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Immersive Imagination in Urban Oases of Mindfulness: The VR-SenseCity Toolbox for Sensible, Emotional and Measurable Experiences in Future Smart Cities

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1 ABSTRACT

Quality of life, health and well-being, as well as the creative potential originating from positive experiences and interaction with our environment and interaction are pivotal human factors underlying a rich and productive social context. Respect and careful treatment of users, i.e., the citizen who will populate, co-create and co-operate in the scenarios, mandate overarching topics for developing user centered design schematas. Virtual Reality (VR) technologies have recently offered tools to anticipate the affordances of future scenarios. In the serious game VR-SenseCity (Paletta et al., 2017) we created tools for the imagination of affective and sensory experiences, in particular, referring to visual affordances that enable induction of imaginated sensory experiences in real urban environments. We investigated the potential for the motivation of elderly people, in particular, persons with dementia, to encounter their daily environment in positive attitude, with pleasant and aware sensory experiences, the purpose to improve their cognitive reserve (Stern, 2009). The functionalities were developed in cooperation with a Co-creation group of four elderly persons providing substantial critical and constructive feedback for the development of the toolbox.

Keywords: emotion and sensory experience, imaginations, immersive experience, elderly people, eye tracking

2 INTRODUCTION

In the VR-SenseCity experience, we created nine virtual portals each for a different specific imaginatory sensory expeience, such as, for visual, auditory, olfactory, taste, touch imaginations, as well as for social encounter, reflecton, travel and playful experiences. We created an immersive virtual environment with multisensory feedback loops as a vehicle to measure, analyse and experience situation awareness in interaction, such as, for mindfulness oriented interventions. The VR-SenseCity environment is operated using VR head-mounted devices (HMD), in-built eye tracking measurement and motion capture technology. The virtual city is built to represent characteristic aspects of present or future urban environments and in which certain trigger events involve the user to explore its own basic senses – visual, inertial, auditive, etc. – as well as social attention cues. The immersive environment represents a mixed reality lab to perceive, enjoy, and interact with urban places as well as to interact with those to be planned and to be built urban architectures, potential products and their function in urban space, as well as experiment with various social interaction frames. Eye tracking technology was used within VR to track the visual preferences of the users and provide a gaze based interface for mindful observation.

A study with ten elderly persons was performed, using the Freiburg mindfulness questionnaire FFA-14 (Walach et al., 2004), the multidimensional mood questionnaire (Steyer et al., 1997; applied before and after a VR session of about 20 minutes), as well as the SUS usability questionnaire (Brooke, 1996) in order to assess the mental state of the users – resulting in improved activation and more positive mood after the session – as well as in good acceptance of the approach measured by the SUS questionnaire.

The results appear to be very promising and therefore the VR framework will be further developed in another Austrian research project (OpenSense).

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(a)  (b) 

(c)  (d) 

Fig. 1: Investigation of fundamental design parameters for the development of efficient Virtual Reality (VR) technologies in cooperation with different co-creation and study groups: (a) Joyful and focused experience of direct and imaginated perceptions. (b) User in the pilot study. (c) The co-creation group contributed substantially to the design process by means of positive user experience - meeting at the Human Factors Lab[1], (d) end user in the VR-based prototypical study.

3 VISION FOR IMMERSIVE PERCEPTION OF URBAN ENVIRONMENTS

3.1 Motivation

A fundamental motivation is to get aware about intro- and exteroceptive perception in order to increase the quality of life of elderly persons as well as target well-being effects by means of a conscious and mindful experience within the own space of living in the urban enviroment. This work pursues the vision of a technologically assisted 'oasis of mindfulness' which could be purposefully integrated in urban planning and developments, and provide a low thresholded access to technical triggers and interaction spaces that refer to channels of various senseful experiences. The technological contribution is in the development of an innovative multisensory research toolbox, i.e., VR-SenseCity, in order to evaluate the efficiency of a method, i.e., a technically developed trigger, in the frame of a function for the support of attention, mindfulness and sustained motivation for the senseful perception of the elderly. In terms of an appropriate 'AAL technology'[2] a head-mounted display (HMD) with eye tracking for VR experiences was configured since perceptions can be performed in a very focused way within immersive VR environments and to enable a quantitative analysis of the elderly gaze behavior. In the context of immersive experiences the following process steps were implemented, (i) application of experience samples for triggers of various perception levels, (ii) determination of a resulting, efficient 'trigger portfolio', (iii) estimation of the acceptance of the target group for trigger and interaction methods for the support of immersive perception by imagination, and (iv) sketching of technical trajectories for emerging AAL-technologies for urban spaces.

3.2 Conceptual Framework

The fundamental concept underlying the VR software installation 'VR-SenseCity' consists of a symbolic representation of 'human perception' in an urban environment. In the center there is a fountain as a symbol of individual sensuality and representing the fluid and dynamic character of perception. Doors in terms of 'portals' were implemented as 'archetypical spaces of senses' and associated with specific modalities of

[1] www.joanneum.at/humanfactors

[2] AAL stands for „active and assisted living" in terms of non-invasive, ubiquitous and pervasive technology for the elderly.

senses and perception, such as, 'tasting', 'seeing', 'reflection', 'hearing', 'meeting', 'playing', and 'smelling' (Fig. 4a). Virtual visitors are welcomed by means of an intrdouction in to the theme of senseful well-being supporting perception as well as into the interaction methods at the virtual place 'SenseCity' which is easily understandable by the elderly. In the sequel the visitor can choose to experience between various portals and the user is able to navigate by manual interaction through a dashboard like graphical user interface.

4 USER CENTERED DESIGN WITH CO-CREATION TEAM

4.1 Co-creation Team General Setting

The created VR setting and environment was tested by two groups of elderly. The enjoyment and excitement of the groups gathering laid in the focus of these studies, for which qualitative and quantitative methods were combined. The interviews and questionnaires were rounded up by an open discussion. The group experience and guidance by technicians and well-known project partners helped to reduce anxieties and critical attitudes. The main focus is on sensory experiences of elderly people – touch, vision, listening, taste and smell – rounded up by body perception. The most important questions in this context were, as follows, how to encourage conscious pleasure of all senses throughout everyday life, which kind of positive effects, such as, awareness can trigger and how to integrate positive sensory impressions into VR technology.

The framework for mindful involvement and guidance of elderly people in technology development processes requires several considerations concerning participation and co-creation. Within the team, it is important to behave respectful to each other, taking responsibility for development progress co-equally, the individual differences are the quantity of resources in time and know-how and personal experiences, to communicate on one level and go further in small steps trusting each other. In this context, the 'rules of the game', i.e., for successful participation processes, can be summarized, as follows,

- Keep the whole team informed from the beginning until the end.
- Involve the elderly in every project phase.
- Use a language and vocabulary that is understandable to everybody.
- Provide a reliable contact person.
- Provide sufficient opportunities to discuss important unforeseen points and to clarify uncertainties.
- Define clear roles for everyone and explain the different, specific responsibilities.
- Work together equally at one level. Show respect to the different experiences and expertises.
- Invite involved elderly to join dissemination and exploitation activities.
- Provide an appropriate expense allowance to show your gratitude for the elderly people's inputs.

4.2 "Genussschule": Selecting Age Relevant Stimuli for Senseful Enjoyment and Awareness

For the selection of age appropriate stimuli, a group of four people met regularly (7 times) in a relaxed and enjoyable surrounding at the elderly's organization to work on each human sense one after the other (the succession of smell, touch, taste, sight and hearing was based on accessibility). Everyday objects were presented, which the participants should experience with the day's relevant sense. The most important questions in this context were, how to encourage conscious pleasure of all senses throughout everyday life, what positive effects awareness can bring and last but not least, and how to integrate positive sensory impressions into VR experience. In the 'Genussschule' following Koppenhöfer (1990) we learned to train our human senses and remember some already forgotten or hidden sensory experiences. We experience pleasure in daily life. Some basic guidelines (according to Koppenhöfer 'Genussregeln'), are as follows,

- Take time to experience pleasure.
- Give yourself permission to experience pleasure.
- Train your particular attention to sensory impression and avoid interfering influences.
- Experiencing pleasure is a matter of taste – to each their own.
- Less can be more – limitation and concentration on fewer stimuli strengthens experience of pleasure.

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- Stay open minded for new experiences of pleasure.
- The best source of pleasure is daily life.

Fig. 2: Employment of the co-creation team in 'Genussschule' and participative engagement. Genussschule: (a) visual stimuli, (b) tactile stimuli, (c) sense of olfactory experience, (d) participatory engagement in public workshop.

After getting involved in the relevant sense through experiencing all the stimuli, the participants choose their favourite object and explained why. After each session the participants were invited to bring their personal favourite object from their everyday life to the next meeting and share it with the others. This helped to strengthen awareness towards the sensory impressions, helped to activate positive memories through imagination and helped to create an independent self-image. Concentration was laid on positive impressions, memories and the 'here and now' experience. The meetings took place in a trustful setting, the office of the seniors' organization, GEFAS STEIERMARK. For scientific relevance, quantitative studies were conducted through questionnaires concerning the mood state of the participants and their preference of stimuli. Out of the set-up of Genussschule (Koppenhöfer, 1990) resulted a selected set of stimuli useful for the elderly generation that created and encouraged imagination and memories for every sense. Above all, stimuli out of the fields of nature, seasons and weather were preferred by the participants.

4.3 Co-creation Team for VR Development: Setting, Assistance, and Experiences

A co-creation team was built out of four elderly and around six project partners with different professions and responsibilities (minute taking and participant observation, VR developers, occupational therapists). The head of the end user organization was well-known to the seniors and created an environment of trust through an open communication about the whole project in a language that is always understandable to all sides. The elderly did not have to answer questionnaires while only knowing about a small part of the project: Instead, they were actively involved in the whole process as well as listened to carefully, also when talking about philosophical, moral or critical thoughts.

The co-creation team was accompanying the development of the VR implementation from the beginning to the end. Meetings took place once a month, in total seven times, at 'Human Factors Lab'[3]of JOANNEUM RESEARCH DIGITAL, a technologically exciting but primarily unfamiliar surrounding to the elderly.

[3] www.joanneum.at/humanfactors

Throughout the meetings new developments were presented through the head-mounted display and were simultaneously visible on the screen to share experience between everybody in the room. The group was cooperatively working towards designing a virtual environment and interaction space within 'VR-SenseCity' that would become enjoyable for all human senses and creating positive moods with joy and stress release.

(a) (b) (c)

Fig. 3: End user teams assisting the design process of VR installation 'VR-SenseCity'. (a) appropriate setting of head-mounted device and calibration, (b) manual interaction using hand and finger detection device, (c) experiences shared within the team.

After visiting and travelling through VR environments, the group was discussing all individual impressions, feelings and different preferences. Project partners took detailed notes about the participants' behaviour when using VR, their body languages and mimics, spontaneous reactions on presented VR versions, attitudes, discussion points and ideas for improvements in the VR.

In the end of each session the team was asked to work on a personal diary and to answer relevant questions for every co-creation step. These documents were filled out by the seniors at home to reflect on the session and to prepare for the next one. A discussion of diaries was the starting point for each new meeting. The diaries were also copied and collected for qualitative evaluation and analysis. Project diaries included a summary of the meeting's agenda, space for memories, impressions and thoughts, positive and negative points and a specific question relevant for each step of co-creation, as for example, such as, 'what is responsible for a good entrance into the VR?', 'what is important for a good exit out of it?', 'how would you like the surrounding when testing the VR?', and so forth.

Important results of this experience were, that a positive approach towards meaningful VR took time. Curiosity and trust in the team were important prerequisites. In including our target group from the beginning to the end into the development of the VR based scenarios we accomplished to create an affective, trusting and positive opinion of the technology. Our co-creation team enjoyed their active part in an environment usually not accessible to them and are willing to self-confidently spread their experiences.

4.4 Conclusions from Cooperation with Co-Creation Team

On the basis of the cooperation with co-creationteam the computer scientists encountered numerous insights into the requirements for an efficient interaction design with elderly people. One important dimension resulted in the feedback in terms of presence supporting modalities: For an efficient meaningful and objective related perception of the technical triggers, it was necessary to implement an introduction that puts the user into a mental model that is capable to perceive and attend to stimuli that were presented in terms of technical triggers and that convey meaning for joyful perception and awareness. Among the variety of users there exists a variety of preferences upon whether aestethical oder interaction based perception would raise the immersive impressions of presence and joyful experience. It appeared that aesthetic perception refers merely to female and interaction based perception to male based preferences. Relatives, caregivers or trustful persons are very important to reduce any anxiousness upon primarily unknown interaction experience.

A sitting position was relevant to raise trust and confidence in an overall highly immersive experience. Users require a learning phase in which they can accommodate with requirements of interaction and the specific perception opportunities using the immersive VR medium. Only after that there is opportunity for a period of more profound joyful experience, senseful openness and development of mindful perception.

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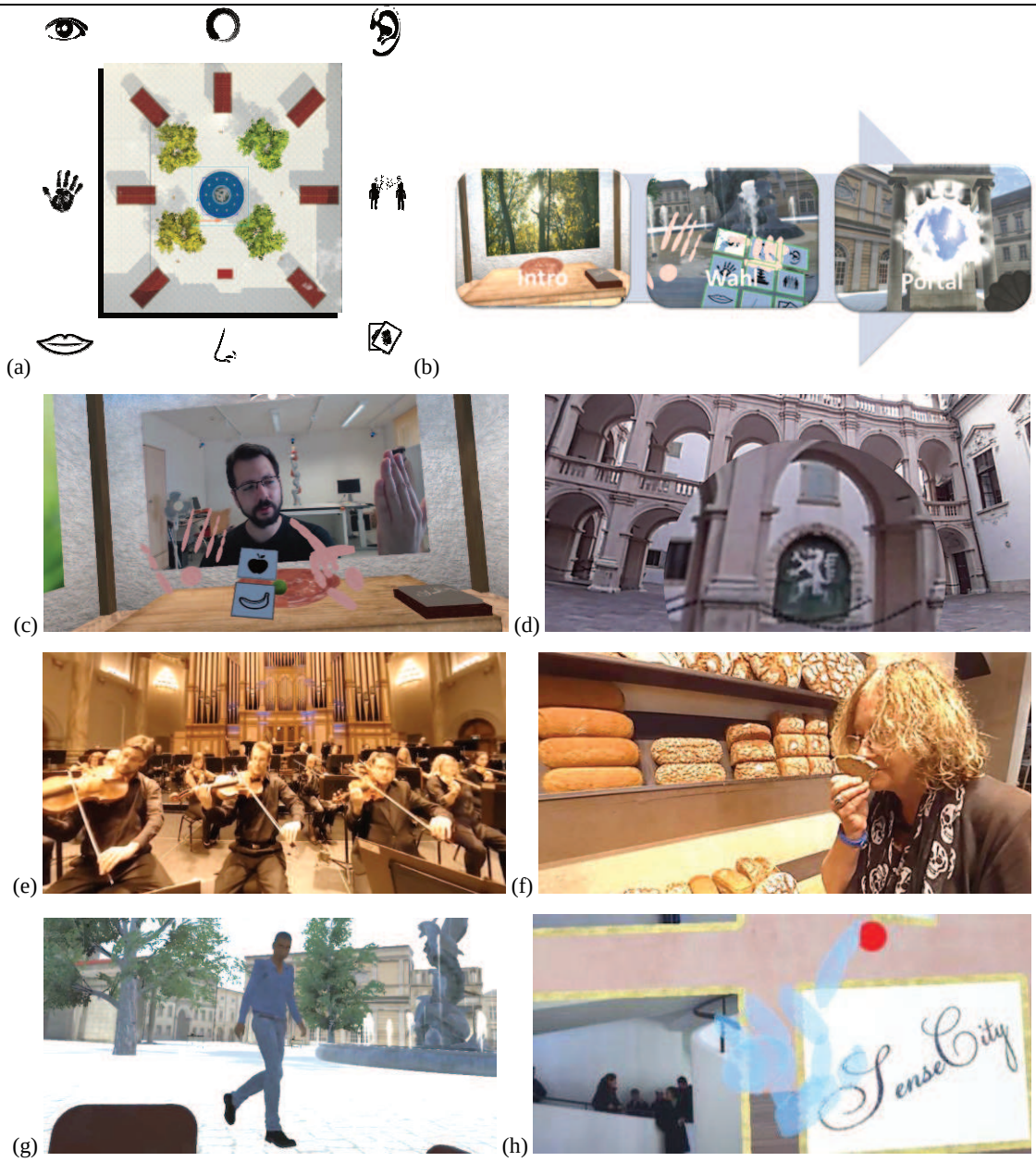

Fig. 4: Concept of the VR-SenseCity platform. (a) Urban enviroment VR (overhead view): fountain (central), specific portals associated with senses and perceptions (symbols used, from left bottom, 'taste', 'touch', 'vision', 'reflection', 'hearing', 'encounter', 'play', 'smell'). (b) Sequence of components, video presentation as introduction (left), selection of portals using manual interaction in a graphical user interface, video activation in portal 'vision'. (c) Introduction into interaction methodology (video), (d) automated magnification for mindful observation, (e) portal 'hearing', (f) portal 'smell', (g) 'encounter', (h) 'play'.

5 VR-SENSECITY: SENSIBLE, AFFECTIVE, AND MEASURABLE EXPERIENCES

5.1 Virtual Space for Senseful Experience and Interaction

In total there were three development stages and iterations of the VR-SenseCity environment for senseful experiences. The first version contained a detailed urban enviroment, opportunities for finegrained navigation with manual control devices as well as human-like avatars in motion that populated the urban space and interacted with the observer (Paletta et al., 2017). The Co-creation Team decided against this kind of design due to an overwhelming amount of details in the design that led to 'visual confusion', against the navigation model ('complicated usability') and against interaction with avatars ('making anxious'). A second version limited the mode of navigation in terms of enabling only stepwise 'teleportation' to virtual portals that would invite to senseful perception. The visual representation of the portals in the navigation interface was implemented by cristal spheres with a panoramic view of the portal and its senseful experience. The Co-creation Team rejected this kind of interface due to lack of intuition in the representation. The third and final

version was based on manual interaction based on an IR camera mounted on the HMD for the real-time detection and pose recognition of hand and fingers. The users were following well this type of interaction which allowed a comprehensive implementation of related technical triggers in the portal components.

Fig. 5: Portals of specific perception channels: ‘vision’, ‘hearing’, ‘touch’, ‘smell’, ‘taste’ (top row), ‘reflection’, ‘encounter’, ‘travel’, ‘play’ und ‘fountain’ (bottom row).

5.2 Measurability of Attention, Mindfulness, Emotion and Situation Awareness

5.2.1 Visual Attention

Through the application of the Tobii Pro VR Hardware with the HMD it is possible to receive data about the intersection of the human gaze vector with the VR objects in 3D and with panoramic images and videos in 2D space, respectively. Firstly, a calibration procedure based on the ‘Five-Point-Calibration’ was performed. The user concentrated in this component, with a minimum cognitive load, sequentially on five relevant points that were presented like target icons. Image coordinates were computed relative to the orientation of the eye orientation axes which served as a basic measuring unit for the quantification of attention.

5.2.2 Eye Movements, Mindfulness and Situation Awareness

Several methods for the analysis of eye movement behaviour were implemented in order to be able to estimate features of mental processes during VR experiences. For this purpose we fistly applied the fixation detection method from Salvucci & Goldberg (2000). Fixations (stationary motion of eye movements) and saccades (detected leaps in eye orientation) defined in the sequel an innovative method that was applied particularly for the component ‘mindful vision’ within the portal ‘vision’. Once this algorithm determined a certain amount of dwell time and low bound of saccade frequency and gaze translation, being classified as ‘concentrated dwelling’, it automatically provides a magnification of a currently gazed image region part (Fig. 4d). The objective of applying this method is to support the user in a more detailed, profound, and meditation like observation of the visual information and enforces in this manner a mindful reflection in general as well as improving overall situation awareness.

5.2.3 Affective States

Pervasive measurement of affective state by means of non-invasive interactions might be a central focus of investigation in emerging mental health technologies. By means of the method by (Dini et al., 2019) a non-invasive mood measurement can be attained from features of eye movements, measured during a serious game that is played during observation of affective imagery, and that enables to keep track of the actual mood state of the observer. The VR-SenseCity Toolbox incorporates this serious game based mood measurement in order to be able to keep track about the affective state of the user, in a manner of pervasive computing, i.e., without explicit, conscious involvement of the user. The VR based method for mood measurements has been tested with 40 young participants in a large feasibility study. In future work, the method will be evauated with elderly users as well. The results obtained from the feasibility study demonstrate a correlation between the mood state and preferences of attention with respect to specific types

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of affective images. A linear classifier that is built from linear regression of the correlating feature values enables estimates about positive or negative valence of mood with a precision of ca. 75 %.

5.3 Triggers

The technical triggers for the nine portals were developed according to the stimuli recommended by the co-creation team and from experience in prototypical studies. Among the triggers. 25 panoramic videos and two panoramic images were thematically appropriately selected from the youtube database, and 11 panoramic videos and two panoramic images were produced by own scene production and using a panoramic high resolution camera. Content generated appeared to be a highly time and resource consuming process.

6 EXPERIMENTAL RESULTS

6.1 Technical Data

For the visualisations in VR using the head-mounted display (HMD) a HTC Vive (resolution 2160x1200 Pixel, frame display rate 45 Hz) was used with eye tracking facility of a Tobii Pro VR configuration, using an Alienware Aurora Mid Tower Gaming Desktop as PC based server. The frequency of the gaze orientation on the basis of the eye tracking unit was 120 Hz with an estimated precision of □0.5°. A 'Five-point' calibration method was applied before each individual session. A leap motion controller[4] with Infared camera and vertical and horizontal view angle of 180° was applied to recognize the motion of the hands. To acquire panoramic imagery and videos two Kodak SP360 4 Karat cameras were used. These serve for a complete coverage of the human view area and for the interaction with a view sphere, including the degree of freedom for horizontal (360°) and vertical angular (180°) motion.

6.2 Studies on Emotion Induction, Motivation, and Acceptance in the Context of Technical Triggers

6.2.1 Prototypical Study with Healthy Elderly in the Lab

In a first prototypical study with N=10 healthy elderly people (Mage = 71.1, SD = 7.3 years) a first version of VR-SenseCity, with full functional capacity and only one trigger for each portal has been applied. The users were free to decide upon which portal to select for senseful experience. Fig. 6a depict the preference of the users for the experience with specific portals. In particular, users preferred 'audition', 'vision' and 'play'. The duration of each session was about 15 minutes (see Fig. 6b). For an evaluation of emotion induction, the multidimensional mood questionnaire MDBF; Steyer et al., 1997) was applied to measure mood valence, alertness and arousal. Two different versions of the MDBF; i.e., the MDBF-A and MDBF-B were applied before and after the session, respectively, to allow comparison and measurement of emotion induction. The state of mindfulness was acquired using the mindfulness questionnaire FFA-14 (Walach et al., 2004). Usability of the VR-SenseCity application was tested using the SUS (system usability scale, Brooke, 1986). The results about affective state induction (Fig. 6c) demonstrate that a significant increase in mood valence (GU), alertness (WM) and arousal (RU) has been attained. The SUS measurements result in M = 77.8, SD = 16.1 in terms of 'good usability' that is understood to be represented by values of 68 and above, therefore the result favours a positive acceptance of the system which was consistently obtained from interviews.

6.2.2 Pilot Study with Cognitive Impaired in a Nursing Center

A pilot study with ten participants (8 females, 2 males), i.e., persons with dementia (Mage = 80.9; SD = 8.8 years) with light and mid grade of disease, was performed in cooperation with the Geriatrische Gesundheitszentren Graz (GGZ) and under ethical approval of the Medical University of Graz (EK-Nummer: 30-474 ex 17/18, dated August 16, 2018). The study took place at a Nursing Center of the GGZ. After a comprehensive information and introduction phase, the information consent was acquired and socio-economic data were retrieved. Questionnaires like the MDBF (Steyer et al., 1997), the FFA-14 (Walach et al., 2004) and SUS (Brooke, 1986) were filled. Participants could take as much time in VR-SenseCity and select any and as many portals and triggers as they wanted. The results of this study demonstrate again a positive induction of mood states: the valence of mood was increased from M = 14.8, SD = 3.7 before to M = 17.5, SD = 3.3 afterwards, alertness from M = 13.4, SD = 4.7 before to M = 16.1, SD = 3.6 afterwards. The SUS was comparable moderate being M = 70.4 (SD = 13.4) and above the threshold for 'good usability'.

[4] https://www.leapmotion.com/

Eye movements features (mean number of dwells per second) that represent comparably calm state of mind were measured and correlated positively (r = .98) with the degree of mindfulness (FFA-14) of the participants.

6.3 Stimuli Selection for Triggers with Imagination of Positive Emotion

The 'Genussschule' (Koppenhöfer, 1990) trains the five human senses, smell, touch, taste, sight and hearing. In each of the weekly meetings out of ten people concentrated on one sense in the order presented above. Stimuli were selected by the facilitator fitting to season and living environment of group. Additionally, a few stimuli estimated to be unpleasant were chosen as well to demonstrate differences to pleasure. All stimuli were nicely presented on a table at wich the group was sitting. The presenter guided the process and took care of the 'Genussregeln'.

Participants selected stimuli that encouraged memories, imagination and pleasure for the elderly. Stimuli related to 'smell' were roses, oranges, coffee, to 'touch' were trees and wood, splashes of water or rain, pets, hugging, to 'taste' were chocolate, bread, fresh fruits and cooking, to 'vision' were water, sky and clouds, flowers and grass, to 'hearing' were bird's twittering, sound of water, and steps in leaves and grass.

Development of triggers in the virtual reality was then based on the above selection of stimuli. The quality of the trigger is determined by 'translation and performance' of stimuli into panoramic pictures and videos, as well as meaningful citations about senses, as implemented in VR-SenseCity. Imagination is needed to trigger a holistic experience of pleasure for the user. Imagination here is the ability to produce images, ideas and sensations in the mind without any immediate input of the senses. It can also be seen as the forming of experiences in mind, which can be re-creations of past experiences, like vivid memories with imagined changes or invented scenarios; positive emotions can be experienced and reconstructed by imagination.

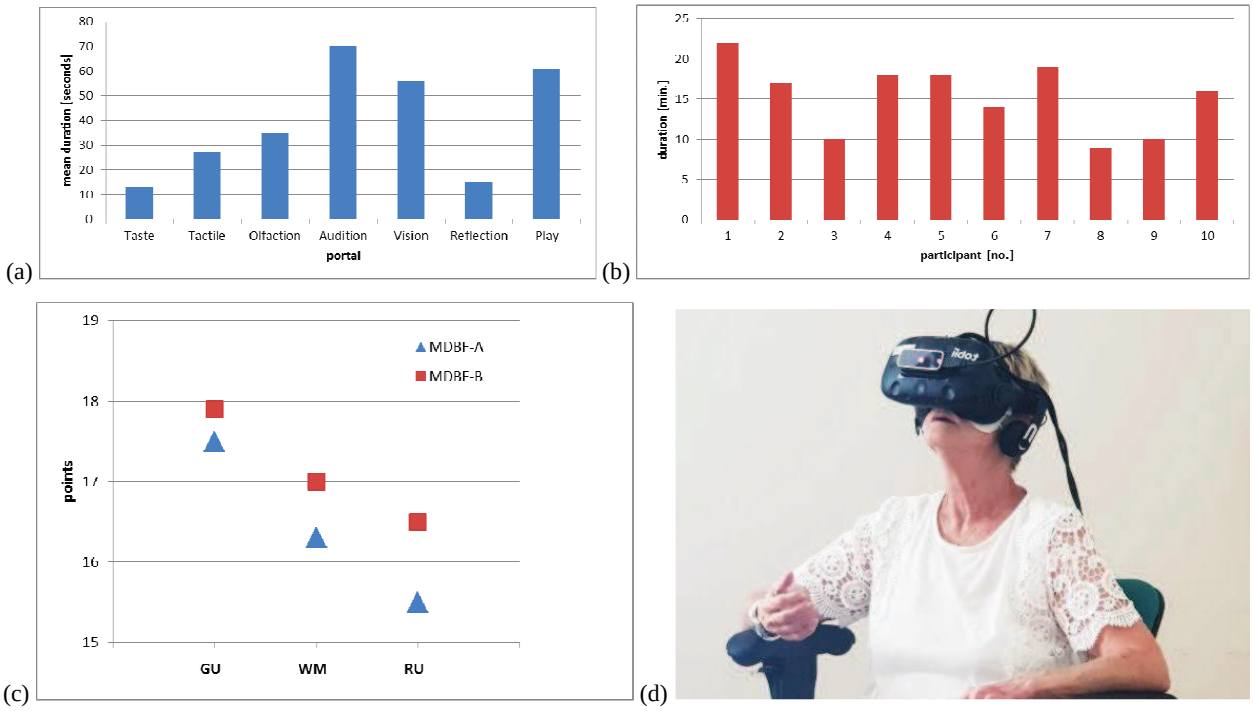

Fig. 6: Mood induction in a prototypical study with healthy elderly. (a) Preference in the selection of portals and corresponding senseful experience. (b) Duration of voluntary presence in VR-SenseCity. (c) Emotion induction: mood before (MDBF-A) is lower than mood after the VR session (MDBF-B) demonstrating a significant increase in mood valence (GU), alertness (WM) and arousal (RU). (d) Typical user in the prototypical study.

7 CONCLUSIONS

7.1 Scenarios for Urban Technical Triggers

In the frame of future technologies that could emerge from the presented technological, psychosocial and affective framework, the following technical trajectories were identified and prioritised, as follows,

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- Mobile VR Solutions. A community based space for mindful experiences for elderly, to enconunter joyful, senseful perceptions with the objective to relax, to connect to positive aspects in the urban living environment, pleasure and senseful experiences. A VR based system solution would present selected triggers representing stimuli from within the near surrounding, and triggers would make users feel curious and eager to search for end enjoy these sensefl experiences. Tourism agencies could prepare special rooms and spaces at locations that would be easily accessible by elderly tourists, I order to motivate to visit interesting locations in the hosting city.
- Urban Displays. Potential targeted technologies for urban displays are curved OLED[5] projection displays that could be applied in central locations of public space , for joyful perceptions and interactions with VR-SenseCity components. These components could be installed at roofed bus or train stops. Alternatively, mobile containers could be placed at central locations (parks, pedestrian zones, railwy stations) representing urban oases in the city center, in order to foster awareness about senseful, affective perceptions in the urban living space.

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[5] OLED: organic light emitting diode