D8.4 - EXPERIMENTAL PRODUCTION SCENARIO RESULTS

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1.0 - 15/07/2022	UPF prepared a shell to support CREW as leaders
1.1 - 05/08/2022	Updated version with CREW substantial contributions
1.2 - 20/08/2022	Reviewed version Incorporating CREW revisions, and contributions from partners
1.3 - 31/08/2022	Final version for submission

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1. Executive Summary

This report describes / evaluates the Experimental Productions (EP) and also provides some assessment of the tools that were developed by the technical partners Inria, UAU, CM, FS, challenged for integration in the EPs .

It comprises of:

- **Delirious Departures I&II**. A collaborative VR environment for agents & immersants,
- **Soulhacker I&II**. A VR based environment for therapeutic use,
- **Adam**. A screen based application for therapeutic use.

The deliverable mentions their relationship to the Use Cases, experiments, preparatory work, demos, and performances. It also includes a short summary of the evaluations carried out by two academic partners, UAu and Inria, in the sections related to the EPs where their contribution was most significant.

As indicated in the conclusions, through the EPs, PRESENT outcomes went into museums and professional environments, and allowed us to evaluate them continuously and on a large scale and a broad spectrum. We should especially mention the new perspective offered through working and evaluating in clinical environments. As this deliverable will be showing, the results of the EPs and their evaluation exceed the expectations.

The next section, Introduction, discusses the role of the EPs, their relationship to Use Cases and Pilots, and provides an overview of the different EPs. The following sections are devoted each to one EP, with its variants, presenting technical details and the evaluation. A final section summarises the deliverable and presents the overall conclusions.

2. Introduction

The *Experimental Productions* (EPs) in PRESENT complement the more industrially oriented *Pilots* by setting interactive artistic experiences which aim at challenging the technologies developed in PRESENT in a different situation.

Let us remark that the conceptual and implementation process of EPs is quite different from industrial use cases, which start with well defined requirements. As indicated in *D8.2 Interim Experimental Production Report* "*... a set-up is devised and from there onwards, the concepts continually evolve. This is typical of the artistic process and yields different results.*" On the other hand, the approach goes beyond providing content. Quoting again D8.2 "*CREW has been involved in all steps of the development process to drive development within PRESENT towards use cases which are idiosyncratic and expand the coverage of the project. ... the experimental productions evolve conceptually with the implementations of the other work packages, relative to their characteristics.*" To make the most of this, EPs have taken different manifestations.

We will thus describe and evaluate the five resulting EPs, which have integrated the principles of the different Use Cases (UCs) and experiments that relate to them.

The EP *Delirious Departures* in its different outcomes integrates for example UC *Complex Social Situation* that aims to simulate crowd movements for one-to-many interactions and non-verbal communication with groups of avatars and the UC *Greek Chorus* which is a puppeteering tool for actors to control multiple characters simultaneously.

From the early stages we have been experimenting and simulating these principles with avatars in small and large environments, with varying narratives, graphics and interactions. For the early 'Museum version' of *Delirious Departures* e.g., we simulated the puppeteering principle and a social complex situation by having a live motion-captured avatar-actor in interplay with prerecorded avatar-animations and with an avatar-immersant/visitor. We performed and evaluated the EP with real world audiences and set up two different spatial solutions. The *'SIGGRAPH version'* of Delirious Departures then takes it a step further by adding intelligent agents/NPCs. Let us recall that EP *Delirious Departures* is closely connected to Inria research related to 1-N interactions and connected to CM locomotion generation and gaze research and that D8.2 reported upon the two UC principles that drive the EP. Multiple agents were added to two scenes of Delirious Departures, which altered the nature of the work quite substantially. Specifically, the agents fill the gap between animated figures and the live actor, blurring who is "real" and who is not. This is further exacerbated by the use of semi-abstract avatars. As such the experience is much more oriented towards the presence of digital humans than the environments and the VR dramaturgy (props, walking in air etc) in previous versions. The simple but efficient gaze system has a large impact in terms of feeling acknowledged, and the use of groups of agents creates an illusionary feeling of having a virtual body.

The EPs have uncovered integration challenges for some aspects of the innovations developed in PRESENT. These integration limitations are probably due to a combination of the very detailed component-wise description of the proofs of concept, the difficulties of having face-to-face meetings and of discontinuities in the motion capture sessions needed to obtain data both derived from the pandemics situation. These aspects are also discussed here. In this type of evaluation CREW acts as creative technology integrator, in much the same way as quite a few FS employees do - this type of evaluation is discussed in the companion deliverable on *Pilots*, as it seems to fit better there because of the industrial context.

The restrained working conditions during the pandemic inspired us to reorient the research, delving from another angle into sentience and emotional sensitivity, aspects that are at the core of PRESENT. This resulted in EPs *Soulhacker* and *Adam*. *Soulhacker* EP has two very different manifestations, an artistic one, and one in a very novel psychiatric setting. Adam is exclusively for therapeutic use.

VR is an experiential medium with a certain level of agency. It implies acknowledging the *presence* and by extension the *emotional presence* of the immersant/user. *'How is your emotional presence being read and understood? What does it generate on the other side? How to control it and how to work with it as a director?'* And: *How to measure it?*

Soulhacker then is an exercise that gave us a good insight. It is an experimental VR therapy that in a clinical context aims to induce and extract emotion amongst others by using interaction with particular virtual environments. Reactions are being observed (and measured), but still need to be understood in the totality of observations of the therapist versus his individual patient. *Adam* is another exercise for therapeutic use, closely related to the research on multimodal sensory integration by UAu. In this deliverable we report the *Soulhacker* and *Adam* evaluation as well as summarise the more academic evaluation by UAu.

We have brought different manifestations of the EPs towards professional and clinical users and have evaluated results in different ways. We see artistic productions/EPs also as a way to share our research with real world audiences/end-users. We obtained a high visibility and interest with these : EPs in major museums like the Royal Museum of Fine Arts KMSKB Brussels and the Museum for Contemporary Art S.M.A.K. Ghent, in the festivals *Europalia* and *Designfest*, at SIGGRAPH Vancouver in the *Immersive Pavilion* and in Athens, Greece during a state visit of the Belgian Royal couple. We had the honour of having the King and a State Secretary for Scientific Development as very interested immersants.

Some of the work will be continued after this project: Soulhacker for example will be refined and tested into novel large area applications and extended with roleplaying modalities using the lessons learned from PRESENT technology.

2.1 Terminology and acronyms

- **EP**: Experimental Productions.
- **UC**: Use Case.
- **NPC**: Non-player character.
- **IK**: Inverse Kinematics.
- **Inria**: Institut national de recherche en sciences et technologies du numérique.
- **UAU**: University of Augsburg.
- **CM**: Cubic Motion.
- **FS**: Framestore.
- **Mocap**: Motion Capture.
- **IF**: Interaction Field.
- **SSI**: Social Signal Interpretation.
- **KMSKB**: Royal Museums of Fine Arts of Belgium.
- **S.M.A.K.**: Municipal Museum of Contemporary Art [of Ghent].
- **VR**: Virtual Reality

3. Delirious Departures

This section reports on the evaluation of the EP 'Delirious Departures'.

CREW was art-commissioned by Europalia Festival (Belgium) to create a new immersive work around railway stations. This fell together well with the interest that partner Inria was having towards train stations as excellent locations for understanding / simulating group behaviour and interaction.

It was seen as a work that could be adapted and enhanced along the development of the PRESENT components into an ever more interactive work.

3.1 Museum Version

3.1.1 Setup and context

CREW scanned a large number of railway stations during the pandemic and was inspired by the difference in human movement and interaction compared to normal times (before the pandemic).

Delirious Departures was expressed in two forms:

1. **The SQUARE**: CREW created a 10x10m VR experience, where the immersant is confronted with static 3D scans of people, animated avatars and a live actor in a mocap suit.
2. **The RIDE**: the immersant is led by a voice actor and is walking behind an electric wheelchair steered and manned by the actor. The actor performs live by narrating and switching VR scenes with avatars in different forms.

https://vimeo.com/659576232

3.1.2 Technical Integration Evaluation
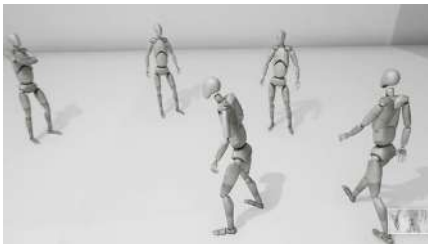
Inria's Interaction Fields and UMANS software was used for scenarizing a large number of interactions, congruent with the Complex Social Situation Use Case. The tool was found to be very intuitive and productive.

UMANS was integrated into the game engine Unreal Engine 4, but only gives the position of all agents, they still have to be animated. Because of the lack of mocap data and animation algorithm from Cubic Motion due to covid issues, CREW developed its own animation system that is based on the Unreal Engine 4 plug-in Motion Symphony, which works with Motion Matching, the same technology as pursued by Cubic Motion. This proved to be challenging. Animation was erratic and it was very difficult to create a form of interaction, of presence, which felt for the immersant as if he was part of the virtual population. CREW made an in-depth analysis of this problem and informed the other partners of the non-triviality of this component.

The Greek Chorus was explored, with different IK solutions for manipulating avatars in real-time with multiplication of actors in different embodiments and so forth but after a few tests, this path was no longer pursued as it did not seem applicable within this EP, it does remain relevant however for other endeavours.

The SQUARE and the RIDE work with different tracking solutions. *Straptrack* tracking, a large area tracking method that CREW developed with Steven Maesen was

found to not be ready for real world deployment due to issues of lag and accuracy. Therefore the SQUARE works on an enlarged 10x10m SteamVR tracking area, with great precision and performance. The RIDE was tracked with the inside-out tracking of the Oculus Quest HMD, with the safety boundaries disabled. This provided a large, almost unlimited tracking area, with corridors up to 80m. However, drift was a continuous problem and markers had to be applied to the museum walls in order to keep tracking stable.

3.1.3 End-user evaluation

We recall key evaluation criteria from D8.2 / 6.1:

-When the EPs were sufficiently mature to be shown to an audience, CREW evaluated audience responses in immersive productions, using questionnaires and interviews administered by the CREW team.

-An Expert User Group was set up at an earlier stage. It consisted of professionals from a wide array of concerned fields e.g. futurologists, actors, digital artists, media professionals, theatre directors, psychologists. The User Group was to evaluate aspects of the EPs through questionnaires and interviews. The original Expert User Group was replaced by the professional audiences at SIGGRAPH (see further)

This report thus includes:

- Questionnaires of the SQUARE variant in KMSKB en S.M.A.K.
- Questionnaires of the RIDE variant in KMSKB.
- Depth interview of the SQUARE and RIDE variant in KMSKB.
- Questionnaire of the final SQUARE in SIGGRAPH

-Questionnaires of the *SQUARE* variant in KMSKB and S.M.A.K., comparison of results (KMSKB 18/11/2021-21/11/2021 & 25/11/2021-28/11/2021 and S.M.A.K. Museum of Contemporary Art S.M.A.K. 26/04/2022-28/04/2022.)
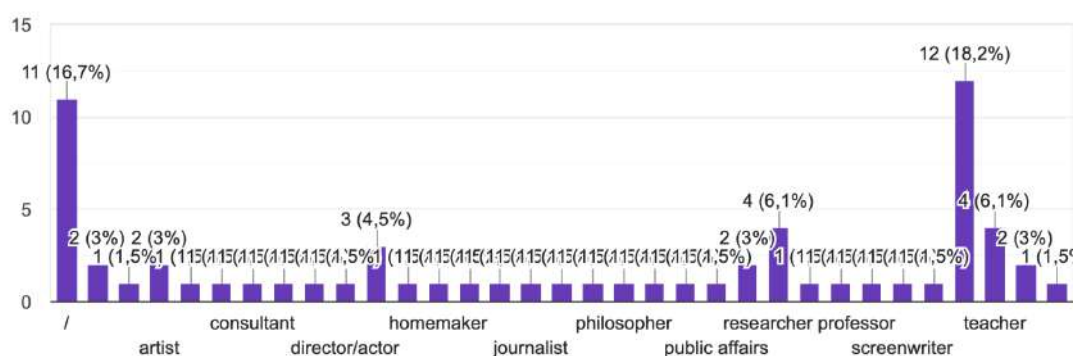
SQUARE variant:

KMSKB:

Age
40 antwoorden
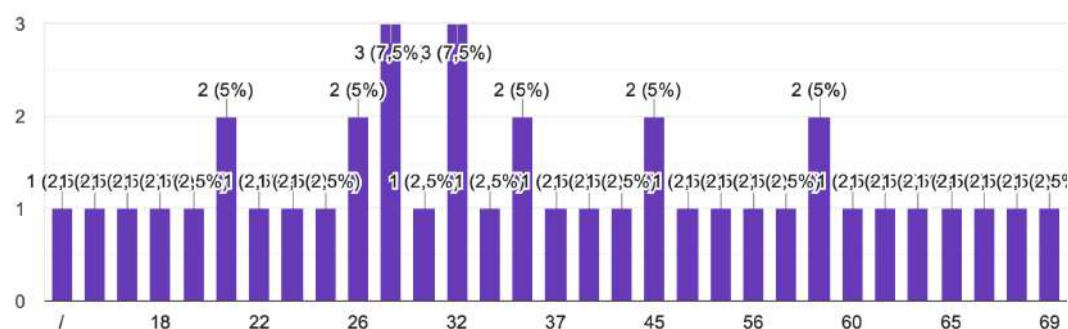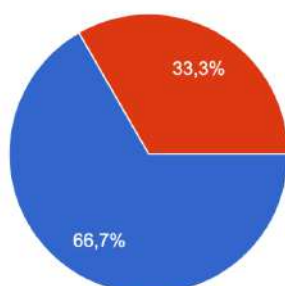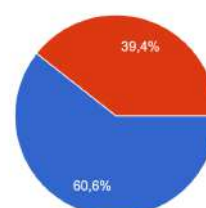

Occupation
66 antwoorden

KMSKB (left)   S.M.A.K. (right)

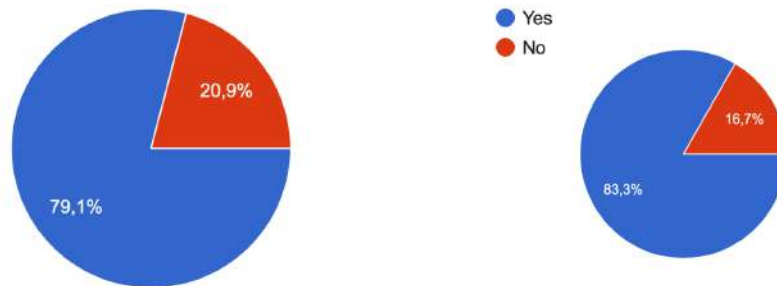### Did you ever participate in a VR experience?
9 antwoorden

- Yes
- No

If you did, does the concept of this VR experience strikes you as entirely different?

43 antwoorden

Comments KMSKB:

-"not a game or film, but an experience in which you can make decisions and walk around completely new world, like post disaster, nice to go over the floor / still a great experience, like other vr artworks / previous was 360 video, mixing virtual environment with real places, easily move around / different, but at the same you know you remain in reality, so you can feel safe and discover / the visual artwork is modern and full of details, i really enjoyed it / I was not sitting in a chair, not a game or film, but an experience in which you can make decisions and walk around / artistic and aesthetic appeal of the environment / it's vr, but also an artwork / completely new work, like post disaster, nice to go over the floor / you can experience something you will never experience. It combines things you recognize with another perception / relation between space and body / spectacular

good but not entirely new to me / Similar to other experiences, but this one is more immersive and free / Not fundamentally different, but some new aspects such as the interplay between different levels, the loose narrative which calls you to explore / the data is artificial

You have to be active / Closer to a dream, I like the exploratory nature, interaction with objects / Much more interactive, a couple of steps forward from my last VR experience / higher level of interaction and a more versatile, changing world was great / not just a game, there is no clear purpose here

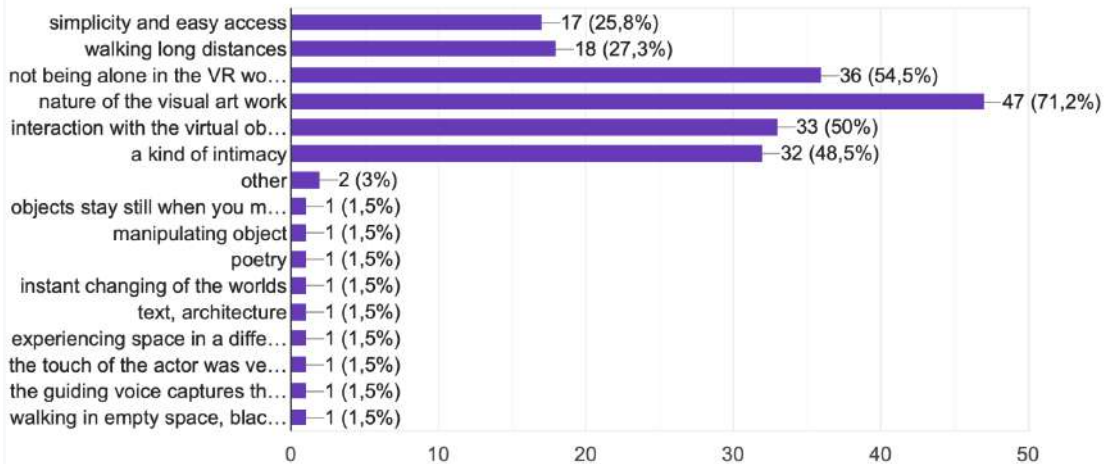watching familiar places in an abstract set is a really strong experience"

Comments S.M.A.K.:

"More interactive / in this project I needed to move around all the time / I am familiar from computer games the methods with which you are fooled. You know there are stairs or great heights but your body reacts. This was much more beautiful and the sound and text added a lot."

KMSKB:

Which component of this environment / production is most interesting to you? Mark 3 of your choices.

66 antwoorden

simplicity and easy access	17 (25,8%)
walking long distances	18 (27,3%)
not being alone in the VR wo...	36 (54,5%)
nature of the visual art work	47 (71,2%)
interaction with the virtual ob...	33 (50%)
a kind of intimacy	32 (48,5%)
other	2 (3%)
objects stay still when you m...	1 (1,5%)
manipulating object	1 (1,5%)
poetry	1 (1,5%)
instant changing of the worlds	1 (1,5%)
text, architecture	1 (1,5%)
experiencing space in a diffe...	1 (1,5%)
the touch of the actor was ve...	1 (1,5%)
the guiding voice captures th...	1 (1,5%)
walking in empty space, blac...	1 (1,5%)

S.M.A.K.:

Which component of this environment / production is most interesting to you? Mark 3 of your choices.

9 antwoorden

simplicity and easy access	2 (22,2%)
walking long distances	2 (22,2%)
not being alone in the VR world...	1 (11,1%)
nature of the visual art work	8 (88,9%)
interaction with the virtual objects	7 (77,8%)
a kind of intimacy	5 (55,6%)
other	0 (0%)
esoteric and relaxing	1 (11,1%)
content of the walk	1 (11,1%)
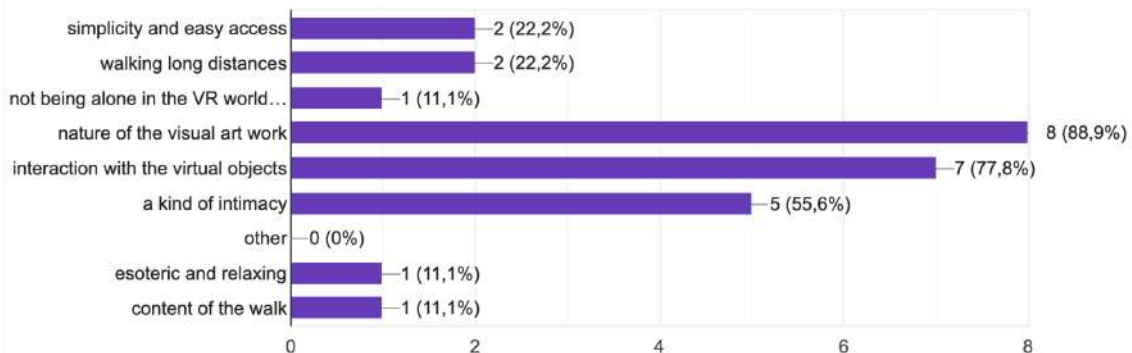
KMSKB (left)   S.M.A.K. (right)

Did you at any given moment experience dizziness/uncertainty?
66 antwoorden

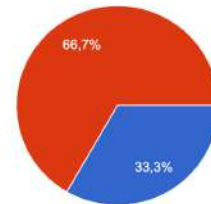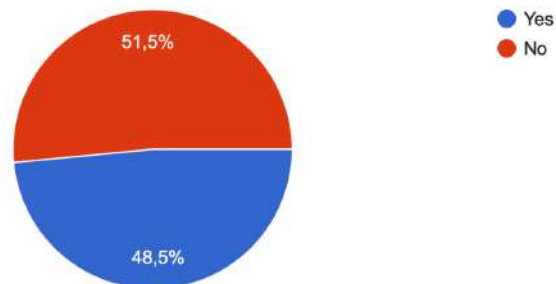This question should have been differentiated. The participants who respond positively refer to the effect of 'the balcony' and the going down of 'the steps', not adverse reactions to the VR experience in itself.

Did you feel a need to meet other people in the environment or VR world?
66 antwoorden
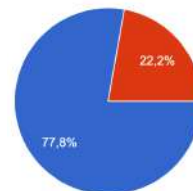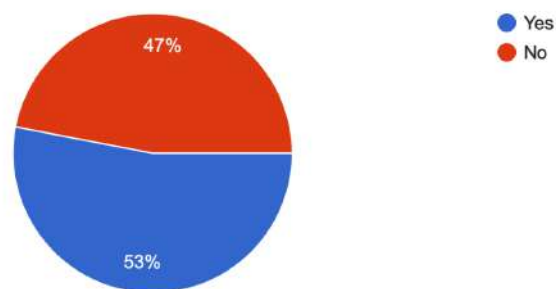
Did you feel a strong presence, as being part of the virtual world?
66 antwoorden

Which moment do you remember most? Which was most intense?

Comments KMSKB:

By far the walking in the air has been retained:

"jumping into the void, stairs / the beginning, stepping into the empty, recognizing stations / floating in antwerp central / falling from antwerp station / when I felt like I was falling / jump-walk into the void, walking in between avatars, bones creatures / floating in space, couldn't do it, same for sink hole / waking into the void, terrible but I succeeded / breaking physical laws in antwerp central sta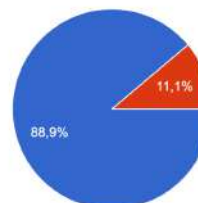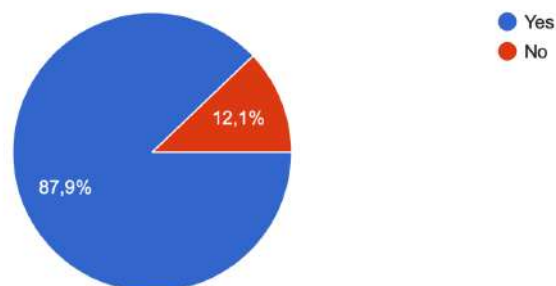tion / did not like the hole and the void / stepping of balcony / in the cathedral, vertigo / walking through air / the moment you're at the church and you have to go down / going over the barrier into the void was very intense / walk in the air / walk into emptiness / stairs, air / The void / When I walked in the vacuum (felt this way) / flying being alone / balcony, being alone in the station, being lonely because everyone passes by but no one notices you / be near of the virtual people / walking in the air, other passengers / stone figures that walk by me, garbage can, multiple figures, one with a body / the void, beautiful spaces, people / last scene / the first space, in the black / darkness / walking in mid air, trash can / walking in the air, interacting with objects / receiving an object, walking in the air / object in trash can / recognizing the stations, walking in mid air / brussels north / When the building around me was fully visible and it felt you could cross it, it felt the most real"

Comments S.M.A.K.:

"The stairs / The stairs and looking from the height was also spectacular / Balcony / When I was asked if dying is like a departure / walking / the hole and the glass floor / the edge of the station"
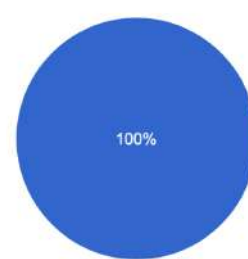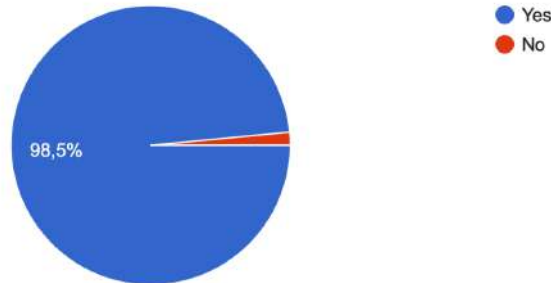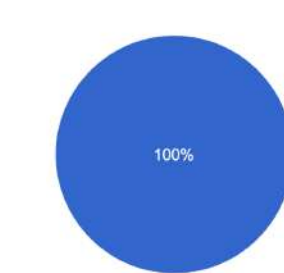
Are the resulting visual experiences convincing, novel and original?
66 antwoorden

Do you think the technology used, enhances creativity and productivity?
66 antwoorden
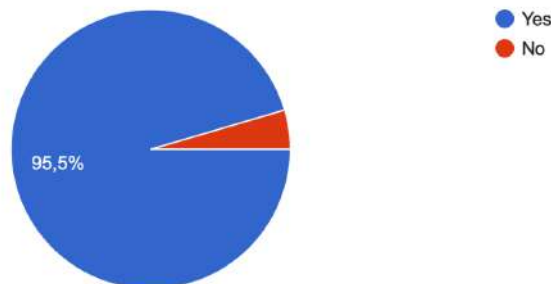
"Not sure / art should always use the most recent technologies / new beginning / creativity yes, the figures you meet for example / yes to creativity / I think it enables us to apply our creativity in digital environments which is more environmentally sustainable / I couldn't tell / creative yes, productivity I don't know. environmental concern / might be, but I see greater value in the experience per se / technology can bring art to new places, but I like analog work as well / It is what you do with it. Mostly technology takes over from content, it should be the inverse / I have never seen such a thing as this performance, so it must be creative. to link art with technology in this experience / but I would like to try more and I wish I hadn't seen the black block before going in / design is original, experience floating / amazing how real it becomes. The lady who always got up, but never left made me think of "the departure" by Ivo Michiels, a departure that was never fulfilled. Congratulations! / I like the text but sometimes felt I had to choose between text and virtual walk, they were not always strongly linked to me / questions combined with visual effects / I like the fragmented photogrammetry look, it is an interesting style which can be developed further. I would like to move more. live actor was nice but a bit limited, I don't understand what his role was in the story / there is so much more to discover / more please / it was great / congrats / great and realistic"

<u>Comments S.M.A.K.:</u>

"Creativity yes, however not so sure about productivity / It is an interesting medium to explore, something that involves different art forms and more public parts of it, influence it. / I sometimes miss the auditive aspect of sound, to be able to concentrate / It was a form of interactive meditation"

How would you, in a few words, describe your connection with the actor/guide?

"I felt I could completely trust him / Her presence made me feel confident and at ease / I felt guided and safe / She guided me around well and I did not have the feeling I was alone. / Good, you feel safe and curious about what happens. / Strange to have a connection with a human when you see a sculpture. Would be nice to be able to dialogue with the actors"

-Questionnaires of the *RIDE* variant in KMSKB (18/11/2021-21/11/2021 & 25/11/2021-28/11/2021)

Did you ever participate in a VR experience?
52 antwoorden
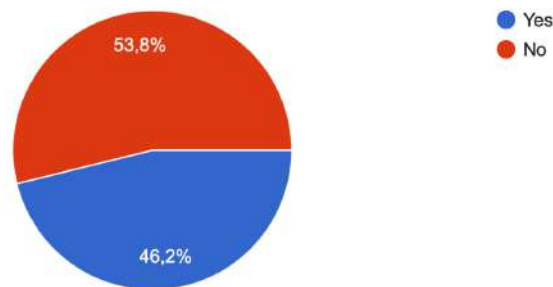
If you did, does the concept of this VR experience strikes you as entirely different?
29 antwoorden
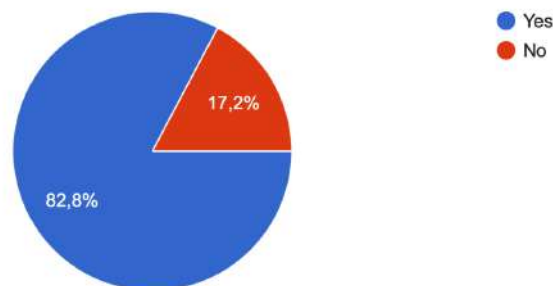
Additional remarks to previous question:

"The fact that you move and are forced to move over areas is very weird. It was also weird when the camera did not move but the wheelchair did. / I didn't see any colours,

just black and white and I had the feeling I saw monsters / impression d'apocalypse / I love the desolate landscape, the non-perfection, really another world / wonderful esthetic environment / The pseudo freedom, endlessness, space world / the broken world and breaking with the rules of normality made it different / the experience was way too real. I've never tried it before. / This one is more dynamic. Movement Feeling is good, very realistic too / more mobile, different scenes, link to reality / This was super well done! The guide was great, it involved more movement / more elaborated, movement in space / The last one was stationary, while this was totally different because you were actually walking around / I got to move my own body and I got to take a risk.

never dared a VR experience by walking. It was amazing / Floating through walls and people and walking over people was a new experience / It was a VR publicity for Boursin where I didn't really feel anything but here I experienced a lot of sensations."

Which component of this environment / production is most interesting to you? Mark 3 of your choices.

52 antwoorden

Component	Count
simplicity and easy access	20 (38,5%)
walking long distances	18 (34,6%)
not being alone in the VR world…	33 (63,5%)
nature of the visual art work	37 (71,2%)
interaction with the virtual objects	21 (40,4%)
a kind of intimacy	15 (28,8%)
other	0 (0%)
questions to be asked, while yo…	1 (1,9%)
Not seeing your own body.	1 (1,9%)
het kunnen rondkijken naar alle…	1 (1,9%)
the further possibilities with this…	1 (1,9%)
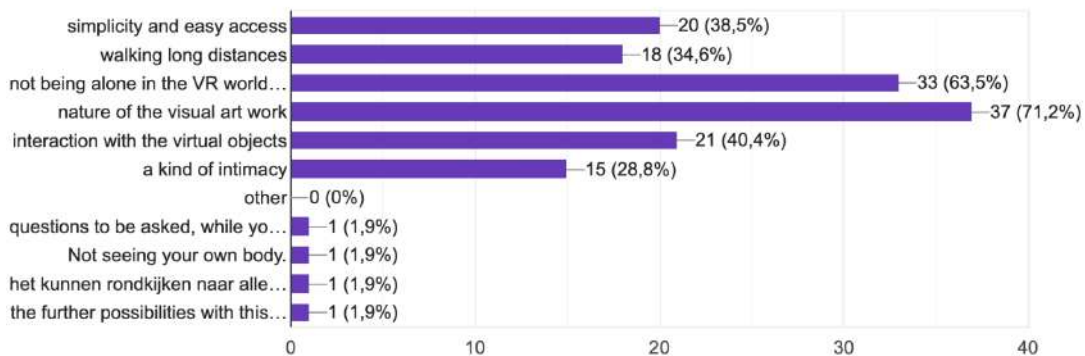
Did you at any given moment experience dizziness/uncertainty?

52 antwoorden

- Yes — 50%
- No — 50%
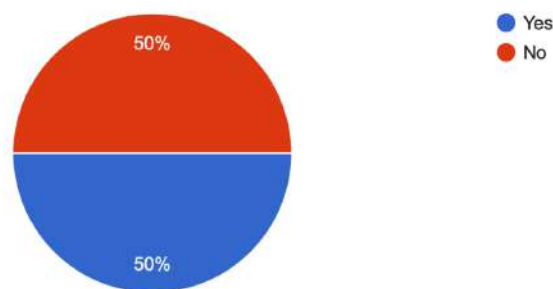
Did you feel a need to meet other people in the environment or VR world?
52 antwoorden

- Yes
- No

67,3%

32,7%
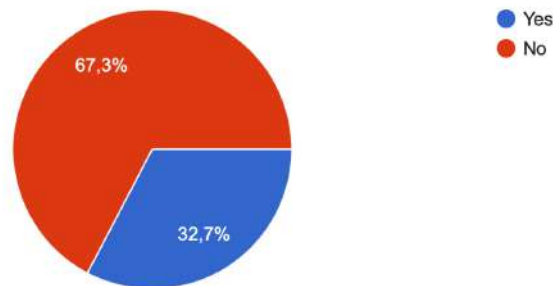
Did you feel a strong presence, as being part of the virtual world?
52 antwoorden

- Yes
- No

25%

75%
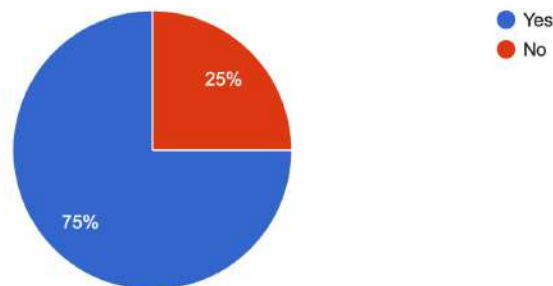
Again the question of 'presence' was not well understood / not well defined by us.

The negative answers all indicate a strong awareness of the 'walking', and clearly was experienced in a sensational way.

"When I walked through the trainstation I almost forgot the I was still in the museum when I took of the virtual glasses / Walking over depths / walking through the walls and pillars /going over the escalator / over de dieptes stappen / when you feel you are going to fall / Stepping over the railing in the station / the first gap / The moment in the museum where I walked into the void and where I descended the stairs / Walking over the rail tracks / moving and going into different spaces / Antwerp Central upside down / the deep eaves / It was wonderful! / All the moments where I walked on a hole and in a hole. I had the feeling I flew sometimes and I had the feeling that I was very small and everyone next to me was much bigger. / Last station was like a dead world / Walking over and through objects that would otherwise be impossible was at first very frightening / the one where we broke through a wall / the first passing a hole / the stairs /when I saw places I know / being inside spaces I knew very well but that I got to see in a new perspective / The passage from one scene to another. The feeling of height and the black holes. Very interesting sculptures. / The one where you didn't really walk on ground but just into space and whenever the space changed suddenly. / The one in front of the bench with the seated avatars and in the hall with those three giants / when I found myself between the 3 standing figures / floating in Antwerp central with 3 giants / Antwerp-station / In the main hall of Antwerp Central, when the figures in the middle

were giants suddenly. All just the moment before when we were observing them from a distance, as if they couldn't see me. Walking through the glass window in the end / Staircase going down to Antwerp-Central main hall / not taking the stairs when you're asked 'ready to take the stairs?' / Encounter with 3 beings in Antwerp-Station / Standing next to the giant figures / The most intense was the first floating. I really liked the transitions from one space to another. / The walking / walking without surface / walking through the walls, the stairs of Antwerp central station / someone in the world, transfer through walls, Antwerp-station / where I had to jump over a fence ' dans le vide' / walking through walls and objects / the transitions / the depths / The transition moments between the different scenes. / the station when more colours were added- where you could clearly see the trash cans and people doors, finding the human figures, being touched by the assistant. the stairs central station waiting in HD"

Are the resulting visual experiences convincing, novel and original?
52 antwoorden

● Yes
● No

98,1%
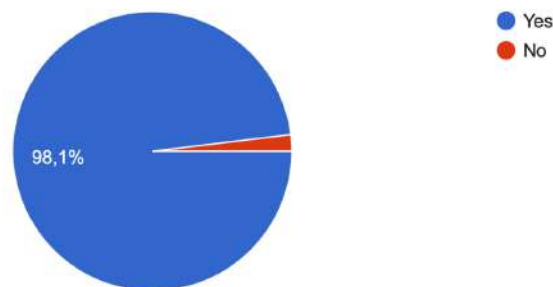
Do you think the technology used, enhances creativity and productivity?
52 antwoorden

● Yes
● No

96,2%
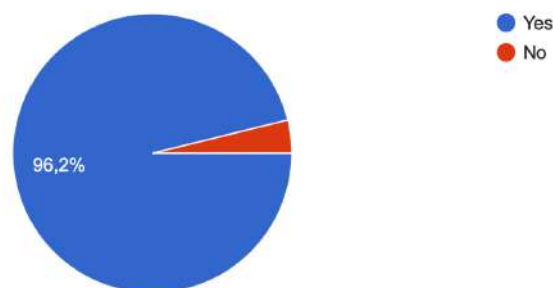
"I'm afraid that through technology you can handle the feelings and the fears of people. / The imagination was triggered! / define creativity. Another way to communicate space and body experience with an audience-user. / yes and no, I think the technology enhances the .. of experiences available to us and that in form may enhance creativity. I have no ideas about productivity though. / I find the use of 3D images from real life quite touching. / There were a lot of strange people next to me, they were in one picture. / Incredible moment. Simultaneously introspective and explorative. Ingenious! / makes sense, no entertainment / the not perfectly scanned VR is beautiful! / It's unsettling but in a very good innovative way / you enter a new world, into another universe and I'm convinced it can make you think in other ways. I also became very aware of the fact that there are so many ways to use creativity."

-In-depth interview with Juliette Bibasse about the SQUARE and RIDE variant in KMSKB (18/11/2021-21/11/2021 & 25/11/2021-28/11/2021)
With in-depth interviews we get information beyond initial and surface-level answers. We started with the same questions as the previous questionnaires that we could alter and refine based upon the feedback. Underneath a summary of the interview together with comments.
Ms. Juliette Bibasse is a curator and has extensive experience with VR.

Q: Did you feel that this experience was different in any way?
"The wheelchair is something I've never seen being used for VR. Knowing what you can and cannot do in VR, I was very intrigued by this physical object and how it is used in VR."

Comment: the wheelchair (with a different configuration and its own tracking) is a solution to have the immersants walk along a parcours with a length of ca 50 meters. The downside of this configuration was that it allowed for less interactivity. Mrs. Bibasse has experienced other installations in which one can freely walk, but not at the size we were using with the SQUARE or the RIDE.

"But maybe it is nice that you don't really know the limits in real space."

Q: Do you think it would be more engaging to have a much larger space with say 200 or 400 m2?
"I wouldn't say, I mean if you have access to really big venues, it could be nice to have a real continuous large space. But the way you had to cheat with the space you had in the museum here, to make it feel bigger in the VR world, was totally fine in my opinion. So, this should not become a limitation in terms of touring the project because then you would need only large space or venues. I think it doesn't take anything away from the experience when you made those cuts in the VR world whereby people would change maps or levels, that was perfectly fine. "

Comment: Mrs. Bibasse is answering here as a curator and partly organizer, taking into notice the problem of space available for VR installations. It is indeed possible to work around the limited space, but what if one had not to do so, how much more potential would be gained?

Q: Do you feel that the immersion is stronger if you walk longer distances or not?
The SQUARE: "I have the feeling to walk pretty big distances and after a couple of minutes you completely lose any point of reference. So actually, when you're doing the experience, I don't think it would make any difference if it was like you were going straight. This is going back and doing it in circles, like you kind of do."
Wheelchair: "The space felt larger with the wheelchair than the free walking experience. I think because when you are free walking, your brain wants to keep a sense of reference to the walls, and it is difficult to let go. Whereas with the wheelchair you trust the person and you totally forget about the real space, so it felt big when I did the wheelchair version."

Comment: (as for the wheelchair) the assumption is not quite right: in fact, she *did* walk very long distances, most of them even going straight.

This brings Mrs. Bibasse to a remark upon a somewhat lacking of 'physicality' as she coins it.

"Like what you could see in the physical phase before being in the VR environment.
...it works really well to add some physical objects. Either for visitors (../.) as to intrigue and motivate people who would pass by and want to do the VR because of these objects. And once you have done the experience and you leave the VR world back to the real world, seeing these objects reconnect you with what was in the digital world. "

Comment: We did have some of these physical objects, like the bench upon which you would sit, and in the first serial of performances a piece of trash was given to you that had to be thrown into a trash bin.

Q: In the wheelchair you had a voice guiding you by microphone and in the SQUARE experience, you had the avatar of a live and motion captured actor. Which of the two did you find the most 'present' to you?
"The most present I would say the wheelchair but the most exciting I would say the SQUARE. I think I liked feeling on my own even with this performer, more freedom to explore this universe, rather than the wheelchair felt like I had a companion whom I was following and chatting with this person but then being less of an explorer myself. "

"And I think the active presence of the performer in SQUARE was the right balance to invite me at some moments to do things on my own, explore, look around and be attracted by what I wanted. (./.) I enjoyed the storytelling very much in the soundtrack of the SQUARE version. And I particularly liked the story moments that came when the performer was not telling me to do things. I would say that it is important to limit what you must be active in. And it either would have to be physically active into something with the performer or I would have to be active with my imagination, listening to the voice telling me some stories about travels and places. "

"The wheelchair version felt a lot less like storytelling. It felt more like a nice walk around, chatting with someone about the surroundings but this part didn't really trigger my imagination."
Comment: the actors performing with the wheelchair were indeed more classic trained actors, using text as a way to tell. When the actors of the SQUARE would do the RIDE, they would use the moving and the driving of the wheelchair as the performative tool.

Q: When you were interacting with the performer, for you what is his role? Did you use him as a guide or as an ally or as a protagonist or someone who changes roles or ...?
"For me he was not a guide but more like a bridge in between two worlds. My favourite part was when he got a shade like the artefacts of the 3D scans of the people and that he could become like one of them. And at some other moments more like me. (../.) So for me that was definitely his role by changing forms. (../.) My favourite thing in VR experiences is when you are not sure about what is real and what isn't. (../.)

For example these moments where there are a lot of small pieces that look like joined in midair (../.) ...then you realize that some of these shapes are actually the joined fragments of the performer, ... you want to avoid these shapes and another time you

want to go through them…to see which one is real and which one is virtual. (../.) For me it's really this thin line in between the reality and the virtuality that is more interesting."
Comment: this is confluent with our own vision on the 'transitional space, the zone in between the real and the virtual.

Q: When you were interacting with the actor, were you always able to see who was the real actor or the animation?
"No, not on time. And for me this is really like liking to be fooled by magic tricks. So, for me it was fine that at some moment I wouldn't know. It actually felt like a connection and a relationship when you would feel like you're being played with. And at some other moments I liked that the reveal was a bit obvious, like kind of a wink. But I think it should not be obvious all of the time. Because then I think you go much further away with your imagination than the possibilities of programming and I think that's nice. It's the same with regular magic."

Q: There was a very strong physical presence of the actor, but you did not have a physical presence of your own. Did that bother you that you did not have a virtual body or hands ?
"No, I like it when it comes for a reason, like when something will happen. But if not, I don't find it necessary. (../.) For me I'm happy to move my hands even if I don't see them in the virtual space. But it would be nice at one moment. It would go well with this bond with the performer. Like when he transforms, you transform too. But I don't think it's necessary in the version I tried."
Comment: this is in line with previous observations (e.g. VR performances Hands-on Hamlet), with an interesting evolution (See further with SIGGRAPH version/
social agents)

Q: Do you feel that it would be interesting to have someone else in the immersion except for you and the performer?
"No, I don't think so. Maybe I'm wrong because I've never tried anything with more than one performer. But I think it would make the space too crowded very quickly. More the mental space than the real space."

Q: Did you feel a sense of intimacy inside the installation?
"More with the wheelchair because she would talk in my ears. A connection yes, but more something playful than something intimate."

Q: Because you mentioned adding more physical objects, the tracked object (the can) was not to your liking?

I didn't like the things to put in the garbage bin. The objects that I mentioned before were more like supporting objects. Like something that would make you comfortable, (../.) like something solid. I didn't like the can because it took me too much focus to understand what to do with it, only to throw it in the garbage while nothing happened. It didn't participate in the storytelling either. Because I did the SQUARE first and then the Wheelchair, at one point I thought with the Wheelchair we would go to the garbage to pick up the can. This would have given me the connection between the two experiences. And up to today I'm still not sure if I put it in the right garbage bin and that still bothers me. So maybe that's a good thing…, that I keep this as a memory of the experience but to me that was unnecessary piling of instructions. Even after that it took

me a few seconds to get back into the rest of the experience. It really took me out of it for a little bit.

Comment: We removed the can in the later days of the exhibition because we thought indeed it was not productive and that it took people out of the immersion.

I could have given the can to the performer and maybe the performer would the drop the can? That would even be more interesting than putting it myself in the garbage.

Comment: at some point, the actor used it very much the way Ms Bibasse suggested, the can would take the immersant to a different space. Every performance is unique, much initiative is left to the actors and they come up with different solutions.

Q: What do you think of the visual nature of the artwork?

I really like it. I think I have a trained eye for 3D scanning and I know what artefacts you get from it, so I could tell what was made as a texture or like decided aesthetics and what came out of the 3D scanning. I found the floors a bit dry compared to the rest.

And about the cube that is the starting point and point of the Wheelchair: it felt like something would happen with it because it didn't match the rest of the aesthetic. I think that if you keep it like that, it has to be part of what happens to the virtual world.

I especially liked the aesthetic treatment of the people. I don't know what to think about the big holes at the beginning. I think there was maybe too many of these and some of them could have some glow of light sources that could make me imagine other spaces being hidden there. I really liked the navigation between the constructed and deconstructed type of spaces. The level of detail was fine, apart from the floors.

It did feel a little bit dry and too concrete in general. Even if you did not want to animate these spaces because of the story, I felt it would add a lot of life I you would add e.g., moving particles and a bit of glow or even in some parts a bit of warm colors.

Interviewer: I respectfully disagree. (See further notice at end of interview)

Did you feel that the spoken text added a lot to the experience?
Yes, for sure, I don't remember all of it but some sentences really got me started on asking myself some questions and thinking about previous moments. Like I remember this question 'If you've been somewhere for more than four days, does it mean that you're leaving a place that have become yours'. Because I travel a lot for work, I am often in that type of situation. So, it got me started to think about after how many days does it becomes a new place to me. And I also liked the question about ...-I don't remember what the exact comparison between translations and airports was- but it got me wondering if it feels different in terms of experience. I think it was really good because it triggered things in my imagination. I wouldn't say that I was told a story but I remember liking some of the open questions that I was asked.

Q: What did you think of the sound design?
It was good. I remember thinking that the trains were not on the platforms and the realisation that I am in a train station that's rather empty because of Covid, so it made

sense that it was not any noisier. I liked (it happened twice) that the real space got a little bit noisy, I liked it that it came in the virtual experience and added a bit of sound.

Q: Except for when you were touching the can, did you stay in the immersion most of the time or were you like constantly going in and out the immersion and searching interactions.

Not really searching, the experience was pretty fluid.

You already said you lost the notion of space; did you also lose a notion of time.

Yes, the only thing that always brings me back to the notion of time is when the headset starts to become painful. Without that, I would definitely lose the notion of time.

Q: The backpack, did you find it cumbersome or was it ok?

It was fine. I liked having something connected to reality.

Q: Did you understand that there were two structures? There is one structure with the train stations with almost no animation in it, except sometimes the actor. And in the other you see animated bodies but there is almost no scans and architecture. Did you understand the relationship between these two layers?

I understood that there were two environments and that one was much more static than the other. But I didn't realize it was two layers.

Interviewer: We wanted to keep this really frozen atmosphere of the stations and then put all the dynamics in a kind of sublevel which was very minimal and bare.

I understood indeed that the train station is very frozen because it tells this specific story during covid-times.

There is one more thing I want to say since you disagreed on what I said about the aesthetics. An anecdote will illustrate this better. We recently visited the natural caves of Han in Wallonia. These underground caves are really long, it is a 45 minute walk. It had been observed that if the same lighting system was used all the way, at one point people would stop looking around. But if small lighting differences were used, this would keep people alert and curious. So that is what I meant: if you keep all the time the same aesthetic this will make you less curious and attentive to details. Even super subtle changes may get your attention.

3.2 SIGGRAPH Version

3.2.1 Setup and context

CREW developed Delirious Departures in such a way that it would be easy to drop-in PRESENT technology when ready, which was achieved in the SIGGRAPH version.

3.2.2 Technical Integration Evaluation

The locomotion component is now functional and can be used to animate the UMANS simulations, for ambient movement of crowds and direct interactions, as is the purpose

of Complex Social Situation Use Case. While the animations are not perfect, they feel natural and responsive, with little foot sliding. The simulation interacts with both the person in VR and the live actor. The interaction is fluid and noticeable but also subtle. There is an amount of inertia, quick movements for example do not create an immediate response and an agent can then pass through the person in VR. However there are proven methods to handle this type of interaction in game engines already, so we don't feel this is pertinent. The goal is not to make an interactive game, but to feel a more real life social space simulation, a criterium which has been achieved. The Cubic Motion gaze system is of particular efficiency to enhance the feeling of presence and interaction with digital humans and can be used to dramatic effect.

3.2.3 End-user evaluation

Questionnaires of the SQUARE variant, presented at SIGGRAPH. This replaces the original Expert User Group. The PRESENT technology was integrated into the EPs at a very late stage. So, we have chosen to replace the professional audience on SIGGRAPH.

SIGGRAPH:
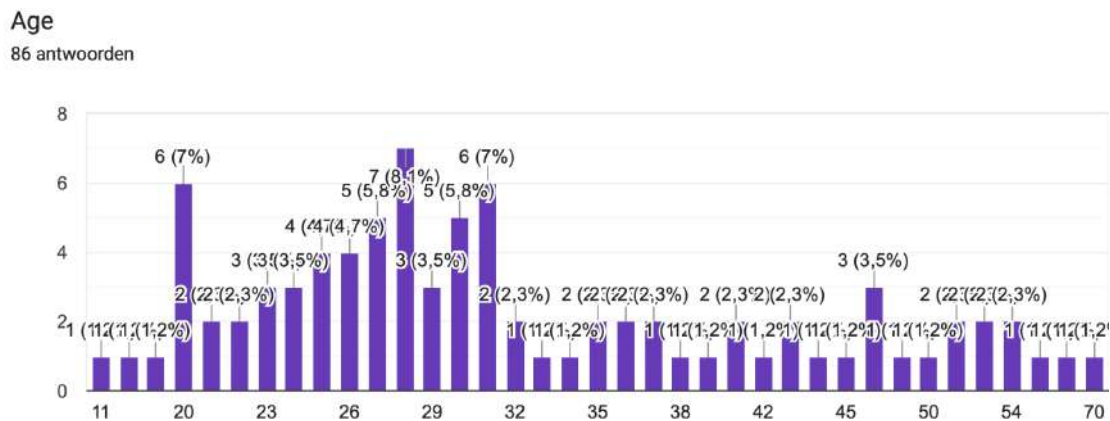
Profile: a mix of interested and educated people: Artists, professors/academics, researchers, (software) engineers, product designers, product directors, (PhD) students (the largest turnout), AI researchers, VR/XR developers, lecturers, composer, animators, video producers, Research scientist, techwriter,...

SEX

87 antwoorden
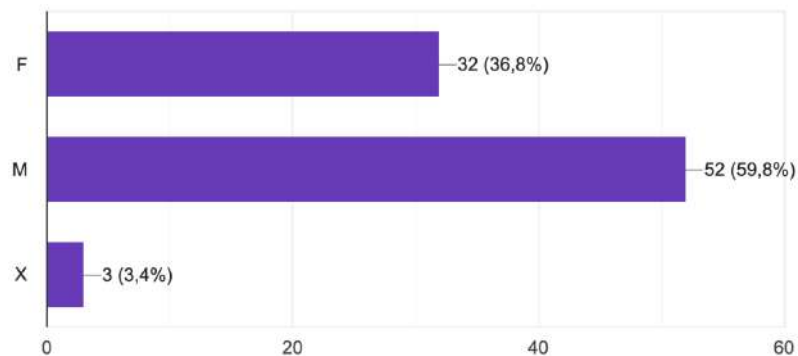
Your experience with VR ?

91 antwoorden
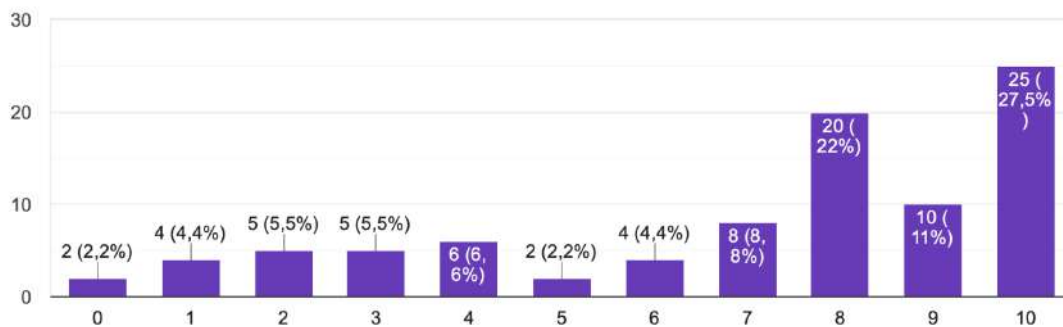
60,5 % rated their experience with VR between 8 and 10 on the scale.

Of these, 59.6 % is male, 34.6 % female and 5.8 % non-binary

In this professional environment at SIGGRAPH, we note that there are no striking differences between age and experience.

Does the concept of this VR experience strikes you as entirely different?

91 antwoorden

Additional remarks to previous question:

"This is one of the very best pieces I have seen. / It was a very strange experience because sometimes I couldn't tell if it was a real person or not. / Different and interesting, good use of scanned environment and li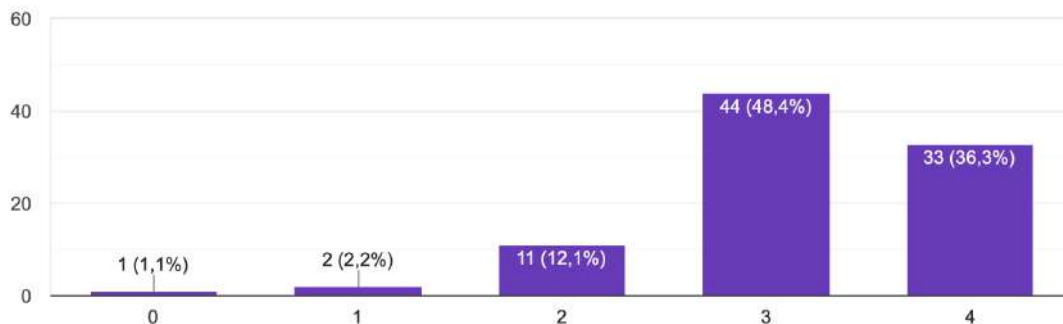ve actor. / Following the real person in VR is a very new and interesting experience. Never experienced anything like this./ Live actor and intelligent agents were very visceral in vr. / Thoroughly enjoyed! I haven't experienced physical interaction in VR before. / I found this experience so much more engaging than other experiences I have tried. I liked the abstraction. / Spectacular! / Artistic vision and interactions are very unique. More projects like this at SIGGRAPH please! / Extra props help with immersion! :) / Love the live acting / I love the integration of real people. / Terrifying and wonderful / Slower and contemplative. Very enjoyable. / Having other people to interact with / Love the idea of separate bodies / ways of interacting with the environment. Like someone with VR and someone with body scan / I've seen some artistic pieces doing similar but not on this concept. / I've done docent VR experiences prior to this yet not with real scan decor sets. / Mix of live actor, physical objects in VR intriguing. / Interactive NPCs were a great touch./ Not entirely different but artistically varied. / Very cool! Wish there's some way to simulate the going down the staircase feeling. / I enjoyed the novel factors like heights or stairs./ I loved the use of performance & real-life interaction. / Because there was an actual person thesis in the experience with you, having a human guide reacting, and a real world changing environment feels amazing. / I have seen similar experiences, but the approach was new to me (voice, aesthetics). / It's focus on intimacy was very unusual but not in a bad way./ Leaves in to disorientation in exciting ways. / Love it, especially walking around (downstairs and balcony). / It was super immersive! I like that I can walk around freely and interactions with actress was very interesting. The sound was really helping. / The use of space is fascinating. / Excellent expression. / It's not theatrelike, the way the end matches physical objects is something I haven't experienced since the early days of VR! / Amazing performance. A good symbiosis of art and VR. / Unique in the fact that it's abstract and doesn't follow a linear path like a VR game. More choice going/not going in a specific direction."

Which component of this environment / production is most interesting to you? Mark 3 of your choices.
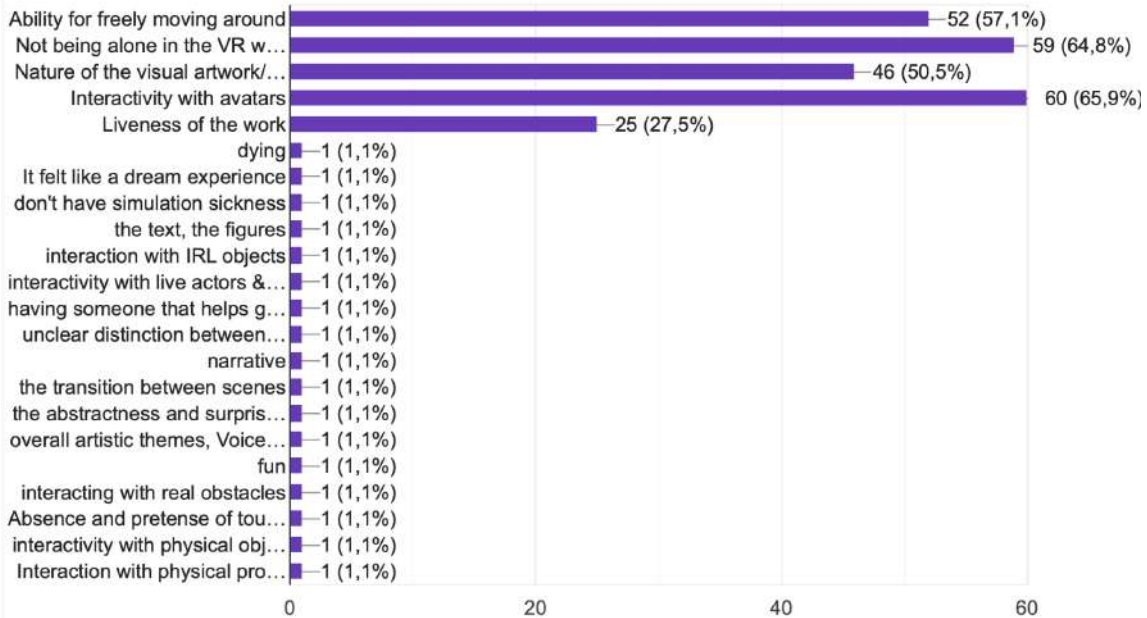
91 antwoorden

Did you at any given moment experience dizziness/uncertainty?

84 antwoorden
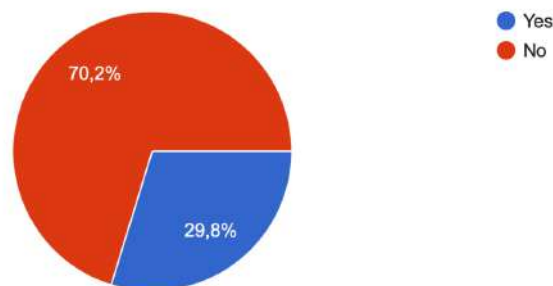
The participants who respond positively refer to the effect of the stairs and the balcony.

20% of the people who indicated that they experienced dizziness or uncertainty clearly stated as an additional comment that they did not experience dizziness but rather uncertainty.

There is no significant link with previous VR experience.
17,9% of people who indicated that they experienced dizziness or uncertainty gave a rating between 0 and 4 on the experience scale earlier.

21,4% of people who indicated that they experienced dizziness or uncertainty gave a rating between 5 and 7 on the experience scale earlier.

60,7 % of people who indicated that they experienced dizziness or uncertainty gave a rating between 8 and 10 on the experience scale earlier.

Did you feel a need to meet other people in the environment or VR world?
84 antwoorden
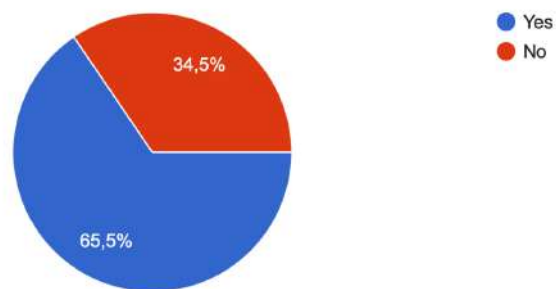
In terms of presence, did you feel yourself well immersed, part of the virtual world?
84 antwoorden
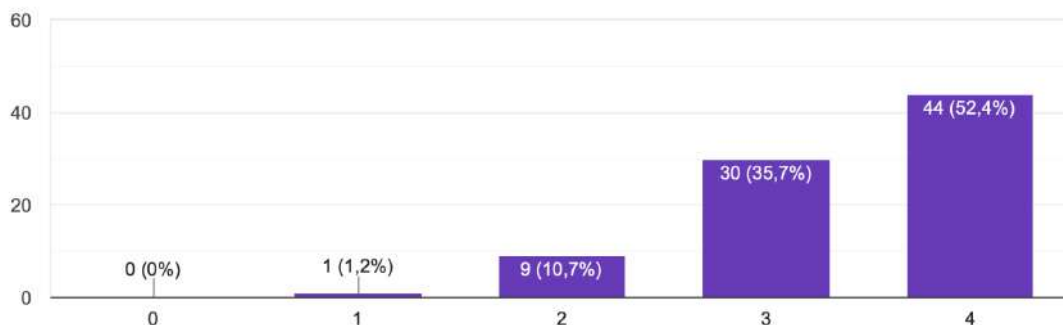
Did you feel like being acknowledged in the virtual world?
83 antwoorden
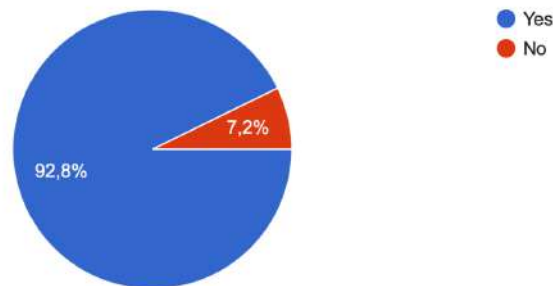
Did you have the feeling of having a body in the virtual?
84 antwoorden
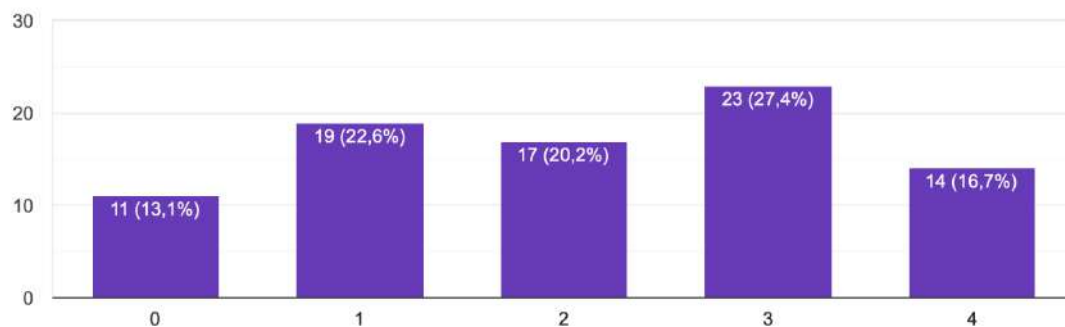
A score of 0 was indicated to be "no feeling of a body". The predominantly positive responses are remarkable, considering the fact that the immersant does not have a virtual body. A visual body representation is therefore not necessary to experience a body.

The social distance created by the NPCs again makes people feel noticed and therefore their perception of their own body is experienced as positive/present.

In a previous VR project of CREW, also with a live motion captured (and dialoguing) actor and animated avatars, the majority answered 'feeling like a ghost', not having a virtual body.

Could you distinguish the different levels of liveness in human representation going from static, to animated loops, to interactive agents, to live performer?

83 antwoorden
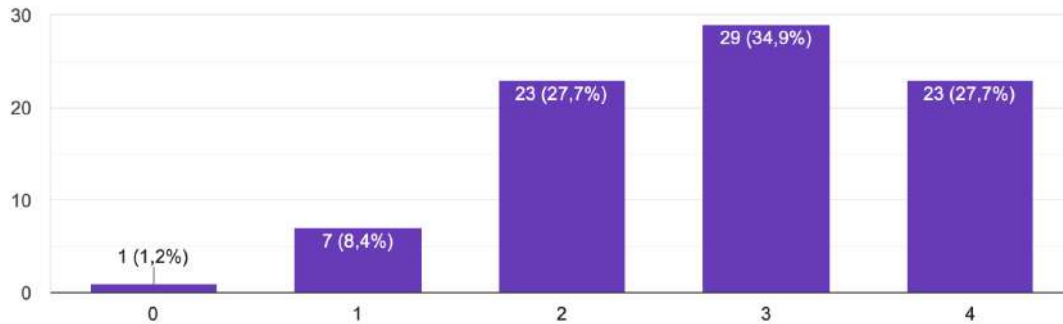
Additional remarks to previous question:

"It was cool to see these blended. That first moment in the train station was really affecting./ I didn't focus on that theoretical/conceptual aspect./ Sometimes depending on the actor./ Some are distinguishable, some are not. I could not definitely tell with a live performer. / I searched for the performer and knew when I found them./ Walking through the fence. / I actually enjoyed the surprise of not knowing which was which./ Real actors' models slid around sometimes. Sometimes I could tell by the nature of their movement (direct interaction)./I felt that unless the actor was going to improvise, the time that seeing what was happening to other people while I waited took away some of the mystery - surprise factor, which are great aspects in the experience./ Could not see my own body so was a little disorientating./ Super cool to have someone show you around./ I could tell the difference especially with a live performer. Interactive agents are le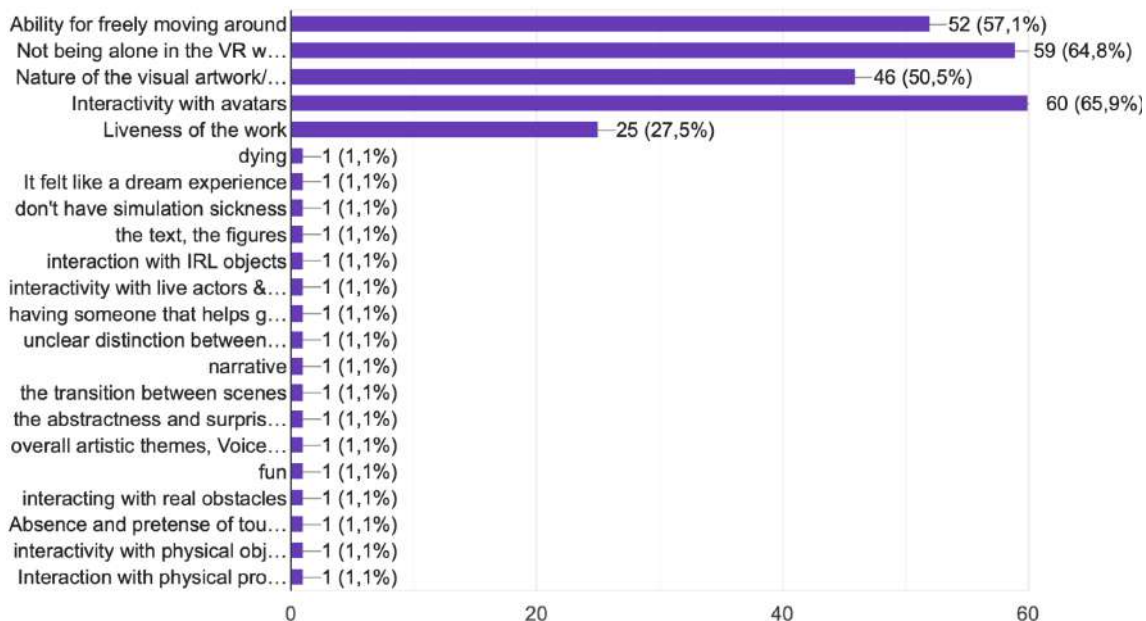ss able to distinguish from non-interactive agents./ Couldn't tell which were interactive agents. Others listed were clear./ I bet it's really remarkable./I saw these levels as artistic and conceptual choices/ It felt isolated because I couldn't interact physically with the environment through touching the special effects in the game./I often wasn't sure, but that made it exciting!/I think I didn't notice the 'interactive' agents./ The interactive agents were very cool. Having the performer guide you through the experience is excellent./ The transitions were very well done./ Sometimes - when something reacted to me, I noticed./ It was hard because the characters were so abstracted./ Very confused when the avatar sat inside me, thought it was a live performer./ The models inside look all the same in the beginning (kind of like a blob) but later near the ending, it was more clear with the wooden character./ It was blurry in a great way./ The live performer was obvious./ The live performers were very cool. I like the animated agents dodging me./ Faces turning are a nice touch./ I noticed the difference between the live actor and the animated loops on some occasions. Crowded sequences made it more difficult to distinguish."

It has to be noted that not every participant is confronted in the same way with the agents. In the corridor scene, if the participant is in a certain location, he can escape interaction with the agents. More in depth feedback from participants would have been

good, because the question is not very precise and self-awareness is not always correct.

Which component of this environment / production is most interesting to you? Mark 3 of your choices.

91 antwoorden

Component	Count
Ability for freely moving around	52 (57,1%)
Not being alone in the VR w…	59 (64,8%)
Nature of the visual artwork/…	46 (50,5%)
Interactivity with avatars	60 (65,9%)
Liveness of the work	25 (27,5%)
dying	1 (1,1%)
It felt like a dream experience	1 (1,1%)
don't have simulation sickness	1 (1,1%)
the text, the figures	1 (1,1%)
interaction with IRL objects	1 (1,1%)
interactivity with live actors &…	1 (1,1%)
having someone that helps g…	1 (1,1%)
unclear distinction between…	1 (1,1%)
narrative	1 (1,1%)
the transition between scenes	1 (1,1%)
the abstractness and surpris…	1 (1,1%)
overall artistic themes, Voice…	1 (1,1%)
fun	1 (1,1%)
interacting with real obstacles	1 (1,1%)
Absence and pretense of tou…	1 (1,1%)
interactivity with physical obj…	1 (1,1%)
Interaction with physical pro…	1 (1,1%)

The feeling of the opportunity is very much present.

3.3 Summary of academic evaluation (Inria)

3.3.1 Creativity & Usability of Interaction Fields technique

As explained above, the Interaction Fields technique was used to scenarize *Delirious Departures* and introduce complex social situations in EPs. In summary, Interaction Fields (IFs) is a technique that allows their users to quickly and intuitively design interactive behaviours for NPC entities. To do this, the user sketches around a source velocity field that will influence each NPC. Several fields can be superimposed allowing complex and varied behaviours. Finally, the sources can be other NPCs characters or people immersed in the scene, allowing to set up complex interaction dynamics.

In the work around Interaction Fields, we had the opportunity to demonstrate the ease of use of our technique. We report below the results of this evaluation. To evaluate the efficacy of IFs and the IF editor for non-expert users, we conducted a user study with 22 users who were familiar with computer animation but not with IFs.

Our goal was to evaluate how easily they could learn to independently sketch IFs to design specific agent interactions. All participants completed the study at the Inria institution with the experimenter present, using two 24-inch screens with 1 GUI window

to draw the fields and 1 simulation window to see the resulting behaviour. They could always update their IF sketch interactively until they were satisfied with the simulation results. All participants started with a short video-guided training session, where they could freely explore our IF tool and interact with the experimenter.

After the introduction phase, participants were asked to sketch IFs for scenarios of increasing complexity.
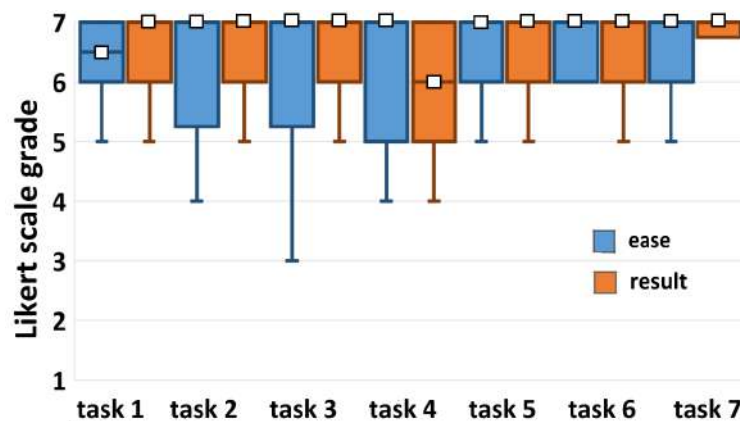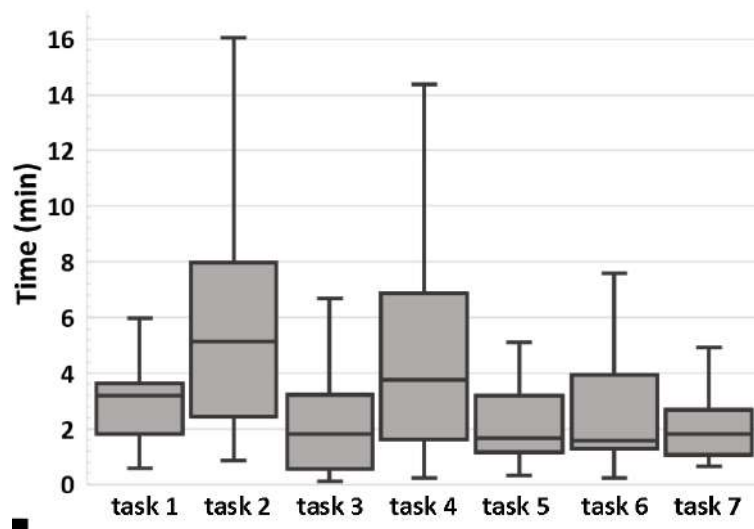
Fig A:

Fig B:

 - Results of the user study, per task. Box plots show medians, interquartile ranges and maximum/minimum values (excluding outliers). Figure A **Top**: user ratings for the ease of design (in blue) and satisfaction with the result (in orange). Figure B, **Bottom**: completion time for each task (in minutes).

Each scenario started with a video example and training tasks covering a specific concept, such as controlling the velocity or creating parametric IFs. Each training was followed by one or more evaluation tasks, where participants were asked to create a given scenario based on a number of high-level instructions. There were seven of these evaluation tasks in total.

The tasks were designed to require a small number of IFs each (e.g., one orientation IF and one velocity IF), and ordered so as to gradually introduce the users to all IF features (e.g., by saving parametric IFs for last). After each evaluation task, participants reported their satisfaction with their result on a 7-point Likert scale using an online form. They also filled out a usability questionnaire based on SUS[1] at the end. The time to complete the study varied between participants but never exceeded 2 hours.

The figures show that the participants found the tool easy to use and were very satisfied with the behaviours they designed. The average completion time per task was between 2 minutes 24 (for the fastest task) and 5 minutes 43 (for the slowest task). The final usability questionnaire showed a high average score of 80.6 percentile, which gives our IF editor a A- rating on the Sauro-Lewis Grading scale[2]. Knowing that the IF editor is a simple interface not yet designed for commercial use, this grade shows a very high usability performance.

Overall, our study suggests that novice users can easily use the IF editor to sketch agent interactions.

4. Soulhacker

This section reports on the evaluation of EP Soulhacker in its different expressions.

'Soulhacker' is an experimental therapeutic environment for dealing with depression thereby using VR immersion as a tool. It was conceived by Dr Georges Otte and neurologists of Brai3n (Ghent, BE) together with CREW. It was worked out during the lockdown period.

W.r.t. PRESENT *Soulhacker* gave us an excellent insight of *emotional presence* from another angle. Soulhacker aims to induce and extract emotion amongst others by using particular virtual environments, assisted by the voice of an actor or therapist. The environments are conceived as visual metaphors of the emotional state of the client; they facilitate dialoguing about them, while at the same time have the client take actions that make him experience change. (In a professional use the sessions need to be seen as part of a wider dialogue of the psychiatrist with his individual patient)

'Psychiatry oriented Soulhacker': during a serial of clinical sessions led by Dr Georges Otte EEGs were being taken before and after the sessions as to measure the level of 'change'. They complement the other evaluation methods of questionnaires, depth and group interviews.

The 'Artistic Soulhacker' allowed us to research/develop the general concept, its tools and its 'large area' use, with real world general, professional and clinical audiences: at an experimental stage with 'Cosmic Flower' at the Coup de Ville art festival 2020 in St

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[1] BROOKE, JOHN. "SUS: a quick and dirty usability scale". Usability Evaluation in Industry 189 (1996) 10

[2] LEWIS, JAMES R and SAURO, JEFF. "Item benchmarks for the system usability scale". Journal of Usability Studies 13.3 (2018) 11

Niklaas Belgium and during public showings at the Designfest-festival 2022 at the S.M.A.K. museum of contemporary art Ghent.

We will also mention tests and experiments that lead up to Soulhacker e.g. Straptrack.

4.1 Artistic Soulhacker

4.1.1 Setup and context

The 'Artistic Soulhacker' version allowed us to research/develop the general concept, its tools and its large area use, with real world audiences.

The first trial with the Soulhacker concept ran under the name of 'Cosmic Flower' (October 2020). The main principles (imagery, voice, interactivity, large area) were assembled and tested with a general audience. Some reacted highly emotionally, certainly the timing (Covid-19 measures had just been relaxed) had a part in it. It made use of a 'large area' aspect that we had tested and performed as 'Straptrack' during the Impact Festival at Hasselt 2019. What became evident during these performances was the heightened level of spontaneity of the immersants. The 3D imagery of Cosmic Flower was slightly adapted for the later Soulhacker (28~30/04/2022). Both presentations were open to regular audiences during Art & Design Festivals.
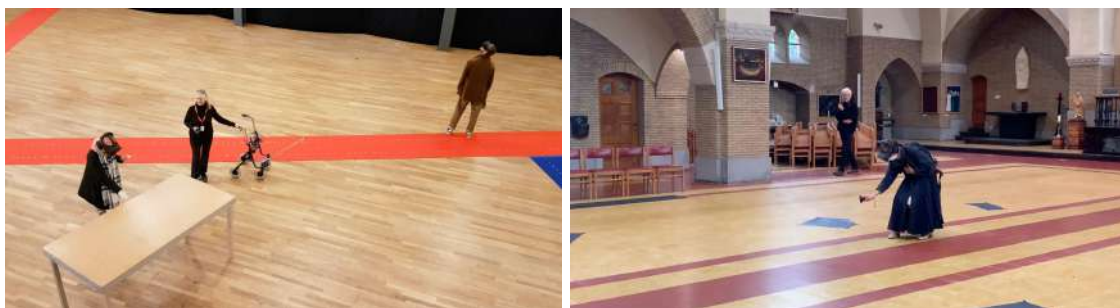
4.1.2 End-user evaluation

Interviews *Soulhacker* S.M.A.K.

The interviewees are remarkable as they were apparently deeply immersed but at the same time very much aware of their own reactions and emotions, and were observing what it did to them. They all noticed the relation of the extended 'free' space to the therapy, they were all emotionally involved and related it easily to depressive people and to their own situation. They all report in detail the emotional effect of the actions.

The interviews are short and can be seen behind this link: https://vimeo.com/733210527

Underneath some meaningful exerts:
Architect:
 "It was very easy actually. Because I was a little bit anxious to work with the joysticks. I don't know how to navigate. But to grab things, it was very easy."

 "I really liked the voice because it was really calming. First, I was a little bit anxious, in the beginning of the experience. Waiting in the hall, because you don't know anything. Should I walk around or should I stay here? The voice kept talking, should I start walk around and listen? Then it got more obvious what I had to do. The voice is really important to immerse you in the space, keep you there. Otherwise your thoughts will come and start questioning things."

The (throwing an planting of -sic) tree was nice, but it was too repetitive after a while. It becomes like a task rather than a internalization of the experience.
 "I would want more different things, maybe not always trees, maybe not always picking up and throwing, maybe freer. Maybe it's hidden a bit and you have more time to walk around. To make more movements and enjoy the things around you. Now you hop and hop but of course this was a very short experience and I really liked it."

Designer:
... I felt this multitude of feelings and I couldn't experience what depressive people experience, which is super difficult obviously, but it reminded me of my sister. She has a depression already for ten years and kept on reminding me of these memories that I have from here. So, this forest is like really quiet, you could feel the solid too it, there was no one there. It was you and you were just looking around and trying to find your path. And there was some much space. The 3D was really well done, you could feel that the space fading away. You felt the depth of your life."

"It was nice to plant these trees, to plant this kind of light, power (../.) I was not having a good day today but when I was planting those trees I felt wow and they were growing bigger and bigger so that was cool."

Q: And the change with the light? How was that?
"I got really scared about the light. Because I had all these creations of my own but when I had that white light, and it was a fading one it was no good. It felt like the white gave me stress. Usually white is a good colour but now I felt like, 'where is my stuff'. I was in this world and suddenly I came down to some other places. I was a bit lost but I liked the transitions."
Comment;: the white light was used as a transition in between two environments

Q: How was the actor, the guide?
"It was perfect. I felt really guided. It was very personal because right on the back of my ear so it was really intimate. One thing that I can also say is that in the last forest, with lighter and greener, I could feel this warmth on my helmet. I felt drifting away because the actor told me to. it was a mix of feelings, a rollercoaster. But it made me feel better today.
I felt the warmth and the actor narrated really nice."

Comment: the warmth he describes was produced by an infrared lamp that we hold at moments.

Q: Was it the volume, the tone?
"The tone for sure. It was not the way of talking but the whisper voice. It kind of controlled my mood in a certain way. I really got into the experience."

Q: So, you liked it?
"Yes, I really did. It was also really personal and perfect because of my sister. Like I felt a little bit more in touch. When I planted the trees, it felt like she was planting them. Metaphorically obviously."

Manager:
"..it was my first time experiencing a full scale immersive theatre therapy type. I found it very much on a whole different level. First of all, having the space to maneuver, but also the visuals that come with that space I found it to be very kind of powerful, very sort of connective. I actually got a little emotional on a certain point, moving through it. I think that for people whom really suffer from depression, this is potentially a great kind of tool for them. Or at the very least, this is a great kind of stepping stone in combining these two kinds of worlds and I'm very excited about the experience itself."

Q: How would you describe the whole experience in a few words?
"Very transformative and also very interpersonal in a way. To me, it feels like there is this kind of personal tapping in to a lot of certain emotions and sensations and feelings. And it feels like this experience does that so well? I imagine that it's not just me but also others who feel that way and to be complete honest, I felt extremely relaxed and very happy by the end of the experience so I think of whatever the team is doing, they are doing it right.
I look forward to seeing more projects like this come to our direction and to get a chance to experience. Especially in the collaborative role."

Questionnaires: Comparison of results Cosmic Flower 03/10/2020 with survey Soulhacker S.M.A.K. 28~30/04/2022.

https://docs.google.com/document/d/11fmrtwrH-Wso-X7M9z4Ie-4AbsD1K5Md8M5Wzw2rT3s/edit

Cosmic Flower questionnaire: 19 of the 27 immersants took part in the survey.
Soulhacker S.M.A.K. questionnaire: 40 of the 40 immersants took part in the survey.

Gender of the Respondents:
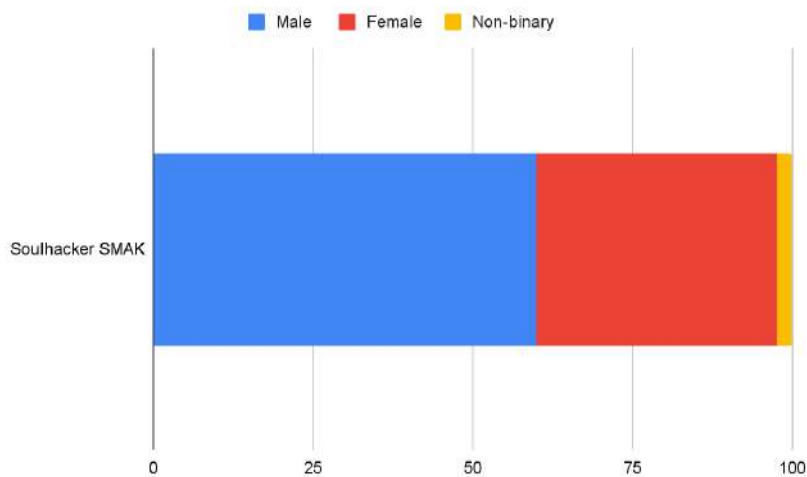
Ages for Soulhacker S.M.A.K.:
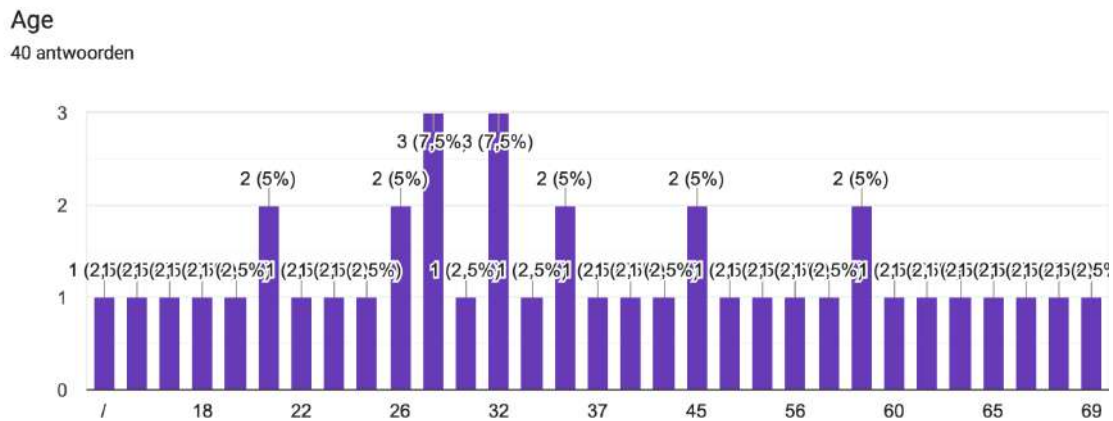
Profile: both have a mix of interested and educated people: Cosmic Flower:

HR Consultant, IT project manager, medical doctor, curator, psychologist, notary, child caretaker, teacher-artist, photographer, teacher, developer, researcher, physiotherapist , Soulhacker S.M.A.K. had a high percentage of students (12,5%), architects (7,5%), creatives (product designer, VR creator, researchers, developers,engineer, consultants, and educational and medical professions :teacher, psychotherapist, strategist, yoga therapist,...

Questions:
Did you ever participate in a VR experience?
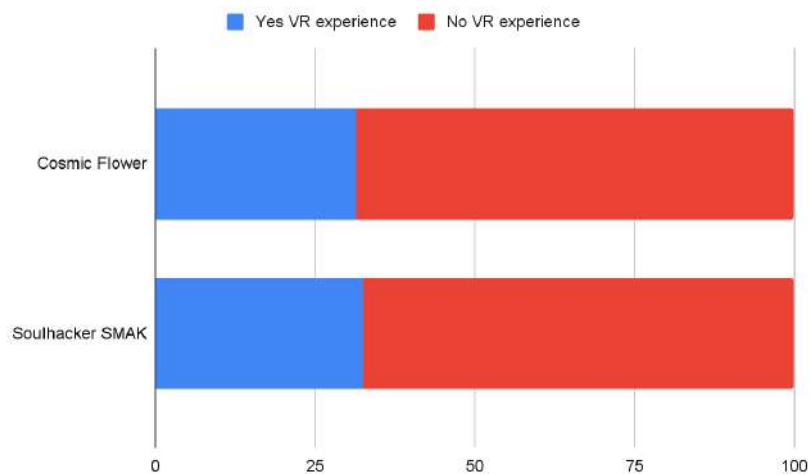
Generally speaking the number of people who have experience with VR has significantly grown over the years, but still appear to be a minority. People with more experience tend to be younger.

Of those who answered 'YES experience' the medium age is 34.2 years old
Yes has 4 younger than 20 years old, 2 elder than 60 years old

Of those who answered NO experience the medium age is 46.5 years old
No has 0 younger than 20 years old, 3 elder than 60 years old.

If you did, does the concept of this VR experience strikes you as entirely different?
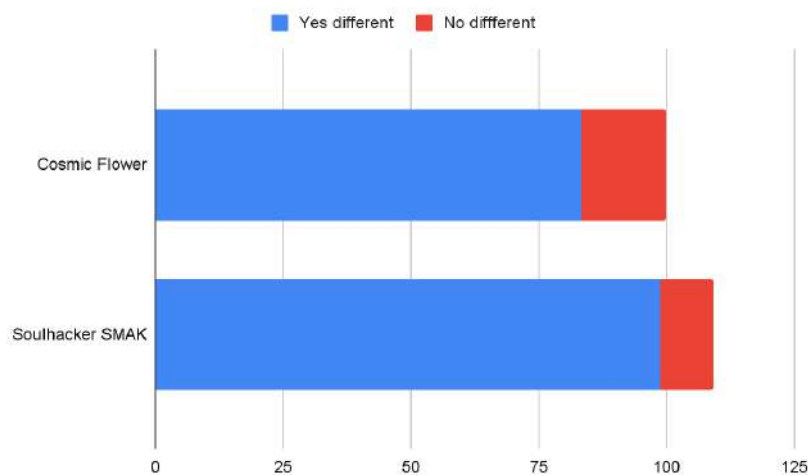
Some people notice as differences:
 -'The experience of walking around, the "sense of discovery.'
-'The part with live voice guidance is different and adds an extra dimension. Especially when the voice responds directly to something you do/see. I would find it interesting if the voice would ask you to bring a personal memory to mind and then throw it away.
-'Active participation / engagement (medic)
-Because I pulled it out of a game context it brought positivity to my brain.
-"Using VR is ideal to create empathy for situation" (researcher)

People who answered 'no' are into gaming:
- *'visually it was similar, mentally it was different.*
- *'You feel transported into another world in every VR experience, but the concept and goals are different'.*

Which components of this environment / production is most interesting to you? Mark 3 of your choices
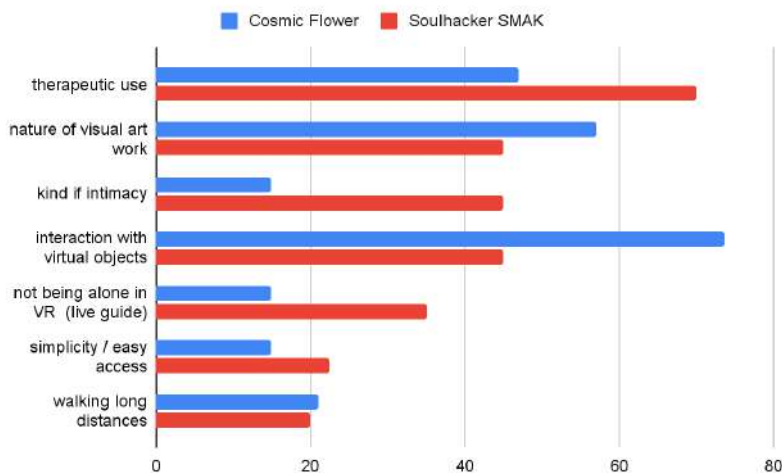
Interaction with the virtual objects was more popular in Cosmic Flower probably because of the more outspoken physical engagement (large area), which may explain also the lower ranking of intimacy, and less concentration of the fact of not being alone

S.M.A.K.: A kind of intimacy: 45 %
        marked this choice: in relation to sex (50/50%) ,
        w.r.t. age: the bulk of intimacy yes answers are between 20 and 50 years old .
Of the people who marked this choice 70,7 % had a VR experience before, vs VR experience no 29%
                        Presence: for these respondents all except one experience is high,
                        Actor/guide: as expected this connection is high (88%)
                                psychologist

Walking long distances: People who have experienced VR before appreciate this significantly more (87,5%)

Did you at any given moment experience dizziness/uncertainty?
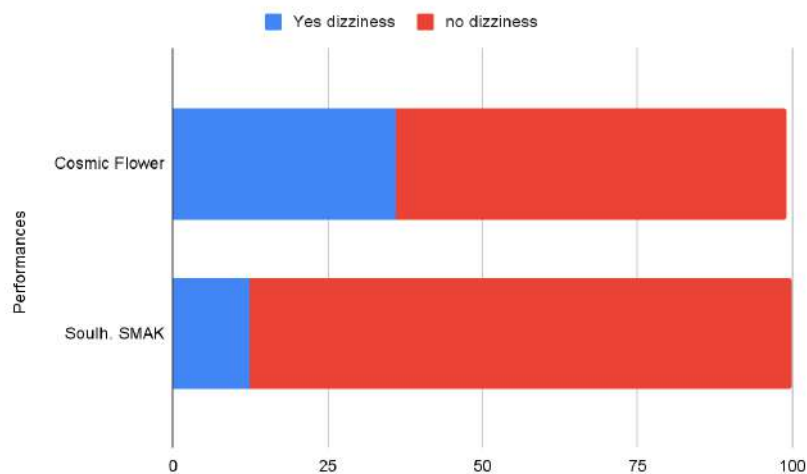
In Cosmic Flower 47% indicated feelings of uncertainty related to the mirrored environment and its *depth*, 2 people declared thereby suffering from height anxiety
For Soulhacker S.M.A.K. we took out types of images that could provoke height anxiety.
 (of the 'Yes dizziness'' answers 37,5 % indicate having had no previous VR experience so there is no significant link to 'previous VR experience'.)

Did you feel a need to meet other people in the environment of the VR world?
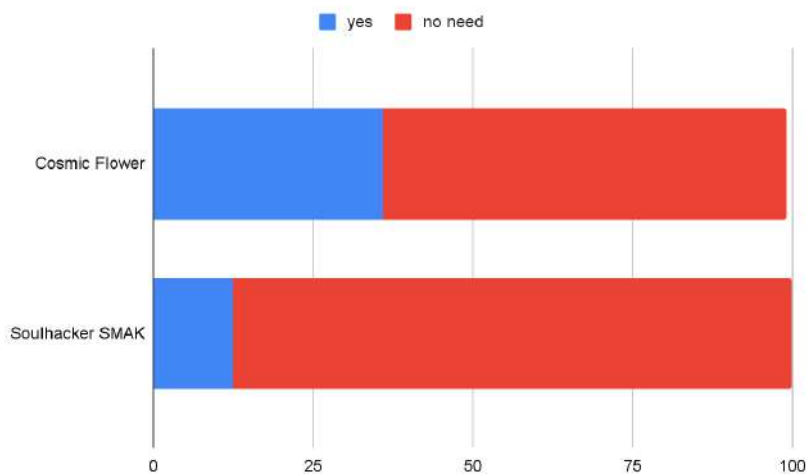
Since the approach is therapy-based and highly personal, even intimate, this may explain the lack of need for other people around (in contrast to the results of Delirious Departures)

Based upon your actual experience, do you feel this technology could be used for having therapeutic encounters with people?
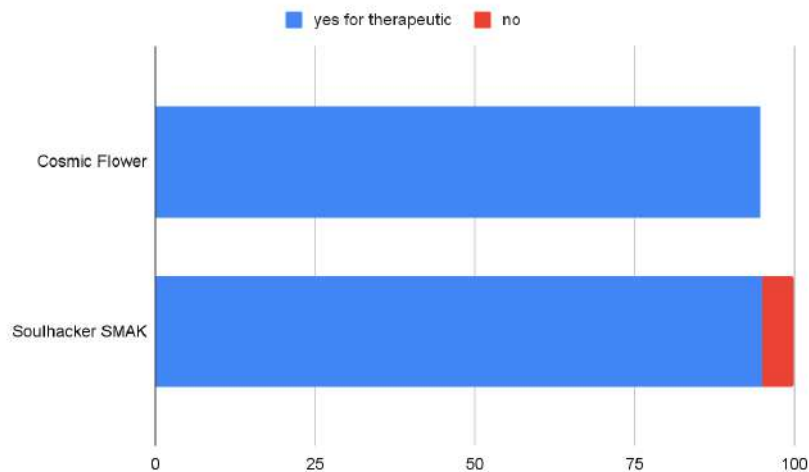
Did you feel a strong presence, as being part of the virtual world?
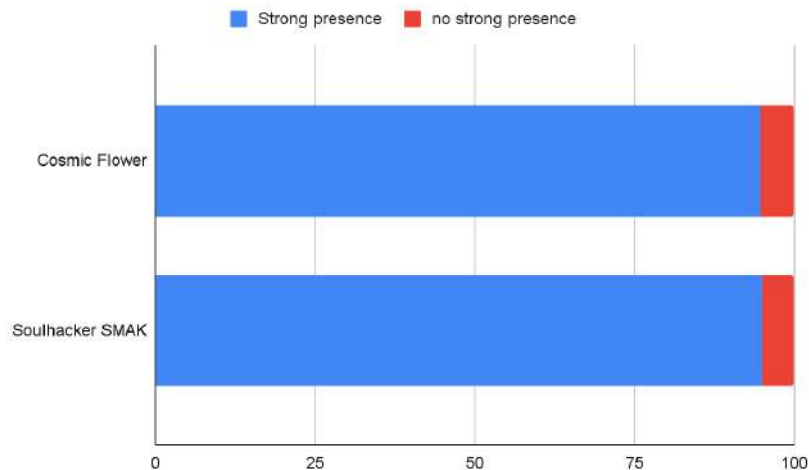
About the 'no's': clearly the notion of 'presence' was not known by everybody and should have been explained by us, since the same people indicate in other comments an extreme notion of presence.

Which moment do you recall most? Which was the most intense?

The majority describe 'changes' or transformative experiences as the most intense:
'...entering the wood, planting the trees, the sphere changing as you do something, moving to another environment,.., stepping through the wall,...'

Clearly planting of the 'the trees' with its creative process is best remembered:
In their comments people associate the act with *'creation, 'life', light-shadow,* :
-*'Feeling a tree grow, contrast light-shadow', 'The planting of trees, this fast gratitude of planting something with so much light and power',*
Some see it as the making of a forest:
-*''The creation process and the result, other factors such as the rain and warmth. The illusion of a tropical forest.''*

-'Walking on the hills prior to starting my own forest & a bit later noticing that one of my trees was incomplete', 'De eerste bal, het eerste zaadje van mijn bos',

Some refer to emotional states*: 'because of my own depression', '..emotion of the dark,*
-'The dark was very intense. The immersion was huge…'
-"When I left falling the first sphere I felt an intense feeling of stress'

Sensorial perception*: 'Standing inside a tree - a feeling of being held/enclosed - But my skin wanted to feel it too.' 'The warmth of the sun', "The creation process and the result, other factors such as the rain and warmth. The illusion of a tropical forest." "The end, the environment & sound had a clear influence on my mood. Along with the voice that guided me in a calm manner."*

The rain was not appreciated by everybody.

The beginning when I cross the wall and I am free to explore the care environment around me, it gave me a sense of ease and excitement.

Some mention the sitting, that is: after the 'creation': *'Sitting in the chair and experience the different reality'*

Can you describe how you felt in the first scene in the wood?

The overwhelming majority of the immersants empathises with the metaphor of the dark forest for a depressed person and indicate emotional, sad and dark feeling

-'I felt the darkness and a sad feeling.' 'Very dark, alone, depressed even'

-'Dark - no colour, Emotional.' 'I nearly cried, feeling connected to my own well of sadness, 'Felt quite lost, distracted, Alone,…'.

-'kind of an ultimate escape (isn't this dangerous?)'. (researcher)

-'dark & creepy, even horror touch (developer)

-'beetje verdwalend. Indrukwekkend, nadien rustgevend (curator)-

'I entered a dream, bit scary

-'insecure

-'lost, no perspective, oppressive'   (psychologe)

'The dark emotions are less explicit in Cosmic Flowers: apparently some are rather impressed by the visual and graphical aspect of the 3D environment.

-impressive feeling, calming (physiotherapist*)- 'vol I felt like really walking a forest*

-'peaceful, calming'

-'enchanting, idyllic'

Others indicate a more distanced Meditative or curious attitude:

'Mostly curious about the environment. A little bleak in contrast with the waiting room', 'Like Alice in Wonderland',

-'At peace, Curious, Quiet and intrigued', 'To discover,'

-'I felt good, Comfortable/ Lighting was very realistic and it felt like a real place I could settle, no need to explore too much,…'.

Can you describe how you felt when working with the trees?
The comments all indicate positive creative feelings of joy, magic, 'like child', fulfilment , empowerment,
-*I felt empowered. I had a chance to direct and to make something out of this dark situation.*
Many indicate that they wanted to achieve in making a forest
-*'Geeft me een gevoel van zelf iets moois te creëren door de bomen te planten: ik wilde er zo een nieuw bos te creëren.'*
Some indicate the aesthetic joy:
 -*"colours make me happy, joyful. I am very sensitive to colours. I have a moodboard myself. The colours were exceptionally beautiful, they have a profound effect on my mood. I feel beauty here. Ik slaak een diepe zucht van opluchting, ontspanning."*-*'Visually outstanding, positive feeling of creating something yourself'* (teacher/artist)
Cosmic:
-*'Creative feeling/fascination. Feeling of being able to create something beautiful. Leaves a very relaxed feeling'.*   (physiotherapist)
-*'Planting the trees could give endorphine & happiness in creating 'things".* (researcher)
-*'Gives feelings of power & joy. Excitement when finding a ball, fun when throwing. But the trees were unpredictable, missed possibility to interact with them. '* (developer)
-*'Productief, taking the burden from my shoulders, something to keep busy'.* (psychologist)
Some more technically notice that
'doing things participating in a VR space augments 'feeling part'. (curator)-funny and easy
-*'interaction, influencing own environment'* (IT project manager)
Several people showed strong emotions. A   person that was in tears after the performance: *"For an emo chicken like me, this was a very intense experience. Too short. It is the emotional kind of world (esp. the forest) that makes me feel deeply happy. Wanted to stay there. Emotional maybe because of the inner child / the beauty of it /the contrast with the harsh real world. Merci merci! If ever I end up in a psychiatric hospital this is the therapy that I want.*
-*Beautiful experience, I was thoroughly moved!*

How would you, in a few words, describe your connection with the actor/guide?
The actor clearly has been appreciated in his approach. Nearly all the immersants judge him as close, quiet, helpful, and reassuring:

- Good and close. I think it is because he used my name -Safe and helpful -Very peaceful voice and good guidance -Comfortable -Feeling of not being alone -Really good, I felt a strong sense of security and trust -The relaxing voice made me calm. I entirely trusted my guide. 'Sense of empathy', '-Trustful', 'I felt comfortable and guided. His voice was reassuring. I felt like I could trust him', 'He had a soft calming voice', 'At first the actor feels like a guide, later it becomes more of a companion. I feel that a longer experience would deepen the connection', - 'Nice, the feeling that you're not alone in that immersive wood', 'Trust. -Ambient noise also helped ground me in the real space,' 'Really personal, I enjoy his voice guiding me', 'Rather strong' - 'A calming voice in the back of your mind that guiding but, also, making you comfortable', 'a very agreeable voice, clear and soft. That puts you at ease', - 'I really enjoyed it, the voice was very calming and grounding. Instructions were clear. I liked having a "trip guide" which immersed me way more',

'Nice person, warm personality. The interaction was however a bit limited. Kind of one way (not too much talking, but <u>doing</u> instead, but that was not disturbing)' 'A reassuring voice', 'Intimate, like someone very near to me', 'warm, happy, intimate', 'a calming voice that you can rely on.' 'I trusted him completely but could autonomously make decisions. I would have liked to start a conversation with him, but he did not react to that.' / 'immediate trust'

A minority sees it as a bit more distant. *-More focused on the world itself. But still added a lot to the overall experience.', 'He is at a proper distance.', 'The guidance was quite neutral.'. -At the background, 'rather technical but comforting'.*

How do you see the role of Mixed Reality technologies in the future art?
(only S.M.A.K.)
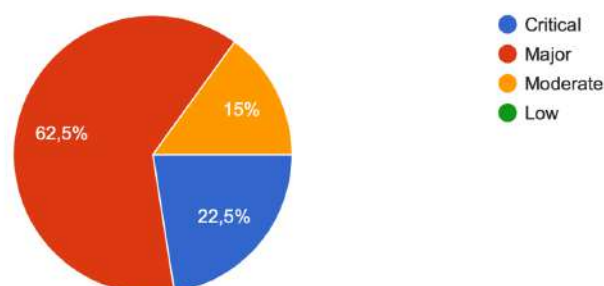
4.2 Psychiatry oriented Soulhacker

4.2.1 Setup and context

Soulhacker was set-up in a rented location for clinical trials. The therapist accompanies the patient through voice. EEG recordings are made before and after the experience. Additional data is collected in the form of heart rate recordings with a smart watch,

voice analysis with the UAu SSI framework and logging of the spatial data of head and hands, linked to different events in the virtual world eg. a tree being planted, transition to a different virtual environment etc.

Procedure clinical test in Ghent by Dr. Otte and CREW team:

1. The patient is first welcomed by the neuropsychiatrist.
2. He shows them the room, after which he takes the patient aside to have a short intake interview and then take the EEG. The EEG scalp electrodes remain attached to the patients, in order to enable an immediate 2nd EEG after the VR experience.
3. After the first EEG, the neuropsychiatrist guides the client to the 'stage' (1), a technician equips the client with a VR backpack, goggles, headphones and watch.
4. The client is immersed and guided by the neuropsychiatrist with audio and direction (3).
5. At the end of the experience, the patient is asked to sit down and the technician strips them of all computers and technology.
6. The neuropsychiatrist takes the concluding EEG to conclude the study. (4)
7. The neuropsychiatrist also takes a written test of emotional valence & arousal
8. Analysis of the data (Columbia University NY)

4.2.2 Technical Integration Evaluation

While doing the research for the biometrics, it was quickly found that it is not possible to rely on biometrics in a realtime fashion. Signal to noise ratios are rather weak. Outliers can be removed by filtering, but this increases the time window, making it less realtime, which was a requirement for the therapeutic aspect, which relies on steady vocal expression, combined with strong transients in the virtual space. Similarly, a VR HMD precludes the use of a webcam, which is required to get solid results from the SSI pipeline. EEG is not suited for real time control because of the data analysis requirements and noise induced by movement.

More interesting is post-factum analysis of the data, combined with questionnaires and interviews, which help to sketch a more complete image of how the patient has experienced the session.

4.2.3 End-user evaluation

The clinical evaluation thus comprises:

- Questionnaire comprising emotional valence and arousal before and after the session

- Written survey after 3 months to evaluate long term results
- Statistical analysis of the EEG data. These will indicate the relation and (dis)harmony of the default, the salience, the execution and depression networks. It is a blind analysis executed at Columbia University NY. Results of the study are expected at the beginning of September.
- Heartbeat data were supplementary and also provided a safety control. The variability, the correlation to emotion is still difficult to differentiate and to analyze if combined with bodily movement.
- The recognition tool of UAU did not produce stable results as the VR headset does not allow facial recognition. (the tool is in its current state better fit for a screen-based application like Adam, see further)

Dr. Otte compared at the actual stage the arousal/valence/control scores of 27 patients before and after the experience.
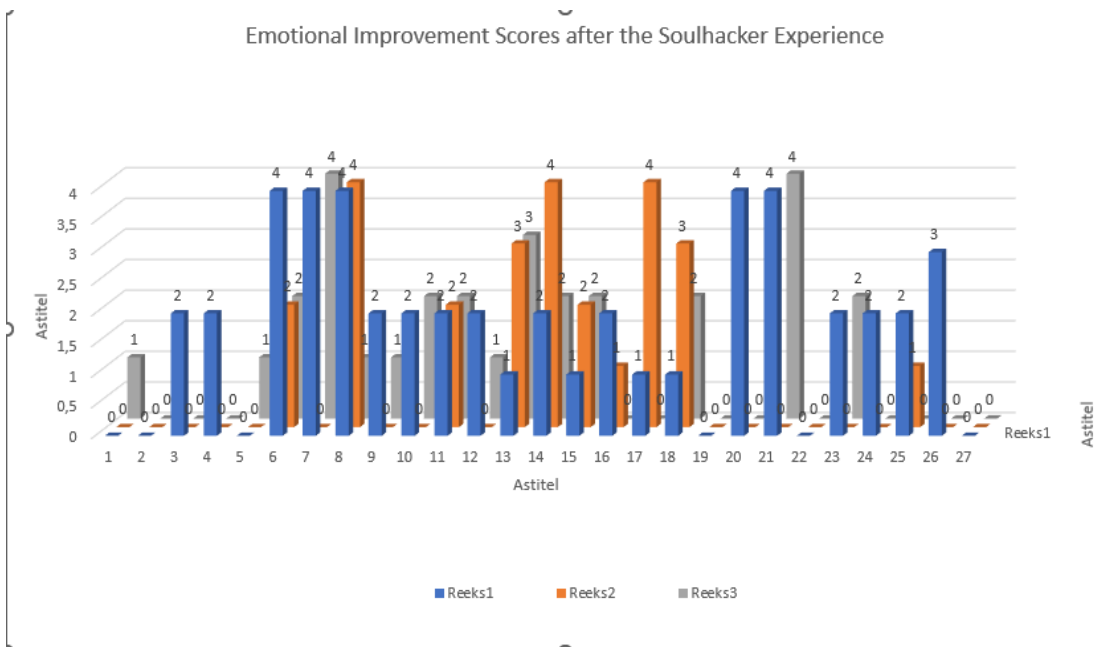
These all showed a significant positive evolution. Four patients had a neutral score, so in total we can conclude preemptively that there so far was zero negative effect of the experience.

Dr. Otte was even surprised by the clearly positive effects. The data seem to confirm the results of the evaluation we had during the S.M.A.K. performances, and particularly with the in-depth interviews where immersants literally states that they felt better after the performance, a result that we considered remarkable since this was a regular audience in a museum context.

The final results of the analysis/study will affect the continuation and eventual changes.

Also, a new round of tests will test the effect of the practice of the 'large area practice of the therapy.

Dr.Otte will publish the results of the aforementioned tests in a medical journal: *'Soulhacker : evaluation by EEG of the therapeutic impact in patients with mild depression and anxiety of a V.R embedded, guided metaphoric exploration.'*

In order to conduct the tests on patients, a permission was granted by the ethical commission , see annex

## 5. Adam

5.1 Setup and context

CREW has proposed the Adam EP and UC, which is an "emotional mirror set-up". The avatar (displayed on a monitor) will imitate the user's perceived emotional state. This creates a loop whereby the user tries to steer the avatar's reaction. It was speculated this to be an application with affective computing that could be of benefit to society, of use to autism patients in order to teach them to understand, process and express facial emotional expressions.

There are quite some VR- and screen-based applications for treating autism on the market. They mostly seem oriented towards helping a client to understand a particular context, like a social situation or like the event of crossing a street. We did not find an application on the market that concentrates on the facial expression of emotion. This lacking may be due to the needed level of realism/rigging and of the integration with voice and emotion, both which are a major achievement of the PRESENT research of FS, CM and UAU.

Adam uses the Framestore Hi-res Gareth, with the CM facial motion generator driven by UAu SSI framework with voice and webcam input. Additionally a set-up is provided in which a therapist can control the valence-arousal vector space with an XY-joystick controller.

We have presented three different uses of Adam/Gareth:

1. Mirroring by Gareth of the facial expression of the participant by using facial recognition)
2. Mirroring by Gareth of the emotional expression of the participant by using voice and facial recognition of the participant
3. Gamepad application that allows to generate different expressions of Gareth (without sound)
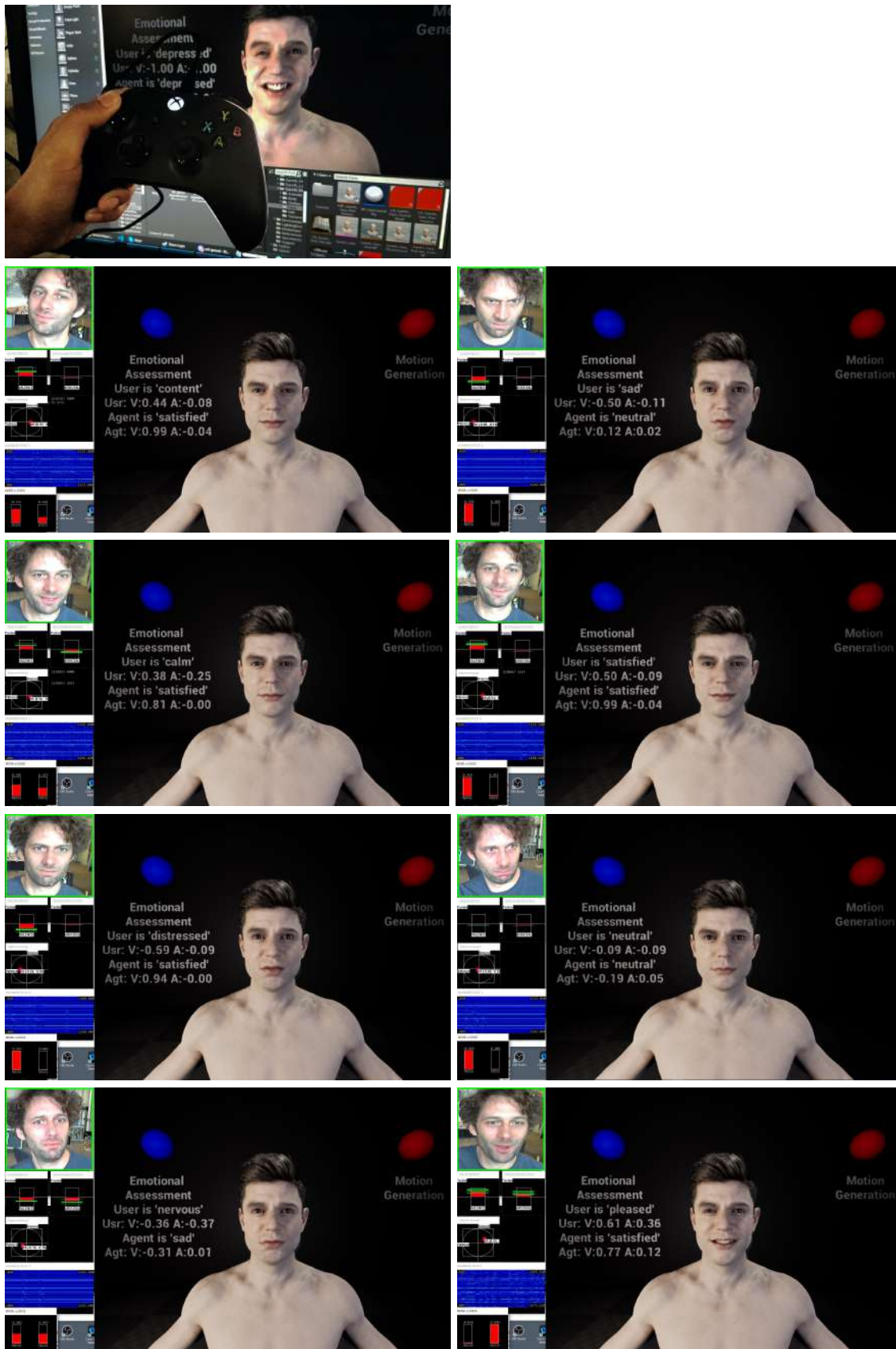
5.2 Technical Integration Evaluation

Adam integrates several components from PRESENT:

- UAu's SSI
- FS's high resolution Gareth
- CM's Gaze

UAu's SSI component was used to determine a participant's emotional state by analysing their voice and face using a separate standalone program developed by UAu. This data came in the form of *Valence* and *Arousal*, both floating numbers between -1.0 and 1.0. Using these values and an emotional map, SSI also gave a textual human-friendly description of the participant's emotional state, such as 'distressed' or 'content'. These three values provided a clear starting point to utilise the data.

Framestore provided an integration of SSI with the Reference Implementation in UE4. The data values from SSI were sent to UE4 via a local UDP data link. These data values could then be accessed and used by the MidRes and HiRes Gareth assets who had the necessary facial animation bindings implemented too. Unfortunately at the time CM's Gaze components were not implemented with the HiRes Gareth asset and were only present with the MidRes version.

This well-structured pipeline meant that development for Adam went smoothly, with only some minor scene tweaks and a different display for values. While first proposed as a simple debug solution, we quickly came to realise that using a gamepad to puppeteer Gareth's emotional expressions could possibly prove to be a useful tool as well for therapists.

5.3 End-user evaluation

An Expert User Group of medical health professionals evaluated Adam. They used the three different applications themselves. We preferred not to work with their patients since the approval of the ethical commission (for Soulhacker) took up so much time . The Psysense centre for autism suggested however to have some of their volunteers and/or collaborators that have an autism background evaluate it. We plan to do this in September.

- Demo and group discussion with psychologists/psychotherapists Els Ronsse and Valerie Verstraete of Psysense
- Demo and Interview with Dr Otte
- Material of Adam at Vimeo: https://vimeo.com/745008277/12cc2b6723

5.3.1 Demo and group discussion with psychologists/psychotherapists of Psysense Els Ronsse and Valerie Verstraete 18/07/2022

Comments during the demonstration and use of the application, by both experts:

- Concerning the set up: when sitting in front of the screen, the client ideally should see his own facial expression (video) together with the answering expression of Gareth and with a text that indicates the nature of the emotion. The other data that are actually shown on the screen should be brought to a minimum in order to enhance focus and concentration. We proposed to change the lay-out as indicated (right image) and keep the other data on a separate screen for the therapist
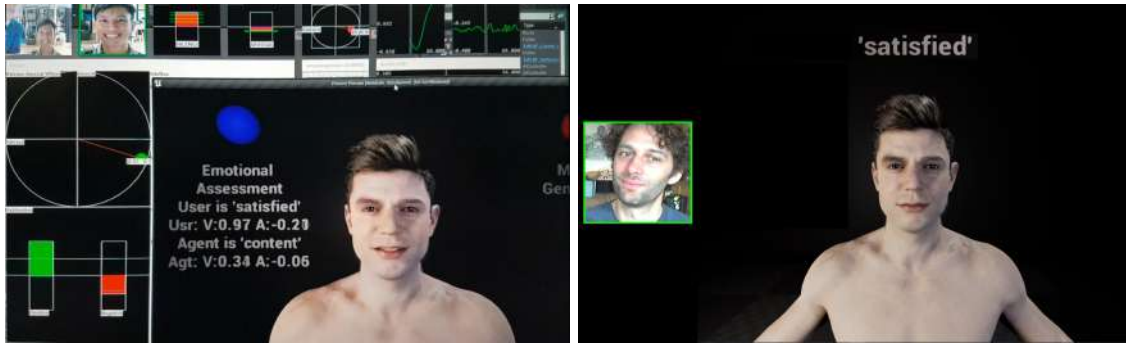
- Concerning the different different ways of using the application: for the experts each of them shows clear advantages and all fit in the logic of a gradual building up of the expressive abilities of the autistic participant:
- The tool for mirroring by Gareth of the facial expression of the participant by using facial recognition is considered by the experts as ideal for the training of basic emotions: many autistic patients are not aware of their facial muscles that allow expression of nuanced emotions. Installing an awareness of the diversity of expressions -all the nuances in between primal emotions like joy and anger- is considered a very important step.
- The tool for mirroring by Gareth of the emotional expression of the participant by using voice and facial recognition of the participant: we noticed that participants started testing the reactions of Gareth during lively sessions and were at length talking to him, that became very engaging when adding voice. Conversely we could say that the participants were rather training their own expression in order to get a certain result from Gareth. The experts explained that as a next stage emotional nuances could be taught well with this tool. E.g. for a workshop: *'which emotions do you have, and how to recognize this in yourself, can you now recognize them in others?'*
- The tool of a gamepad application that allows to create different expressions of Gareth (without sound): this would work well with children. E.g. for a workshop: *'what expression do I like, can I do that myself? How do I think that mama or papa looks?'* Or: *'show 10 different expressions and tell us which you have seen /recognized?'*
- Concerning speech: it is not necessary to have Gareth speak. On the contrary: for an autistic person the amount of information to be processed is already problematic, there is a real risk that they would concentrate on the speech, and not on the facial expression.

Quality of the image: the experts highly appreciate its realism. Realism is important; cartoonish representations would not work well. Improvements could be made: the frontal nudity of the body is strange, some expressions seem not to work or are somewhat awkward (angriness e.g.), Gareth seems to keep his teeth together, and is rather symmetrical in his expression. We could show the experts in answer to these remarks a new version of Gareth, in which the expressions will be more natural, for a main part because of the nodding of the head, more flexible use of the jaw and casual clothing, ... Implementing these little changes would immediately increase the range of expressions. A good example is the illustration underneath right, that shows a seductive type of smile, and expression that was not possible with the first version.
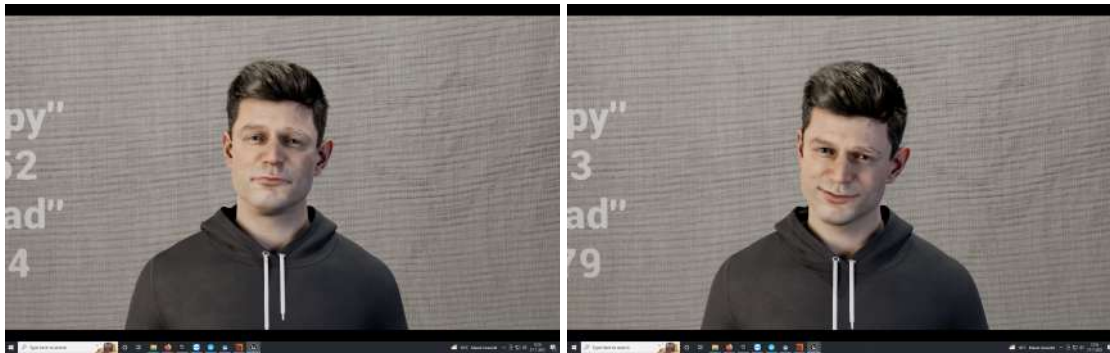
The experts also see as advantages: the image is not threatening or intimidating (in contrast to a training with a real person), it has endless possibility of (self)training (in contrast to working with pictograms a.o.), it would be useful for the client to be able to practise this at home or online.

It is not necessary to work with stories or narratives

5.3.2 Demo and group discussion with neuropsychiatrist Dr Otte 14/07/2022 with the team of CREW

The discussion was mostly on trying out/evaluating the characteristics of the actual version of Adam/Gareth, in particular on the tool for mirroring by Gareth of the emotional expression of the participant by using voice and facial recognition of the participant.

Dr Otte was very positive about the general concept, and spent considerable time dialoguing with, and trying out Gareth. Although the expressed emotions for the moment lack 'calibration', the act in itself of trying to provoke expressive emotions is already a useful exercise.

- He suggests to have the values reflected in an existing transition chart:
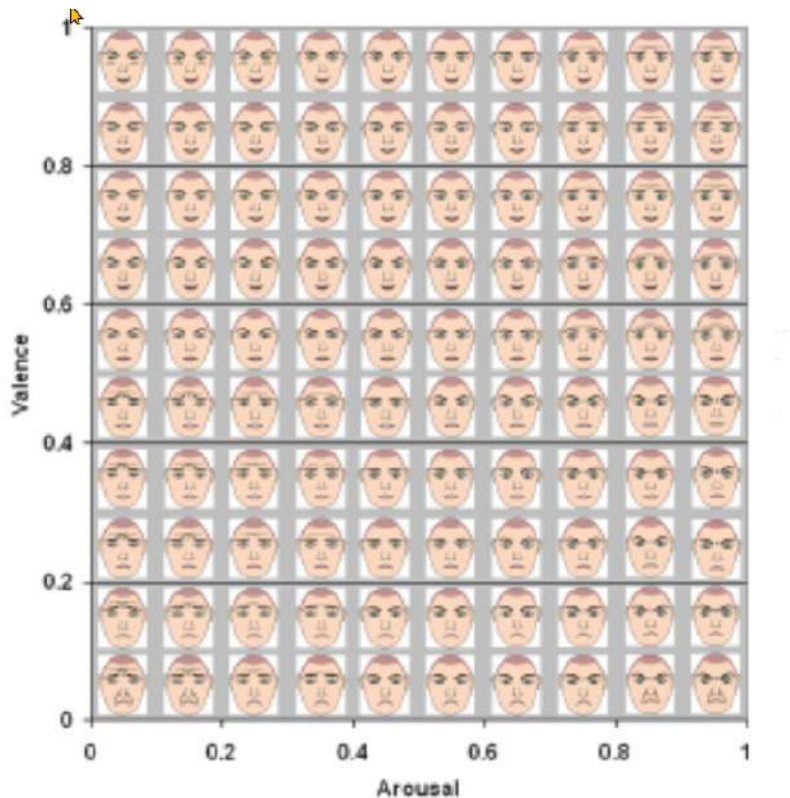
- It would be useful if the therapist has a choice out of several emotions. E.g. a multiple choice exercise: Therapist chooses a certain Arousal vs Valence value, the user/patient does not get this information. *'What is the emotion that you see expressed here?'*
- For installing a 'natural' link to Gareth Dr. Otte suggests that Gareth would not be at a standstill when not being spoken to, but would keep busy with little movements and tics.
- Another possibility that came up was introducing a 'cycle', with Gareth being taking notice of you, kind of welcoming and curious to you, working with you, pausing, leaving you when you are idling…
- Also, would it not be better that Gareth has some unpredictable tics or movements, as to make him more natural and give him more personality.
- As autistic persons have a problem with making eye contact it would be good to integrate gaze.
- On the quality of the expressions:
- It is yet impossible to get Gareth angry, even with a Valence of max -1 arousal max 1. Gareth thereby does not use the eyebrows or show his teeth, major signs of angryness. With Arousal 0 and Valence 1 he should be smiling, but he doesn't. With Arousal _1 and Valence 0.6 he should look positive, but on the contrary looks insecure.
- In the negative values there is less differentiation. The coordinate or reference system seems not working well, this might be a matter of calibration (this were the first tests). At the same Dr Otte feels that the Valence Arousal scale is too simplistic, and that more dimensions should be included.
- Furthermore Gareth has not many wrinkles, keeps his teeth on each other all the time, the curling sides of the mouth are somewhat strange and unnatural (FS is working at the lips at this very moment)

5.4 Summary of academic evaluation (UAu)

5.4.1 Evaluation of Multimodal Valence-Arousal Recognition

The accuracy[3] of the valence - arousal recognition system based on facial expressions is on par with the baseline presented by authors in ("Openface 2.0: Facial behaviour analysis toolkit." Baltrušaitis et al. 2018), but applies a more lightweight (MobileNetV2 instead of AlexNet) architecture - giving us the possibility to implement a computationally efficient recognition module that can even be run on mobile devices. It is trained on the same database (AffectNet), which consists of emotional facial expressions collected from the web together with high quality emotional annotations in continuous valence-arousal dimensions.

	AlexNet (Baseline)		MobileNetV2	
	Valence	Arousal	Valence	Arousal
RMSE	0.37	0.43	0.40	0.37
CORR	0.66	0.54	0.60	0.52

Audio based paralinguistic analysis has originally been set up as a two staged transfer learning approach. Well annotated affective databases with focus on audio data are sparse, so we had to come up with a very custom solution. We use a pre-trained convolutional network for the pre-processing of audio data. SoundNet[4] exploits the leading edge of computer vision algorithms - which are in general very accurate in classifying objects and scenes in video data - to generate labelled data for audio classification. SoundNet is trained to recognise scenes based on present sounds in the audio channel. Of course, scene classification is not the target of our emotional analysis. However, the output of the last pooling layer of the pre-trained model represents a compact and focused distillation of the audio signal that is well suited for further processing. We feed the output of the last pooling layer (pool 5) of the SoundNet architecture into two additional fully connected layers which are meant to map the representation. These are trained on the SEMAINE database ("The SEMAINE Database: Annotated Multimodal Records of Emotionally Colored Conversations

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[3] *Performance is measured in RMSE (Root Mean SQUARE Error - the predicted error aggregated over all sample points within the predicted and actual curves, where an error of 0 would indicate perfect prediction) and CORR (Correlation Coefficient - the linear correlation between trends in the predicted and actual curve, where a value of 1 would indicate perfect correlation).*

[4] http://soundnet.csail.mit.edu/

between a Person and a Limited Agent." McKeown et al. 2011) and deliver continuous valence-arousal estimations. For evaluation of the voice analysis system we use an excerpt of the external database and carry out a leave-one-out cross validation.

	Transfer Learning (SoundNet)	
	Valence	**Arousal**
RMSE	0.47	0.35
CORR	0.09	0.59

The RMSE and CORR for arousal recognition are in most aspects on a comparable level to the accuracy of facial expression analysis. The valence analysis however underperforms in arousal estimation. This shows especially in the case of the very low CORR score, which means the signal is often trending in the wrong direction. We therefore mainly used the arousal score from audio analysis, but are currently integrating an alternative paralinguistic model: Wav2Vec is a recently presented transformer-based approach, in which speech data is transformed into a sequence of discrete units, similar to the words in a text sentence ("Dawn of the Transformer Era in Speech Emotion Recognition: Closing the Valence Gap." Wagner et al. 2022). The model features a very promising performance in the valence domain and will be included in the final architecture.

5.4.2 Evaluation of the Reinforcement Learning Algorithms

To establish rapport with the user we implemented an online reinforcement learner that adapts nonverbal aspects regarding expressiveness of the agent's backchannel behaviour to the user preferences. Thereby, the agents tries to find an optimal backchannel style, which encompass a combination of prosodic component (no spoken backchannel, softly and slow uttered backchannel, or loud and fast uttered backchannel) and a nodding part (no nodding, low range and slow nodding, or high range and fast nodding).This combination additionally is either applied once or twice. To find the most efficient parameters and algorithm for the live system, we simulated this scenario in a reinforcement learning simulation.

5.4.2.1 Simulation Setup

We simulated a K-Armed Bandit, Q-Learning and the gradient-based TDC algorithm. The Bandit is modelled more simply, because the actions directly correspond to the overall backchannel style (e.g. no spoken backchannel using a high range and fast nodding, which is applied twice). In contrast, the overall backchannel style of the state-based algorithms (Q-Learning, TDC) is encoded into the state, where actions alter only one nonverbal aspect at once. This results in actions altering the state to another

style, which only distinguishes from the old state in one aspect. Hence, coming from a state "no spoken backchannel, no nod, applied twice" the action "increase speaking expressiveness" would result in the state "softly and slowly backchannel, no nodding, applied twice".

Concerning the parameters, we modified among others the tradeoff between exploration and exploitation using an $\epsilon \in [0.05, 0.1, 0.2]$. Regarding the K-armed Bandit and the Q-Learner we additionally investigated the best learning speed using $\alpha \in [0.1, 0.2, 0.3]$. Since the gradient has 2 learning rates, which according to literature have to be defined in dependency of each other, we defined $\alpha \in [0.9\beta, 0.7\beta, 0.5\beta]$ and $\beta = \dfrac{1}{k}$, whereas k is equal to the number of features in the state space (7 in our case). Since we aim for a quick adaption and we assume the agent to approximate a linear function, we chose the fourier base of the TDC algorithm to be of order 1 using a coupling of 1. State-based algorithms can further be configured, how far they consider future rewards. Therefore we set a $\gamma \in [0.5, 0.7, 0.9]$ for the Q-Learner and the TDC algorithm. Testing each permutation of these parameters results in 9 experiments for the K-Armed Bandit and 27 for each state based algorithm.

To also include the nondeterminism of our environment into the experiments, each parameter configuration is conducted using 4 different noise probabilities (uniformly assigned to the user and sensor noise): never (0.0), rarely (5%,10%) and frequent (30%) noise. Since we simulate a user and every user can have individual preferences, we initialize every experiment with a new random preference for the simulated user. Additionally, our agent learns in a nonstationary environment and should therefore be able to recover to preference changes. Therefore we added a simulated user preference change to another random preference in the middle of all experiments. As a performance metric we calculate the average reward for each step. This averages all obtained rewards over all episodes for a particular step. Hence the plots in the following section contain the reinforcement learning steps on the x axis and each step the averaged reward over all episodes on the y axis.

5.4.2.2 Simulation Results

K-Armed Bandit

For each Bandit experiment permutation we conducted 30 episodes with 100 steps. Within the same exploration rate (e.g. 0.05), we observed higher α's (e.g. 0.3) to be better at the beginning and after the preference changes, compared to lower α's. Hence, increasing α didn't unexpectedly result in worsening the performance. Although higher exploration rates help the agent to recover faster, they also worsen the performance on a long-term basis. The following plot depicts the best found configuration of $\alpha = 0.3$ and $\gamma = 0.05$.
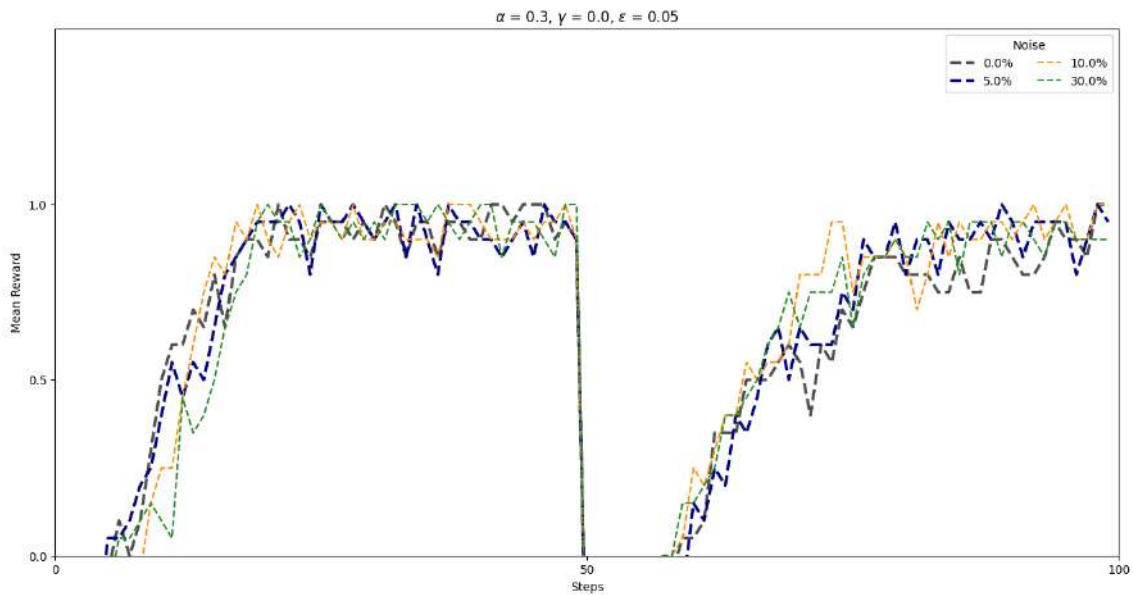
Using this configuration the agent adapts quickly on new preferences (initially, middle) and stays relatively stable even when noise is present. Increasing the noise slightly increases the noise of the graph (e.g. 30% noise compared to 10%).

Q-Learning

Each Q-Learning experiment has been conducted with 200 steps over 30 episodes. We observed lower γ's to perform better, particularly for new preferences (initially,middle). We presume, that in this case the agent's approximation for future values are temporarily false and have to be learned again, before they can serve for an estimation of other states. Hence, for higher γ the agent weights future approximations too high and therefore struggles adapting to preference changes. So we consider γ=0.5 to be the best value. For the other parameters, our Q-Learning experiments follow the Bandit experiments. This results in the best configuration of $\alpha = 0.3, \gamma = 0.5, \epsilon = 0.05$, which is depicted by the following plot:
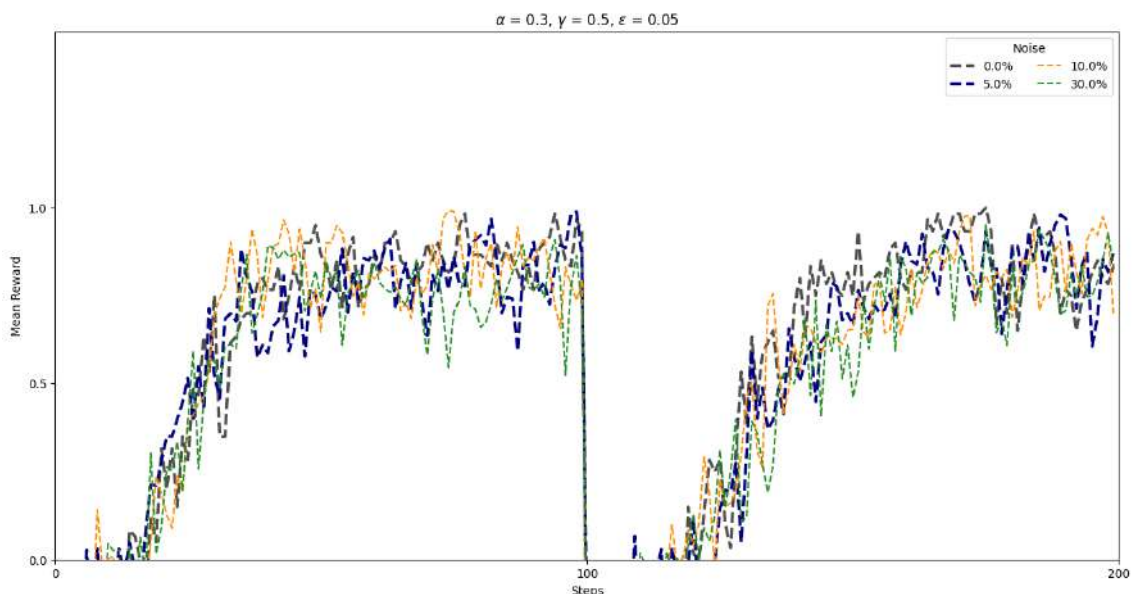
Although the Q-Learner is also relatively stable once a preference is learned, it needs more steps for stabilizing compared to the Bandit (initially, after preference changes) and is influenced slightly more negatively by noise. We presume that this comes from the more complex modeling of the Q-Learner. Similar to the issues concerning the γ parameter, choosing a suboptimal action, as it is the case for exploration and noise, has first to propagate over different state-action approximations, before it can show in a perceivable effect.

TDC

We conducted our TDC experiments with 1000 steps over 1000 episodes. Similar to and for the same reasons as for the Q-Learner we chose $\gamma = 0.5$ and $\epsilon = 0.05$ to be the best parameter. Since function approximation considers all values at once and therefore it happens faster to overestimate values, the smallest $\alpha = 0.5\beta$ is considered to be the best. This best configuration is depicted by the following plot:
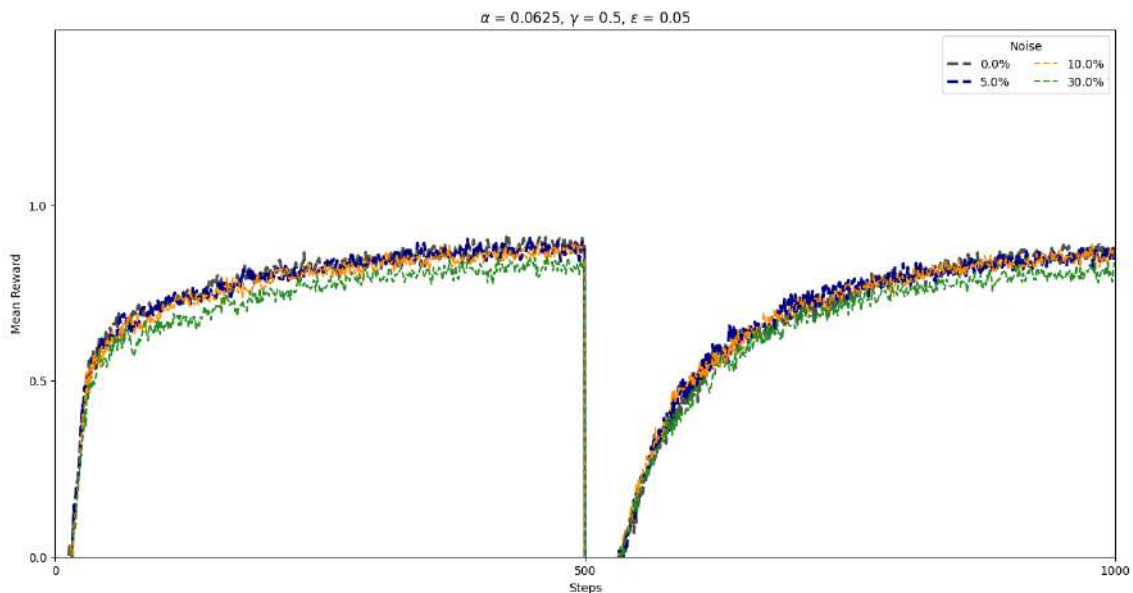
Although this algorithm is able to adapt to the user preferences, it turned out to have a slow recovery after new preferences are set and similar to Q-Learning is more prone to noise. Choosing a suboptimal action (compared to Q-Learner) also introduces difficulties to find back to the optimal state-action pair. This is presumably even more complicated by the TDC's nature of learning all states at once for an action. We presume that its actual strength for generalization can not apply, because the learning problem may not be complex enough for introducing enough generalisation capabilities and the algorithm itself may then be too heavy to take use of the gradient based reinforcement learning capabilities. The fourier base is already chosen as simply as possible. Choosing a more complex base would result in a more heavy learning problem.

5.4.2.3 Recommendations

To find the best algorithm and best parameter configuration for our live backchanneling agent, we conducted simulation experiments.

It turned out that state based agents performed best, when $\gamma = 0.5, \epsilon = 0.05$ is used. This way the temporary false approximations are not taken too seriously into account of

current updates and the agent doesn't behave too randomly on a long term. Since direct encoding of the backchannel style into actions is more simple, the Bandit performed in many ways better than the state based pendants.

Although, the state based models take longer to find a preference, they introduce more behavior consistency. This lies in the fact that they only alter one backchannel feature at once. Depending on the requirements for the system, another version should be chosen. If the emphasis is rather on a consistent behavior than finding the user preferences quickly, we recommend using the Q-Learner, because it learns faster than the TDC addressing the same learning problem. However, in some systems (as it is the case for our PRESENT live agent) the learning performance may be more important. In this case we recommend the K-Armed Bandit. It converges faster to the user preferences and is more stable with noises. We don't assume that the user changes his preference too often. Hence, the Bandit also will lead comparatively fast to a consistent backchanneling behavior.

6. Summary and Conclusions

6.1 Summary

This report described how we have brought the EPs into the real world and how we have evaluated them with general, artistic, professional and clinical audiences/users. On a general level the EPs aim to push emotional expressiveness and install a sentient and social condition of avatars, immersants, actors and of the virtual environments themselves. We started with working hypotheses on the potential effects of PRESENT technology-to-be-developed and went on simulating and evaluating these on an early basis in productions like 'Delirious Departures'. At SIGGRAPH we showed and evaluated a semi-final version that fully integrates the final technology of Inria, FS, and CM.

From Inria's point of view, we have developed techniques that claim to allow novice users (in character group animation techniques). While we have conducted an academic evaluation of these usage features, the opportunity to have an end user for our technologies is invaluable. Long-term exchanges between Inria and CREW have allowed us to explore real-world usage conditions for technologies that were in the laboratory prototype stage.

CREW's implementation of UAU's SSI component in Adam shows the possibilities of applying this research in real world applications. The consulted psychologists and psychotherapists were enthusiastic about the technology and agreed that it has possibilities as a tool for their practices.

Finding novel and meaningful solutions w.r.t. PRESENT technology became an urgency during the Covid 19 pandemic, we took it as an opportunity. An opportunity that materialized in 'Soulhacker' and 'Adam' integrating UAU, FS and CM technology, and enabling us to research and test the emotional effects of expressiveness and behaviour in two EP's.

6.2 Conclusions

The fact that we could show the outcomes in museums and professional environments allowed us to evaluate continuously and on a large scale and a broad spectrum. The working and evaluating in clinical environments gave us a deeper understanding of the emotional and sentient aspects, apart from the fact that both projects contribute to novel solutions for mental health issues that became ever more urgent by the pandemic crisis.

The results of the EPs and their evaluation exceed the expectations. The appreciation of the artistic and the technical concepts and results of the Delirious Departure performances was high, the same is true for the therapeutic value of Soulhacker and Adam.

Our hypotheses and working principles (in some cases against prevailing beliefs) have proven to be correct and functional: performing in large areas enhances the range for emotional and spatial experiencing, a puppeteering aspect and a partial live presence help the 'grounding' of presence and emotion, non verbal communication through a group experience works well (better) with non visually realistic avatars. The (illusionary) perception of the own body is remarkable in comparison to previous VR projects by CREW, with live actors and animated loops but without NPC's/agents. In these projects (e.g. Hands-on Hamlet) that were evaluated the participants did not claim to sense a body and described themselves as 'ghosts'.

If we look at the results, and the possibility of their continuation in the near future:

Soulhacker and Adam are nearly ready for integration in real world clinical use. Soulhacker will be taken further with clinical tests (with the same patients) for tests in large areas in autumn and will be extended towards new possibilities in artistic workshops in October (with R.I.T.C.S. filmschool Brussels and with Dr.Otte: our medical partners see a real future for introducing role- playing possibilities in large area VR sessions, a mixture so to say of Delirious Departures and Soulhacker. The Adam application will be taken into experimental use by Psysense BE (centre for treating autism) in autumn. The PRESENT results will be taken up in MAX-R, a new Horizon 2020 project of which CREW is a partner. The large area use will be technologically improved in combination with (online) multiplayer modalities.

Delirious Departures did not see its end station either: its findings (the interactive agents, the social agents, the 3D scans, the embodiment) will lead to a fully interactive and large area production in a multiplayer version that we foresee fall 2022-spring 2023. Inria expects that the future envisaged for the Delirious Departures demo will be an opportunity to extend the interactions with the CREW team. Many points remain to be developed on the basic idea of Interaction Fields.

Annex

Licence of the Ethical Commission for 'Evaluation of the clinical- and neurophysiological effects (effect on brain network dynamics) of the deployment of a metaphorical VR based environment in the treatment of patients suffering from depressive symptoms.'

UZA'

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Evaluation of the clinical- and neurophysiological effects (effect on brain network dynamics) of the deployment of a metaphorical VR based environment in the treatment of patients suffering from depreessive symptoms.

Project ID 0596 - Edge n/a - BUN B3002021000200

Datum: 14/02/2022

DEFINITIEF GUNSTIG ADVIES

Geachte collega

Het Ethisch Comité van het Universitair Ziekenhuis Antwerpen en de universiteit Antwerpen bevestigt dat bovenvermelde studie voldoet aan de criteria gesteld in de wet van 7 mei 2004 en geeft een gunstig advies dd. 14/02/2022.

De antwoorden op de brief d.d. 10/01/2022 werden besproken op de vergadering van 14/02/2022. Het Ethisch Comité is van oordeel dat er voldoende rekening gehouden werd met de gemaakte opmerkingen.

De volgende bijlagen werden volgens de ICH-GCP richtlijnen door het Ethisch Comité goedgekeurd:

Document Type	File Name	Date	Version
GCP	certificate Dr Otte_pdf	25/08/2021	1.0
Accompanying letter	conceptnota Soulhacker_	01/09/2021	1.0
Protocol	Soulhacker project and study documentation	01/09/2021	1.0
CV	CV Dr Otte engels	01/09/2021	1.0
Default	Patient brochure SOULHACKER	01/09/2021	1.0
IB	SOULHACKER Investigator Brochure	01/09/2021	1.0
Questionnaire	BDI HADS scores	01/09/2021	1.0
Technical Data	SOULHACKER Stappenplan voor medewerkers	01/09/2021	1.0
Insurance	verzekering AF dekking Soulhacker studie	20/01/2022	1.0
Remarks	Soulhacker project and study documentation	21/12/2021	2
ICF	Soulhacker Informed Consent	21/12/2021	2
Remarks	Patientbrochure	21/12/2021	2
Remarks	Soulhacker Conceptnota	21/12/2021	2
Remarks	Soulhacker Investigator Brochure	21/12/2021	2
Remarks	Soulhacker Stappenplan medewerkers	21/12/2021	2

Deze goedkeuring is geldig tot een jaar na bovenvermelde datum. Wij verzoeken u ons te melden wanneer de eerste deelnemer werd geïncludeerd, wanneer en waarom de studie (vroegtijdig) werd stopgezet of nooit werd opgestart.

Indien de studie nog loopt na een jaar verwachten we een follow-up rapport waarin eventuele voorvallen worden gemeld.

Page 1 of 2

Tot slot wijzen we er op dat, voor in het UZA lopende studies, de ernstige ongewenste voorvallen dienen gerapporteerd via het incidentenmeldingssysteem.

Met vriendelijke groeten

Prof. dr. Greet Ieven

Ondervoorzitter Ethisch Comité UZA/UAntwerpen

(elektronisch gevalideerd door de ondervoorzitter d.d. 14/02/2022)

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Emeritus Professor Hilde Bortier	MD, PhD
Prof. Dr. Patrick Cras	Vice-Chair, Physician
Ms Ingrid De Meester	Pharmacologist
Ms Elyne Debaetselier	Nurse
Professor Francois Eyskens	Physician
Ms Lina Fierens	Nurse
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Mr Kris Ides	Physiotherapist
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Ms Barbara Michiels	General Practitioner
Mr Peter Michielsen	Chair, Physician
Ms Inge Michielsens	Legal
Mr Pieter Moons	Coordinator Bio- and Human Tissue bank
Mr Bernard Paelinck	Physician
Mr. Michaël Pössel	Healthy volunteer phase 1
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Mr. Kris Smulders	Nurse
Mr Jan Van den Brande	Physician
Mr Filip Van den Eede	Physician
Mr Pieter Van Dyck	Physician
Mr Guy Van Honste	Patient Representative
Ms Dominique Van Praag	Psychologist
Mr. Yves Vandermotten	Healthy volunteer phase 1
Mr Thierry Vansweevelt	Legal
Ms Griet Wyers	Pharmacist