MindSpaces

Art-driven adaptive outdoors and indoors design

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D7.1

Use cases, requirements and evaluation plan

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Abstract

D7.1 describes an updated version of the pilot use cases D2.4 , as well as a first version of the user requirements, which derive from the analysis of the updated pilot use cases, the prior user experience and market needs. The deliverable also includes the evaluation methodology, which will be used in order to assess how the final components and the entire MindSpaces platform have fully realised the project objectives.

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Executive Summary

This deliverable is an updated version of the pilot use cases (PUC), user requirements and the preliminary evaluation plan as documented in the project proposal, the DoA and the deliverable **D2.4 Design needs in architecture and urban scale and use case scenarios**. More specifically, the PUC scenarios are updated and elaborated based on the extensive feedback provided by project partners, consisting of architecture professionals both academic and practice based, local stakeholders, artists and art residents. Initial storyboards have been also used to provide more concrete information on the way use cases can be developed.

The deliverable capitalizes on an updated methodology for eliciting user requirements, which explores and consolidates the information and feedback collected by four sources 1) from partner meetings and discussions,2) by questionnaires, interviews and four focus groups 3) from the analysis of market and industrial requirements. 4) from the analysis of the design parameters of the use cases.

In addition, the deliverable describes the updated user requirements that have been elicited, as a result of the updated methodology that has been followed. More specifically, we identified 6 High Level User Requirements (HLUR) from the analysis of the three PUC scenarios, 5 HLUR through structured questionnaires and interviews, 8 HLUR through the Market analysis and industrial requirements and 1 HLUR from the design parameters analysis. A “merging” task was necessary in order to remove conceptually overlapping HLUR, resulting in 13 HLUR that provided the high-level context in order to group a list of 82 User Requirements (UR). The Moscow Framework has been used for assigning priorities to UR according to business benefits and needs, designating in that way potential implementation timelines of the respective technical requirements that will be specified in “***D6.2 Technical requirements and architecture***”.

Finally, the deliverable elaborates on the user-oriented evaluation methodology that will be used to evaluate the platform against each user requirement. A detailed evaluation plan is also given along with the planning for key demonstration events.

Abbreviations and Acronyms

ABPS	Agent Based Parametric Semiology
AR	Augmented Reality
CFD	Computational fluid dynamics
DOA	Description of Action
EEG	Elecroencephalography
HLUR	High Level User Requirements
ICT	Information and Communication Technology
PUC	Pilot Use Case
ROV	Remotely operated underwater vehicle
UR	User Requirements
VR	Virtual Reality

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1 INTRODUCTION

MindSpaces aims to create a novel approach to urban and architectural design by generating 3D-VR immersive and emotion-adaptive 'neuro-environments' that will help in designing emotionally-relevant spaces. The emotional aspects of an environment will be captured through the use of mobile EEG (Electroencephalography) headsets, wearable bracelets/watches, and other physiological sensors that will be embedded with a VR-headset, so as to allow capturing the neuro-feedback of a VR-experience. The neuro-feedback will allow the virtual space to be adapted accordingly, resulting in an emotion-adaptive space. The 'neuro-environments' will be used at two levels of granularity.

At the first level, artists and creatives will experience the 'neuro-environments' with the intention to improve the emotional-relevance of the urban space through the neuro-feedback of individuals, that have very-well developed the perception of aesthetics in what refers to symmetry and harmony but also to unconventional thinking leading to unexpected solutions.

At the second level, the 'neuro-environments' will be experienced by the potential occupants of the urban space, so as to improve the emotional-relevance of this space through the neuro-feedback of individuals that have developed through experience the perception of space usability, comfort and functionality.

This will allow MindSpaces to combine the transversal competencies and unconventional thinking of Artists, with the empirical and pragmatic perception of actual occupants, so as to drive the development of unconventional and unexpected solutions in the design of urban spaces.

This deliverable includes an update of the pilot use cases, which have already been documented in the deliverable **D2.4 "Design needs in architecture and urban scale and use case scenarios"**, the elaborated user requirements and the description of the evaluation plan to be implemented. To this end, we extracted and aggregated requirements collected from: a) proposed pilot use cases; b) prior user experience, as this is expressed with the aid of questionnaires from user partners (including users not directly involved with the project); c) results of related market analysis and d) The analysis of the PUC related design parameters (**Figure 1**).

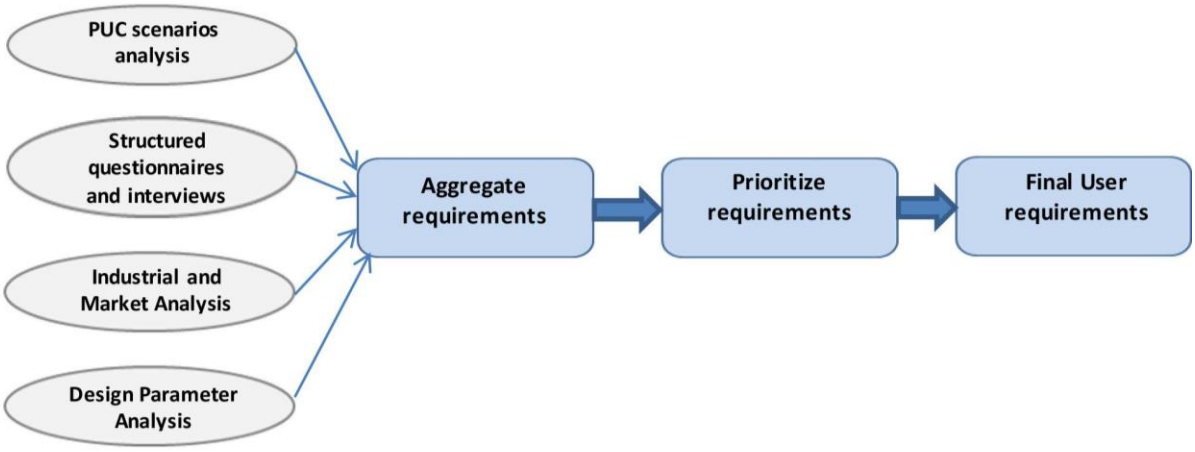


Figure 1: User requirements extraction methodology

More specifically, Section 2 presents the four focus groups that have been set up consisting of people from user partner organizations who are either directly involved in the project or they are simply experts in the field. The focus groups have contributed to the elaboration of PUC scenarios and the refinement of user requirements, while they will be the main target audience for the initial evaluation of the operational and the 1st prototypes. Therefore, we can assume that the four focus groups are a subgroup of the MindSpaces User Group (UG).

Section 3 documents the updated PUCs, presenting an extended description of the scenarios along with the requirements that have been extracted from each scenario at a higher level (High-Level User Requirements - HLUR). In addition, storyboards and function diagrams have been included to further elaborate the envisioned functionality of the final MindSpaces system. Similarly, sections 4, 5 and 6 present the High-Level User Requirements collected from focus groups, the industry needs and the design parameter analysis.

Section 7 provides details on the aggregated high-level requirements defined in Sections 3, 4, 5 and 6 along with the complete list of the individual (atomic) user requirements that correspond to the higher-level ones. Lastly, section 8 provides a concise evaluation plan that will be applied after the implementation of the MindSpaces prototypes and revised accordingly throughout the project procedure.

2 METHODOLOGY

This section analyses the approach that has been adopted to update and further elaborate the PUC scenarios and the user requirements. In particular, it describes the focus group creation, the PUC scenarios elaboration based on the outcome of the focus group discussions and the methodology for the refinement of the user requirements.

2.1 Focus group creation

Focus groups are used in many research fields to investigate new ideas. In respect to software engineering, the focus group method is a cost-effective and quick empirical research approach of obtaining qualitative insights and feedback from practitioners that can be used in several phases and types of research. In MindSpaces, this method is used in order to elaborate the initial PUC scenarios, to formulate the prior user experience which will be furtherly incorporated in the elaborated list of user requirements. Specifically, four focus groups have been created consisting of: a) Architecture professionals, b) Local stakeholders, c) Artists and art residents (Open Call) and d) Older people .

The first focus group, related to all PUCs, consists of both architecture professionals from the industry and academic environments. The second focus group is formulated by local stakeholders mainly related to PUC1 and PUC3 (L'Hospitalet, Espronceda and E-Seniors). The third group is consisted of Artists from the open call and partners of the project. Lastly the fourth group mainly related to PUC 3 is formulated by seniors. The focus groups members come from the user partners research team and associates, who participated in the discussions throughout the procedure of the proposal phase as well as the regular users meetings being conducted on a bi-weekly schedule.

At this stage, the involvement of the focus groups is mostly revolved around the first articulation of the needs of the users and the defining of user requirements lists and then, based on these needs, the use case elaboration. However, we expect members of the focus groups to be involved at further stage in order to enrich the implementation of use cases and ensure that they reflect current needs of the stakeholders as well as at the evaluation cycles of the developed prototypes.

2.1.1 Architecture, Building Industry, Professionals (ZH/ AUTH)

The architecture-related focus group involves architects, both practice-based and academically focused, experts on design software and the various fields of architectural design, and other professional stakeholders related to the building industry. The focus group is not limited to users who currently use advanced design application software (e.g. Rhinoceros 3D) in their technology stack and their design workflows, but deliberately is open to allow for comparison with other existing workflows and tools, applicable to non-specialized software users.

Being related to architectural and urban design for all use cases, this focus group includes a wide spectrum of expertise in the creative industry, ranging from architecture concept design, architectural design of temporary elements and installations, indoor and outdoor design, urban design arrangements, construction detailing, construction management. More specifically, architectural studios, as well as autonomous working artists, are represented in the focus group. Regarding academic communities, a broad spectrum of users is involved, ranging from teaching staff specialized in advanced design technologies, academic staff related to architectural, urban and landscape design, as well as students of all levels, undergraduate, postgraduate, PhD candidates and members of broader communities related to architecture and design.

Additionally to architects, designers, creatives and architectural consultants the focus group will seek stakeholders in the building industry such as building owners and professionals dealing with corporate real estate.

2.1.2 Local stakeholders

During the development of all PUCs, local stakeholders defined issues related to the place and suggested required changes. For the outdoors design scenario, MindSpaces partners L'Hospitalet and Espronceda have described how art environments can be integrated into citizens' daily lives creating positive emotions through urban design. One of the main issues has been identifying contemporary worries in order so that citizens feel emotionally connected and identified with such outdoors environments. Also, the historical and social background of the Tecla Sala building (being a symbolic factory managed by a woman in the beginning of the 20th century) has been an essential point in order to draw a complete scenario of the place. For workspace design, MindSpaces partner ZHA addressed issues related to the creation of functionally efficient workspaces, increased worker interaction,

improved emotional and mental wellbeing of employees, resulting in increased productivity. They will communicate the specific challenges faced in workspaces and how to tackle them by integrating the measurements of user feedback to the MindSpaces VR representations. Furthermore Architects will collaborate with artists to propose innovative designs that create functionally senior-friendly environments, and also incorporate emotionally relevant design elements, relevant to the aesthetic preferences of the elderly, that aim is to improve their overall emotional and cognitive wellbeing. The definition of the interior design use case is implemented with the inclusion of seniors who want to improve their home, architects and artists in user workshops, questionnaires and one-to-one interviews.

2.1.3 Artists and art residents (Open Call)

This group will examine the connection between arts and emotion, by examining relevant literature, from various perspectives, including psychological, neurological and aesthetical ones. This will provide a solid foundation for interpreting the effects of art and discovering how emotional and behavioural responses can be invoked by art and will define a novel working model between artists and technology oriented partners and users. The potential for resulting societal benefits will be investigated, so as to understand how they should be used within the context of MindSpaces.

MindSpaces is a rich and complex project where designers, artists and creatives are called to collaborate at all levels with the partners and the different methodologies and techniques. An open call for Artists and creatives offers cross-disciplinary residencies of a collaborative nature. Residents are expected to present their proposals concerning emerging technologies, and/or interactive installations, VR installations, architectural design and art in public spaces.

The projects proposed by applicants are connected with one of the following use cases of the MindSpaces project:

PUC1: The first pilot concerns an outdoor urban setting of important cultural interest. MindSpaces architects and the selected artist from the Open Call will use advanced modelling software to produce blueprint documentation of the area, and propose new urban design schemes that showcase its cultural importance, generate new types of social interaction, and draw attention to social, environmental pollution and mobility (e.g. air or water pollution, traffic congestion, lack of green spaces) issues the area is facing. During the

open call artists for this use case were asked to think, research and propose artistic inputs, installations or actions for the creation of VR solutions allowing citizens and other users to experience renewed designs of these spaces, move in them, interact with others, to assess their functionality and understand their cultural and environmental history and value.

More specifically the selected artist from the open call regarding PUC 1 will be working on a deep sea immersive installation that tells stories about types of microbes living in deep sea vents (small underwater volcanoes). By working on this theme they will be acquiring 3D scans of seafloor landscapes, microscope images and microbial life, alongside underwater 360 audio recordings. The material will be converted into a multiplayer VR experience that allows people to interact with and explore simulations of deep sea worlds. This project will contribute to the MindSpaces research program by building a bridge for collaboration between field biologists, environmental data technologies and art forms excellent at wide public exposure at festivals and museums globally. The project will explore and share questions of how to use environmental data meaningfully, and how to design experiences capable of impacting people in the long term. It will also explore how immersive technologies can change our perspectives on time and scale, as well as ideas of individuals and the environments they live in.

The project that will be conducted for the MindSpaces program expands on a body of work that they have been working on for six years. Within the MindSpaces project they aim to create a large scale immersive installation regarding deep sea ecosystems that can be converted into a VR piece and can travel to festivals internationally. The intention is to make an interdisciplinary platform where the same project can be shown in a plethora of forms.

The budget attributed to the selected artist will be spent on the production and use of lidar scanners in order to visualize ocean health, but also on organized trips with an explorer ship that specializes in deep sea research with the deployment of ROV (deep sea robots that can film and photograph underwater). As a result the budget will primarily be spent on the development and collection of source material such as audio and images, as well as the project management.

PUC2: For the second pilot, talented artists and creative thinkers were called to propose ideas, concepts, interventions, and designs for new and innovative solutions on designing more inspiring and effective offices of the future. Artists were asked to contribute on rethinking the notion of how offices can be designed, as well as creating interventions and full design proposals for office spaces that can potentially take on the following roles:

• Conceptualise fundamentally new approaches to office design which provide productive user requirements / considerations that contribute to the development of the MindSpaces platform.

• Design virtual 3D VR interventions for existing office spaces or architect's designs.

• Design virtual 3D VR office space designs entirely.

• Propose and install physical interventions in real world office spaces.

One artist selected for PUC 2 proposes a project that addresses artificially constructed atmospheres in workspaces. Their aim is to direct virtual architectural modelling, scanning, and sensing tools towards rendering computational fluid dynamics of a workspace. Their goal is to use these hermetic environments to see how workers and machines shape and share the single fluid medium of air, medium that the artist is familiar with through their previous decade long work.

The MindSpaces Platform real time fluid simulations of a workspace will be used to inform VR artworks. The artist is familiar with 3D modelling (Rhinoceros 3d) and animation programs through their artistic practice. Up to now their work has primarily focussed on analogue visualizations of turbulence patterns using smoke with lasers in wind tunnels. During the MindSpaces residency the artist will explore computational fluid dynamic simulations (CFD). Agent Based Parametric Semiology simulation software, that has been developed by Zaha Hadid Architects, to simulate autonomous collective human decision-making, movement flows, occupancy behaviour, and environmental simulation tools relevant to office spaces. The artist will interact with ZHA and the ZH ABPS platform while developing and testing additional CFD based simulation tools. Rhinoceros 3D by MCNEEL has powerful CFD capabilities, while the expertise of up2metric can help manipulate virtualized flows using VR interfaces to produce something that no traditional media could offer.

Potentially, real world sensor and camera based empirical behaviour research will be carried out in the ZHA workplace pending approval. In addition, MCNEEL has provided a complete testbed to facilitate the research and development activities related to the technologies relevant to PUC 2. Concretely, the offices of MCNEEL in Barcelona will be used as a living lab, in which cameras and sensors will be installed to capture data for research purposes. In addition, an EEG/VR lab is being deployed for onsite data acquisition from subjects participating in experimental design experiments. The scientific objectives behind the lab are to make as dynamic as possible the relationship between the architect, the design space, and the people that dwell in this space. This testbed will also be used to engage the artist with the technologies and solutions developed in the project, and pertaining to the applications defined for PUC 2.

The artist will use the full 18 months of the residency to complete a new installation based artwork accompanied by a booklet, website logging the accumulated research and a short-film that moves beyond just the documentation of the project. The artist has divided the period of their residency into trimesters. The first trimester is dedicated to introductions with the MindSpaces team and facilities dedicated to research questions based on particular facilities and conversations. The research will be systematically documented through an online webpage. This documented material will be composed as a printed booklet along with its outcomes. During that time frame there will be several on-site visits to the relevant MindSpaces partners to seek out associations and most relevant resources available to cultivate the project further.

During the second trimester the engagement with partners to tune research and production will deepen. During this phase a series of models and drawings will be elaborated in dialogue with partners. As virtual models they employ the remote collaboration and spatial capacities pioneered by some of the partners and pave the way for the final work. These models are documented and will be included on the webpage and the print documentation. The models and prototypes are distilled into drawings for fabrication of an installation artwork to be realized in the final trimester of the residency period. This penultimate product is the result of the resources, research, and dialogues throughout the year and as such cannot be defined before that process is undertaken.

PUC3: Artists and creative thinkers were called to propose innovative, art related ideas concerning the quality of senior friendly environments and the level of emotional and functional friendliness. The third use-case addresses challenges of a sensitive audience, i.e. senior people and their domestic inhabitation. The selected artist in collaboration with architects will propose an art installation for a senior individual's living space. Additionally, solutions for practical issues can be potentially suggested, since they are of a sometimes more explicit character (accessibility, security, life rhythm, health, etc.).

In Particular the artist selected for PUC 3 is showing interest in the process of memory formation & consolidation as well the neural connections between toolmaking and communicating. They aim to combine art and tech via AR/AI and/or VR to explore these fields of research while relying strongly on physiological signals and visual data to monitor emotional states.

The artist intents to explore the potentialities of Art and Tech to help preserve and improve neurological, cognitive and emotional functions, while also taking into consideration in their approach the crucial question of mental health. Art & Technology can merge & brainstorm on how to help people - either by suggesting a modification in their living space or by composing an artwork that can function as a tool tailored to seek improvement in people's well-being.

Recent uses of VR apps and headsets in elderly care homes have given positive results on patients suffering from the late stages of dementia and Alzheimer’s, in order to improve general mental health and trigger back memories. In this context, they want their residency to be focused on ethically gathering physiological and behavioural data - centred on the necessity of improving people's emotional and psychological state while also addressing issues of social isolation and lack of social interaction.

Their research could lead to the conceptualisation of an interactive artwork or system using VR that encourages seniors and their relatives to participate in a joint action, as a way to consolidate an intergenerational emotional bond. More specifically, they are interested in the idea of sharing/passing on memories, knowledge, skills, and how they can be recalled, transmitted and re-appropriated, while taking into consideration that their input is accessible to someone who is not tech literate. Their expectations include the production of

a piece of work as part of the residency using AI and/or VR , but also writing and making public engagements as a way to efficiently disseminate the production of the residency and its ambitions internationally.

2.1.4 Older people

Regarding the interior design, MindSpaces partners E-Seniors determined challenges that seniors face in their daily life, how they tackle them, and how they believe MindSpaces can help improve the design of their domestic environment. E-Seniors is an older people association working for seniors' well-being and active ageing. Thanks to its wide network of seniors and its members (mainly older people), the association conducted 2 focus groups and 3 interviews to collect user requirements regarding the technology to develop, as well as seniors' artistic and architectural conceptions of their home spaces.

E-Seniors have recruited older people who participated in the user requirement phase of MindSpaces. 2 focus group discussion groups involved 27 seniors who were recruited through the association common communication channels. The focus groups lasted 2 hours each and allowed E-Seniors to gather relevant results about older people's view on the issue of loneliness, how they feel in their own homes and what parameters can be worked on so that they can feel better.

To go deeper into the users' requirements research, interviews were also conducted by E-Seniors by telephone and addressed with individual seniors the same issues as in the focus groups. Thanks to this technique, seniors could talk more freely about their feelings concerning art and E-Seniors researchers could gather more relevant data.

2.2 Pilot use case creation methodology

The PUC scenarios, which have been initially outlined in the proposal phase and described in the deliverable **D2.4 "Design needs in architecture and urban scale and use case scenarios"** are now further elaborated based on extensive feedback and experience provided by the partners during discussion sessions in regular teleconferences taking places on a bi-weekly basis, as well as physical meetings.

The starting point of the MindSpaces PUC scenarios was the initial descriptions during the proposal phase. The main criteria, which were taken into account for the use case creation

at that phase, were: a) the relevance to the MindSpaces challenges, b) the interest of the stakeholders.

For all PUCs, an initial space documentation procedure took place, producing 3D models of existing environments, which will serve as the basis for innovative design ideas, being implemented by MindSpaces partner U2M. Additionally, the MindSpaces partner UPF will conduct textual analysis for all pilot cases.

Eventually, partners have agreed upon one scenario for each one of the three PUCs. For PUC1, design interventions in an outdoor urban environment, including the Tecla Sala building complex that consists of an Art Centre, a Library, a private foundation and an artist's residence, specified by the city council located in City de L'Hospitalet, Barcelona, Spain. The area of L'Hospitalet has been selected as a case of an urban area of special cultural interest (i.e. city square, old market, riverside, etc.)but also for its proximity to the Torrassa subway station that in the near future will be a main attraction for citizens and tourists. Additionally, this selection takes advantage of the proximity and knowledge of the selected place by project partners, L'Hospitalet de Llobregat City Council and the Espronceda Centre for Art & Culture, both based in the Barcelona area.

For PUC2, the partners have decided to focus on the case of designing friendly, emotionally sensitive, and high performance workspaces. MindSpaces partner Zaha Hadid Architects has an extensive knowledge of the design of corporate office space. Within the ZHA team there are several research departments with many years of experience focused on computation for design and simulation, workplace analytics, and VR/AR. Specifically the ABPS platform team has focused on the development of a software framework for the multi-objective evaluation and prediction of workplace design performance. Development of the platform includes simulation of human life process behaviour, workplace analytics, and environmental analytics in relation to workplace design features as well as empirical occupancy behaviour research using cameras and sensors in the ZHA office space. ZHA's stake in this design territory and background research knowledge provides a strong momentum to develop this use case's domain. The ABPS platform will be used in PUC 2 for the evaluation and prediction workplace designs through the design and testing of potential iterative designs in virtual VR environments. Potentially, real world sensor and camera based empirical research will be carried out in the ZHA workplace pending approval. Additionally, the office facilities of MindSpaces partner McNeel Europe will be used as a testing environment based on their knowledge and familiarity with the selected working environments and practices.

For PUC3, the partners have decided to focus on the case of redesign and refurbishment of existing homes, or the designing of new ones for senior people. The goal is to make domestic environments emotionally and functionally senior-friendly. As well as to design objects and spaces that evoke positive cognitive emotional experiences and memories, by following design trends and aesthetic values likely to be appreciated by the elderly living there. The PUC's location is selected based on the proximity and knowledge of MindSpaces partner E-Seniors.

2.3 User requirements extraction methodology

In order to gather the user requirements that will drive the design of the MindSpaces architecture and the specification of its main components, a combined approach has been adopted. This approach has been articulated in various parts, so as to ensure the credibility and coherence of the procedure. More specifically, the approach comprises five steps as outlined below (**Figure 1**):

a. Collection of user requirements from the analysis of the MindSpaces PUC scenarios.

b. Collection of user requirements through structured questionnaires and interviews distributed to focus groups.

c. Collection of user requirements through market analysis and industrial requirements derived from "***D8.2 Market analysis and industrial requirements"***.

d. Collection of user requirements from analysis of design parameters.

e. Aggregation of requirements from (a), (b), (c) and (d)

f. Prioritisation of the requirements

User requirements are hierarchized as high level user requirements (HLUR) and refined user required (UR). HLURs are placed one level up in the hierarchy and include abstract notions of user needs that might include sets and combinations of UR. Such HLURs derive from step (a), (b) and (c) and might be common across these steps. UR is the simpler form of HLUR that will drive the actual development of the MindSpaces components. Usually a HLUR relates/consists of one or more UR.

The first step (a) of the adopted user requirements' elicitation methodology is to extract user requirements from the PUC scenarios. More specifically, members of the focus groups participated in several discussions and user meetings in order to conclude with a set of requirements which are directly related to the drafted PUC scenarios. The outcome of step (a) is documented in section 3 (3.1.5, 3.2.5, 3.3.5)

Thereafter, the second step (b) of the elicitation methodology is to extract user requirements from prior user experience. Artists, citizens of the Tecla Sala area, seniors and members of the consortium have been requested to give their feedback with the aid of questionnaires and interviews. The user profiles of the participants have been evaluated, in order to understand the validity of ideas and concerns and whether those should be reflected in the HLUR. The outcome of step (b) is documented in section 4.

The third step (c) of the elicitation methodology is to extract user requirements from the industrial requirements that were based on the initial market analysis reported in "***D8.2 Market analysis and industrial requirements"***. The members of the focus groups analysed the industrial requirements and translated them into user requirements. The outcome of step (c) is documented in section 5.

The fourth step (d) of the elicitation methodology is to extract user requirements from the design parameters. Users defined the parameters they considered necessary to be implemented into the MindSpaces tool. There is an extensive analysis of the parameters that can affect the use cases. The outcome of step (d) is documented in section 6.

Once the first four parallel steps are completed, four sets of HLUR requirements were identified. The first set contains a list of HLUR requirements as derived by the analysis of the MindSpaces PUC scenarios (section 3). The second set contains a list of HLUR requirements collected through the structured questionnaires (section 4). The third set contains a list of HLUR requirements derived by the analysis of the market and the industrial requirements (section 5). The fourth step contains a list of HLUR requirements that emerged from the design parameter analysis (section 6).

In step (e), the lists of HLUR are merged into one single list of HLUR where common HLUR across different sources are aggregated and produce the final list of HLUR (section 7).

In the final step (f), the final list of HLUR requirements are further analysed to more detailed user requirements (UR). Each UR is analysed according to the following properties:

- Associated HLUR: This column contains the HLUR associated with the specific user requirement.
- Detailed description: This column provides a detailed description of the specific user requirement.
- Functional or Non-functional: This column is used to identify whether a user requirement is functional or non-functional.
- Priority based on MoSCoW framework: The column is used to assign the priority of the user requirements according to the MoSCoW framework which provides four options of “Mo”,”S”,”Co”,”W” standing for ‘Must have’, ‘Should have’, ‘Could have’, ‘Won’t have’, respectively.

This step involves a prioritization exercise following the MosCoW Framework, which was proposed by Dai Chegg as part of Dynamic Systems Development Method. The MosCoW Framework assumes that all requirements are considered important but the prioritization method is used to establish delivery timelines of the requirements with regards to the business benefits and needs. More specifically, it considers the following categories:

- **Must Have:** Requirements labelled as ‘must haves’ have the highest priority in the development and delivery timeline. These are the requirements without which the program would not make sense form a business perspective and the project delivery is considered not successful.
- **Should Have:** Requirements labelled as ‘should haves’ are quite important but not considered as necessary as the ‘Must have’. They are less time-critical and often have alternatives to fulfil their purpose in the program.
- **Could have:** Requirements with ‘could have’ label are mostly requirements which are desirable but not necessary. These requirements are considered to be developed in case of extra resources.
- **Won’t Have:** Requirements labelled as ‘won’t have’ are the ones agreed as the stakeholders as least desirable and have the lowest priority and are usually not planned in the development plans.

3 PUC SCENARIOS

This section elaborates on the three PUCs, as they have been already described in D2.4. It provides detailed descriptions and updated information that have been following the project's development. It presents a related storyboard overview. Finally, it elaborates on the associated High Level User Requirements (HLUR), which have been initially defined during plenary meetings, as well as through the continuous collaboration and discussions between the focus group members. The PUCs are therefore described with relevance to the users' needs and requirements as well as their business perspective.

Each PUC is described in a separate section with the following structure:

Executive summary, which contains a brief summary of the PUC.

Rationale, which describes how the PUC will exploit MindSpaces so as to demonstrate the system's capabilities and enlightens the way in which MindSpaces could benefit the PUC's business processes.

Detailed description, which provides a thorough documentation of the PUC, including the factors that are involved, along with its motivation and usability.

Initial storyboards and diagrams, which dictates how the PUCs can be implemented in a real life environment and defines the factors that are involved and the use of MindSpaces components.

High level user requirements (HLUR),That have been compiled so far. They describe the special requirements of the particular PUC and the users' needs for the realisation of the PUC.[1]

[1] Dynamic systems development method.

3.1 PUC 1 –Outdoors urban environment

3.1.1 Executive summary

Scenario Topic: Interventions in City de Hospitalet

The pilot use case for "Designing of improved, attractive city spaces", intents to improve urban design in a rapidly expanding city by addressing new challenges that may arise related to the city's functionality, mobility, attractiveness, protection of culture and environment. MindSpaces will aim to increase sensitivity and awareness towards the cultural significance and current issues of the city, related to the environment and mobility, through innovative art installations in key locations. Thus, MindSpaces will raise visibility of the city's cultural value and increase awareness of issues related to its expansion, particularly environmental, mobility and other socially sensitive concerns. It can also generate environments that are amenable to new types of social interaction and new degrees of social connectivity with the urban fabric. This, in turn, will improve touristic potential, the wellbeing of citizens, quality of life in the area, as well as its overall economic activity. The pilot will use advanced modelling software (e.g. Rhino, Grasshopper) to produce blueprint documentation of the area, and propose new urban design schemes that showcase its cultural visibility and importance, generate new types of social interaction, and draw attention to issues it is facing regarding environmental pollution and mobility (e.g. air or water pollution, traffic congestion).

The use case is focusing on the city of L'Hospitalet de Llobregat, a city located in the metropolitan area of Barcelona. Being Catalonia's second city, with a population of more than 262.000 inhabitants, it faces major challenges regarding high urban density, high levels of multiculturalism and an industrial past, which has shaped the city. The past 20 years have brought intensive urban, economic and cultural programs creating a dynamic metropolis that attracts artists, new companies and new population. The Tecla Sala Cultural Centre and surroundings are the focus point of the urban outdoor design procedure of the first PUC, the spatial base of work that will host the artists' installations, and will also serve as a final exhibition space of the resulting work led by the selected artists.

It is a central area of Tecla Sala, which holds several projects of contemporary visual arts regarding training, creation, production and exhibitions. It is also a pleasant urban park connecting the north and the south of the city and a future neuralgic area with new perspectives of flows once the intermodal metro and train station, which is currently under

construction, will be opened. The pilot is targeting City councils and municipalities that want to renovate outdoors urban spaces, architecture offices that want to democratize the design process and improve outdoors urban design, architecture academic units studying trends and innovations in outdoors urban design, VR/AR companies that want to deploy realistic city scenarios in their games.

3.1.2 Rationale

A professional architecture office (ZHA) and an academic architecture unit (AUTH), have been assigned to collaborate with city council of the City De L'Hospitalet, art curators (Espronceda Centre of Art and Culture) and artists (MoBen, AN, Art Residents (Open Call)) in order to produce outdoors architecture and urban design proposals for an urban area of special cultural interest. ZHA and AUTH will cooperate with the artists selected by the project's 'Open call' to deploy artistic projects that are aligned with the mission of MindSpaces and STARTS, bringing technology to urban design, human centred thinking, ethics and values closer to its technical deployment. The citizens will experience the proposed urban design in the outdoors area itself, through artistic interventions potentially expressed via media façades and/or new spatial installations linked with a VR environment. Art projects (virtual or physical) will contribute to the definition of a psycho-geographic and economic character of the city, catalysing new processes of local identification with public spaces within local neighbourhoods.

Art installations may provide direct representations of cultural assets, reproductions or projects on the historical urban fabric. Urban challenges, like mobility issues or environmental pollution data, aim to elicit interest and engagement in these issues from city dwellers and visitors. Additionally, installations may generate a platform for new types of social interaction within the urban context. User's emotional and cognitive responses will be indirectly assessed by a combination of environmental and physiological sensors appropriately chosen for each installation (EEG, motion sensors, activity sensors, video etc.) **(Figure 2)**. The MindSpaces public installations will dynamically change according to the artists' sense of aesthetics, in response to the sensor feedback from the public, so as to arrive at the most emotionally appealing and functional design proposal, which will be generated through the collective behaviour of the participants.

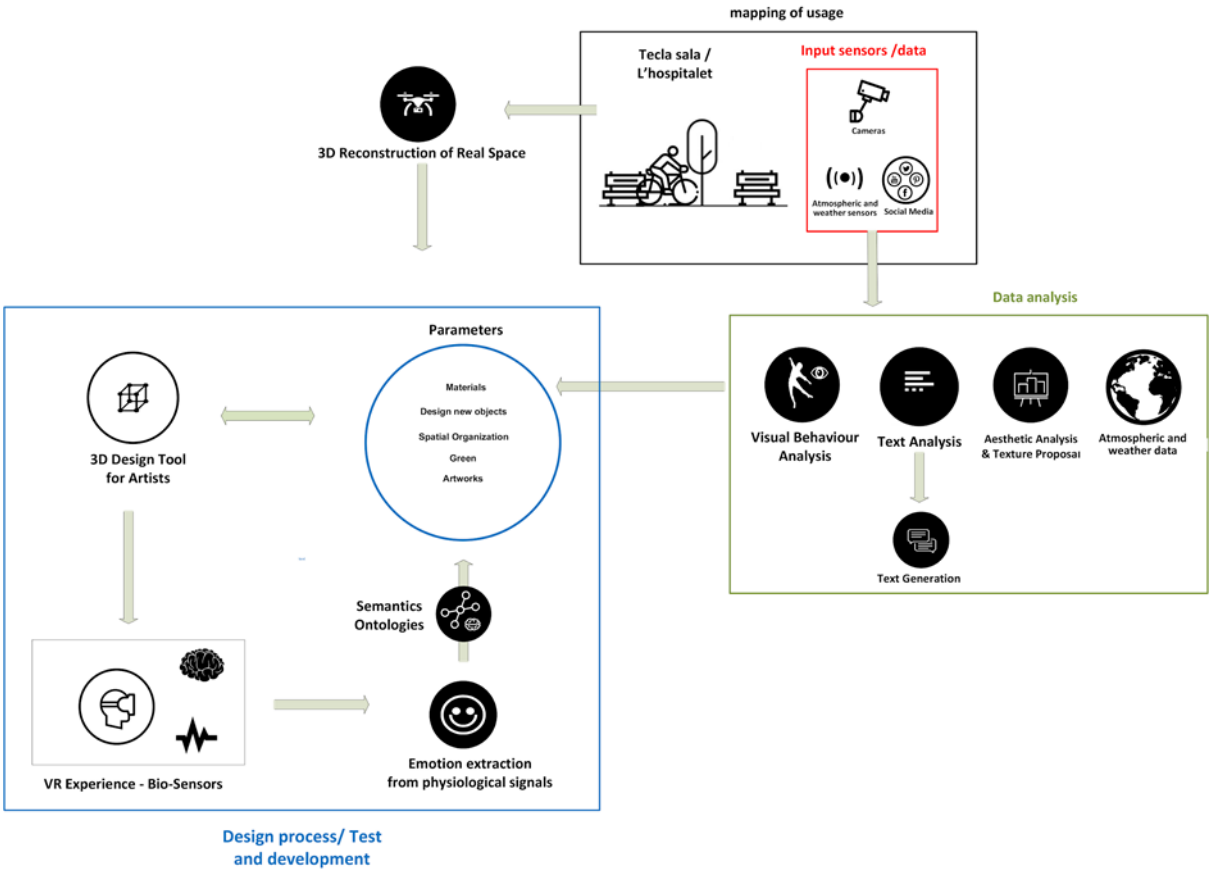


Figure 2: Diagram Pilot Use Case 1_Interventions in City de Hospitalet

3.1.3 Detailed description

The selected building complex of Tecla Sala and its urban outdoor surroundings**(Figure 3, Figure 4, Figure 5)**, an old factory complex that dedicates nowadays its several buildings to visual arts: The Tecla Sala Metropolitan Arts Centre, the Tecla Sala Central Public Library, the Arranz-Bravo Arts Foundation and the private TPK Arts Centre. The complex is surrounded by a dynamic urban area that will host during the next years a central intermodal train and metro stations that will bring new circulations and mobility into the area.

The process for PUC1 will start with the creative collaboration between architects, artists and technological partners inspired by all the obtained data. This process will actually settle an innovative methodology of work based on transversal cooperation and co-creation. This

procedure will generate material for a potential exhibition on new methodologies and co-creation in STEAM universes applied to MindSpaces. Once the VR Tecla Sala inspired platform is produced, along with the art installation(s) ,whose number is yet to be determined, the PUC will be developed into a real citizen experience that takes place in the Tecla Sala area for a fixed period of two weeks. The art installation(s) are conceived as an experiential setting, open to any citizen and visitor. The installation(s) will include a temporary pavilion accommodating the following experiential zones, all focused on citizens experience and participation, a) The VR computers zone to test the platform, b) The documentary exhibition zone showing the methodology of the process with all the compiled material and c) The meeting zone where speeches, seminars and workshops will be held.

In addition an Art installation by artists (MoBen, AN) is under development and there will be soon more details regarding the project. The result will be a public event about art-driven innovation conducted as an experiential activity for citizens.

Figure 3: Images of the area of the city de L'Hospitalet_Tecla Sala Metropolitan Arts Centre

Figure 4: Images of the area of the city de L'Hospitalet_Tecla Sala Metropolitan Arts Centre

Figure 5: Images of the area of the city de L'Hospitalet_ Tecla Sala Metropolitan Arts Centre

3.1.4 Initial storyboard and function diagram

MindSpaces partner U2M will produce2D and 3D documentation of the urban environment that architects (ZH, AUTH) and artists (ESP, MoBen, AN, Art residents (Open Call) will work on. Additional input might be available through citizen participation and social media data. U2M will fuse multimodal information captured via aerial (drone) and close range ground cameras, a dedicated mobile mapping platform developed for Mindspaces needs and terrestrial 3D Scanners, based on best practices and local stakeholders permissions. The captured data, i.e. images, point clouds, geolocalization and inertial data, will be optimally combined to provide the necessary level of detail for processing in MindSpaces platform.

Architects (ZHA, AUTH) will use the urban documentation material as a basis for collaboration with well-known artists (ESP, MoBen, AN) in order to produce artistically and aesthetically rigorous, interactive public installations that will lead to a redesigned, better emotionally and functionally operating urban public space. The installations will utilize aspects of the ZHA Agent Based Parametric Semiology research of social crowd behaviour within the generative design process. It will engage city dwellers and visitors by appealing to their emotions and connection with the city, its history and environment. It will provide a platform for new types of social interactions within the city. City users will interact with/within the VR (ZH, NURO) installation(s). Cognitive, emotional and environmental sensor measurements will be collected from the users. Visual data from video cameras and sensors for physiological signals (e.g. EEG and HR) will be utilized aiming to get data related to the sensing environment under study. The raw data from sensors will be used by intelligent services (Visual Behaviour Analysis, Emotion extraction service) aiming to provide new insights which will be taken into consideration for generating improvements and alterations of the installation(s).

3.1.5 High level user requirements

Based on the aforementioned use case the following user requirements have been elicited.

HLUR	HLUR Title	HLUR Description
HLUR_1.1	User interaction and control	Architects can collect onsite, geolocate and aggregate biometric/behavioural data in 3D reconstructed environments.
HLUR_1.2	Manipulation of spatial conditions	Architects and artists can use spatial conditions to increase social interactions and communicate artistic concepts
HLUR_1.3	Data Analysis for understanding social needs and human values	Artists can use data Analysis for understanding social needs and human values
HLUR_1.4	Adaptable public spaces	Citizens can have to have adaptable public spaces depending on their needs.
HLUR_1.5	Space use prediction	An architect/designer can predict the potential uses for new spaces by analysing previous behavioural data.
HLUR_1.6	Intelligent projects based on feedback	An architect/designer can produce social intelligent projects based on feedback (emotional and rational: opinion on the internet)

Table 1: HLUR extracted from PUC1

3.2 PUC 2 – Inspiring workplaces

3.2.1 Executive summary

Scenario Topic: Inspiring workplaces

Inspiring Workplaces is a Pilot Use Case designed to test and develop the MindSpaces platform specifically for designing better quality workplace environments. MindSpaces research partners collect and analyse behavioural, emotional, and textual data from people inhabiting workplace environments physically and virtually (AR/VR environments) to develop design and analysis tools used in designing workplaces. Artists, architects, and designers will leverage the tools and data insights to explore and envision improved workplace environments.

In recent years, aesthetically and functionally innovative workspaces are being created which are more capable of enabling the dynamic communication that is needed within today's networked society. Increasing opportunities for positive social interaction in work environments leads to improved productivity and creativity across departments and teams. The pilot use case for "Inspiring Workplaces" aims to create emotionally appealing work environments that are inspiring, allow more dynamic and diverse social behaviour, lead to increased and improved worker collaboration, productivity and well-being.

Designers have the potential to guide modern workplace design in unexpected directions, but also to improve its appeal and effectiveness. To do so we must consider current cultural office trends that lead the changes in needs and requirements for effective workplaces. Today, businesses are treated as ecosystems required to support and enable increasingly adaptive and interdisciplinary collaborations. More businesses are embracing the Gig Economy which has given rise to the exponential growth of co-working spaces in past 10 years globally. Building owners are increasingly looking to curate not only the type, but also the size and stage of development of occupiers, to create a synergistic mix of entrepreneurial and established businesses. This requires us to consider designs which are more adaptive and flexible for building stakeholders, business owners, and building users. There is a concerted effort to enable both curated and unexpected spontaneous collaboration. Our designs must not only allow for such collaboration, but actively encourage and enable more dynamic social interaction and collaboration through connectivity. Additionally, in a war for retaining talented workers, businesses are increasingly considering

ways of providing a better work-life balance through increased and diversified amenities, more exposure to natural light, green spaces and pleasant stress reducing working environments which feel less like the cold office spaces of the past.

Today's design processes must be driven not simply by intuition, but through deeper data driven insights that unlock the features that enable a high functioning workplace. To gain insights we must utilise predictive analytics to solve multi-objective workplace design problems. Additionally, we need to unlock and measure how workers feel about their work settings and instrumentalize them. Today architects see massive opportunities at each step of the design process in gaining insights from data to increase design performance and reduce risks to clients. From environmental data to social data, design consultancies are increasingly being commissioned to integrate real world data as well as simulated data to provide early insights to directly influence workplace design geometry and organization. The multi-faceted pressures felt by all stakeholders in workplace design (Corporate Real Estate Managers, CEOs, users/workers, and designers), require new approaches to the design process. Through Pilot Use Case 2 the consortium will collect and analyse both empirical and simulation data surrounding the design of workplaces to gain actionable insights that improve the design process.

3.2.2 Rationale

Internet of Things (IOT), camera vision and AI, and smart building technology present us with new opportunities to integrate feedback mechanisms for real data about how people work and interact to influence design decisions. VR and AR provide new ways to experience and respond to design options in a simulation environment. Textual analysis and language processing give us opportunities to understand trends and sentiments across groups of people who use these office spaces. In order to leverage these powerful data sources, we identify and analyse the key parameters of workplaces we are designing with, such as light, materials, spatial organization and form. From these parameters, we begin to identify relationships with human emotion and behaviour.

The planning of workplaces is a well-defined design problem with clear parameters and constraints. Some of these parameters are specific to workplaces while others can be generalised to many architectural design problems, which provides a useful testing and development case for the overall MindSpaces ambition.

While there has been great interest and wide agreement for decades that there are relationships between human behaviour, workplace performance and well-being with the design organization and features of office spaces, there is very little operational knowledge. This is due to many factors including the fact that architects rarely have access to or pursue effective post-occupancy analysis of their designs. Lack of consistency and rigour in post-occupancy analysis methods as well as the range of focuses of success criteria coupled with the high dimensional space and range of office space design parameters have led to a convoluted view of how spatial design influences workplace performance, forcing architects to work from a "rule of thumb" methodology. As stated by Sailer and Penn, the relationships between workplace performance and behaviour and design organization are both "spatial" and "transpatial," suggesting that individuals may relate to each other in a dual way, i.e. either by means of spatial closeness (spatiality) or by means of conceptual closeness (transpatiality) (Sailer and Penn 2009). Some aspects of well-being and performance in relation to spatial design are potentially generalizable in offices while others are specifically affected by aspects of office culture and social relationships. [2]

By gaining deeper insight into how people behave and interact in workplaces both real and virtual we can begin to cull out uninspiring and ineffective design solutions and focus on models which are highly performative across multiple objectives. The development of a design simulator in VR enables us to test many design options and parameters without the expense of changing physical designs. Understanding emotional and physiological feedback in these virtual environments gives us the means to gather generalizable and specific insights to be applied in generating new models in an iterative process. Textual data can help us gain insights into people's sentiment, likes, dislikes, and feelings surrounding existing designs and workplaces in general. This added layer of data provides a high-level specific degree of understanding of parameters that are not so easily simulated. While we cull and prune inappropriate design options we begin to focus on key parameters and provide solutions tailored to how specific company cultures would weigh various design objectives.

[2] Sailer, K.; Penn, A.; (2009) Spatiality and transpatiality in workplace environments. In: Koch, D. and Marcus, L. and Steen, J., (eds.) Proceedings of the 7th International Space Syntax Symposium. (pp. p. 95). Royal Institute of Technology (KTH): Stockholm, Sweden.

3.2.3 Detailed description

The implementation of PUC2 involves artists, architects, and researchers collaborating to develop and test designs for workplaces. Through this process the consortium partners will test and develop the MindSpaces platform for designing better quality workplace environments. MindSpaces research partners collect and analyse behavioural, emotional, and textual data from people inhabiting workplace environments physically and virtually (VR environments) to develop design and analysis tools used in designing workplaces.

Additionally, video cameras will be setup in real workplaces to gather data over time of human occupancy and behaviour. Researchers will analyse video feeds using advanced computer vision and artificial intelligence to identify and quantify **behavioural patterns over time**. Researchers will analyse how individuals move in relation to spaces, spatial features, and other people. Additionally, researchers will analyse pairwise and group behaviour of people in relation to spaces, spatial features, and other people. This data will be considered in relation to time in terms of frequency, time of day, and duration. The goal is to find correlations between architectural elements that can potentially be parameterized and human behaviour, time of day, and other human occupancy. The research seeks to find useful relationships between human behavioural events such as movement patterns, social events and conversations, forms of collaboration, with physical spatial features.

In parallel with studying real office environments, a series of experiments will be conducted by producing 3d virtual workplace environments which can be experienced in virtual reality. Each experiment will involve changing 1-2 design parameters such as material or lighting conditions, colour, proximity to natural light, and features and organizational office layouts. Human users will experience each variation in VR while researchers collect physiological and EEG data to understand the user's emotional and physiological signals in relation to what they experience. Among others, researchers will study emotional and physiological data in response to different options for artificial and natural lighting, materials and material contrast, colour, spatial proportion, spatial organization, and specific spatial conditions. These insights will then be generalised to guide the biasing of parameters in the design of improved workplaces.

Textual data surrounding workplace design features and specific workplace designs will be extracted through web crawling and analysed using language processing and sentiment analysis to provide useful insights relating to how people feel about specific workplaces,

design parameters, and design features. Textual analysis will be segmented by types of workplaces and attributed to design parameters and design goals such as spatial organization, spatial features, interactable design elements, visual connectivity, and others.

Zaha Hadid Architects' Agent Based Semiology Research team has developed tools for generating the design of workplaces, simulating human life process behaviour, and simulating environmental factors. These tools will be utilised to iteratively develop and test workplace designs for a series of social and spatial performance metrics. The toolset will enable designers to test simulation options and predict how people would behave within them. Some of the metrics include producing spatial occupancy maps, quantifying spatial and asset utilisation, producing 3d spatial vision maps, quantifying and visualising social encounters and group behaviours, and simulating environmental conditions. This will be coupled with spatial and asset analysis to predict how well a workplace design would perform.

Potential designs for 3d virtual workplace environments will be produced and tested in virtual VR environments leveraging the ABPS platform to simulate and predict workplace performance and iteratively improve the design performance through this feedback.

3D virtual models of work environments are created and serve as the basis for innovative design ideas. The latter will arise through the synergy of artists, creatives and architects, whose propositions will be presented in VR installations to end users. Online feedback from EEG, physiological sensing, integrated with environmental sensing, and Agent Based Parametric Semiology (ABPS) life process simulation modelling analysis will guide modifications to the initial designs. To create environments that truly appeal to the people working in them and provide a platform for high quality and productive social interactions.

3.2.4 Initial storyboard and function diagram

MindSpaces partner U2M will use terrestrial laser scanners and data from a custom-built 3D sensing platform to build 3D models of the original workspaces, which will be re-designed by architects (ZH, AUTH) and artists (ESP, MoBen, AN, Art residents (Open Call)). ZH's Agent Based Parametric Semiology life process modelling will be used to simulate and test social behaviour within proposed workplace designs **(Figures 7, 8, 9, 10, 11)**. Users will participate in art-inspired immersive VR ABPS simulation design environments in Unity 3d game engine.

These simulations coupled with direct user feedback data will be used as training data for an ABPS machine learning model in order to generate improved workplace designs **(Figure 6)**.

In this pilot the targeted organizations are big companies, which occupy more than 200 employees, and need to renovate their workspace so as to maximize the engagement, productivity and interaction of their workers and also architecture offices that design efficient functional and relaxing workspaces **(Figures 12, 13, 14)**.

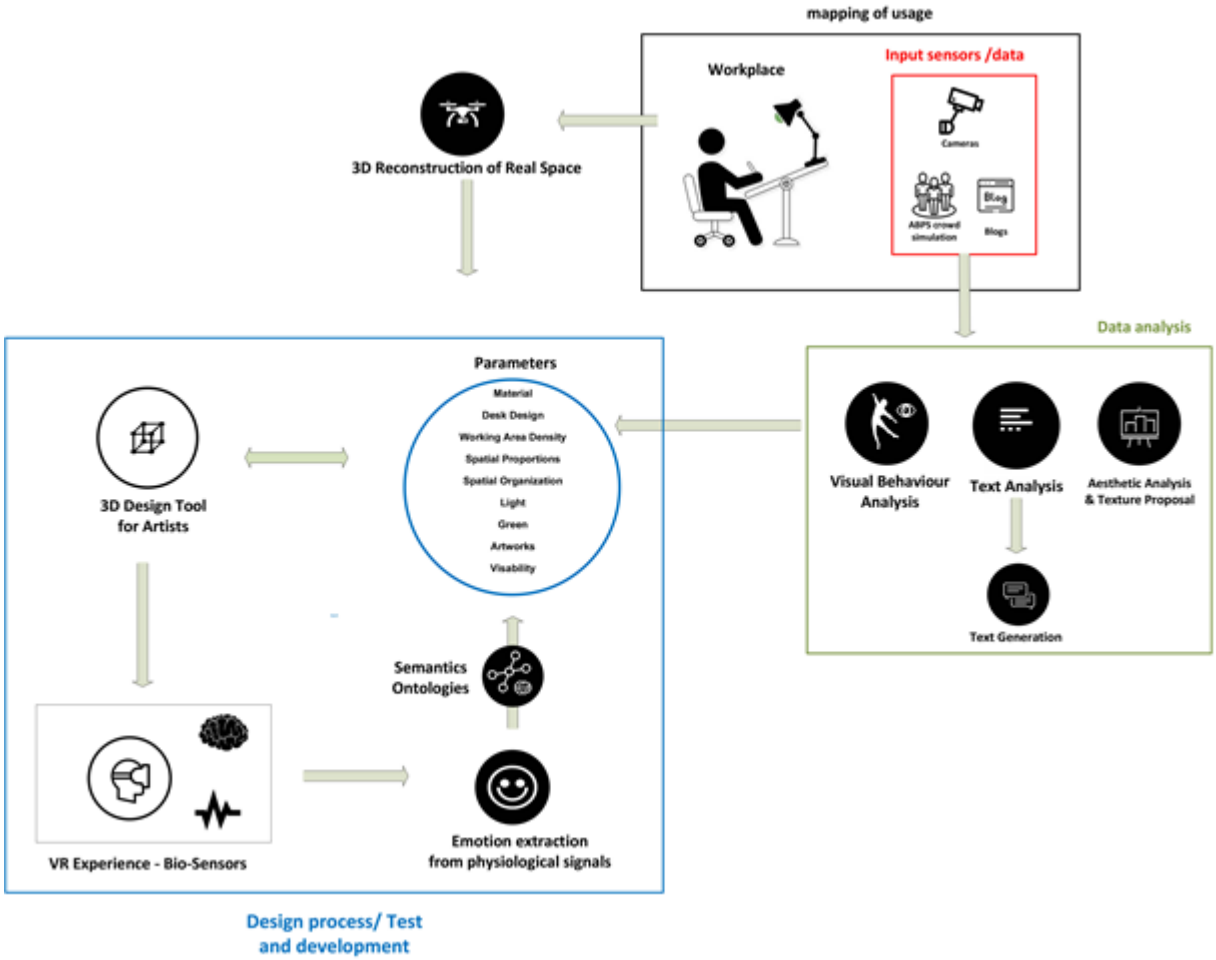


Figure 6: Pilot Use Case 2 Diagram: Inspiring workspaces

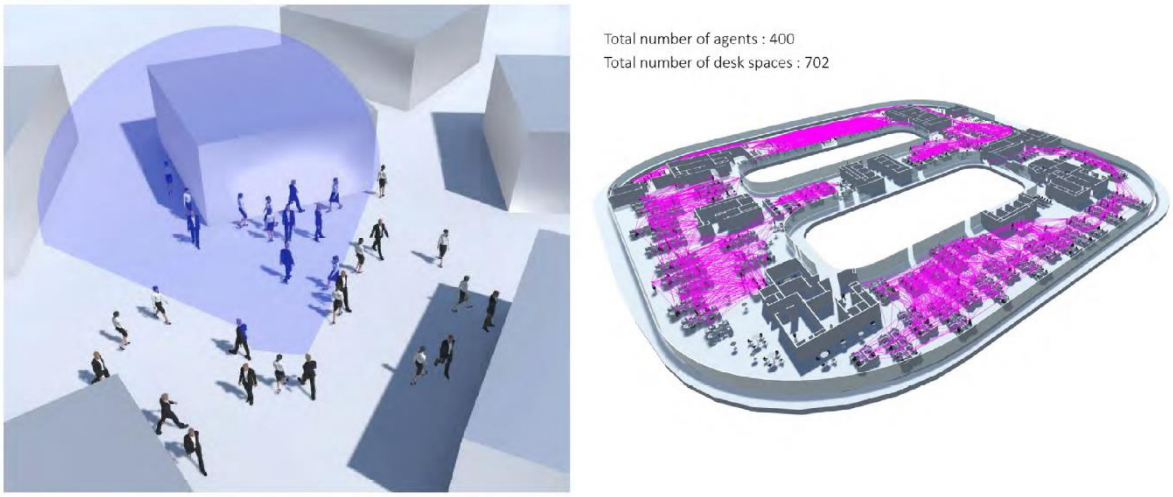


Figure 7: Autonomous Agent Simulated Perception

Figure 8: Autonomous Agents Simulation

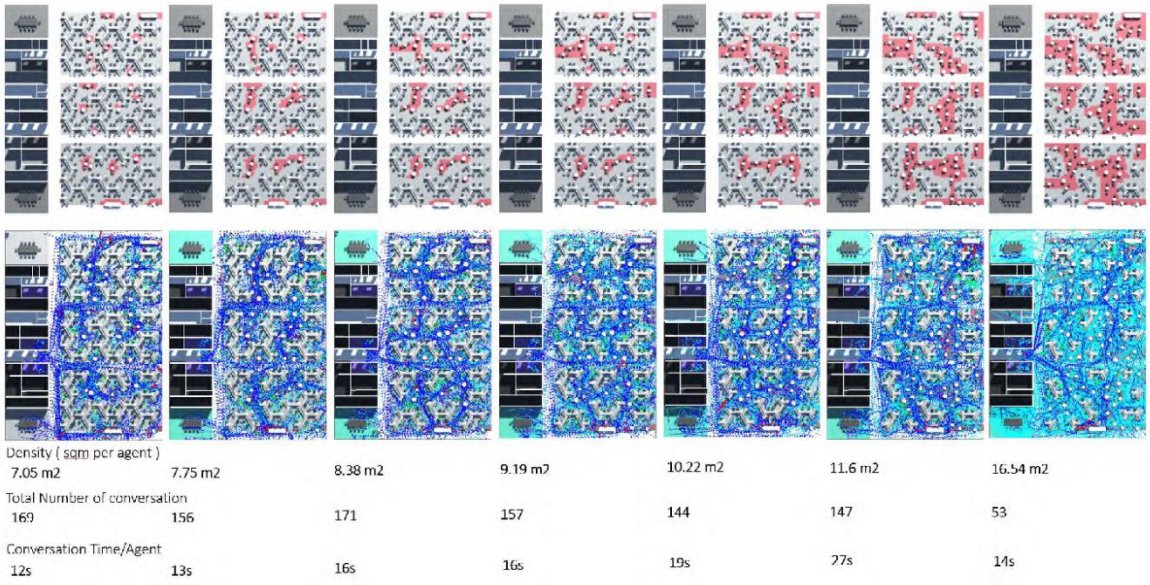


Figure 9: Spatial Organization Simulation Experiments

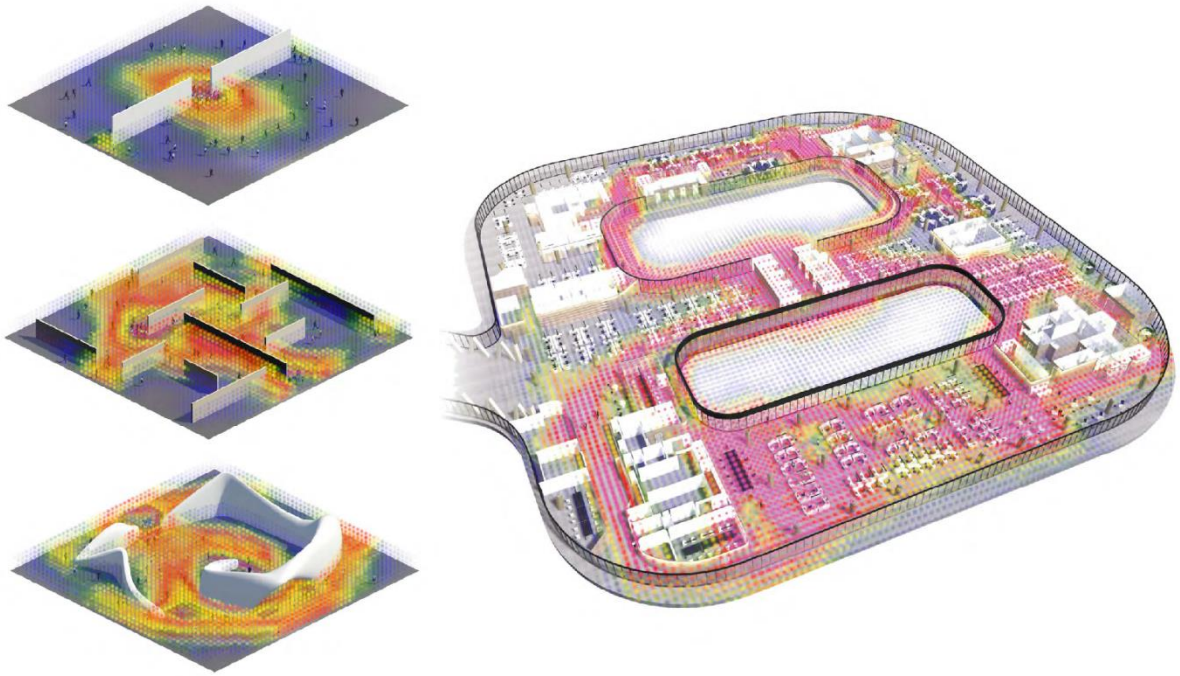


Figure 10: Data Visualization

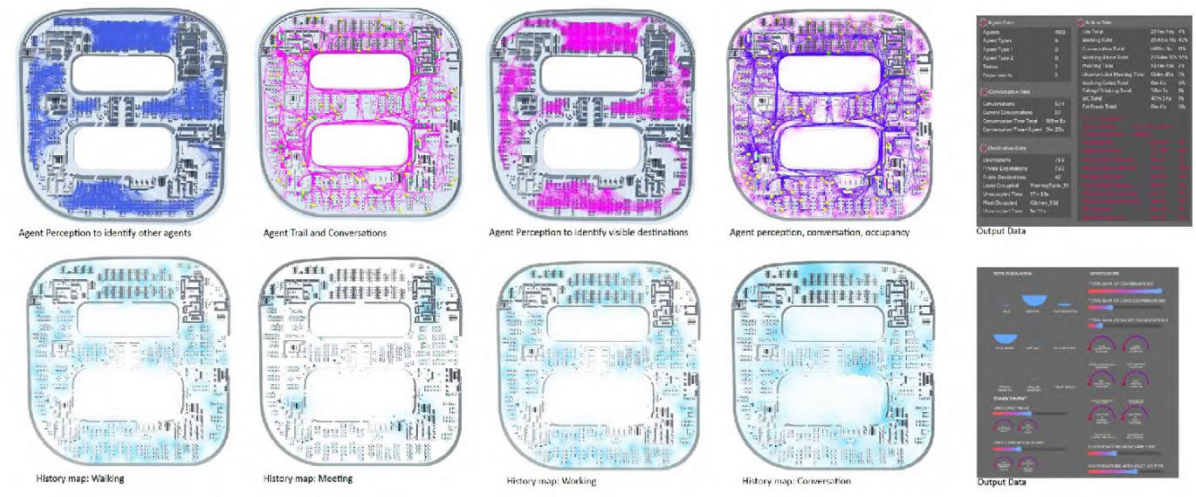


Figure 11: Data Visualization

Figure 12: VR Workplace Environments

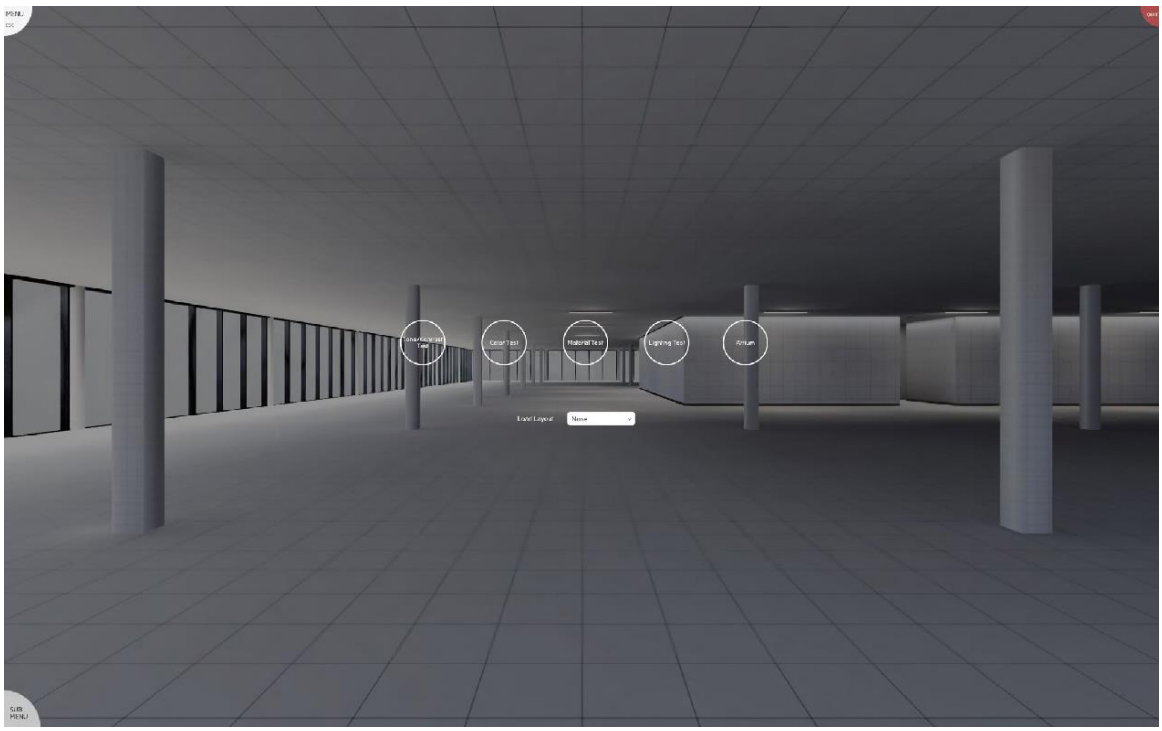
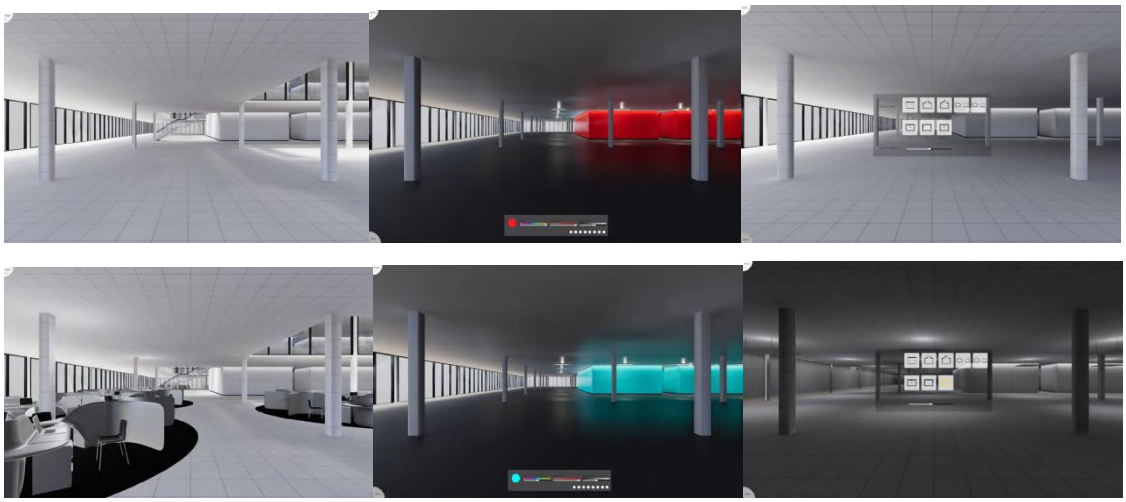


Figure 13: VR Workplace Parameters Experiments



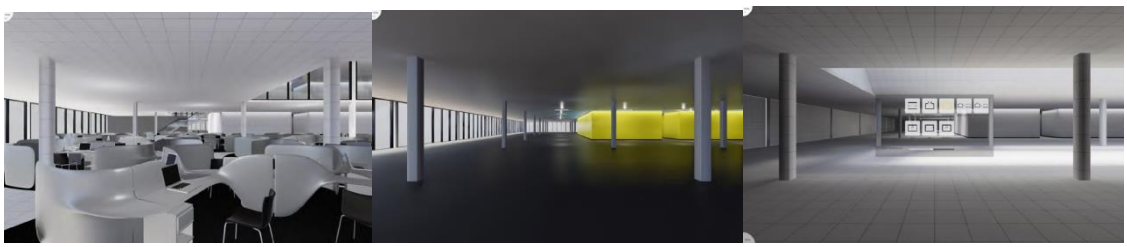


Figure 14: VR Workplace Parameters Experiments

3.2.5 High level user requirements

Based on the aforementioned use case the following user requirements have been elicited.

HLUR	HLUR Title	HLUR Description
HLUR_2.1	User interaction and control	Architects can collect onsite, geolocate and aggregate biometric/behavioural data in 3D reconstructed environments
HLUR_2.2	Correlation of a user's space attributes with their emotional state	An architect can correlate spatial quality and environmental attributes of space with the emotional state and behaviour of the users.
HLUR_2.3	Adaptable workplaces	An office worker can have an adaptable workplace depending on their needs
HLUR_2.4	Data Analysis for understanding social needs and human values	An artist/designer can use Data Analysis for understanding social needs and human values through social interaction with spaces
HLUR_2.5	Space use prediction	An architect/designer can predict the potential uses for new spaces by analysing previous behavioural data.
HLUR_2.6	Intelligent projects based on feedback	An architect/designer can produce social intelligent projects based on feedback (emotional and rational

Table 2: HLUR extracted from PUC2

3.3 PUC 3 – Emotionally-sensitive functional interior design

3.3.1 Executive summary

Scenario topic: Emotionally-sensitive functional interior design

Architectural and interior design has always aimed at creating emotionally appealing and functional environments. But it is only in recent years that emotional effects and the usability/functionality of a designed space are being assessed in an objective and quantifiable manner Quantitative data using multiple sensors are now showing great potential to support design. Additionally, the widespread availability of digital representations of past aesthetic trends and features enables their innovative re-use and integration in new designs. MindSpaces will combine these trends, enabling the realization of aesthetically sensitive interior design that integrates the end user's responses and leverages specific aesthetic features that appeal to certain target groups.

3.3.2 Rationale

An association for seniors (E-Seniors) will aska group of architects, such as a professional architecture office (ZH) collaborating with an academic unit (AUTH) to make a proposal for the re-design and refurbishment of an existing home, or the design of a new one, with the goal of making it emotionally and functionally senior-friendly. Architects (ZH, AUTH) in collaboration with artists (AN, MoBen, Art residents (Open Call)) will design objects and spaces that evoke positive cognitive and emotional experiences and memories, by following design trends and aesthetic values likely to be appreciated by the elderly living there. 3D-models of the proposed designs will be imported in a VR environment in order to be evaluated from the end-users based on their EEG and other physiological measurements.

3.3.3 Detailed description

The third pilot (PUC3) of the project took place in a senior individual's home in the city of Paris. The senior is between 60 and 85 years old, with no particular illness that lives independently.

The user has been recruited through E-Seniors common channels, which include contacts with social centres, mailing lists, events, ICT classes and participation in previous European projects related to technology. E-Seniors researchers have already met the user several

times in order to prepare for the pilot phase. During these meetings, the researchers explained the goals of the project, the expected results, the methodology, the technology used in the pilot test at home and all the implications of the participation in the project. Then, the senior signed an informed consent, an information sheet and an image consent form, to comply with the ethical requirements.

The evaluation of the first prototype will start from M13 to M20 and will be overseen by E-Seniors staff, by being present at all stages of the project accompanying the senior, ensuring a successful contact with the technical team in charge of the deployment of the pilot (CERTH, U2M, UPF), informing and answering pressing questions.

The proposal for PUC3 is to work on the themes of emotional support and affective state. Issues such as affective deficit (solitude, loss) and memory will be addressed. At this stage (M10),3 interviews and 2 focus groups with seniors have already been conducted in order to define their needs, their views and expectations. The focus groups involved 27 seniors in 2 different sessions: 12 and 15 seniors aged between 65 and 80 (19 women and 8 men). The main results gathered thanks to these focus groups and interviews are that, in general the seniors are looking for in an artistic creation, to feel a wide range of emotions. To feel inspired, to connect with others and to understand the world around them. There is generally a positive feeling at home, a feeling of safety, but issues such as noise, limited luminosity and the small size of Parisian homes or crowded interior living spaces were pointed out. Seniors responded that they highly value the contact with nature and the outdoors in general, as well as that they appreciate a comfortable and well equipped house **(Figures 15, 16)**. The issue of autonomy is also a prominent one as it influences the well-being at home. Finally, it should be noted that ageing individuals often try to stay active and boost their creativity. Many of them consider their houses to be their shelter and a source of inspiration. In PUC3, the goal of MindSpaces will be therefore to re-design and re-furbish a senior's home to be emotionally reactive, comforting, appealing as well as inspirational.

Figure 15: The interior of a senior's home

Figure 16: The interior of a senior's home

3.3.4 Initial storyboard and function diagram

Project partner U2M will use 3D-scanners for the 2D and 3D-modelling **(figure 17)** of existing interior objects and spaces, forming the basis for new architectural design proposals at indoor level or space reconstructions by architects (ZH, AUTH). Sensor based feedback of the users' responses (by mobile EEG, physiological sensing, visual tracking of activities, behaviour and use of space) will be used by architects and artists to guide the architectural design and artistic exploration. Their initial design ideas will be imported in a VR environment (NURO) and will be assessed by the end-users via sensor feedback, leading to emotionally-adaptive design solutions **(Figure 18)**. The targeted organizations are people that want to refurbish their dwellings, associations for the elderly, nursing homes and architecture offices that specialize in interior design.

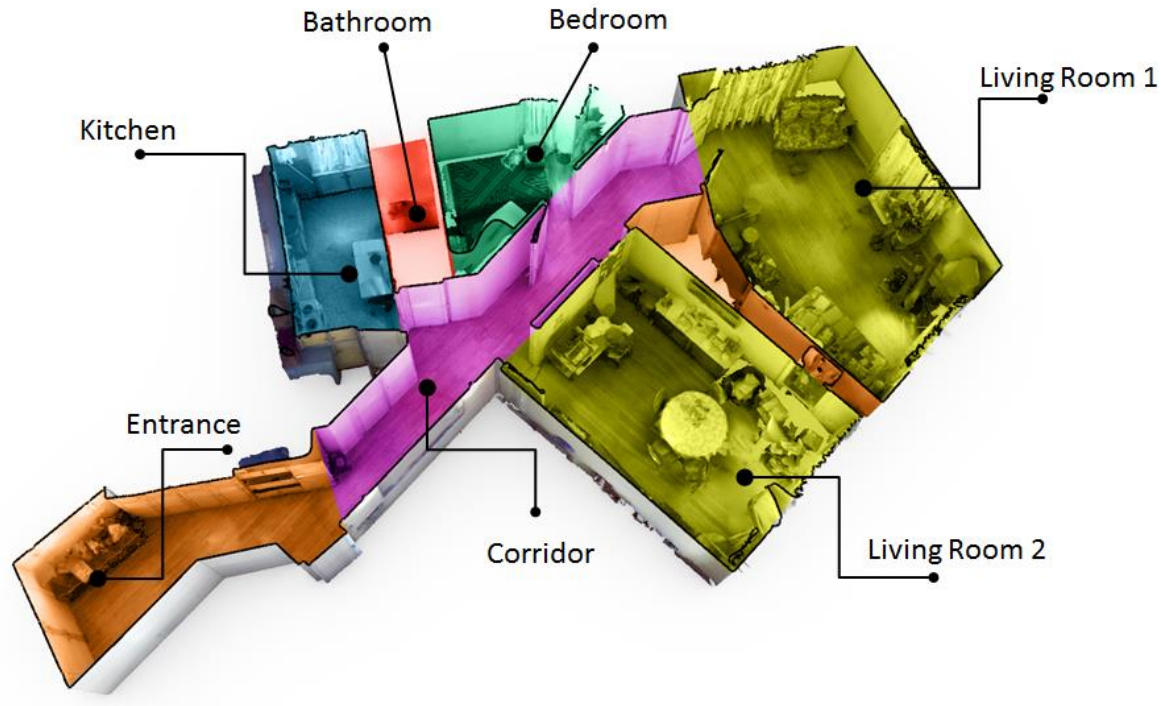


Figure 17: Interior 3D model created by project partners U2M, including marked the uses of the senior's house.

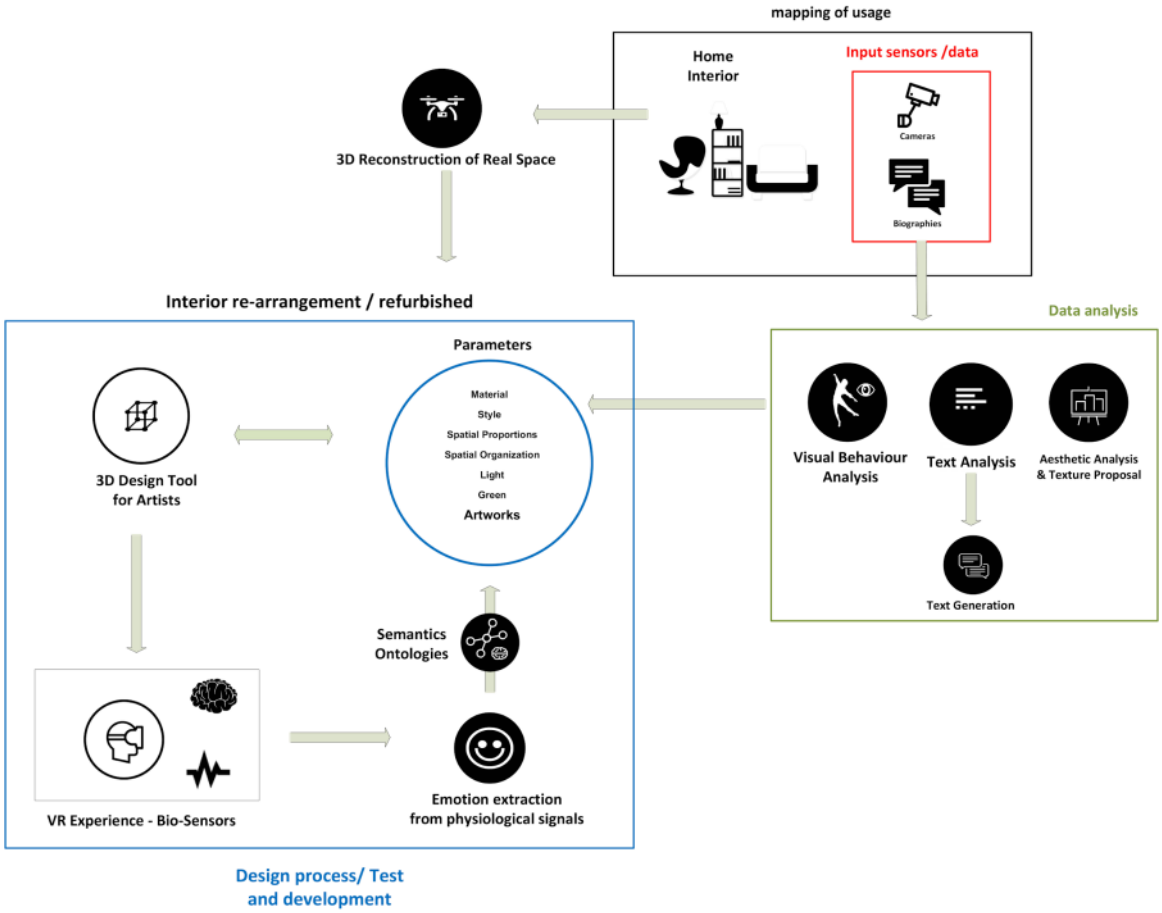


Figure 18: Pilot Use Case 3 Diagram: Emotionally-sensitive functional interior design

3.3.5 High level user requirements

Based on the aforementioned use case the following high level user requirements (HLUR) have been elicited.

HLUR	HLUR Title	HLUR Description
HLUR_3.1	User interaction and control	Architects can collect onsite, geolocate and aggregate biometric/behavioural data in 3D reconstructed environments
HLUR_3.2	Manipulation of spatial conditions	Architects and artists can use spatial conditions to increase social interactions and communicate artistic concepts
HLUR_3.3	Data Analysis for understanding social needs and human values	An artist/designer can use Data Analysis for understanding social needs and human values through social interaction with spaces
HLUR_3.4	Adaptable houses	A senior can have an adaptable house depending on their needs
HLUR_3.5	Space use prediction	An architect/designer can predict the potential uses for new spaces by analysing previous behavioural data

Table 3: HLUR extracted from PUC 3

4 ANALYSIS OF PRIOR USER EXPERIENCE

We have enriched the focus groups with artists, citizens of the Tecla Sala area, seniors and members of the consortium and we have requested their feedback with the aid of questionnaires and interviews. The questions were selected through a collaborative exercise between user partners. Two categories of questions have been decided: general and in-depth ones. Essentially we tried to cover all high-level features/requirements (already addressed in the proposal phase) and created a list of questions that will enable to obtain user's scope on these features/requirements and to discover "undreamed of requirements" Most of times, questions evolve naturally as we think through the implications of a feature. The questionnaire was created by the MindSpaces user partners in such a way to receive constructive feedback. Then, the questionnaires were distributed in a selected group of 35 people, divided into professional architects at practice and academic level, artists, seniors, and tecla Sala citizens. All participants in the questionnaire procedure have actively given their consent to submit their forms. The original questionnaire that was given to the experts is provided in Appendix A.

User requirements have not been plainly statistically derived from the set of answers received through the questionnaires. The user profiles of the participants have been evaluated, in order to understand the validity of ideas and concerns and whether those should be reflected in HLUR. Due to the nature of the questionnaire, answers have been carefully interpreted and understood, taking user profiles of the participants and their priorities into account.

Based on the aforementioned analysis of the questionnaires and interviews the following high lever user requirements (HLUR) have been elicited.

HLUR	HLUR Title	HLUR Description
HLUR_4.1	Collaborative tool	A collaborative tool for collective spaces were co-workers can work together on several tasks
HLUR_4.2	Adaptable Public Spaces	Citizens can have adaptable public spaces depending on their needs.

HLUR_4.3	Communicative software	software that can communicate/interact with each other
HLUR_4.4	Simple and clear visual UI	Simple and clear visual UI (User Interface). Simple enough for non-specialised users
HLUR_4.5	Architectural design tool to form innovative ideas	Architects and designers have a tool that can assist in formulating new, innovative architectural ideas

Table 4: HLUR based on prior user experience

5 ANALYSIS OF MARKET AND INDUSTRIAL REQUIREMENTS

The paradigm shift brought on by digital technology has changed systems, processes, and production. For instance, in the context of Architecture, previously, to showcase how an apartment would look, they would have to set up a demo apartment for clients and investors to see and get an idea of what the building would look like when completed. Nowadays, some architectural firms and organizations have begun employing digital technology as a replacement. Either through their in-house team or partnering up with another studio (which specializes in such services), they can now produce a digital apartment using various game engines like Unity or Unreal (it is worth mentioning here that Unreal has a special plugin called Datasmith which was developed for this purpose). This so-called “Architectural Visualization”, with the help of VR technology, can allow clients and investors to virtually check the apartment and determine how it would look by the end. There are several advantages of using digital technology:

1) It is cheaper to produce than conventional demo apartment.

2) It is faster to produce than conventional methods.

3) It is highly flexible. This means that parts and sections of the digital apartments can be modified, edited. Objects inside the apartments (such as tables, chairs, couches, etc) can

also be added/removed/edited, in real-time or after getting feedback, to provide an even more in-depth and informative showcase.

One such application of MindSpaces is Architectural Visualization, which is aware of all the benefits (as listed above) and would properly exploit them in order to provide an engaging and innovative experience for users and clients alike and would aid in the further development of such technology and more. There are more applications of MindSpaces, all of which have similar interests and benefits which would be properly exploited.

MindSpaces also uses Electroencephalography (EEG) device. EEG is a method of monitoring the brain and brain activities, for research, mapping, and diagnosing. It includes placing several electrodes on the person's scalp, and then measuring the voltage fluctuations caused by brain activities. Although originally developed for medical purposes, it has been widely used in other areas as well, such as psychology, cognitive sciences, research and so on. With that said, MindSpaces would be one of the first and few platforms that uses this technology. The EEG device would be placed on users' head, and the data would be gathered based on their reaction. The data would serve as a form of feedback, giving valuable and unbiased data on the project and determine the areas that need to be edited, added, or removed.

5.1Architecture Market: Digital Technology / Data Driven Design

The pace of change impulsed by the digital transformation is accelerating. In particular, the volume of data continues to double every three years [3] as more data pours in from digital platforms, wireless sensors, virtual reality applications, and billions of devices. This, coupled with the plummeting cost of data storage, the unprecedented availability of computing power (including cloud-based services), and the rise of ever more intelligent algorithms, are setting off many industry disruptions, including in the fields of architecture, design, and design research[4] , and posing new challenges for organizations active in these fields [5] . The direct implications of these disruptions can be seen in the accelerating evolution of CAD

[3]Cyclone Interactive Multimedia Group, Inc. "The Digital Universe of Opportunities: Rich Data and the Increasing Value of the Internet of Things."*Sponsored by EMC*, April 2014.

[4] Sanders, E. B. N., & Stappers, P. J. (2014). "Probes, toolkits and prototypes: three approaches to making in codesigning". CoDesign: International Journal of CoCreation in Design and the Arts, 10(1), 5–14. doi:10.1080/15710882.2014.888183

[5] Henke, Nicolaus, et al. "The Age of Analytics: Competing in a Data-Driven World." *McKinsey & Company*, 2016.

software and the rise of trends such as generative design, parametric design, and smart architecture.

Currently in the market, there is a scarcity of high-end products capable of effectively digesting the available data for the design, and support data-driven 3D modelling and complex analysis processes (e.g. site analytics, energy studies, etc.), as well as that of virtualization and AR/VR [6]. Despite this, there is currently a large market demand for such high-end products, and trends predict that this demand is set to strengthen and increase in the coming years. The challenges that market products need to meet, from a technology stance, can be summarized in the following four key aspects: 1) supporting real-time data acquisition and processing, for instance, to empower practices such as site analysis and hardware-in-the-loop tests for tech-powered components (e.g. for automated energy systems). 2) Providing scalable and flexible processing power (e.g. adopt a hybrid cloud/PC model) to enable the execution of complex algorithms. 3) Supporting high-end dynamic rendering and reactive architecture simulations, among other complex real-time processes. 4) Integrating artificial intelligence (AI) with 3D CAD software to identify design factors and inform the 3D modelling experience. Presently, only a limited number of products have incorporated AI and ample opportunities still there for companies to introduce AI-based solutions.

In this context, the global 3D CAD software market size is poised to reach an estimated US$ 14.5 Billion by 2026, as it continues to grow at a solid CAGR (Compound Annual Growth Rate) of 6% [7] . It is worth mentioning that around a fifth of the users of 3D CAD software solutions are architects and interior designers.

[6] "3D Rendering and Virtualization Software Market Size, Status, Top Emerging Trends, Growth and Business Opportunities 2024." *MarketWatch*, 11 April 2019

[7] 3D CAD Software Market – Global Industry Analysis, Market Size, Opportunities and Forecast, 2019 – 2026. *MarketWatch*, 12 July 2019.

Based on the aforementioned Market analysis the following high lever user requirements (HLUR) have been elicited.

HLUR	HLUR Title	HLUR Description
HLUR_5.1	Easy development of 3d environments	Easier way to develop 3D environment than traditional tools
HLUR_5.2	Novel textures based on the aesthetics of famous paintings	Create novel and inspiring textures that are based on the aesthetics of famous paintings and other images of artwork that do not exist in current 3D modelling market.
HLUR_5.3	Architects and designers aesthetics gallery	Understand the aesthetics of design structures (i.e. interior objects, buildings, materials etc.) and provide it to architects and designers as a gallery.
HLUR_5.4	Intelligent concept extraction	Intelligent concept extraction taking advantage of both linguistic and statistical parameters

Table 5: HLUR based on industrial requirements Architecture Market: Digital Technology / Data Driven Design

5.2 Architecture Market: Workplace Design

According to WorkDesign magazine, a publication dedicated to exploring the evolution of workplace culture, research, and design, four main trends dominate workspace design in 2019: wellbeing, co-working, the incorporation of technology (including AI), and the use of metrics or parameters to inform workplace design and acquisition decision [8].

These trends are at the core of the concerns addressed in MindSpaces, and the technological solutions that this project is developing to support the design and redesign of workplaces reflect each of these trends clearly. In fact, the project pretends to advance the state of the art of the design and redesign practice by focusing on the wellbeing of co-workers, fomenting collaboration and social interaction in the workspace, incorporating suitably designed technological solutions, and using parameterized metrics to assess the design and configuration of the office space accordingly.

So far, in order to engage their employees and management as actors in the design process of their own workspaces, companies have sought the help of architecture and design consultancies, which usually use surveys and interviews to identify the focal points of the design exercise, and to inform the design process of possible solutions. Some have used virtualization as a form of providing feedback to the engaged actors, as AR/VR starts to become more mainstream in design.

In contrast, MindSpaces aims to provide solutions that support an experimental design process that is more participatory in nature, taking advantage of advances in sensors and data analysis technologies, especially with respect to biofeedback and emotional state recognition from physiological signals applications. These are far more immersive solutions that engage actors more effectively and tie them more closely to the design process of workspaces.

For this reason, the solutions developed under the MindSpaces project are perfectly suitable for the workspace design and redesign market, which is a segment of the Workspace Transformation market. The Workplace Transformation market encapsulates the activities pertaining to the renovation, rejuvenation, redesign, refurbishing, and upgrade of workplaces, and it includes the deployment of infrastructure, and construction. This market

[8] Fox, Bob. “Work Design Magazine's 2019 Workplace Trend Predictions.” Work Design Magazine, 31 Jan. 2019.

has been growing with a CAGR (Compound Annual Growth Rate) since 2016, and is expected to exceed US $ 22 bn by 2023 according to the Global workplace transformation market projections by P&S Market Research.[9,10](**figure 19)**.

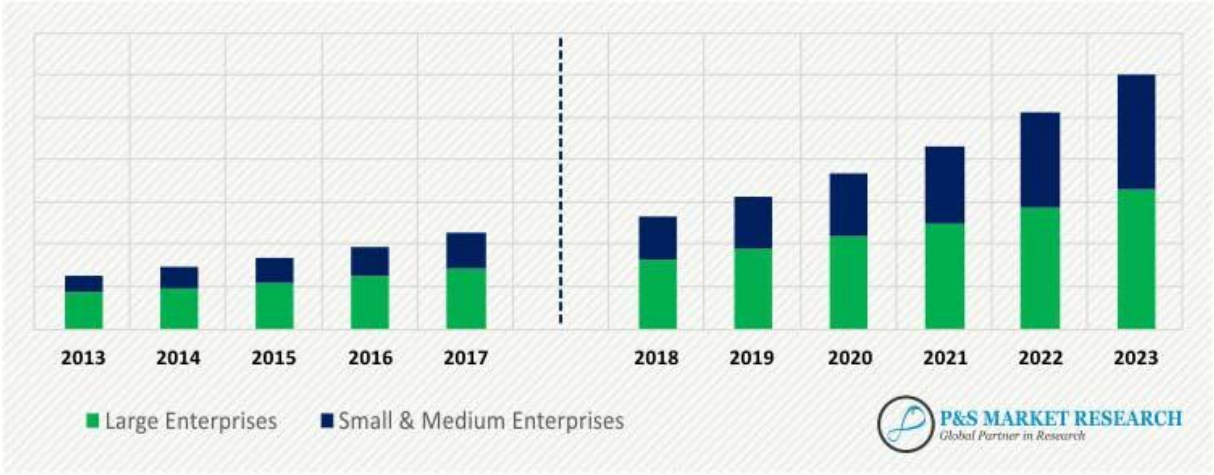


Figure 19: Global workplace transformation market projections by P&S Market Research

In this market, the workplace architectural and interior design and redesign sectors are the most pertaining to the applications of MindSpaces. It is estimated to represent around 8% of the entire workplace transformation market or a total of US $ 1.75 bn by 2023. As the total amount of companies all over the world is approaching 200 million, the opportunities and demand in workspace design and redesign sectors keeps on growing, fuelled by accelerating trends within the market.

[9] Workplace Transformation Market 2019 Global Analysis, Segments, Size, Share, Industry Growth, Expansion Strategies and Recent Trends by Forecast 2023. April 2019. Market Research Future.

[10] Workplace Transformation Market by Service – Global Market Size, Share, Development, Growth, and Demand Forecast, 2013–2023. Published June 2018.

Based on the aforementioned Market analysis the following high lever user requirements (HLUR) have been elicited.

HLUR	HLUR Title	HLUR Description
HLUR_6.1	Data-driven behavioural and emotional analysis to workplace wellbeing.	Capacity to incorporate data-driven behavioural and emotional analysis to workplace wellbeing.
HLUR_6.2	Process can be easily pivoted to other domains	Process can be easily pivoted to other domains where managed semi-public spaces are central.
HLUR_6.3	Highly flexible models of wellbeing	Highly flexible compared with approaches using fixed models of wellbeing.
HLUR_6.4	Easy sharing, reusing and configuring of implemented framework.	Easy sharing, reusing and configuring of implemented framework.

Table 6: HLUR based on industrial requirements Architecture Market: Workplace Design

6 ANALYSIS OF DESIGN PARAMETERS

The table of parameters includes the quantified and non-quantified parameters that can affect the platform. The users and mainly architects have defined all the parameters that consider necessary to control the MindSpaces tool. There is an extensive analysis of the parameters that can affect the use cases.

The different parameters are described in separate tables below.

	PUC1		
	INPUT		
	QUANTIFIED/ NON QUANTIFIED	**UNITS**	**MEDIUM**
1	Topography (elevation, height maps /urban form)	Meters	Aerial and Close range Imagery/ Mobile Mapping Platform/ 3D Scanners/ Google earth
2	Materiality (color, texture, pattern)	_	Aerial and Close range Imagery/ Mobile Mapping Platform/ 3D Scanners//Video
3	Vegetation	Number/% of plants	Aerial and Close range Imagery/ Mobile Mapping Platform/ 3D Scanners//Cameras
4	Existing infrastructure (energy, roads, gglighting network)	Number	Aerial and Close range Imagery/ Mobile Mapping Platform/ 3D Scanners//Cameras/Videos
5	Light (natural /artificial lighting conditions)	Percentage brightness	Aerial and Ground Images/Video

6	Movement (human: individual, crowds /non-human: fauna, machinic)	Flow/direction	Drones/Video
7	Environmental/Sensor input (sound,voice/smell/hapticity,feeling)	frequency(dB)	Sensors
8	Environmental/Climatic (latitude, average temperature, nearby water, humidity, prevailing winds)	Meter / Celsius / %/ m/sec	Environmental data / Sensors
9	Historic context(old maps/photos)		Old Maps/photos
10	Behavioural Input(Social interaction, lively/less bored, happy/positive, Private /non private (personal/common)	%	Social Media/ Video /Special Manual Recordings
	OUTPUT		
	QUANTIFIED/ NON QUANTIFIED OUTPUT		
1	3D terrain, blocks		
2	Materiality, VR texture		
3	Trees, Shrubs, Green masses (high, low)		

4	VR roads, pedestrians, equipment
5	VR Lighting(existing/artificial lighting conditions)
6	VR Movements (people/crowds, fauna, vehicles)
7	VR Environmental sensor input (sound/voice/smell/materiality)
8	VR Environmental climatic mappings (pixels, contours)
9	Environmental images/mappings (Paths/edges/landmark/districts/nodes)
10	Behavioral mappings (Social interaction, lively/less bored, happy/positive, Private /non private (personal/common)
11	Views / Interior-Exterior space connectivity
	ANALYSIS
1	Behavioural mappings (Social interaction, lively/less bored, happy/positive, Private /non private (personal/common)
2	Added/ creatives/value (architecture, artistic)
3	Environmental mappings' analysis

Table 7: Design Parameters related to PUC 1

A number of three parameters were chosen, related to PUC 1 in order to demonstrate the way in which the parameters could affect specific aspects of the project, the first parameter diagram is the manipulation of topography **(figure 20)**, the second diagram presents how the materials of a model could change **(figure 21)** and the third is representing an increase /decrease of vegetation (**figure 22)** .All diagrams are using a common base, that of a 2D or 3D model of the area of Tecla Sala.

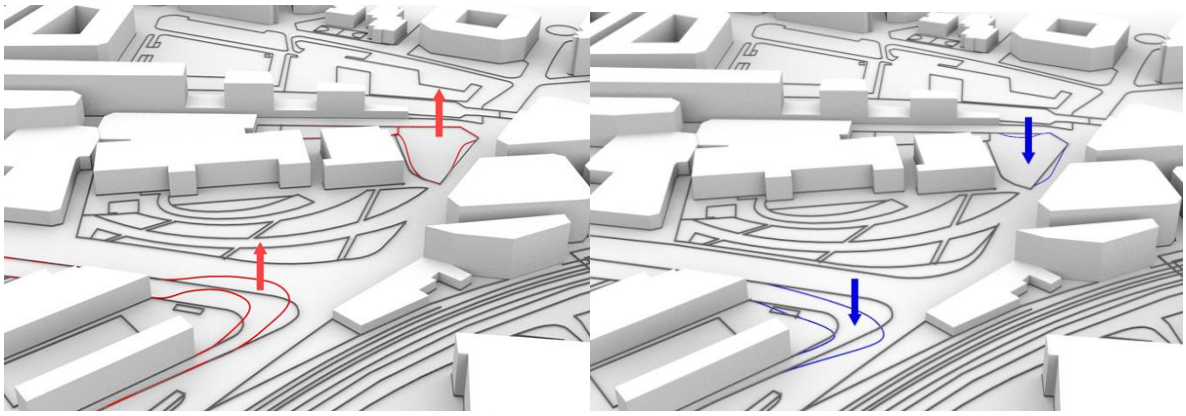


Figure 20: Diagram showing the topography manipulation, pulling the terrain upwards and downwards respectively.

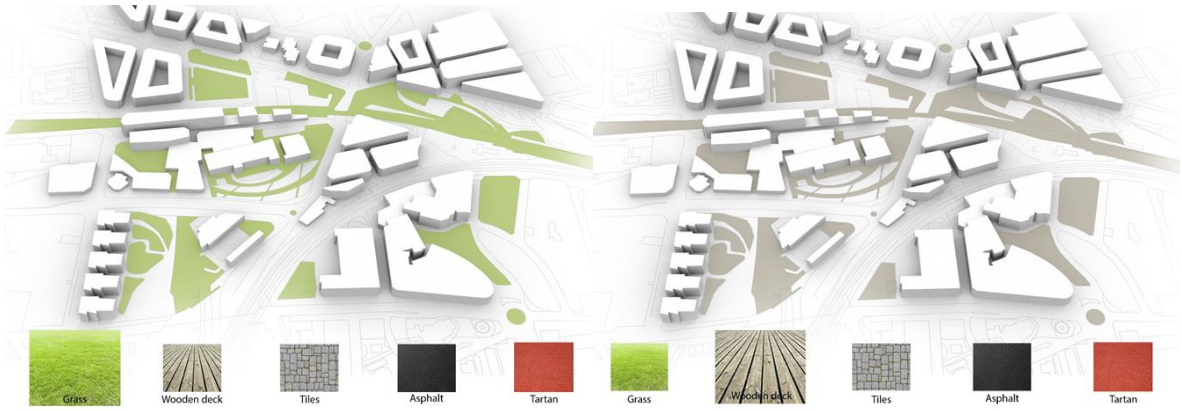


Figure 21: Diagram showing the application of different materials on a selected area of the model

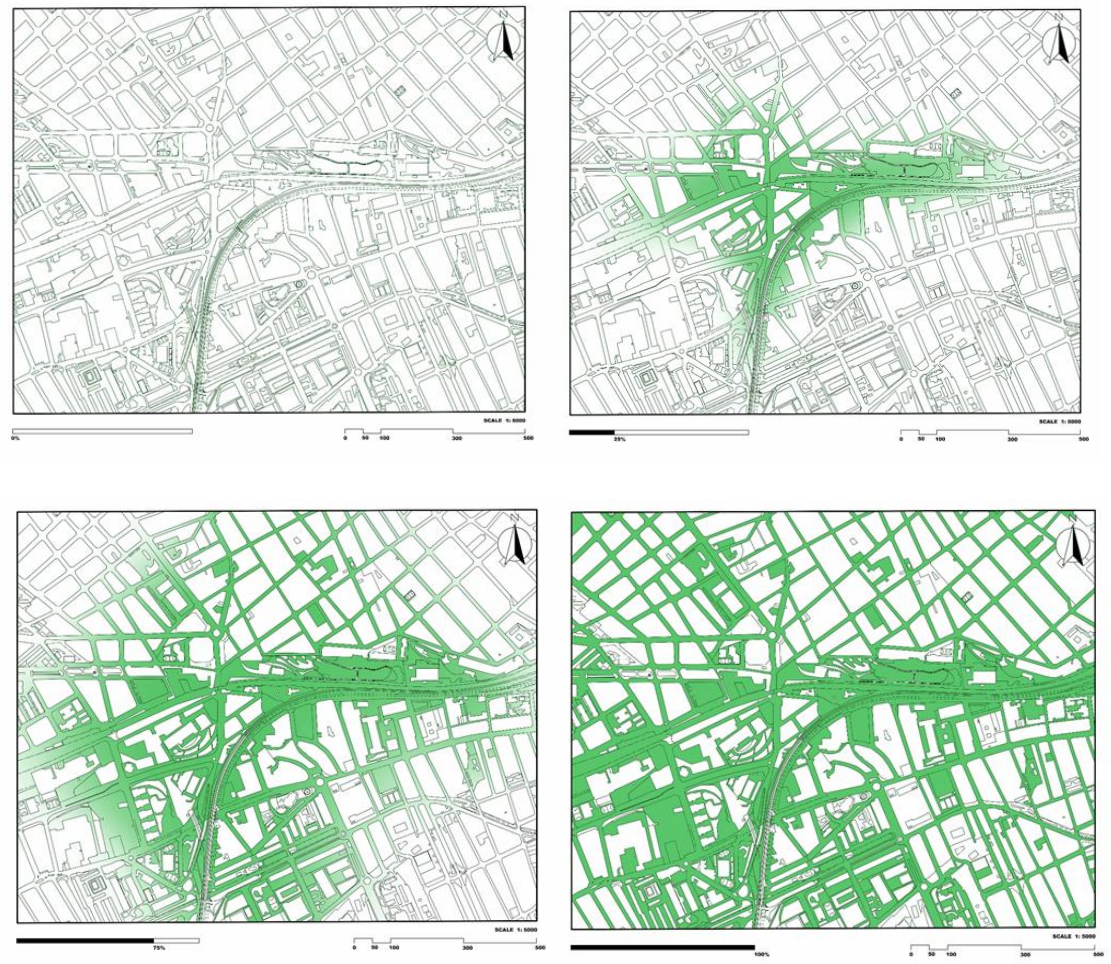


Figure 22: Diagrams of vegetation showing the vegetation as parameter that increases/decreases as a percentage factor on 2D map of the area of Tecla Sala

	PUC2		
	INPUT		
	QUANTIFIED AND NON QUANTIFIED INPUT	**UNITS**	**MEDIUM**
1	Interior space geometry	Meters	Close range Imagery/ Mobile Mapping Platform/ 3D Scanners/Cameras
2	Materiality(texture/colour/material)	_	Close range Imagery/ Mobile Mapping Platform/ 3D Scanners/Cameras/Videos
3	Interior vegetation	Number/% of plants	Close range Imagery/ Mobile Mapping Platform/ 3D Scanners/Video
4	Interiors equipment (furniture, small objects, decoration)	Number	Close range Imagery/ Mobile Mapping Platform/ 3D Scanners//Video
5	Light (existing/artificial lighting	Percentage brightness	Sensors

	conditions)		
6	Movement (human: individual /non-human: pets)	Flow/direction	Sensors
7	Environmental / Sensor input (sound, voice/smell/hapticity, feeling)	frequency(dB)	Sensors
8	Environmental/Climatic (latitude, average temperature, nearby water, humidity, heating/cooling)	Meter / Celsius / %/ m/sec	Environmental data / Sensors
9	Historic context(old architectural drawings /old photos)* in case of listed building only	-	Old Maps/photos
10	Behavioral Input(Social interaction, lively/less bored, happy/positive, Private /non private (personal/common)	%	Social Media/ Video/Special Manual Recordings
	OUTPUT		
	QUANTIFIED/ NON QUANTIFIED OUTPUT		
1	model		
2	Materiality, VR texture		

3	Trees, individual plants, Green carpets
4	Existing equipment(furniture, small objects, decoration)
5	Light (existing/artificial lighting conditions)((Drones/video)
6	Movement (human/non-human)
7	Environmental sensor input (sound/voice/smell/hapticity)
8	VR Environmental climatic (temperature, water, humidity, heating/cooling)
9	Environmental images/mappings (Paths/nodes)
10	Behavioural mappings (Social interaction, lively/less bored, happy/positive, Private /non private (personal/common)
11	Views / Interior-Exterior space connectivity
	ANALYSIS
1	Behavioral mappings (Social interaction, lively/less bored, happy/positive, Private /non private (personal/common)

2	Added/ creatives/value (architecture, artistic)
3	Environmental mappings' analysis

Table 8: Design Parameters related to PUC 2

	PUC3		
	INPUT		
	QUANTIFIED AND NON QUANTIFIED INPUT	**UNITS**	**MEDIUM**
1	Interior space geometry	Meters	Mobile Mapping Platform/ 3D Scanners/
2	Materiality (texture/color/material)	_	Mobile Mapping Platform/ 3D Scanners/video
3	Interior vegetation	Number/% of plants	Mobile Mapping Platform/ 3D Scanners, cameras
4	Interiors equipment(furniture, small objects, decoration)	Number	Mobile Mapping Platform/ 3D Scanners, cameras
5	Light (existing/artificial lighting	Percentage	Software

	conditions)	brightness	
6	Movement (human: individual /non-human: pets)	Flow/direction	Sensors,Software
7	Environmental / Sensor input (sound,voice/smell/hapticity,feeling)	frequency(dB)	Sensors, Software
8	Environmental/Climatic (latitude, average temperature, nearby water, humidity, heating/cooling)	Meter / Celsius / %/ m/sec	Sensors, Sofware
9	Historic context(old architectural drawings /old photos)* in case of listed building only	-	Old Maps/photos
10	Behavioral Input(Social interaction, lively/less bored, happy/positive, Private /non private (personal/common)	%	Social Media/ Video/Special Manual Recordings
	OUTPUT		
	QUANTIFIED/ NON QUANTIFIED OUTPUT		
1	model		
2	Materiality, VR texture		

3	Trees, individual plants, Green carpets
4	Existing equipment(furniture, small objects, decoration)
5	Light (existing/artificial lighting conditions)((Drones/video)
6	Movement (human/non-human)
7	Environmental sensor input (sound/voice/smell/hapticity)
8	VR Environmental climatic (temperature, water, humidity, heating/cooling)
9	Environmental images/mappings (Paths/edges/landmark/districts/nodes)
10	Behavioral mappings (Social interaction, lively/less bored, happy/positive, Private /non private (personal/common)
11	Views / Interior-Exterior space connectivity
	ANALYSIS
1	Behavioral mappings (Social interaction, lively/less bored, happy/positive, Private /non private (personal/common)
2	Added/ creatives/value (architecture, artistic)

3	Environmental mapping analysis

Table 9: Design Parameters related to PUC 3

Based on the aforementioned design parameter analysis one the following High level User requirement (HLUR), consisted of 8 UR, have been elicited.

HLUR	HLUR Title	HLUR Description
HLUR_7.1	Insert / Import/control parameters in MindSpaces platform.	Insert / Import parameters from urban and interior space in MindSpaces platform.

Table 10: HLUR based on analysis of Parameters of the users

7 AGGREGATION OF MINDSPACES REQUIREMENTS

We have described so far the HLUR that have been collected from three different sources (use cases, focus groups and industry). In this section, we present the aggregation of the HLUR so as to create a single point of reference of high-level user needs under which the more detailed (atomic) requirements (Table 8) are categorised and prioritized (based on the MOSCOW framework). Table 8 presents the aggregated HLUR that are used as references in Table 9.

Final HLUR		Source			Final HLUR Title	Final HLUR Description
	PUC analysis	Prior user experience analysis	Industrial requirements analysis	Design Parameter Analysis		
HLUR_1	HLUR_1.1 HLUR_2.1 HLUR_3.1				User interaction and control	Architects can collect onsite, geolocate and aggregate biometric/behavioral data in 3D reconstructed environments
HLUR_2	HLUR_1.2 HLUR_2.2 HLUR_3.2				Manipulation of spatial conditions	Architects/Designers and artists can use spatial conditions and environmental attributes of spaces with the emotional state and behaviour of the users, to increase social interactions and communicate artistic concepts
HLUR_3	HLUR_1.3 HLUR_2.4 HLUR_3.3				Data Analysis for understanding social needs and human values	An artist/designer can use Data Analysis for understanding social needs and human values through social interaction with public/private spaces

HLUR_4	HLUR_1.4 HLUR_2.3 HLUR_3.4	HLUR_4.1 HLUR_4.2	HLUR_6.1 HLUR_6.2 HLUR_6.3		Adaptable spaces	Citizens/office workers and seniors can have adaptable spaces indoor and/or outdoor depending on their needs.
HLUR_5	HLUR_1.5 HLUR_2.5 HLUR_3.5		HLUR_6.2		Space Use Prediction	An architect/designer can predict the potential uses for new spaces by analysing previous behavioural data
HLUR_6	HLUR_1.6 HLUR_2.6		HLUR_5.4		Intelligent projects based on feedback	An architect/designer can produce social intelligent projects based on feedback (emotional and rational
HLUR_7	HLUR_2.3	HLUR_4.1 HLUR_4.3	HLUR_6.4			A collaborative tool for collective spaces were co-workers can work simultaneously on the same tasks.
HLUR_8		HLUR_4.4				Simple and clear visual UI (User Interface). Simple enough for non-specialised users.

HLUR_9		HLUR_4.5	HLUR_5.4		Architectural design tool to form innovative ideas	Architects and designers have a tool that can assist in formulating new, innovative architectural ideas
HLUR_10			HLUR_5.1		Easy development of 3d environments	Easier way to develop 3D environment than traditional tools
HLUR_11			HLUR_5.2		Novel textures based on the aesthetics of famous paintings	Create novel and inspiring textures that are based on the aesthetics of famous paintings and other images of artwork that do not exist in current 3D modelling market.
HLUR_12			HLUR_5.3		Architects/ designers aesthetics gallery	Understand the aesthetics of design structures (i.e. interior objects, buildings, materials etc.) and provide it to architects and designers as a gallery.
HLUR_13				HLUR_7.1	Insert / Import/con	Insert / Import parameters from urban and interior

					trol parameters in MindSpaces platform	space in MindSpaces platform

Table 11: Merging of HLUR from different sources

In Table 9, we present the complete list of the detailed user requirements UR and their associated HLURs. The table also illustrates the type of each requirement (functional or non-functional), as well as its priority, as this has been specified by the users involved in requirement elicitation.

UR	Associated HLUR	Detailed description	Functional or Non Functional (FR/N-FR)	Priority based on MoSCoW framework
UR_1	HLUR_1	As an architect I want to be able to connect parametrized models with live data streams and follow their morphing process in different conditions	Functional	M
UR_2	HLUR_1	As an architect I want to reconstruct a 3D environment in order to contextualize my work in realistic settings	Functional	M
UR_3	HLUR_1	As an architect I want to be able to apply aesthetic and structural transformations or modifications on the reconstructed 3D environment	Functional	M
UR_4	HLUR_1	As an Architect I want to acquire biometric and behavioural data from subjects thought onsite experiments, through sensor-based data acquisition mechanisms	Functional	M
UR_5	HLUR_1	As an Architect I want to be able to geolocate the biometric and behavioural data in virtual space	Functional	M

UR_6	HLUR_1	As an Architect I want to be able to aggregate biometric and social media/biographies data by subject, subject groups, location, and any possible configuration of meaningful parameters	Functional	M
UR_7	HLUR_1	As an Architect/artist I want | to have a self-explanatory system that would describe what changes and alterations were applied in VR and why, for their empirical evaluation and studying of correlations between behavioural and emotional patterns, and visual, aesthetic, and structural aspects	Functional	M
UR-8	HLUR_1	As an Architect I want to identify chokepoints, stress points, and other focal points of an environment by analysing biometric and social media/biographies data acquired from subjects dwelling in this environment	Functional	M
UR_9	HLUR_2	As an Architect/ artist/ designer I want to have a gist of a particular aspect or topic summarized based on opinion data from the internet	Functional	M
UR_10	HLUR_2	As an architect I want to correlate material palettes and colours with the emotional state of users in designed workplace environments	Non Functional	M
UR_11	HLUR_2	As an architect I want to correlate the amount / quality of light with the behaviour and/or emotional state of users in designed workplace environments	Non Functional	M
UR_12	HLUR_2	As an architect I want to correlate the quantity and location of entry points, walls, tables, chairs, desks, and other architectural features with the behaviour and/or emotional state of users in designed workplace environments	Non Functional	M
UR_13	HLUR_2	As an architect I want to correlate the ceiling / spatial height with the emotional state and/or behaviour of users in designed workplace environments	Non Functional	M

UR_14	HLUR_2	As an architect I want to correlate the size/shape of a personal working desk/space with the emotional state and/or behaviour of users in designed workplace environments	Non Functional	M
UR_15	HLUR_2	As an architect I want to correlate amenities with the emotional state and/or behaviour of users in designed workplace environments	Non Functional	M
UR_16	HLUR_2	As an architect I want to correlate the location / type of green or exterior space with the emotional state and/or behaviour of users in designed workplace environments	Non Functional	M
UR_17	HLUR_2	As an architect I want to understand which spatial conditions enable and encourage more effective social interactions and collaborations	Non Functional	M
UR_18	HLUR_2	As an artist I want to be able to use spatial, material and time dimension to communicate artistic concepts	Non Functional	S
UR_19	HLUR_2	As an artist I want to be able to use VR as a simulation environment to test new designs	Functional	M
UR_20	HLUR_3	As an artist I want to able to use data (sensors, camera, internet) to understand social needs	Functional	M
UR_21	HLUR_3	As an artist I want to be able to rethink social systems and human values through social interaction with spaces	Non Functional	S
UR_22	HLUR_4	As a citizen I want to feel comfortable in an open urban public space	Non Functional	M
UR_23	HLUR_4	As a citizen I want to be able to interact socially and maybe technologically with confidence in public space	Non functional	S
UR_24	HLUR_4	As a citizen I want to empower myself being conscious of my role of citizen shaping and giving sense to open public space	Functional	C
UR_25	HLUR_4	As a citizen I want to see open space as a gate to discover culture and identity	Functional	M
UR_26	HLUR_4	As an architect/designer I want to be able to design/provide for public authorities safe and nice open public spaces	Functional	M
UR_27	HLUR_4	As an architect/designer I want to be able to design spaces that show cultural diversity and richness	Functional	M

UR_28	HLUR_4	As a public authority I want to use public spaces to show public policies	Functional	C
UR_29	HLUR_4	As an office Worker I want a platform to support design parameters for productive collaboration	Non Functional	M
UR_30	HLUR_4	As Worker in an office I want to be more healthy, happy, calm, and productive at work	Non Functional	M
UR_31	HLUR_4	As an office Worker I want to feel I have privacy while not feeling isolated and working close to productive colleagues	Non Functional	M
UR_32	HLUR_4	As an office Worker I want to easily communicate effectively with my colleagues	Non Functional	M
UR_33	HLUR_4	As an office Worker I want access to light and green space	Non Functional	M
UR_34	HLUR_4	As an office Worker I want to understand how to navigate and use a space	Non Functional	M
UR_35	HLUR_4	As an office Worker I want to feel I am in a contemporary and high quality space	Non Functional	M
UR_36	HLUR_4	As an office Worker I want to not feel bored by the repetition of working	Non Functional	M
UR_37	HLUR_4	As an office Worker I want to maintain a high energy level at work while reducing stress	Non Functional	M
UR_38	HLUR_4	As an office Worker I want to be motivated and productive	Non Functional	M
UR_39	HLUR_4	As a senior I want to communicate with my entourage	Functional	M
UR_40	HLUR_4	As a senior I want to have the opportunity to socialize/feel socially included	Non Functional	S
UR_41	HLUR_4	As a senior I want to experience positive and empowering feelings/emotions	Non Functional	M
UR_42	HLUR_4	As a senior I want to experience a space adapted to potential impairments (visual, hearing, mobility)	Non Functional	S

UR_43	HLUR_4	As a senior I want to have the technological support adapted to my visual or hearing impairments (accessibility of the technology)	Functional	S
UR_44	HLUR_4	As a senior I want to experience an aesthetical pleasant space	Non-Functional	M
UR_45	HLUR_4	As a senior I want to experience a space that evokes positive memories	Non-Functional	M
UR_46	HLUR_4	As a senior I want to feel closeness/proximity/presence/ to repel the feeling of loneliness	Non-Functional	S
UR_47	HLUR_4	As a senior I want to feel comfort (physically) and comforted (emotionally)	Non-Functional	M
UR_48	HLUR_4	As a senior I want to remain independent as long as possible	Non-Functional	C
UR_49	HLUR_4	As a senior I want Privacy by Design	Functional	M
UR_50	HLUR_4	As a senior I want a space responding to my affective and intimacy needs	Non Functional	M
UR_51	HLUR_4	As a senior I want to control the transmission of information (coming from my set and getting to my set)	Functional	S
UR_52	HLUR_4	As a senior I want my living space to be bright	Non Functional	S
UR_53	HLUR_4	As a senior I want to be connected to nature (ie: plants) when in my living space	Non Functional	S
UR_54	HLUR_4	As a senior I want that my living space inspires my creativity	Non-Functional	S
UR_55	HLUR_4	As a senior I want to keep objects from the past at home	Non-Functional	C
UR_56	HLUR_4	As a senior I want to feel safe at home	Non-Functional	S
UR_57	HLUR_4	As a senior I want my living space to inspire/be adapted to/ physical activity practice	Non-Functional	C

UR_58	HLUR_4	As a senior I want to my living space to be inspired/be adapted to/ physical activity practice	Non-Functional	C
UR_59	HLUR_4	As a senior I want to be able to welcome people in my house	Non-Functional	C
UR_60	HLUR_4	As a senior I don't want to be cluttered by too many objects in my living space	Non-Functional	S
UR_61	HLUR_4	As an architect/Designer I want to have the capacity to incorporate data-driven behavioural and emotional analysis to workplace wellbeing.	Functional	M
UR_62	HLUR_4 HLUR_5	As an Architect/Designer I want to be able a process that can be easily pivoted to other domains where managed semi-public spaces are central.	Functional	M
UR_63	HLUR_4	As an Architect/Designer I want highly flexible models compared with approaches using fixed models of wellbeing.	Functional	M
UR_64	HLUR_5	As an architect/designer I want to predict use of the new spaces by previous behavioural data	Functional	M
UR_65	HLUR_6	As an architect designer I want to be able to produce social intelligent projects based on feedback (emotional and rational: opinion on the internet)	Non Functional	M
UR_66	HLUR_6	As an architect/designer I want Intelligent concept extraction taking advantage of both linguistic and statistical parameters	Functional	M
UR_67	HLUR_7 HLUR_4	As an office worker I want a collaborative tool for collective spaces where co-workers can work simultaneously on the same tasks.	Functional	S
UR_68	HLUR_10	As an architect I want an easier way to develop 3D environments than traditional tools	Functional	S
UR_69	HLUR_7	As citizen/office worker I want a software that can help me communicate/interact with other citizens/co-workers	Functional	S

UR_70	HLUR_11	As an architect/Designer I want to be able to create novel and inspiring textures that are based on the aesthetics of famous paintings and other images of artwork that do not exist in current 3D modelling market.	Functional	M
UR_71	HLUR_12	As an architect/designer I want to be able to extract the aesthetics of design structures (i.e. interior objects, buildings, materials etc.) and have them as a gallery.	Functional	C
UR_72	HLUR_8	As an architect/designer I want a simple and clear visual UI (User Interface). Simple enough for non-specialised users	Functional	M
UR_73	HLUR_9	As an Architect/designer I want to have a tool that can assist in formulating new, innovative architectural ideas	Functional	M
UR_74	HLUR_9	As an architect I want to be able to have Intelligent concept extraction taking advantage of both linguistic and statistical parameters	Functional	M
UR_75	HLUR_7	As an Architect/Designer I want to Easily share, reuse and configure implemented framework.	Non Functional	M
UR_76	HLUR_13	As an architect I would like to be able to define/change the topography of an urban space in MindSpaces platform	Functional	M
UR_77	HLUR_13	As an architect I would like to be able to define/change the material of an urban/interior space in MindSpaces platform	Functional	M
UR_78	HLUR_13	As an architect I would like to be able to define/change the light of an interior space in MindSpaces platform	Functional	M
UR_79	HLUR_13	As an architect I would like to be able to introduce the user movements to the platform	Functional	M
UR_80	HLUR_13	As an architect, I would like to be able to introduce the environmental sensor input to the platform.	Functional	M
UR_81	HLUR_13	As an architect, I would like to be able to introduce Environmental/Climatic (latitude,	Functional	M

		average temperature, nearby water, humidity, heating/cooling) input to the platform.		
UR_82	HLUR_13	As an architect I would like to be able to have the historic context of the urban space	Functional	M

Table 12: Complete list of the detailed user requirements UR and their associated HLURs.

8 OUTLINE OF THE USER-ORIENTED EVALUATION METHODOLOFY

The evaluation of a system can be **system-centric** or **user-oriented**. The former is performed by testing the system with specific benchmark data and comparing its performance against well-established performance indicators, such as the ones specified in "***D1.1 Project management and quality assurance plan"*** and "***D1.2 Data management and self-assessment plan v1"***, while the latter is based on structured user feedback as derived from usability reviews and testing.

The current section focuses on the **user-oriented evaluation** and presents the first version of the evaluation plan. More specifically, the following sections present a literature study of current evaluation approaches, which focus on evaluating the impact of the system, the user interface, the user experience, the user perspective and the quality of the system, and the methodology that was finally adopted by MindSpaces.

a. Background on user oriented evaluation

i. General approaches

Nowadays there is a great variety of evaluation methodologies. There is not a perfect methodology for everything or a specific methodology for each case. Each method offers advantages and disadvantages. To achieve more validity and objectivity reasons, a combination of one or more evaluation methodologies is usually followed.

Although there is no common methodology with regard to user-oriented trials, there has been some relevant research in the past. Borlund discusses the history and principles of user-oriented evaluation (Borlund, 2009). She proposes an "Interactive Information Retrieval (IIR) Evaluation Model". This is centred on the idea of defining a realistic scenario for the

user, called a "simulated work task situation." This consists of a short “cover story” that creates a simulated information need. It also provides some experimental control by guiding the test subjects towards certain goals. The scenario should also provide "situational relevance," which makes the task at hand relevant to the user. Such a scenario may change over time and may be context-dependent. In a well-defined simulated work task situation, the user can identify the task at hand. It may also include genuine information needs, such as test queries from real users.

Saracevic (1995) stresses out the need to consider evaluation on multiple levels and to integrate these. It is pointed out – for instance - that information retrieval methods should be evaluated with regards to the efficiency, coverage of the area, algorithmic performance, the user and usability, the fitness-of-use of the end-product or service and the impact of the product on real-life behaviours. It may be tempting to focus on one low-level area (such as recall or accuracy) or a higher-level area (such as usability), but to fully evaluate a system, all such levels should be considered together.

More detailed discussion and guidance are given by Stone et al. (2005), where the focus is on the design and evaluation of user interfaces. They discuss the importance of considering users, tasks, environments and domains as separate aspects for user-oriented evaluation. One crucial aspect of user-oriented evaluation is the need to create working prototypes of the system, even if only a subset of the desired features has been implemented. There should be a clear and well-justified decision of which features to include. The prototype should include an attractive, robust and user-friendly interface. Given the limited time that test users will have, they should not be required to spend a great deal of time learning how to use a cumbersome interface. In fact, evaluation and trials in other projects have proven the significance of a well-developed interface for the success of the whole process.

ii. User test plans

The “user test plan” is a brief document that specifies the objectives of the particular user-oriented evaluation exercise including, what will be evaluated, how, where, when, who the participants are, who the test team are, and how the test results will be documented. The user test plan includes simulated work task situations. The specific plan depends on the status of the prototype at the time and also on the specific use case scenario in question.

iii. Evaluation context

The aim is to ensure that there is a good match between the evaluation exercise and the application of the system in the intended situation. The main points to consider include:

- **Involve the right participants***:* Involve participants that are either current users or likely future users. This could include architects and game developers or those previously involved in the project, through questionnaires and focus groups.

- **Choose the right situations***:* Choose situations where the system will be used and consider the different aspects of the environment, timing, interests etc. that may have an effect on its use and perception. This is particularly important for requirements relating to context-sensitive search.

- **Set relevant user tasks***:* Choose user tasks that make the participant seek information and are in accordance with situations that have been identified. Set realistic tasks that are a natural part of the users' current or intended activities. These tasks should also be related to specific WPs.

- **Document results in the situation***:* Results are most accurate if recorded in the situation. Evaluation results and observations can be recorded before, during, and after any tasks given to participants, but they should be recorded or logged whilst still in the situation (i.e., location, environment, time). It is often simplest to directly log user interaction with a software system, such as recording click rates, session data, the number of query reformulations, etc.

- **Document the context***:* This may be needed to distinguish results within and between participants in addition to helping retrieve and recall details of specific cases. This will help with the reliability and validity of the user evaluations.

- **Use relevant evaluation approaches and measures***:* Each stage of iterative development and evaluation may have a slightly different sub-goal within an overall objective. Hence, different evaluation approaches and measures may be appropriate for different stages. No single evaluation measure will be universally applicable. In particular, the different MindSpaces use cases will require substantially different approaches.

iv. Iterative development and evaluation

User-oriented evaluation, in common with other evaluation approaches, should not be considered towards the end of the project when there will be no time to benefit from the results. Similarly, it may not be possible to specify far in advance the optimal evaluation techniques. Instead, system development and evaluation protocols should both be improved iteratively and should inform each other as follows.

- **Iterative development**: Improve both the system and the information in it, based on the results of each evaluation conducted. Early iterations may have only a few system features and limited data sets. Later iterations may have more features and updated, expanded data sets, such as larger sets of indexed content. Generating realistic and timely data is an important aspect of the evaluation process and should not be neglected.

- **Iterative evaluation**: Improve and redesign the evaluation process iteratively. This is important in ensuring that we are on track with respect to the overall objectives and expectations. Each evaluation exercise can provide additional information for time and resource planning of the subsequent evaluation cycles, and so outcomes, including problems, should be shared between partners at all stages.

- **Scale up the number of participants between the experiments**: Start with a small number of participants in the first evaluation cycle and carefully scale up between the evaluation cycles. This will help progress from formative to summative evaluation, and gather more evidence for conclusions.

- **Shorten the time spent per participant between the experiments**: Carefully scale down on the amount of time that is spent with each participant. The quality of our information and information system would normally improve between evaluation cycles. Spending gradually less time per participant enables us to scale up the number of participants without necessarily increasing the amount of resources spent on the evaluation.

- **Specify user test plans***:* Since each evaluation exercise can reveal problems, it is important to record the plan and any changes so that when improving the system or

the information in it there is a clear trail of reasoning. This makes it easier to fix any problems in the evaluation or the system. It also helps improve the plan for the next evaluation. The plan is the driving document for conducting evaluation. Without it, the results would be less accurate and more difficult to communicate to others.

As each evaluation cycle is completed, the results should be shared with the partners.

v. Participants

The exact choice of participants depends on the current research question. During early stages of the evaluation, it is inevitable that the prototype system and the evaluation protocols will have imperfections. It is therefore recommended that early iterations make use of "friendly" users. These could be people that are involved in the project directly, or colleagues or other contacts that are sympathetic to the project and its aims. This helps to reduce the number of dropouts. Later stages will have more robust prototypes and protocols, and so these can be tested on the wider public as appropriate. Care may have to be taken to reduce the number of drop-outs or "junk" responses. Where available, students often make a good group of participants, especially if they are interested in the subject due to their studies.

vi. Usability testing

According to ISO 9241-11 (the standard covering the ergonomics of human-computer interaction), "*usability is understood as the extent to which a product can be used by specified users to achieve specific goals with effectiveness, efficiency, and satisfaction in a specified context of use".* More precisely, usability testing needs to measure the level of effectiveness, efficiency, and satisfaction that is experienced by users when they use the MindSpaces system in order to achieve specified goals (Barnum, 2010).

Again, the ISO 9241-11 provides definitions for these three criteria:

- **Effectiveness:** depends on to what extent the user is able to fulfil the task and to achieve his goals.

- **Efficiency:** depends on how the effort the user needs to invest relates to the accuracy and completeness of the results.

- **Satisfaction:** depends on how satisfied the user is by working with the system

Formative and Summative Usability Testing

Depending on the time when the testing is done and the specific goals of the usability tests, we can distinguish between *formative* and *summative testing*.

- **Formative testing** is carried out during the development phase and focuses on identifying and fixing problems.
- **Summative testing** validates whether the finished product meets the user requirements.

The distinction between formative and summative testing is highly relevant not only with regard to the different goals of these tests but also with regard to the design and very specifically to the scope of the evaluation. *Formative testing* aims at providing developers with insight on how users evaluate a specific status of the prototype within the development cycle. It is not (or less) about metrics or statistics, but about finding out what works best for users (Barnum, 2010). The findings from formative testing will feed directly into the development process and might also – to some extent – modify the understanding of the use case scenarios and the user requirements. *Summative testing*, on the other hand, will focus on evaluating the integrated system, assess how the individual modules work together and test whether working with the final system in general is effective, efficient and satisfying **(figure 23)**.

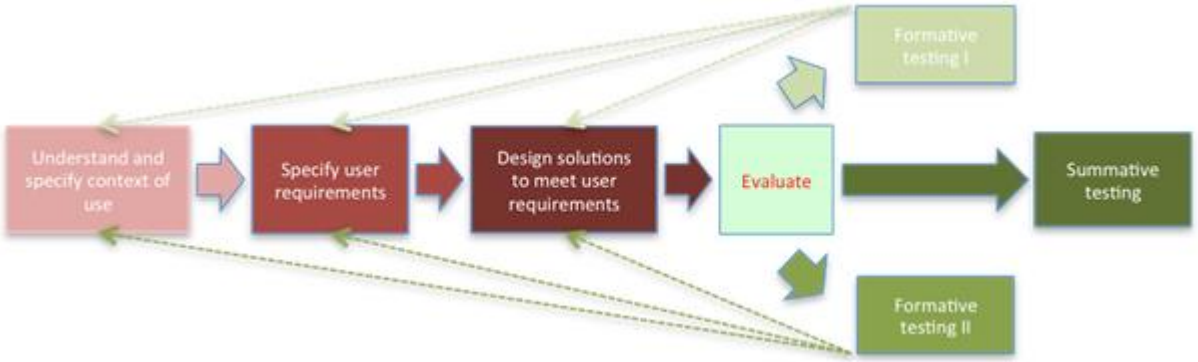


Figure 23: Evaluation Process

b. MindSpaces user-oriented evaluation methodology

Although the MindSpaces solution is relevant to a broad range of users, such as architects, designers, professionals, stakeholders, we expect that the developed tools will be of similar nature (i.e. software components with user interface for content access, reuse, repurpose and design) and therefore a common methodology for evaluating all PUCs will be applied. In this section, we present the approach we will follow to test the usability of the platform in the different evaluation phases, as well as the KPIs that will be used, considerably extending the lists of KPIs described in ***"D1.2 Data management and self-assessment plan v1"***

i. Usability testing

With regard to the MindSpaces evaluation process, formative usability testing will take place within the individual work packages, as well as during the user evaluation of the *first* and the *second* MindSpaces prototypes, while summative usability testing will be carried out during the evaluation of the *final* MindSpaces system at the end of the project.

In addition, we have decided to carry out *formative* testing at the beginning with only small groups of users who are very familiar with the project and its goals. Some very obvious advantages of this kind of approach are that small usability studies

- can be incorporated into the system development cycle at little cost;
- can be incorporated into the system development cycle without affecting or disrupting the development timeline;
- can be easily repeated more often.

Additionally, recent research has proven that – at least during formative testing – small usability studies are more beneficial than conducting large studies. Nielsen has shown that testing with ***five*** participants leads to the optimal return of 85% of the findings from a particular test to be uncovered. Additional participants would mostly just uncover the same issues and bring little new insights **(Figure 24)**.

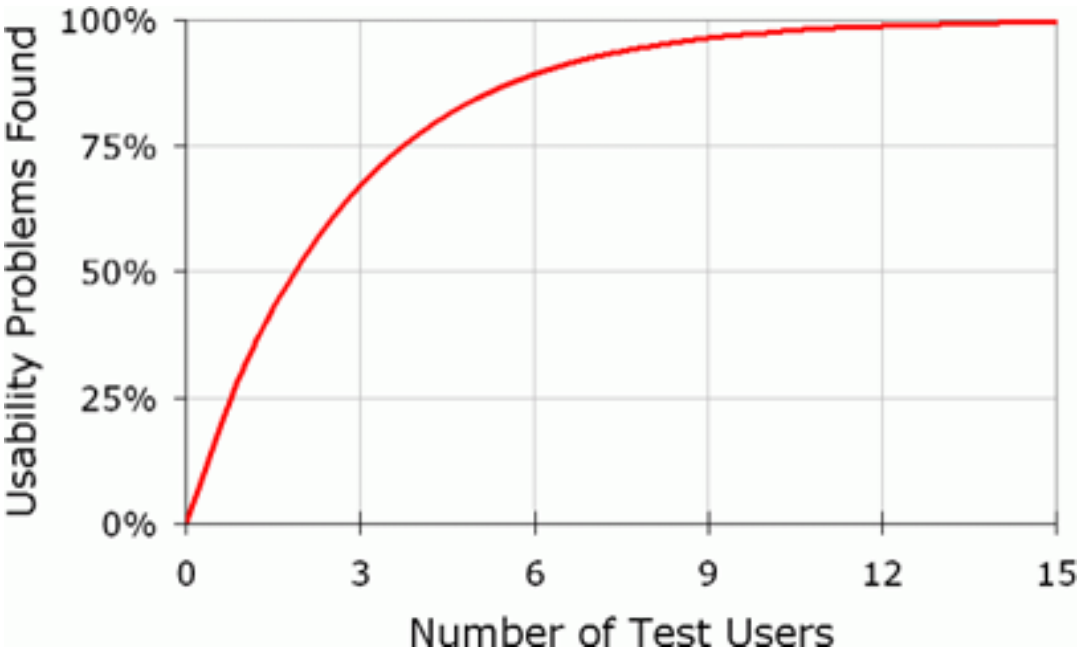


Figure 24: "Why You Only Need to Test with 5 Users", by Jakob Nielsen[11]

With regard to *summative* testing towards the end of the project, we will involve a larger sample in order to achieve evaluation results that are of more relevance. Based on the status of the project, we will also decide at which point to involve the members of the UG in the evaluation. In any case, the evaluation methodology needs to take into account that all MindSpaces use cases are aiming for rather broad and diverse target groups that will offer a certain freedom to the number of available participants.

[11] Nielsen, Jakob, and Landauer, Thomas K. A mathematical model of the finding of usability problems,Proceedings of ACM INTERCHI'93 Conference (Amsterdam, The Netherlands, 24-29 April 1993), pp. 206-213.

ii. Formative usability testing (1st and 2nd prototype)

With regard to formative usability testing of the first two prototypes, we have therefore chosen a mix of *expert reviews* in a *concurrent think aloud process*, followed by a *standard questionnaire* (including some heuristics with regard to the interface) and a *concluding discussion*:

- **Expert reviews:** In the context of the MindSpaces evaluation, expert reviews means that we will select specialists from different domains who will use the MindSpaces system in a typical working environment by performing specific tasks that are common to their day-to-day work.

- **Concurrent think aloud process:** We want to understand participants' thoughts when they interact with MindSpaces by having them think aloud when performing their tasks. Although this approach can interfere with the work on the tasks itself, it will lead to more direct and authentic feedback.

- **Standard questionnaire:** After having performed the tasks, participants will be asked to fill out a questionnaire that will ask questions about the general experience when using the MindSpaces system. This approach will deliver a more general assessment of effectiveness, efficiency and satisfaction and will also enable us to test some heuristics with regard to the interface.

- **Concluding discussion:** The evaluation will be concluded by a guided discussion between evaluator and participants that will allow for clarifying some ambiguities with regard to the tasks, the systems' performance and the answers that have been given. This discussion will also be an opportunity to mention additional aspects that have not been covered by the tasks and the questionnaire.

- **Focus group discussion:** Where possible and appropriate, we will complement expert interviews by focus group evaluation. In these focus groups, the evaluator will present the prototype and will subsequently allow participants to test individual features. This phase is concluded by a group discussion about the benefits of the prototype and its shortcomings. This less formal approach will create additional benefits as participating experts are likely to come up with different ideas and aspects when confronted with their peers in a discussion than in a one-to-one situation with the evaluator alone.

- **Involvement of the User Group (UG) and other external experts:** As pointed out before, the first formative evaluation session of the first prototype is built on small groups of users who are very familiar with the project and its goals. At this point of the project, we intend to involve members of the UG as well as other external experts in the formative testing of the second prototype.

The goal of formative usability testing will be to support technical partners in the further development and improvement of the MindSpaces system. At this stage, developers need to know how the users receive the main functionalities. As MindSpaces is following a modular structure, we need to reflect this modularity by testing individual functionalities rather than the overall system. Hence, at least during the first two evaluation iterations, the focus will lie on tasks that specifically test the performance of individual modules from a user's point of view. The more advanced the system becomes and particularly during the summative evaluation of the final system, focus will shift to the performance of the integrated MindSpaces system in general.

Obviously, the design of the different evaluation sessions very much depends on the development status of the prototype, its individual modules and the interface. The general evaluation plan, as described in this deliverable, is therefore subject to change whenever and wherever it is necessary. Also, the findings from evaluating the first prototype might lead to changes when planning the second evaluation iteration.

iii. Summative usability testing (final system)

The evaluation of the final system will follow the rules of summative testing. Normally, summative testing requires a larger sample of test users in order to compute metrics, such as task completion rates, error rates or average time on task (Barnum, 2010). Summative testing will focus more on the integrated MindSpaces system but might as well – for better comparison – use the same set of tasks and scenarios that are known from the first two (formative) evaluation iterations. The optimal number of participants and the design of summative evaluation, as well as of specific user tasks, depends on the status of the prototype, its individual modules and its interface.

iv. Effectiveness, efficiency, and satisfaction metrics

This section presents the Key Performance Indicators for assessing the effectiveness, the efficiency and the satisfaction of the developed system, considerably extending the lists of KPIs described in "***D1.2 Data management and self-assessment plan v1".***

8.2.4.1Effectiveness metrics

Effectiveness is defined as the extent to which the user is able to fulfil a task and to achieve his or her goals. The more complete and accurate the system works, the more effective it is. We have decided to evaluate the effectiveness of the MindSpaces prototype according to the following metrics:

·Number of tasks performed;

·Number of relevant functions used;

·Number of tasks completed successfully on first attempt;

·Number of persistent errors;

·Number of errors per unit of time;

·Number of users able to successfully complete the task;

·Number of errors made performing specific tasks;

·Number of requests for assistance accomplishing task;

·Quality of output;

·Quantity of output.

8.2.4.2Efficiency metrics

Efficiency depends on how the effort the user needs to invest relates to the accuracy and completeness of the results. It is important to understand that efficiency will be judged from a user's point of view. For example, a summarisation tool might be very efficient compared to other automated summarisation approaches but might not be considered as efficient by the user with regard to the overall task. We have decided to evaluate the efficiency of the MindSpaces prototype according to the following metrics:

·Time spent to understand the application and learn about its functionalities;

·Time spent to perform a particular task;

·Time spent to perform a task compared to the current method of handling the task;

·Time spent to perform a task compared to the use of alternative tools;

·Time spent on correcting errors;

·Time spent relearning functions.

8.2.4.3Satisfaction metrics

Satisfaction depends on how satisfied the user is by working with the system. Some consider this criterion as even more important than effectiveness or efficiency. If users are pleased with the design of and their interaction with the tool, this *feeling* might even trump the fact that the results of working with the tool are less convincing (Barnum, 2010). As mentioned before, the consortium recognises the relevance of the user interface for the project and the evaluation process. Nevertheless, as the focus will be put on the development of back-end functionalities, the MindSpaces evaluation methodology will consider user satisfaction as less crucial than system effectiveness and efficiency.

We have decided to evaluate the satisfaction that a test person experiences when using the MindSpaces prototype according to the following metrics:

·Number of users that rate the system as "more satisfying" than their current method of handling the task;

·Number of users that rate the system as “more satisfying” than an alternative tool;

·Number of users who feel “in control” of the system;

·User rating on a five-point scale anchored with “makes me more/less productive”;

·Number of users who would recommend it to a friend or colleague;

·Number of users that rate the system as “easier to use” than a potential key competitor.

The evaluation tasks as well as the questionnaire will be designed in a way that covers all these metrics. Whether we will use all these metrics at every stage of the evaluation will again depend on the respective state of the prototype. The comparison with other, already existing tools, for instance, is only reasonable if the functionalities and their level of maturity are indeed comparable.

v. PUC- specific details on the evaluation methodology

We will describe more specifically what we will practically do, e.g. **who** will validate the MindSpaces prototype **when** and **how**. In general, the evaluation of the first prototype will be mainly carried out by internal test persons as the system and its performance will be too immature to be tested by external experts. Later stages will have more robust prototypes and protocols, and so these can be tested on the wider public as appropriate.

vi. Timeline

The evaluation timeline with regard to the 3 PUCs will pursue the following steps:

Deliverables	7.1Use cases, requirements and evaluation plan										7.2 Prototypes evaluation and us						
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WP7						Evaluation Plan							Evaluation of 1st p				
Activities													Evaluation of GUI	Evaluation of GUI	participants	Training	User partners intermediate version evaluation

Table 13: WP7 Evaluation timeline

What?	When?	Who?	How?
Evaluation plan	M6-M10	User partners	Definition of evaluation metrics and evaluation plan.
Evaluation of operational prototype	M10 -M14	User partners and Focus Group	Evaluation of the operational prototype focusing on the initial mock-ups of the Graphical user interface for (i) Art in society (ii) Use cases, requirements and evaluation plan (iii)Technical requirements and

			architecture (iv) POPD- Requirement No. 2 (v)GEN - Requirement No. 3
Evaluation of 1st prototype	M14- M20	Focus Group	During this evaluation period we will define the participants that will be involved in the focus group and perform training activities to familiarise them with the platform. The 1st MindSpaces prototype will be presented to the focus groups. They will be asked to validate the overall impression of the first prototype, its main goals, interface and usability as well as specific functionalities that are already available. The focus group will also be asked to assess the performance of the first MindSpaces prototype in comparison with other already existing tools and the improvement that it brought in Rhino platform The received feedback will be incorporated in the development process of the 2nd prototype and the evaluation plan will be further adjusted according to the feedback taken during the evaluation.
Evaluation of 2nd prototype	M21-M28	User Group	During this evaluation period we will define the participants that will be involved in the focus group and perform training activities to familiarise them with the 2nd prototype. The 2nd MindSpaces prototype will be presented to the user group (consisting of focus group members and externals) and similar feedback with the 1st prototype will be requested. The received feedback will be incorporated in the development process of the final system.

Evaluation of Final System	M29 -M36	User Group	During this evaluation period we will define the participants that will be involved in the focus group and perform training activities to familiarise them with the final system. The final system will be presented to the user group and the open public and similar feedback with the 2nd prototype will be requested.

vii. Demonstration workshops and open days

The MindSpaces consortium will organise a number of events during the project duration. Among these, a number of events are aimed at demonstrating the MindSpaces system to the public and receiving constructive feedback in order to improve the supported features and enlarging its potential impact. Below, the most significant open days and demonstration workshops are presented, as they have been decided at the beginning of the project, while the organisation of additional venues will be further considered during the project's lifetime.

·**1st Demonstration workshop:**

The first demonstration workshop will be realized by E-Seniors in Paris after the deployment of the 1st prototype (M22) and its results will be integrated into the next development cycles. This workshop will demonstrate results from PUC3 –Emotionally-sensitive functional interior design. The workshop will have the following objectives: (i) to present the lessons learned in MindSpaces and illustrate its first results by demonstrations, (ii) to offer the interested parties the possibility to experiment with the MindSpaces workbench in "hands-on" sessions, (iii) to provide a user forum for networking with professionals from related areas, (iv) to obtain feedback from the participants, and (v) to create a detailed document on lessons learned for the development of the future prototypes. The target group will be broader than the UG.

·**2nd Demonstration workshop**:

The second demonstration workshop will take place in the AUTH campus after the 2nd prototype deployment (M28). The main goal of this workshop will be to train and present MindSpaces to a group of academic students from various disciplines, create and

fabricate a properly scaled prototype and/or other spatial proposals, physical or virtual, as outcomes of MindSpaces. The workshop will include training seminars, lectures, design studios and actual fabrication of the prototype. All partners will participate, providing feedback, training and expertise. The whole process will provide important feedback for the development of the tool and its usage by end users

·**1st Open Day**: The 1st Open Day will be held by ESP in M28 after the deployment of the 1st prototype (M20), aiming to perform testing and evaluation of the MindSpaces system. The workshop will demonstrate the MindSpaces prototype and tools in a broader audience consisting of academic and market representatives. The event will take place in Barcelona, Spain.

· **2nd Open Day / Final Demonstration Workshop**: The second Open Day will be held by ZH in UK so as to fully demonstrate MindSpaces to a broader group of potential customers, including architecture offices, video game companies, design industry leaders, governmental members, investors and societal organizations. The event will take place in the UK, London.

9 CONCLUSIONS

This deliverable describes the elaboration of the PUC scenarios, the four focus groups that have been set up consisting of architecture professionals, artists and seniors for PUC1, PUC2 and PUC3 respectively. The PUC scenarios development described here strongly supports the initial aim, i.e. to test and evaluate the idea behind the development of the MindSpaces platform. The PUCs are described in detail, along with related scenarios and simulations, both on what is expected as outcome and on the actual user interface.

The deliverable also extensively describes the user requirements based on the PUC scenarios and the stakeholders' shared and distinct expectations in order to enhance the user

experience of the MindSpaces platform. The user requirements incorporate the prior user experience elicited by the four focus groups, with the aid of questionnaires and interviews, the analysis of market and industrial needs and the analysis of the design parameters. The user requirements in this deliverable provide valuable input to **"*D6.2 Technical requirements and architecture*"** for specifying the set of functionalities of the MindSpaces platform and shape the overall architecture.

Finally, the deliverable elaborates on the user-centred evaluation methodology that will be used to evaluate the platform. Key Performance Indicators (KPIs) have been described relevant to performance and usability, which will be assessed in terms of effectiveness, efficiency and satisfaction. An evaluation timeline is also provided, describing who will validate the MindSpaces prototype, when and how**.** Last, the key demonstration events are presented.

The use case scenarios and the user requirements will be further elaborated and extended in the subsequent phases of the project. The tool testing procedures and evaluation steps, will be described in the next version of the deliverable (i.e., "**7.2** ***Prototypes evaluation and user requirements v1***").

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APPENDIX A: QUESTIONNAIRE TEMPLATE

MindSpaces Questionnaire

for the generation of User Requirements

* Απαιτείται

1. **Διεύθυνση ηλεκτρονικού ταχυδρομείου** *

PARTICIPANT'S INFO

2. **Age** *
   Να επισημαίνεται μόνο μία έλλειψη.
   - ◯ 20-30
   - ◯ 30-40
   - ◯ 40-50
   - ◯ 50-60
   - ◯ up to 60
   - ◯ Άλλο:

3. **Gender** *
   Να επισημαίνεται μόνο μία έλλειψη.
   - ◯ Male
   - ◯ Female

4. **Your Profile (profession - city of residence - educational background e.t.c.)(180-100 words)** *

5. **User contact details (Name - mobile phone etc.)** *

6. **I agree that my responses to this questionnaire will be used for the elicitation and refinement of the user requirements of the Mindspaces project. My contact details will only be stored so that I can receive information about the project's progress.** *
   Να επισημαίνεται μόνο μία έλλειψη.
   - ◯ Yes
   - ◯ No

General questions - G1

Regarding all PUCs, to be answered by all users / participants / citizens / office professionals / seniors

AS USER OF AN ART INSTALLATION

Interacting with the physical/ constructed event of an art installation, whether indoors or outdoors

7. **In what kind of places would you like to find an art installation that you could interact with?**

8. **What kind of media(VR, AR, projectors, video e.t.c) would be truly innovative for an art installation**

9. **What do you expect from an art installation / artwork?**

10. **What kind of technology do you find more advanced to an art installation?**
Επιλέξτε όλα όσα ισχύουν.

- [ ] VR
- [ ] Sensors
- [ ] EEG
- [ ] Άλλο: _____

11. **List three spaces (urban, professional, domestic) that are (in your opinion) artistic driven.**

12. **How do you think an art installation could contribute positively in social terms?**

General questions - G2

Regarding all PUCs, to be answered by all users / artists / creatives / architects

AS AN ARTIST / CREATOR OF AN ART INSTALLATION

13. **What are the most time-consuming factors in your work**

14. **What kind of tools would be helpful when performing your daily work**

15. **What are the requests you are mostly confronted with?**

16. **What kind of data do you use for your artwork?**

Επιλέξτε όλα όσα ισχύουν.

- [ ] Enviromental data
- [ ] EEG data
- [ ] Social Media
- [ ] Άλλο:

General questions - G3

Regarding all PUCs, to be answered by all users / artists / creatives / architects / office professionals / seniors

AS USER OF MINDSPACES (SOFTWARE) PLATFORM

17. **What are you expecting from the software platform of an art-driven project?**

18. **What kind of software interface would be truly innovative for an art installation?**

19. **What kind of software / interface interaction would you find interesting?**

Focused questions - F1

Regarding PUC1

PUC1 - AS CITIZEN OF L' HOSPITALET

20. **How often do you visit or pass by the area of Tecla Sala's Art Center?**

21. **How do you feel when visiting the area of Tecla Sala's art center?**
Επιλέξτε όλα όσα ισχύουν.

- [ ] Emotional
- [ ] In harmony with other citizens
- [ ] Sad, confused, lost
- [ ] Indifferent
- [ ] Άλλο:

22. **What would you expect to feel and experience in a public area like Tecla Sala?**

23. **Which atributes do you think describe better the area of Tecla Sala art center?**
Επιλέξτε όλα όσα ισχύουν.

- [ ] Beautiful
- [ ] Peaceful
- [ ] A place full of history
- [ ] Trendy, arty
- [ ] An oasis in the city
- [ ] Noisy, dirty, without care
- [ ] A place with potential but with unclear functions
- [ ] Άλλο: _____

24. **What do you experience as a user of the urban space of L' Hospitalet**

_____

_____

_____

_____

_____

25. **What kind of interaction do you have with other citizens, when living in the city?**

_____

_____

_____

_____

_____

26. **Which items would you like a public art installation refer to if located in Tecla Sala surroundings?**
Επιλέξτε όλα όσα ισχύουν.

- [ ] Items related to local history reminding of the industrial past of the city
- [ ] Items refering to multiculturalism in the city
- [ ] Items related to groups under risk of social exclusion
- [ ] Items related to all diferent ways to communicate within society
- [ ] Άλλο: _____

27. **In your city of residence, have you ever had the experience to experience an interactive art installation in a public space (square, hall, mall, museum, etc.)?**

_____

28. **If yes, could you briefly describe this art installation(s)?**

_____

29. Did you have a positive or negative experience? Please elaborate.

30. Do you believe that an interactive public art installation or artwork can have a positive social effect on your city? Which social effect? How?

31. Is there any mode of interaction or engagement with public art installation that you believe is the most appropriate for your city and its citizens?

32. Whom are the primary target of such interactive installations from your viewpoint?

33. Can you give an example of an artistic public installation that had a positive socio economic impact in the area where it was installed?

34. What type of social interaction do you have or would like to have with other citizens in public areas like Tecla Sala?

QUESTIONS FOR ARCHITECTS / DESIGNERS

35. As an architect / designer what kind of qualities would be necessary for a public space, urban environment?

36. As an artist what type of elements of an urban public space would be used as reference / inspiration for artistic creation?

Focused questions - F2

Regarding PUC2

PUC2 - AS PERSONNEL OF A PROFESSIONAL DESIGN OFFICE

37. What are the most pleasant parts of the office environment?

38. What kind of interaction do you have with colleagues, when performing your daily work?

39. How do you usually appreciate art installations in the office environment?

40. What can be improved in your office environment?

41. **What kind of software interface would you find interesting to interact with?**

42. **In your opinion, what are the greatest challenges in your every day experience in the office space?**

QUESTIONS FOR ARCHITECTS / DESIGNERS

43. **As an architect / designer what qualities would be necessary for a professional design firm environment?**

44. **As an artist what parts of a professional designer's life in their office environment would act as reference / inspiration for artistic creation?**

Focused questions - F3

Regarding PUC3

PUC3 - AS SENIORS LIVING IN DOMESTIC ENVIRONMENT

45. **What do you think of your social environment? How do you feel at home?**

46. **What are the possible solutions to combat loneliness? How to fight loneliness at home? Could interior design at home have an influence on the feeling of loneliness?**

47. **What is your favourite room in your house, in which room do you spend the most time?**
Επιλέξτε όλα όσα ισχύουν.

- [ ] Bedroom
- [ ] Living-room
- [ ] Dining room
- [ ] Kicthen
- [ ] Bathroom
- [ ] Garden
- [ ] Terrace
- [ ] Άλλο:

48. **Feelings at home:**
Επιλέξτε όλα όσα ισχύουν.

- [ ] Comfort
- [ ] Loneliness
- [ ] Hapiness
- [ ] Sadness
- [ ] Presence
- [ ] Absence
- [ ] Safe
- [ ] Unsafe
- [ ] Stressed
- [ ] Relaxed
- [ ] Fear
- [ ] Tranquility
- [ ] Calm
- [ ] Lively
- [ ] Άλλο:

49. **If we talk about objects that interact with you and react to your movements/emotions. It would be useful to use as support:**
Επιλέξτε όλα όσα ισχύουν.

- [ ] Television
- [ ] Radio
- [ ] Sofa
- [ ] Chair
- [ ] Computer
- [ ] Table
- [ ] Floor
- [ ] Oven
- [ ] Fridge
- [ ] Bed
- [ ] Sink
- [ ] Shower
- [ ] Phone
- [ ] Photo holder
- [ ] Coat hanger
- [ ] Library
- [ ] Cupboard
- [ ] None
- [ ] Άλλο: _____

50. **How you would redesign your home in order to feel positive feelings and be senior friendly?**

_____

_____

_____

_____

_____

QUESTIONS FOR ARCHITECTS / DESIGNERS

51. **As an architect / designer what qualities would be necessary for a domestic environment for seniors?**

_____

_____

_____

_____

_____

52. **As an artist what parts of a senior's life in their domestic environment would act as reference / inspiration for artistic creation?**

Να μου αποσταλεί ένα αντίγραφο με τις απαντήσεις μου.