matured in Year 2, based on what we have already learned. The COMPEIT system can, at least to an extent, support users to...
seamlessly move between real and virtual spaces by integrating a range of previously
separated media channels.

The version reported here as, D4.4 Immersive Spaces 1.0 adds a spatial quality of
experience and enhances grounding and social cues by merging video-streams with different
backdrops (jpeg, youtube clips or live video footage), and by representing users side by
side on a backdrop that can be instantly changed. It offers a fun, novel and aesthetically
appealing approach by engaging users in multiple locations to manipulate their real-time
video-streams. Users co-create shared virtual spaces into which they can add and control
features to fit contextual needs. SharedSpaces supports social dynamics by allowing users
to draw and paint together and to move and resize video streams.

A few comments from the Second Review suggest we need to clarify several of the concepts
that range from immersion to awareness, and more explicitly articulate our concern to
support a gradation process from awareness to rich (tele)presence (Markopoulos et al 2009).
As noted by Freeman et al (2001) presence is relevant to understanding users’ experiences
of media specifically because an illusion is generated, whereby a user experiences that s/he
is located somewhere else than her/his local real space: “This illusion can be entertaining
(Lodge 1999), but in addition it might affect users’ performance within mediated
environments (Welch, 1999) and support effective therapeutic applications (North, North, &
Coble, 1997). It remains though, at all times, an illusion”(Freeman, ibid 2001). Presence can
thus be evoked by a range of different media and to varying degrees. Freeman et al suggest
that tradeoffs occur between the different determinants that contribute to the experience of
presence. E.g displays that support a high degree of photorealism may compensate for an
absence of control and manipulation that other devices offer. This discussion is, of course,
relevant to the SharedSpaces component of COMPEIT, which seeks to support presence,
and spatial connectedness from 2-dimensional displays, yet creates the illusion of a
three-dimensional spatial entity. In COMPEIT, the various user tools for co-creation and the
possibility to add contextual information provide the kind of compensation referred above.

In the following, we will elaborate on the component’s capacity to support (social) presence,
immersion, engagement, naturalness, and social connectedness during interaction, i.e. some
of COMPEIT’s user experience dependent variables (See D7.1 Evaluation strategy, Table 4)
that have informed the piloting framework and constructs for the questionnaires prepared
and used in piloting (for details, see D6.1 First Pilot, resubmitted report). For actual findings,
we refer to D7.2 First Evaluation Report, which is still work-in-progress due to delays already
accumulated in year one and progressing in year two, and unfortunately outside our control).
Based on our pilot studies of SharedSpaces we can however conclude that the experienced
levels of presence, immersion, engagement and naturalness were satisfactory and this has
also been confirmed by a smaller study on older adults (Kostoska 2015, Kostoska et al
2016).

Immersion, engagement, and naturalness

A large spectrum of methodologies link presence to concepts such as immersion,
engagement (involvement, attention), and naturalness. As noted by Benyon et al (2005),
immersion is a broad concept: "Immersion is the feeling of being wholly involved within
something, with being taken over and transported somewhere else. You can get immersed in
all manner of things (such as reading a book), so immersion is not about the medium; it is a
quality of the design."

Schubert et al.’s (1999) three presence-related components (spatial presence, involvement,
and realness [approx, how the experience compares to reality]) show strong parallels with
the three main determinant factors identified by Freeman et al (2001), namely Sense of
Physical Space, Engagement, and Ecological Validity. Further, Freeman et al’s concepts
Sense of Physical Space and Engagement correspond closely with two factors that Witmer
and Singer (1998) identify as essential to experiencing presence, namely the terms
Immersion and Involvement, which they regard as interdependent for the experience of presence.

In terms of evaluation methodology, COMPEIT relies on the questionnaire developed by Freeman et al (2001): the ITC-Sense of Presence Inventory (ITC-SOPI). In or piloting of the D4.4 component SharedSpaces (see D6.1 First Pilot), we used a validated abbreviated version from previous research (Kort 2010, 2016). The questionnaire contains 13 items, each item is a statement, and we invited participants to state the level up to which they are or disagree with the statement on through 5-point Likert scale, with 1 = “totally disagree” and 5 = “totally agree”. During the experiment, the researcher makes observation notes. Additional observation notes were taken by the researcher immediately after the experiment, when the participants fill in the questionnaire. Additionally, we had a semi-structured interview with the participants in the end.

The first determinant factor in the ITC-SOPI, a ‘Sense of Physical Space’ is founded on a dependency between spatial factors, engagement and naturalness which can be considered quite relevant to the attempts within COMPEIT: “Presence is likely to be related not only to a user’s sense of being located within a spatially contiguous physical environment but also to his/her personal evaluation of the appeal and the naturalness/believability of the content within the displayed environment.” (Freeman et al, ibid). Their explanation is that the ability to physically control and manipulate aspects of the displayed environment (even using unsophisticated control devices) enhances the sense of being physically located in that environment.

In terms of engagement, our questionnaire includes the questions “I felt like I was responding to what happened in the Shared Space”, “I actively participated in the activity”, and “I was aware of what the other participants were doing”.

Our piloting uses the Sense of Physical Space sub-scale, measuring the experience of “I felt like being in the same space”, and “I felt like the boundaries between my location and the other location(s) disappeared”. Here, we also linked to the concept of Pictorial Measures of Self-Categorization, by Schuber & Otten (2002), based on which, the illustration was used as a prompter in our question: “Which picture below best represents your relationship to the other(s) in the interaction?” (Figure 1.)

1.  
2.  
3.  
4.  
5.  
6.  
7.  

![Figure 2 An example from our piloting questionnaire: “Which picture below best represents your relationship to the other(s) in the interaction?” Overlap of Self, Ingroup, and Outgroup: Pictorial Measures of Self-Categorization, Schuber & Otten (2002).](image)

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The concept of naturalness further supports the above, and is similar to ecological validity, linked to Ned Kock’s (2002) Media Naturalness Theory, which has been tested through questions like “the situation seemed natural”, and “I felt like I could act naturally”.

We hope the above discussion clarifies concerns raised at Second review, e.g. questions in relation to D3.4 First Prototype: “How is ‘immersion’ induced and measured/optimized in the prototype? Why is a shared background seen as an immersive space?” Also in relation to D4.4, reviewers requested that authors clarify “why does paint & point (fig 3) make sense and what are the specs behind it? How does it contribute to immersion? The impression that is given is that it rather spoils it.”

SharedSpaces functionality

Projected on a wall or a large screen, SharedSpaces facilitates life-size, co-present interaction between a large number of remote participants (we have so far tested with up to a dozen user accounts). It supports co-presence and natural communication behaviour (gaze, gesture, posture, incl other nonverbal cues) in ways that Bill Buxton refers to as shared person space [Buxton 2009]. Several existing applications today equally support the notion of a shared task space, e.g. screenshare and co-editing documents in Skype or Google Hangout. Typically, the task space is separated from the person space, while in SharedSpaces it is possible to use any suitable surface, and the Paint and Point features also make it possible to draw together anywhere. This is especially noted in recent iterations where virtual cameras are employed. Further, SharedSpaces supports the use of visual nonverbal cues (e.g. pointing) so that users can refer to objects in the task space (e.g. described as reference space, ibid)– and if unsupported, limits many collaborative tasks. COMPEIT’s MRI component (D5.4) like many others, offers solutions to some of these restrictions: e.g., enabling 3D, view-dependent rendering of participants and supporting gesturing and pointing in the task space.

We realize that we need to clarify the above also in relation to the PixelPresence feature (same holds for PixelPresence (fig 6)). The SharedSpaces component seeks to support a gradation from awareness to rich (tele)presence. This can be referred to as an ambient notification in the background of either a real space (as shown in D2.3, version of PixelPresence) or in a virtual space as show in this report (c.f. Filmclip A Parallel Virtual Workplace 2 – PixelPresence in Virtual Space). By agreement, recognized users within a declared social group, actions are performed through which PixelPresence opens for a full telepresence interaction, once participants feel prompted.

The concepts of spatial and social connectedness that we use are closely related to COMPEIT’s ambition to support gradation. Over twenty-five years have passed since Bill Buxton and his colleagues [Buxton 1992, Buxton 2009] used architectural spaces as a reference for the Hydra studies in which they showed the importance of spatial cues and design as a prerequisite for presence in shared ‘person spaces’ and remote collaboration. They challenged media, as a new field, to achieve what architecture as a mature discipline already does: support physical proximity by activity-based design. Shared activities are central to the experience of social connectedness, of engaged relationships with others as well, addressed by Goffman as Interaction rituals (recurring activities that are the building blocks of our social habits, and can have varying frequencies of occurrence) [Goffman 1961, 1967] and by Clark as shared activities and grounding (social dynamics and cues needed in interaction) [Clark 1996]. Today, the field of presence is arguably mature – nevertheless still lacks in adequate terminology to also discuss how spatial connectedness and the experience of proximity and activity benefit and support the social connectedness. Spatial connectedness indicates that architectural design is as important in mediated (and virtual) environments as in real spaces for human interaction. In architecture, spatial features such as proximity, visibility and layout may stimulate interaction and collaboration [ibid]. Architectural design equally creates spatial dividers, walls and barriers by e.g. geographically separating offices or domestic environments, seeking to harbour privacy, security, but also...
(social) exclusion and loneliness [Gullström 2010, 2012, Kort et al 2013, Gullström et al 2016, IJsellsteijn 2004]. Equally, in shared mediated spaces (and virtual space), the individual experience of presence is negotiated as part of a process to establish trust and confirmation from the remote party/parties IJsellsteijn, W.A. (2003, 2004]. An ongoing construction of a sense of place is informed by a series of spatial and social cues, i.e. 'reality tests' carried out by participants, who seek fast, consistent and reliable confirmation that the interaction can be trusted – in which case they can temporarily agree to suspend their judgment in favour of a 'willing suspension of disbelief' (Coleridge1817).

In a broader context, social connectedness is a layered construct that describes how people relate and connect with one another in society and social groups [Aron et al, 15]. Of further relevance is that social connectedness develops over time through ‘interaction rituals’ (Goffman op cit) (regular moments of contact and shared activities), provided that grounding (social cues) and correct social dynamics are in place [Clark op cit]. The linking factor between spatial and social connectedness is the ambition to design mediated spaces that support and enhance trust-building processes and secure this common ground and interaction rituals.

We hope that the above clarifications show that presence research remains a shared research interest for the COMPEIT consortium, as addressed in the project acronym: Connected Media and Presence. However it is not necessarily based on high fidelity technical components, but as much on design and storytelling. Our interest relate to the gradation process from awareness to rich telepresence. (The current status of the deliverable suggests that the consortium has given up to realize presence and immersion as promised.)

Finally, we expect that our reformulation of a strong use-case, labelled the MediaCube, as part of the future workplan of COMPEIT, will provide further clarifications to how SharedSpaces (the D4.4 component) is at the centre of COMPEIT’s scope. (Authors should clarify this aspect and how this will affect the use cases. In the current status, the delivered work appears largely disjoint from the project.)

Throughout Year 2, we have worked closely in accordance with the objectives formulated in the DoW, possibly these were not sufficiently well clarified earlier.

As a final remark, it should be noted that, the content on the COMPEIT Experience Lab, which is referred to in section 4.4 via the link http://experience.compeit.eu has been replaced since this report was finalised, but we have kept the text intact, like with the remainder of the report.

References to the introduction


Galena Kostoska (2015) Museum Visits for Older Adults with Mobility Constraints: Sharing and Participation through Technology, Doctoral Thesis, University of Trento


Joke Kort J. D8.4 evaluations of TA2 concepts. 2010. Available at:


Markopoulos, P, de Ruyter, B., Mackay, W. 2009 (Eds.) Awareness Systems: Advances in Theory, Methodology and Design, Human-Computer Interaction Series.,


Dissemination of SharedSpaces (main result from D4.4 Immersive Spaces):

SharedSpaces filmclips:
A parallel Virtual Workplace 1 – Livestream backdrop in SharedSpaces
https://www.youtube.com/watch?v=YmvXrLqBmyE
A Parallel Virtual Workplace 2 – PixelPresence in Virtual Space
https://www.youtube.com/watch?v=ZJvhzHEDQn4
A Parallel Virtual Workplace 2 – Arrange to meet in real space and virtual space
https://www.youtube.com/watch?v=YmvXrLqBmyE
Distributed family: A shared message board in real and virtual space
https://www.youtube.com/watch?v=wlfnZMCWcE
SharedSpaces A WebRTC prototype for seamless integration of virtual space and real space - Instruction movie
https://www.youtube.com/watch?v=PXBMeo1A224
Everyone should have a virtual office (Charlie Gullström, KTH, interviewed by Crosstalks webTV, February 2016 on the topic: https://www.youtube.com/watch?v=Rxvd7KI8BF8. In conjunction, she participated in a Crosstalks talk show on related topics: http://crosstalks.tv/talks/form-function-and-beauty-how-design-shapes-our-lives/

SharedSpaces publications:

Galena Kostoska (2015) Museum Visits for Older Adults with Mobility Constraints: Sharing and Participation through Technology, Doctoral Thesis, University of Trento


SharedSpaces events

13 November 2014, SharedSpaces demonstration at EIT Digital Results Day, Stockholm (KTH)
3 December 2014, SharedSpaces demonstration at EIT Digital Results Day, Espoo (KTH, LiveU, LTU, TNO)
11 December 2014, SharedSpaces demonstration for EIT Digital Management (KTH)
19 February 2015, SharedSpaces demonstration for Crosstalks.tv (KTH)
15 April 2015, SharedSpaces demonstration for Open House at KTH Department of Media Technology and Interaction Design
21 September: SharedSpaces demonstration as part of the conference Inspired by Space, organised by KTH Space Center and Congress of Space Explorers (KTH)
24 September 2015 Ericsson Research Open Day, Stockholm, Charlie Gullström presented SharedSpaces
20-22 October 2015: COMPEIT exhibited at ICT 2015 conference, Lisbon
4 December 2015, SharedSpaces facilitated distributed workshop between Dome of Visions Stockholm and Dome of Visions Copenhagen (KTH)
27-29 February 2016, Workshop organisation and Interactive Demo presentation using SharedSpaces at CSCW2016, San Fransisco.
12-15 April 2016, COMPEIT exhibition of results, Smart Cities Week, in Dome of Visions, Stockholm (KTH)
9-12 May 2016 Interactivity Installation with “SharedSpaces Mingle” at CHI2016, San José.

Fall term 2014. KTH master course Presence Production (7,5 ECTS), Media Technology programme, 25 students.

Fall term 2015 KTH master course Presence Production (7,5 ECTS), Media Technology programme, 20 students.
3. Immersive Spaces 1.0

In this Section we describe the features provided in the Immersive Spaces 1.0 component.

3.1. Overview of the feature set

Immersive spaces 1.0 is a software component in the COMPEIT system, with a feature set that allows users to connect and interact with each other over the Internet and perform shared actions, using their web browser. Social interaction is further supported by a series of features that allow users to collaboratively explore and experience the concept of spatial connectedness in real-time:

SharedSpace is the core feature of the Immersive Spaces 1.0 component. [Error! Reference source not found.] It enables users to enjoy chromakey functionalities by choosing among preset backgrounds for the interaction, or upload a customized background. It enables users to design and create a shared 3D virtual environment in which they are represented live from the video stream, and where different functionalities can be allocated to different parts of the 3D space. In its first iteration (the current deliverable), users' video images can be scaled in size and transformed, using the Rearrange feature, which allows the participants to regroup each other inside the virtual space (avatar-like way). (Figures 1,3,4) There is also a Paint & Point feature. This is an overlay technique that enables drawing, painting and writing directly in the livestream.

PixelPresence (Figure 8) is an overlay technique that creates a pixelated view of a livestream, and contributes an ambient presence trigger to enter a mediated interaction. Future iterations will include a notice board that can be moved around and be scaled, and for example a memory wall that represents the users who were recently in the virtual space, and a library wall which allows the users to highlight references of shared interest. Continued design and development will introduce additional cameras to the virtual space, providing multiple view points and inviting users to take control of the viewing experience.

Immersive spaces 1.0 thus strives to enhance users' feelings that they are physically and socially "close" to one another. In its most basic implementation, it is a "group video chat" or a shared video window in which participants develop a high sense being together in one space, from the easy access to a wide range of tools that facilitate co-creation of virtual space and shared actions. What emerges from our design-led research in T4.2 is a digital toolbox of new design features to furnish interiors and create mixed-reality space. Real-time video and audio streams are combined with embedded smart devices and building components that respond to users’ presence by local action or remote interaction. Similar functionality can be found in the other architectural interfaces that are being developed at KTH and LTU such as Little Polyhedron and Little LED Matrix. These two interfaces are low-bandwidth components similar to PixelPresence. Also similar is the Softwall by TUD WhyFactory. The Softwall is currently implemented as a Softwall Puff & Wave prototype at KTH and as a panel version by TNO). There are also similarities, of course, in terms of functionality, to the Tangiball lamp by LTU (work developed in Task 5.1).

Future iterations of the Immersive Space component will integrate additional virtual cameras to the 3D environment (to be reported in D4.5 Virtual Cameras 2.0), enabling participants to share and manipulate various different camera feeds. In the current version of the COMPEIT café, users can navigate around the 3D space (using the space bar) hereby monitoring a basic virtual camera.
3.2. SharedSpaces

In the current implementation of “Immersive Spaces”, the feelings of social and spatial connectedness are targeted by placing all participants in the communication together in front of the same background. This feature is referred to as SharedSpace. The background of the live video stream from each user is stripped from the foreground using a chromakey filter. The video streams are then super-positioned in layers on top of each other to create the illusion for observers that the remote users are all together in the same space or view. A screenshot of the SharedSpace in action is shown to the left in Figure 3 at a mediated group yoga session, with the picture-in-picture showing the composite result of video fed from each of the two nodes. The picture to the right shows a more ordinary meeting situation, with users from three different physical nodes who for an on-looker seem to all be gathering at Beaubourg, the Centre Georges Pompidou in Paris, France. As shown in Figure 4, the participants can scale and transform their respective videostreams, using the Rearrange feature, and in different ways adapt their representation to the background. These shared actions in effect lead to the collaborative design of a shared virtual space, where the process as such arguably strengthens the experience of mediated presence and immersion. In Error! Reference source not found., the participants have chosen a background image with strong three dimensional qualities, which creates an experience of a shared virtual space that can be monitored in various ways, for example by using the Paint & Point feature. The feature allows users to be inventive and creative, and in this way supports socialising and fun, as seen in the screenshots from the prototype.

A key factor in immersive spaces, we think, is the possibility to create something together, sharing various kinds of media and using interaction tools to discuss and share ideas. We have therefore added functions for providing means of input via PCs and mobile platforms; instantiated as a paint overlay function as well as a text-based chat feature. The paint overlay lets users draw together on top of the video chat window, using typical computer drawing tools. These include a brush, an eraser, various shapes, and a color picker. This is a very typical setup, similar to drawing programs such as Microsoft Paint, and should therefore be familiar to most users. In order for all users to have a consistent view of the drawing, each user's actions are shared through WebRTC data channels. By having the drawing area on top of the shared video, new interactions are made possible: for example, users can draw clothes on top of each other or point to each other's drawings.

To further support collaborative creation, a feature currently labelled COMPEIT Café (Figure 7), offers a shared 3D virtual environment in which the chosen background appears on the far end wall. As seen in Error! Reference source not found., the participants have moved to the COMPEIT Café, a space in which the different planes and surfaces in this space offer a great potential for collaborative work and interaction and will be developed in future iterations of the Immersive Space feature set.

Figure 3 Illustration of the chroma key functionality in SharedSpaces. Left: ‘A Mediated Yoga Class with SharedSpaces’. An objective camera shot shows two students in front of greenscreens to facilitate chroma key functionality. Superimposed, a part of a screenshot shows the same two students, now side by side two other students, who are seated in a similar
environment somewhere else on campus. This is an example of student project from the design-based project course Tele Presence Production at KTH. The yoga teacher is remote, and possibly several of the participants too. Credit to our students: Jenny Bern, Hannah Bylund, Ilona Khammatova, Emma Lundin, Malin Westerlind. See filmclip: https://www.youtube.com/watch?v=-3HJBGeM_1Q. Right: Although these five people appear to be in one place, they are actually all hundreds of kilometers apart! The careful observer may see that the illumination of the faces comes from different sides, and that some are wearing a T-shirt whereas others are dressed for colder climates.

Figure 4 Having opted to meet “in Paris”, participants can use the Rearrange feature to better fit the respective livestreams, scale and transform them in relation to the background.
Figure 5 In a background image which has three dimensional qualities, the different overlay techniques serve to create an immersive space in which the participants take different positions in the pictorial space. Here the participants are using the Paint & Point and Rearrange tools to transform their livestreams, inside a drawing by architect Cedric Price of the iconic Fun Palace project.

Figure 6 The Paint & Point features invites users to experiment and to have fun by drawing together on top of their video chat canvas. Note, again, these users are not really in the same place: they just appear that way.
Figure 7 Users can also choose to enter the COMPEIT Café, a work-in-progress 3D virtual environment which, in the current iteration provides a situational framework. Given the right prerequisites it will mature into a customizable shared workspace in which documents can be stored and relevant information can be highlighted in the peripheral areas while maintaining a high level of interaction.

A straightforward way to give people the impression that they are together is to place them all in a common virtual environment. Sharing spaces, or rather sharing sensory stimuli originating from one location with someone located in another space, arguably gives each peer a sense of being together with others. In a first step we have created a common background using a simple chroma key filter. In short, a chromakey filter selects pixels of a certain color in an image or video stream and replaces them with the pixels of a second image such as for example a background photo of a public or private place (e.g. Paris, or a picture of the interior of our labs). When the user is standing in front of a uniformly colored (green or blue work best) background, the resulting image shows the user in front of a new background.

In immersive spaces the video streams from several users are combined. Chroma key compositing is used to place all users in the same virtual environment. Examples are shown in Figures 3.4. Each user peer can set a color range to act as a transparent part of the video image being sent in collaboration with others, but the dominant color range in a user’s video can also be detected automatically and made transparent. This allows video layers to be partially visible on top of each other - key color conveyed as transparent. It also allows a common background, such as a still image or video, to be shared amongst the participants creating a sense of togetherness. Each user sees their own image together with others in the same composite browser window.

In order for chromakeying to function properly, a single-colored background has to be set up visible to the camera. This could be the wall itself, but it is more effective to use a fabric or paper background in a uniform color that does not occur in the foreground, such as signal green, very saturated blue or similar.

The use of chroma key in this context can be observed as a technology transfer from the broadcast industry where chroma key is used extensively from weather forecast presentations to advanced trick photography and film-making. Users are free to re-size and rearrange the chroma keyed videos. Changing the size of the video in the plane of the screen is an effective way to create the illusion that participants are moved forward or backward in the virtual environment (in this case created by a static background image).
Users are also free to upload their own background images. This means that each video chat session can be uniquely customized to fit the users’ current needs.

Taking a step further from a single, flat background, towards a more immersive experience, introducing layers “rendered in 3D” is a natural step. Chromakeyed video streams can also be rendered as textures in virtual “3D” environments. This has many advantages. An important advantage is that the background can be rendered in a geometrically correct way and is not restricted to the viewing geometry of the camera that has created the (static) background. Furthermore and linked to the notion of viewing geometry, it gives the possibility to add perspective cues to the common virtual world.

Linear perspective in images and in the “physical world” is a strong depth cue for people. Earlier research has shown that people are sensitive to incorrect perspective renderings [e.g. 6,7]. In a geometrically correct perspective, the picture on the screen projects into the eye as the real world would. In this case the viewer is positioned at the picture’s center of projection. However, this is usually not the case: that is, usually the viewer is not at the center of projection, which would make the drawing geometrically incorrect. The geometry of perspective rendering is described in [7][8]. A geometrically correct drawing is sometimes also referred to as an Alberti window. Ling et al [7] found earlier that feelings of spatial presence are affected by the perspective. Interestingly, they also showed that the amount of perspective in the image that gives the highest sense of presence is not the geometrically correct perspective, but a perspective that is geometrically correct for a viewing distance of about 1.5 meters in front of the display screen. Pont et al [8] also showed that perspective drawings of a simple wire frame cube were judged to be most geometrically correct for a fixed distance. Using input from task T4.1 (Virtual Camera 1.0) we have added a virtual 3D environment to hold the chromakeyed remote videos. At present we do not know how feelings of presence are affected when the perspective renderings are updated dynamically. That is, of course we know from the literature that the related phenomenon of motion parallax leads to strong perception of depth, but we do not know whether this motion parallax should be calibrated to be geometrically correct or like for static images best be rendered from a slightly incorrect view point.

Known problems associated with chroma keying apply in our software as well. First, and most obviously, a large, monochrome screen or wall is required. This greatly limits the number of users who can make use of the functionality. Second, users cannot wear clothes of the same color as this background screen, since they will be removed from the video. Finally, relatively even lighting is required for the chroma keying to work properly. A possible solution for these problems would be to use depth-based compositing instead of chroma keying. A depth sensor could be used in combination with regular video to remove the background from the video.

The quality of service in WebRTC is foremost limited by each participating computers data throughput capabilities, graphics card rendering, audio capabilities and in some cases also the CPU. In a peer-to-peer setup, there is no server component however to limit the level of data interchange.

### 3.3. PixelPresence

The COMPEIT presence system supports individuals and distributed groups who want to stay close with one another on a regular basis, ready to spontaneously interact in videowindows such as SharedSpace. Whether the context is professional or social, ambient forms of presence are also called for, to support gradation and perhaps especially to prompt users to join a shared virtual space. From the user requirements studies reported in D2.2 and D2.4, we learned that people want to be aware of what others are doing, and also where they are. This, of course, is quite different to keeping a videolink open 24/7. For example, a child’s
use story in D2.2 states: “It’s also nice to have a little bit the feeling about what others are doing”. Children want to know who is at the playground, at this moment. Based on this information, they may decide to join, or not to join. Similarly, professionals have a need to access other people’s schedule, and may choose to drop by the office (or make a phone call) at a time they are sure not to disturb. In traditional office environments, it was fairly easy to know when someone was available or not, because people normally worked in the office environment, but in today's society this is no longer the case, as people have multiple workspaces some of which are virtual. We reported on this already in the D2.3 High-fidelity mock-up report and illustrated the need for ambient presence prompters, such as the **PixelPresence**, the Softwall or Little Polyhedron. These design features form part of the interior environment and take the role as signifiers (with varying meaning, depending on a user group’s preferences), to display a person’s “declaration of presence” or “willingness” to be present in a mediated space.

**PixelPresence** is a feature in Immersive Spaces that we can imagine projected onto a wall, almost like a painting or a wallpaper (Figure 8-9). The pixelation contributes a discrete and aesthetically appealing representation of a remote space(s), and will flicker when users move remotely. From afar, this means we will know when a space is populated, and we may feel prompted to make contact. On agreement, the participants will decide to “de-pixel”, i.e. to see and hear each other, either in a traditional video window, or using the SharedSpace feature. PixelPresence thus promotes continuously open video windows (between friends or colleagues in a social group) using large displays, to render something that appears like a wall-paper or a painting in a physical environment.
The pixel pattern creates a filter through which presence and a flickering movement can be detected for the remote viewer. The video stream becomes an artwork, less revealing and intrusive than a traditional livefeed.

In the current iteration of the Immersive Spaces component, we have not yet implemented all the functionalities we foresee in terms of **PixelPresence**. We are currently experimenting with relevant functionalities in a prototype for a local user which is available here: [http://pmc.research.ltu.se:8003/PixelPresence/gltest.html](http://pmc.research.ltu.se:8003/PixelPresence/gltest.html).

The local prototype allows a user to modify the pixelation in different ways, for example by resizing and remodelling the pixels and their borders. In consideration of the PixelPresence as an artwork in a home environment these are useful features, both for users who want to create their own PixelPresence art work, or who would like to project an existing painting as a basis for PixelPresence. In the screenshots below we have used Paul Klee’s work “Ancient Sound, Abstract on Black” slightly, which will flicker beautifully when someone passes by. (Figure 9)
Figure 9 Illustration of more artistic possibilities for PixelPresence functionalities that are planned for the next iteration of the Immersive Space component.
4. **Wider application areas and use contexts**

In this section we discuss the relationship between Immersive Spaces and user requirements and how we expect to customise the Immersive Space component for the planned piloting in WP6 as well as for wider commercial applications. Tentative scenarios for different target groups that are currently in preparation, are described below.

For example, we foresee that Immersive Spaces components may be customized for three specific target contexts, i.e. distributed work organisations, care centres for young people with special needs, and mobile journalism. Further, an online pilot is in preparation by developing the COMPEIT Experience Lab to attract users from online communities.

4.1. **Immersive spaces for distributed work organisations**

A distributed team can have **SharedSpace** video windows open 24/7, projected onto large surfaces that become wallpapers in a local office environment. By agreement the image is pixelated (**PixelPresence**) in all locations, which means that when there is movement in a remote space, the image flickers on the local wall. This feature supports the experience of shared mediated space, since it also invites the users to take various actions:

- By agreement, **PixelPresence** can be switched to a clear video window. Such actions can be prompted by additional features in the COMPEIT toolbox, for example **Photoframes**, **Tangiball** (Figure 10) and other COMPEIT components that trigger colleagues to declare their presence and availability in real or virtual spaces; and to prompt each other, e.g. as **Softwall**, **Little Polyhedron**, **Little LED Matrix**.

- In an informal context, users may now talk and interact in realtime across two or more locations, for example to enjoy a “mediated coffee break in a park setting”, although everyone actually remains in their respective office interior (Figure 11).

- In a formal context, a slide presentation can be brought into the background, and users can point and draw together (**Point & Paint**). Further, the presenter can choose to be displayed in front of the slides. S/he can use the Scale feature, and will appear to be inside the slides presented. (Figure 11)

- Users can also decide to interact inside the 3D COMPEIT café, which can be designed as a virtual representation of the actual office interior. The **SharedSpace** functionality can be used (currently appears on the back wall). The users’ live videostreams can be scaled, skewed and transformed, hereby allowing users to take different positions in the 3D environment. The planned development of the tool will make it easy to share and visualize files as a ‘library’ (in the current iteration this is represented as bookshelves on the right hand side). The space will ‘remember’ who was recently here, by adding and displaying snapshots of the users on to a ‘memory wall’ (currently the left wall). Virtual representations of tangible devices and architectural features will also be available to prompt actions in the shared workspace.

- In a formal meeting room, the above will allow a seating of participants around a table, where each participant is granted a non-hierarchical ‘round table view’, by monitoring the virtual camera view.
In future iterations, additional virtual cameras will be added, and the possibility to create eye contact/motion parallax will be explored.

Figure 10 Demonstrations of PhotoFrames at EIT ICT Labs in December 2014. Left: PhotoFrames. The portraits reflect an individual’s availability and declaration of presence (in physical or virtual space) using LED indicators. Right: Tangiball, The Tangiball features two LED displays: one for direct communication, and one for displaying data in an ambient way. Three touch points enable simple, tangible interaction, while a Web application provides more fine-grained control (e.g. for setting the ambient light on the Tangiball, sending "light smileys", and creating light animations.

Figure 11 Office workers at Ericsson, Kista, Stockholm, try the SharedSpace as a presenter tool. The participants have chosen a “park environment” as their shared setting and thus appear side by side on the screen. After a moment of introduction in this informal setting with both (all) participants, the video is switched off for all but the presenter. The presenter can scale him/herself and also appear live inside the presentation!

Immersive Spaces components can thus be used in professional contexts, for example as envisaged above by distributed office workers or academics. In our preparation for piloting in WP6, we are in discussions with a unit at Ericsson, Stockholm and with EIT ICT Labs, both interested to implement parts of the system in different work locations and where initial user tests have already taken place (Figure 11)

Further, within our own team of academics and professionals in the COMPEIT consortium, we have integrated several of the COMPEIT features to create a shared work environment between KTH, LTU, TNO and TUD, and also carry out expert evaluations on a regular basis as part of our iterative design process. This is for example illustrated by the research team’s own prototypic environment, the COMPEIT café described earlier, which provides a shared 3d virtual workspace, where we already meet, draw, create whiteboards instantly on various surfaces etc, and soon will explore further, for example by storing frequently used documents.
Expert evaluation of separate features in the Immersive Spaces component have been ongoing in 2014, involving researchers, students and office workers in distributed setting, in a manner that continuously informs the design work. While the above mentioned professional contexts are fairly generic, we also seek to customise specific features from the toolbox to suit particular user needs, as part of the preparation for piloting in WP 6 (D6.2 First Pilot Report). As an example, the **Paint & Point** feature was developed in direct response to user requirements raised in WP2 by a professional medical doctors who contribute remote expertise to colleagues, and expressed the need to draw and highlight features in the live videogreostream, for example to indicate a proposed action relating to a particular parts of a human body, as depicted on the video. This example may lead us to prepare a pilot of this feature with the involved unit at Karolinska University Hospital in Stockholm and the local hospital in Visby, Gotland (a large island in the Baltic Sea that belongs to the same organisation within Swedish healthcare).

### 4.2. Immersive Spaces for socialising and fun, targeting young people with special needs

The same features as described above can be customized to suit the interests and needs of young people with special needs, a piloting proposal currently in development within WP6. From WP2 User requirements we learned that young people want elaborate support for ‘doing things together’ and in the planned piloting we propose to prioritise visual tools (e.g touch/feel/create/design your own) and functionalities for a target group who may have difficulties following text instructions in traditional computer interfaces, as an example.

In a scenario, a teenager lives in a special needs home environment. In his/her room, a computer is connected to a short-throw projector which displays a large image on the wall. Pixeled and like a wall-paper, this creates a mediated extension to a friend’s room, somewhere far away. The pixeled flickering that occurs across the wall, when someone passes by or moves a lot in the remote space, creates a feeling of togetherness, of sharing a space, and an immersive space. The two friends may have agreed that “when Tangiball goes green”, or, “when Little Polyhedron flips over” (or other signifiers) - the pixeled wallpaper (i.e **PixelPresence**) should automatically turn into a video window, so the two friends can interact by seeing and hearing each other in real time. They can also select various features from the **SharedSpace** toolbox, allowing to creatively design and elaborate in relation to their shared interest areas:
In the **SharedSpace** they appear side by side, and can change the background setting to anything they like, by choosing a preset background, or uploading an image, or a live-feed.

They can use the **Paint & Point** function, and also Scale, transform, and skew and their respective video feeds, hereby creating fun 3D effects, also by designing their own 3D virtual space for the interaction. Inside this space, they can move features, build and design artifacts, store digital resources they like, share with other friends, create extensions to other virtual spaces, add cameras.

### 4.3. **SharedSpace as part of BeFirst service for journalists and consumers**

It is of interest to several partners of the consortium to study the potential for commercial exploitation, for example by piloting some components for a specific target group. While the Immersive Spaces feature set already supports socialising and co-creation of virtual shared spaces, it also creates new potential for specific professional contexts.

An example is that **SharedSpace** can be adapted to commercial mobile broadcast settings, for which the chromakey component can be very beneficial to broadcast situations (bringing field and studio together) and where the **Paint & Point** feature enables presenters to point and highlight actions by drawing directly in the livestream video. Indeed, the Broadcast Studio Presence service under development in COMPEIT is closely related to services that LiveU is interested in commercialising. A scenario labelled "Life U" is introduced in D5.3 Broadcast Presence Studio and describes how users will produce and consume video in a broadcast settings. This is a consumer oriented service similar to what LiveU is developing for professional broadcasters such as CNN, BBC and others. For professionals, the "BeFirst" service will allow broadcasters to access broader content than today, since consumers would be able to communicate directly to the broadcasters and become reporters and producers of content.

This development is tightly related with the work on the COMPEIT User Profiler, connecting entities such as content, consumer, broadcaster, elements such as the subject of the report and more. Environmental data from the physical environment, can in some cases lend input to events showing up in the virtual space. As an example, a room being warm, could render a beach-like backdrop with palm trees and umbrella-toting drinks. Similarly, an alert on-screen can originate from a CO2 sensor with a high reading, or, in rooms that are densely populated, thus triggering many motion-sensor events, can show up highlighted in a floor-plan map inside the SharedSpace. The relation between physical and virtual spaces is thus tightly tied together with technology for making collaborative work and communication more lively and immersive.

### 4.4. **The COMPEIT Fun Palace in the Experience Lab**

The COMPEIT Fun Palace is an online toolbox with select features from the Immersive Space component that is available via the COMPEIT Experience Lab, inviting users to create their own **SharedSpace** for socializing and fun. It has been online since October 2014 and was particularly created to invite users from the Fun Palace web community, a UK-based initiative ([www.funpalaces.co.uk](http://www.funpalaces.co.uk)) that we approached since it gave us the possibility to identify test users for planned piloting in WP6 (Figure 13) In the continued preparation for piloting, we find that online communities may be a fruitful target group.

The name “Fun Palace” originates from an acclaimed future-oriented initiative in 1961 by the British architect Cedric Price, film director Joan Littlewood and cybernetician Gordon Pask.
The Fun Palace was intended as a novel and highly flexible public performance place in London, facilitating artistic and architectural experimentation and research based on user feedback loops. Its framework was a building structure where few components were fixed and where interactive media installations would serve temporary performances and events of different kinds. The vision was a completely new form environment “capable of adapting to meet the possibly changeful needs of a human population and capable also of encouraging human participation in various activities.” [9]

The reason we describe this initiative is that, today, it would be fully possible to design a mixed-reality WebRTC Fun Palace and that, in many ways, the Fun Palace serves as a fruitful analogy for our visions with the COMPEIT presence system. [10] Once complete, in 2016, COMPEIT will support a wide spectrum of mediating presence, for example allowing users to control features inside a building (and its virtual representations), in ways not dissimilar to the original ideas of the Fun Palace. The original Fun Palace was designed with the intention to let a building transform, following the interests from its visitors. In line with several other initiatives at the time, the proposed structure incorporated change, chance and uncertainty, as a self-regulating process, modelled on computer programming and Cybernetic thinking and, not least, linked to avant-garde trends such as Pop Art and Fluxus. The project was never realised as a building, which to some extent can be explained by its high ambitions in terms of media and communications hardware, technologies which at the time created very obvious limitations.

![Image of Fun Palace](fumpalaces.co.uk/discover/compeit-fun-palace/)  
Figure 13 The “COMPEIT Fun Palace SharedSpace” initiative, as presented online 4 October 2014.
The online 2014 version of the COMPEIT Fun Palace invited people to meet in joint mediated space via their web browsers, sharing preset backdrops, live video and overlays. (Figure 15) Following simple instructions on the Fun Palace community website, a participant would simply need a laptop with a camera (or a smartphone). A short filmclip was made to show how easy it is to calibrate and create a SharedSpace: Seated in front of something green or blue, one simply opens the indicated web-browser and enables the camera. (Figure 15)

**Select a room**

- Centre Pompidou, Paris
- City Library, Stockholm
- Kulturhus, Luleå
- University of the Arts, Stockholm
- Fun Palace, London
- KTH Reactor Hall, Stockholm
- KTH Reactor Wall, Stockholm
- The Why Factory, Delft
- Street View, Stockholm

(Figure 14) The Fun Palace browser window offers a range of preset architectural atmospheres, such as ‘Centre Pompidou, Paris’ or ‘Fun Palace, London’.
Figure 15 A short filmclip was made to show how easily one creates a SharedSpace: https://www.youtube.com/watch?v=7zyL6GcGiBc
References


Web resources:

COMPEIT Experience Lab: http://www.experience.compeit.eu

SharedSpace web resources:

Filmclip from EIT ICT Labs Stockholm: http://youtu.be/10zp2rzpbu4

Filmclip from EIT ICT Labs Helsinki by Finnish Television MTV (18-minute mark): http://www.katsomo.fi/?progId=419824

Video instruction on how to create a SharedSpace: https://www.youtube.com/watch?v=7zyL6GcG1Bc