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Archives of Thrill: The V-Armchair Experience

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Abstract

Technology for older people is typically concerned either with health care or accessibility of existing systems. In this paper we take a more 'entertainment-oriented' approach to developing experiences aimed at older users. We describe here the design, development and a user study of the V-Armchair, a virtual reality and motion platform based roller coaster experience. The V-Armchair constitutes a blueprint for the digital archiving of physical ride experiences through the simultaneous capture of 360 video, sound and motion. It gives access to thrill experiences to those who may not be able to go on real thrill rides, such as older riders, and it can be considered as a class of technology that could help to support 'active aging' as defined by the World Health Organisation. We discuss strategies for capturing and then 'toning down' motion experiences to make them accessible for older users. We present a study which explores the user experience of the V-Armchair with an older group (median age 63) using a DK2 headset, and a younger group (median age 25) using a CV1 headset, via thematic analysis of semi-structured interviews and a modified version of the Game Experience Questionnaire, and discuss emergent themes such as the role of the presenter, reminiscence, presence and immersion.

CCS Concepts

***•Computing methodologies** → **Virtual reality; •Information systems** → Multimedia content creation;*

1. Introduction

The HCI literature is replete with examples of technology specifically designed for older and elderly users typically concerning health care accessibility. There is also significant work on creating companion robots to support healthy or less lonely lifestyles. While there is work that suggests that older people in general engage less with technology [KN12], that hasn't stopped the community from attempting to make a range of technologies more accessible [dSELJ05]. While the accessibility of current platforms is certainly extremely important, it is interesting to consider the design of technologies simply to provide entertainment. While many entertainment media: books, television etc. are perfectly accessible and familiar, frailty or immobility may limit elderly users' access to many other forms of entertainment. With certain notable examples, more extreme forms of entertainment, from parachute jumps to roller coasters tend to be off-limits, as much for the physical and health considerations as any other reason. However, with the recent proliferation of affordable Virtual Reality (VR), such experiences may become accessible, albeit in virtual form.

We might also consider the fact that much entertainment geared towards the older individual is associated with memories or nostalgia. For example, [NJH03] explores tangible interfaces specifically designed to evoke feelings of nostalgia in elderly users. Similarly, [SFHS08] looks at the potential of using urban screens to evoke nostalgia when walking around specific neighbourhoods. [SR17] takes a similar approach, but transitions the experience into VR, allowing users to take a virtual stroll through the past.

It is widely held that senses other than visuals can evoke memories, for example [WL06] notes the association between odour and specifically childhood-oriented memories. In the proceeding paper, we explore the use of motion along with visuals as a tool for inducing reminiscence, as well as more generally as a way of creating accessible 'virtual thrill ride' experiences, that while softened, nevertheless give a greater sense of presence and immersion than simply watching a film.

To explore this theme, we have taken a 'practice led research in the wild' [BGC*13] approach and developed a system called the V-Armchair with the artist Brendan Walker (`http://thrilllaboratory.com/`). The V-Armchair is a 4D cinematic VR experience based around the simultaneous recording of 360 video and telematics, on a wooden roller coaster. The video is played back on an Oculus Rift while the telematics are played back via a motion controlled chair, essentially a 6 Degree Of Freedom (DOF) Stewart Platform. Recent years have seen the growth of a 4D film industry, and in the case of fairground rides and similarly motion-centric phenomena, the opportunity arises for recording motion rather than simulating it. Some rides use real roller coasters to provide haptic feedback for completely CGI VR experiences such

Figure 1: *An Older Rider on the V-Armchair.*

as those by VR Coaster (www.vrcoaster.com) and RoboCoaster (www.robocoaster.com), however, our aim was to produce an experience that is accessible, in particular to older individuals, or those who may not otherwise have access to thrill rides such as disabled users. In [TMW*17], the authors suggest that the alignment of the motion and visuals in "visual-kinaesthetic experiences" need not be perfect as long as the motion suggests correctness. Applying this principle, we use a motion platform to produce a significantly smoothed out version of the motion experience, while still retaining the essence of the motion. Such an effect may be tailored to the specific audience.

The V-Armchair can also be considered as an archiving of a physical experience. There has been much work undertaken in the area of Digital Cultural Heritage (DCH) over the past few years using both VR and Augmented Reality (AR) , which is concentrated on historical sites and artefacts. Websites and museums which document the history of roller coasters and theme parks exist (for example the National Roller Coaster Museum http://www.rollercoastermuseum.org) and contain archives of photographs, videos and parts of the roller coasters, preserving such information for future generations. However by archiving the required complex digital objects (360 video, recorded motion and the means to play them back), a roller coaster could be preserved and virtually experienced by people long after the physical ride has ceased to exist.

The advent of consumer VR has meant that it is being increasingly used to aid reminiscence. A more serious use is in reminiscence therapy, a popular psycho social intervention in dementia care where the discussion of the past, often with the help of props is used to aid memory and building of life stories. VR image based rendering reminiscence therapy has been shown to be effective in recent years. It was shown, for example in [CGP*14], that VR based therapy appears as effective as traditional techniques while having a number of advantages over them, which has been further ratified in clinical trials [MCB*16]. As an archived experience, the V-Armchair could have use in reminiscence therapy.

The V-Armchair is also relevant as a class of technology that could contribute to 'active aging' as defined by the World Health Organisation, as technology that positively contributes to well being and to positive aging as discussed by Riva et al [RVC*16]. It is also relevant in the discussion of the usefulness of positive experiences in aging such as video games [VSTR17].

The V-Armchair as an artist intervention has been briefly described in [WM17]. However in this paper we present in detail the design of the V-Armchair, and the tools necessary to capture a motion and video experience. We further present a study in which a number of older users (median age 63) are given the opportunity to try the V-Armchair and discuss their experience, and a repeat study with younger people (median age 25) experiencing the same ride but using an updated headset.

This work makes the following key contributions to the field:

- The V-Armchair as an artifact which can replay recorded motion matched with VR audio and video
- Evidence that such a motion experience is both accessible and enjoyable for the initial group of older users using a Oculus DK2 headset, and equally for a second younger user group using an Oculus CV1 headset.
- An in-depth discussion about the role and perception of presenters in 4D film.
- A demonstration of the digital archiving of a motion ride

2. Design

The V-Armchair was designed initially to allow the playback of 360 film in VR with simultaneously captured motion. The opportunity then arose to work with Age UK, to develop a version of the system suitable for older, and even elderly riders to experience a roller coaster that was built in their youth. As such, two core aspects of the design were adapted: 1) The racing seat was removed from the platform and replaced with a comfortable chair similar to those found in many care homes, and 2) The motion of the ride was significantly smoothed in post processing. The goal was to create an experience that replicated some of the *feeling* of being on the ride, while simultaneously toning down the "bone shaking" nature of the roller coaster, both through the smoothing and through the cushioning of the chair. This toning down was deemed sensible in this context as the violent shaking of a fifty year old rollercoaster verges on the painful even for younger riders.

In order to embody the narrative of the experience, in addition to the rider being seated on the roller coaster carriage, a presenter is also seated by them. The presenter uses a familiar chatty style to talk to the rider explaining why the film is being made and a bit about the history of the roller coaster. The intention of including the presenter is to remove the feeling of being alone on the ride, and to provide a focus point for the rider. In section 7 we discuss the relative success of this approach and more generally the use of presenters in 360 video. The system consists of the following steps: capture, post processing, synchronisation, and playback which are discussed below.

2.1. Capture

In order to capture the experience, it was necessary to capture video, audio and motion. To do this we traveled to Oakwood Theme

Figure 2: *A rider's forward view*

Park in Wales, and over the course of a day recorded 10 separate takes of each. The video was recorded using a Freedom 360 rig (http://freedom360.us) holding 6 GoPro Hero 4 cameras (https://gopro.com). The cars on the ride were two seats wide and the camera was placed at roughly head height for a rider sitting in the second seat from the front on the left, while the presenter was sitting in the front right seat (see the forward view of the rider in Figure 2). The presenter's speech was recorded separately with a lapel mic. A stereo recording was made of the roller coaster sound by attaching a stereo recorder to the back of the second seat.

The motion of the ride was captured using a custom made motion recorder. This was built using an Adafruit Adalogger (https://www.adafruit.com/product/2796) along with an LSM9DS0 Accelerometer, Gyroscope and Magnetometer board (https://www.adafruit.com/product/2021). The LSM9DS0 communicates with the Adalogger over an I2C connection, and both are powered by a single 2000mah 3.7v Lithium Polymer Battery. Raw data, along with timestamps, were written to a 64GB microSD card mounted on the Adalogger at 128Hz. The motion recorder could be separately switched on and calibrated, then the logging commenced and completed by the use of a push switch, with an LED to indicate the recording action. This allowed us to use an approximate manual synchronisation with the video and audio.

2.2. Post-Processing

Each Go Pro camera recorded 1920 by 1440 pixels at 60 frames a second. The footage from the six cameras was uploaded and was stitched and post processed using Autopano Pro Video (http://www.kolor.com/autopano-video/). The six video sources were first synchronised using the clapper board sound, and then stitched into a single equirectangular image which was colour corrected. Following that, a 4K equirectangular mp4 video was rendered out. Adobe Premiere (http://www.adobe.com) was then used to trim and grade the footage. The sound was post processed in Audacity (http://www.audacityteam.org). The stereo and lapel microphones were synchronised using the clapper board sound, the levels were set appropriately, and a stereo soundtrack was rendered. The sound and video were then brought together in Adobe Premiere resulting in a final 360 degree video in 4K resolution at 60 frames per second.

The recorded raw motion data was passed first through a Kalman filter to extract pitch roll and yaw values. See [Sab06] for more details on this process, which uses the output of the accelerometer and magnetometer to support the output of the gyroscope. This data was then put through a single-pole infinite impulse response (IIR) low-pass filter to remove some of the high frequency *jitter* from the output. This output was exported to a simple CSV file including the timestamp data. A second IIR filter - this time with a runtime-variable filter constant, was used in the playback system to further smooth the motion and make it appropriate to its audience, however, the data before this second pass is considered the 'gold standard' capture of the experience. Critically, by placing that second filter in the playback system we would be able to tailor the playback experience to the user - though in practice, to preserve comparative validity in our study each user was given an identical experience.

2.3. Synchronisation

All three aspects of the system needed to be tightly synchronised to make the playback work - the video, audio and the motion. At the point of recording a clapper board was used for synchronising the audio and video. The record button was pushed on the motion recorder as close to that snap as we reasonably could. It would have been feasible to use an electronic clapper board to do this perfectly, however it was concluded that the motion synchronisation would be 'good enough' if it were within a few frames. Once the audio and video were synchronised it was possible to determine the offset of the start of the video from the time at which the clapper board had been snapped. We then took this offset, minus an average human reaction time of 0.17 seconds for an audio stimulus, and removed that duration from the beginning of the motion data. This then meant that by starting all three playbacks simultaneously, the audio, video and motion should be sufficiently correctly synchronised.

3. Playback

The V-Armchair playback system is built primarily in Unity3D (https://unity3d.com). Video playback was handled using Renderheads' AVPro plugin (http://renderheads.com/product/avpro-video/), while spatialised audio was handled separately using the Spatial Workstation (https://facebook360.fb.com/spatial-workstation/). Both of these were prepared for playback via a single scripting command, with video and audio pre-cached. A similar approach was taken with the playback of the motion data: The full CSV was initially read in to an in-memory object, and when played back the data were passed through a runtime-configurable low pass filter, and delivered by a separate thread over UDP to the motion platform middleware system.

In order to confirm the relationship between recorded data and the playback to the chair, a real-time test scene was developed which caused the motion platform to respond to the movements of the motion recorder. To facilitate this, the motion recorder transferred incoming data from the accelerometer over serial at a baud rate of 115200, as long as it detected a serial connection at startup. The Kalman filter was also executed in real time and the resulting (IIR low pass filtered) pitch, roll and yaw were sent to the chair. This meant one could hold the box in one's hand, tip it and see the chair respond to that action. Once we confirmed the chair was responding correctly, it was considered safe to play back the recorded data.

The system used either an Oculus Rift DK2 and separate over-ear head phones, or an Oculus Rift CV1 which includes built in on-ear headphones, to deliver the audio and video to the user. Playback was started by a facilitator using a keypress and there was no direct user interaction other than changing head orientation to look around as the video played. We used a Windows PC with a Core i7 processor and an nVidia Geforce GTX1080 graphics card to ensure a consistent and reliable framerate of 60fps (the framerate of the recorded video).

3.1. The Motion Platform

The motion platform (The MDX LOCO `http://loco.mdx.ac.uk/`)design is based on an inverted Stewart Platform. This consisted of 3 major parts: rig, actuators, and controller. The rig is the chair and associated components which riders sat in. For the seated rider, the chair suggested the motions shown by the video, as delivered from the motion log. In some cases the chair was unable to perfectly match the range of movement required by the data, however, as noted in [TMW*17], the suggestion of correct motion may be sufficient to fool a user.

Three pairs of actuators were used on the platform and these were selected from German manufacturer Festo, acting as pneumatic muscles. The unique feature of these muscles was that they could be set to a particular length purely by controlling their internal pressure. The construction of these muscles is such that they can be precision controlled and would not need sensory feedback (position in this case) and the system could sustain its accuracy over a million cycles without needing calibration. In this case the muscles used were 10 mm in diameter and 600 mm long, providing a maximum of 1500 N force per muscle and 160 mm maximum contraction (25% of nominal length).

The controlled movement was achieved by a Festo CPX valve terminal (controller), with a built in Ethernet connectivity, driving 6 proportional pressure regulators acting as valves. The valves had a 0.02 - 6.00 bar range with an overall accuracy of 1%. This served as the local low-level controller driving each muscle to a particular length that corresponded to a given seat position and orientation. Control instructions were provided through a middleware system which received a pitch, roll and yaw value over UDP from the unity playback system and translated them into appropriate commands for the valve terminal, including washout required for movements exceeding the range of the chair. The CPX unit did not have any silencers fitted to the system to amplify the effect of the movement by allowing high pitch exhaust noise.

The air needed to energise the muscle actuators was provided by a portable compressor, and passed through a three-stage service unit - filter, regulator and lubricator with a built-in pressure switch. This was sited on a platform immediately behind the rig, alongside the CPX controller in order to keep the tube lengths to a minimum. The compressor was Jun-Air 18-40, providing 40 litres of air capacity and 150 l/min displacement. This high flow rate was needed to ensure the system could respond to the rapid movements required. Typical tube diameter used was 8 mm throughout the rig. The platform had a safety air cut off valve to allow safe loading / unloading of riders, and an emergency off switch, placed within easy access of the study facilitators. In such a case, the power to the system was maintained but the air supply was interrupted, causing the chair to come to rest immediately.

4. User Study Methods

4.1. Subjects

To evaluate the V-Armchair a user study was conducted with two groups. The first group, hereafter referred to as the Older Riders, consisted of nine participants (four females, five males), both users and staff from the Age UK Barnet day center for older citizens in London. Their ages ranged from 48 to 71 with a median age of 63. The Older Riders experienced the ride at the day center. The second group, hereafter referred to as the Younger Riders group, consisted of fourteen participants (four females, ten males) drawn from the Middlesex University population, mostly junior staff and students of science and technology. The minimum age for this group was 19, the maximum 33, and median 25, and the experiment was carried out on campus.

4.2. Procedure

Participants completed a screening questionnaire, read a participant information sheet, and filled in a consent form. The participant was then briefed on getting into the chair, fastening the seat belt, and how to stop the ride. The ride then lasted around three minutes. The Older Riders used a Oculus Rift DK2 with separate headphones, which was upgraded to the newly released Oculus Rift CV1, with built in headphones, by the time the Younger Riders were tested. Following this, a semi-structured interview was conducted about the V-Armchair experience. Guideline questions included what users thought about the ride, whether they had been on a real roller coaster before, if so how did the experience compare, what was good about the ride, what was bad, and how could it be improved. These questions were the same for each participant and allowed expansion on replies of interest. The participants were video recorded to aid transcription of interviews. While many of the Older Riders group mentioned the presenter without prompting, it was decided to include a question specifically asking what riders thought of the presenter for the Younger Riders interviews. The Younger Riders were also asked if they had ridden on the haptic chair before (as some had already tried a stereo computer generated VR roller coaster ride with the chair using the commercially available *No Limits Roller Coaster Simulaton 2*). None of the Older Riders had used the haptic chair before. Finally participants completed a modified version of the Core Module of the Game Experience Questionnaire (GEC) [IDP13].

The GEQ Core Module measures seven components: Competence, Sensory and Imaginative Immersion, Flow, Tension/Annoyance, Challenge, Negative Affect and Positive Affect. Two of these: Competence and Challenge, were not relevant in this study and were omitted. Furthermore two questions had to be adapted slightly. The statement relating to Sensory and Imaginative Immersion: “I was interested in the game’s story” was modified to “I was interested in the information in the experience”. The statement relating to Flow: “I was fully occupied with the game”

GEQ Component	Older Group Means	Older Group SDs	Younger Group Means	Younger Group SDs	p value
Immersion	3.1	0.7	2.77	0.5	0.19
Flow	2.9	0.96	2.87	0.74	0.91
Tension	0	0	0.14	0.39	0.12
Pos. Affect	0.22	0.34	0.29	0.26	0.63
Neg. Affect	3.47	0.54	3.41	0.62	0.83

Table 1: *Means, Standard Deviations (SDs), and p values for the comparison of the Older and Younger groups by a two tailed (Two-Sample Assuming Unequal Variances) t-test. No comparison is significant at the p<0.05 level.*

was modified to "I was fully occupied with the experience". Consequently the modified GEQ measured five components over twenty three questions. For each statement, participants were asked to indicate how they felt during the V-Armchair experience on a scale from Not at all (0), to Slightly (1), to Moderately (2), to Fairly (3), to Extremely (4).

5. Results - Questionnaire

GEQ scores for each game component are calculated by averaging responses to individual statements for that component. This then yielded a score between 0 and 4 for each rider for each component. From these scores, group means were calculated which are shown in Table 1. To investigate whether there were significant differences between the responses of the two groups on the GEQ Components, a two tailed (Two Sample Assuming Unequal Variances) t-test was applied. As shown in the table no comparisons were significant at the $p<0.05$ level, the two groups responded in a similar way, rating Sensory and Imaginative Immersion, Flow and Positive Affect high, and Tension/Annoyance and Negative Affect low.

6. Results - Interviews

A couple of questions were straight forward in terms of 'yes' or 'no' answers. For example twenty one out of twenty three riders had been on a roller coaster before (only two younger riders had not), and all younger riders and six of the seven older riders who were asked said they would go on the V-Armchair again (one older rider who found the ride tame said they probably would not). Answers to other questions were more complex and are discussed below.

The thematic analysis methodology of Braun and Clarke [BC06] was used for the analysis of interviews to capture, as a collection of 'themes', an understanding of what was really going on. The twenty three transcribed interviews which were loaded into NVivo 10, a qualitative data analysis software package. Nvivo was used to code relevant sentences in the transcripts and in the analysis phase for querying the data when coded. Transcripts were coded using an open coding procedure, during which the coding scheme was inductively defined and refined as the coding proceeded, very much in the spirit of Grounded Theory's constant comparative method. The resulting sub themes were aggregated into the following themes: the presenter, reminiscence, movement, positive affect, factors affecting presence, and factors affecting immersion. In the discussion below quotes from riders are given in Italic and followed by either O for Older or Y for Younger and a number to anonymously identify the rider.

6.1. The Presenter

The presenter spent the first minute of the three minute ride talking to the virtual viewer, telling them facts about the ride, how it was constructed etc. It starts with the ride stationary and he talks up to the first big drop. He then whooped and shouted with excitement as he went around the rest of the ride, adding the odd comment until the car came to a stop and, laughing with exhilaration, he almost loses his glasses. He then chatted away about the experience for the last part as the car slowly returns to the start position. The presenter also directed the viewers' attention at certain points, directing them to look at a ride in the distance and at a rider behind them. Implicit in user accounts is that they felt the presenter was talking to them apart from one rider who thought that the presenter was talking to the technician sitting at the back of the ride. This rider who had never been on a real roller coaster before was also a little confused by him but thought *"he's a good character."*[Y6] Only two riders made overall negative comments: *"I would get rid of the guy who sits next to you . . ."*[O7], and *". . . he was talking during the ride which I didn't like"* [Y10].

Three riders did not comment on the presenter, but the remaining eighteen riders all made positive comments, so overall the presenter was positively received. Rider O2 thought the way he laughed made the experience feel light hearted. Many riders commented that the presenters enthusiasm and excitement was infectious and added to the experience, e.g. *"It was kind of fun to be in the roller coaster with someone else who's getting really excited"*[Y5]. One rider who was scared of heights, particularly liked the talking: *"it gives you something to focus on."*[O4]. Another comment was that riders felt they were not alone, they were on the ride with someone else: *"You feel like you're on there with somebody rather than just on your own"*[O6], and *"It's like sharing the experience with someone"*[Y12]. Two of the six Younger Riders who had previously tried the *"No Limits* simulator specifically commented on the benefit of having the presenter there.

6.2. Reminiscence

There was one question that asked riders to compare their experience on the V-Armchair to that of going on a real roller coaster if they had tried one, thus riders naturally were prompted to reminisce about previous experiences of fairground rides. Riders talked of the various theme parks and places, they had visited by name, or described rides. For a few of the Older Group this was clearly a long walk down memory lane. One rider described the rides she had been on as a child. *"Way back when we were children and you would go to the Helter Skelter . . ."*[O2]. Another rider describes comparing the V-Armchair with the last time he went on a roller coaster which was when *"I was a child, . . . probably well over 50 years ago"*[O7]. This same rider added that *"I probably wouldn't do it again in real life."*[O7] which accentuates the accessible nature of the experience. Although some riders thought the movement was too tame, it helped them to remember how it used to be for them. Part of the reminiscence was memory of the physical feelings of being on a ride: *" . . . there's a wooden roller coaster in Spain and that actually goes really at a pace, and you get that because the sides are built up, so you really get that movement and the jolting movement."*[O1]

It is interesting that the two older riders who were not keen to go on real roller coasters volunteered to try the V-Armchair. The first rider who had only been on a roller coaster once reminisced *". . . we were in America and friends you know they keep on encouraging and encouraging you to go. And we did and it was horrendous"*[O2]. However she reported about the V-Armchair: *"It's exciting and yeah I was fine with it"*[O2]. The second rider described how she had enjoyed going on such rides until about three years ago when she suddenly developed a severe fear of heights while driving on a mountain in France. However after the V-Armchair ride she reported *"I feel a little bit wobbly . . . I did close my eyes for a lot . . . but I thought it was great"*[O4]. As suggested by one or two riders, the V-Armchair could perhaps have a therapeutic role in helping overcome fear of roller coasters or heights.

6.3. Movement

Clearly, a motion platform is limited in its range of movement and the forces it can generate, however, even a little movement can have a big effect on a rider. Not surprisingly, movement emerged as a key theme in the analysis of interviews. Many riders said that it helped with the realism. One rider thought it was highly accurate and detailed. *"It was just like being on a roller coaster. It was really good. Every bit, every bump you can actually feel"*[O8]. However some riders found the movement tame and wanted more movement. *"It's a little bit tame for me."*[O6]. One rider thought the movement was incorrect: *"It barely seemed to tally up, the movement of the chair to the actual video. "The movements weren't very precise"*[Y13] .

6.4. Positive Affect

Although some riders could suggest improvements of features, or said aspects of the experience were tame, no rider said they disliked the experience, and the vast majority of them used positive terms such as like nice, fun, enjoyable, or entertaining.

6.5. Factors Affecting Presence

Following the definitions given in [SW97] we can divide the remaining themes into factors either concerned with presence, the 'immersive response' to the virtual experience, or immersion or 'system immersion' largely concerning the hardware supporting the experience. Presence thus corresponds closely to Sensory and Imaginative Immersion as defined by the GEQ. One factor affecting the sense of presence was the ability to look around and quite a few riders mentioned this explicitly, although sitting strapped into a chair reduces the ability to look around easily, for example *"The ability to look around and feel like you are sat in that position was brilliant, and it was almost as good as the real thing"*. Another factor linked to looking around, is the sense of being there. Many riders also commented on this e.g. *"The good part . . . was you feel like you are in that environment, you are basically inside a theme park."*[Y4]. However users of VR are simultaneously in the real world and in the virtual world, and the fact that riders know they are not going on a real roller coaster also makes them less fearful. Many riders also commented on the fact that while they found the ride realistic and engaging they were aware that it was a simulation.

Nearly all riders (twenty one out of twenty four) spontaneously said that they found the experience to be realistic, for example *"As in the equipment, it was realistic. It felt like you are on the real thing"*[Y1]. Another user suggested that although the ride was realistic and compelling that it would not replace real roller coasters: *" I don't think you would ever replace it. Especially for those who really, really want that thrill, the thrill of genuine danger"*[Y7]. It is interesting to note, given for example the issues around embodiment found in [PGP*16], that only one person made a remark concerning embodiment: *"Well when I looked down, I could see that there was sort of just floor where my legs should be, so that made it feel a little bit strange"*[Y2].

6.6. Factors Affecting Immersion

There were a number of themes around the equipment used that affected the level of immersion in the sense defined in [SW97]: the degree to which the set up provided an "inclusive, extensive, surrounding and vivid illusion of reality". The first concerned the headsets. A few users from each group complained about the comfort of the headsets, the DK2 in the case of the Older Group e.g. *" The headset is not as comfortable as potentially it could be"*[O4], and the CV1 for the Younger Group e.g. *" I don't like wearing the headset"*[Y9]. A few of the Younger Group also complained about light leaking in from the nose area of the CV1 headset.

The video quality of current 360 films (typically 4K for the full 360 degree view) is poor compared to the resolution of contemporary displays. While riders at times described the experience as amazing and realistic, one or two from each group noted the poor quality of video, which is lower than the resolution of either headset. Video quality was also compounded by the stitching errors apparent in the video due to parallax, which was also commented on by a couple of riders. The sound was another issue for some riders. Not surprisingly a few of the Younger Group using the on-ear built in CV1 headphones complained of external noise, for example *"Those headphones didn't isolate the external noises"*[Y12]. While this problem was not reported by the Older Group using over-ear headphones, one or two from each group complained of the sound quality *"the sound wasn't that clear"*[Y12], and *"the sound could just be a bit sharper"*[O4].

Other riders talked about the chair saying it was too comfortable, for example *"I'm not sure why the chair was so comfy and it doesn't really reflect how a real roller coaster would be"*[Y6]. One aspect of the experience that was missing, that was mentioned by two of the Older Group and five of the Younger Group riders was feeling the wind associated with a roller coaster ride, for example *"I think I need the wind there"*[Y2].

7. Discussion

7.1. Effect of Headset

It was not possible to use the same headset with both groups. The key difference between headsets was resolution, the DK2 had 1920x1080 resolution, versus the CV1 which was 2160x1200 pixels. However both the Oculus DK2 used by the Older Group, and the CV1 used by the younger Group, could play back the 4K 360 video at 60 frames per second, and the effective resolution of both was equally limited by the low resolution of the video, regardless of device resolution. The fact that there were no significant differences between the two groups GEQ scores, suggests that there was no strong effect that could of be attributed to differences in headset. Also, regardless of headset some riders in each group mentioned poor quality of sound and video.

7.2. Questionnaire Results

It is perhaps surprising that little difference was found between the two groups in their GEQ components scores, as we could have imagined a younger more technologically savvy group to be less easily satisfied, or for the older group to show more negative affect or tension for example. However, while there are no significant differences between the two groups, there is a systematic trend in the data suggesting that the Younger Group were less satisfied, in that they scored lower than the Older Group on Sensory and Imaginative Immersion, Flow and Positive Affect, and higher on Tension/Annoyance and Negative Affect. Perhaps this trend would yield significant results with larger sample sizes. However we conclude from the GEQ that the response of both groups was overwhelmingly positive to the experience, with high response levels to the positive components of Sensory and Imaginative Immersion, Flow and Positive Affect, and very low response levels to the negative components of Tension/Annoyance and Negative Affect. The results of the GEQ were backed up strongly by, and echoed in, the interviews.

7.3. Embodiment

The fact that riders (apart from one) did not complain about the strangeness of not having a body is perhaps surprising given previous results. This is possibly in part because people have a tendency to look in the direction in which they are traveling. The default forward position is straight ahead, and the fact that riders naturally look ahead to see what is coming next, means that they were not as likely to look down, and therefore notice the lack of a body in the 360 video. Furthermore, the fact that the user's body is being stimulated by the motion may perhaps increase the feeling of the body being present in the scene.

7.4. The Presenter

The role of the presenter in 360 video is the subject of some debate. Classic factual TV, such as the news or documentary, is often presenter led, with the presenter guiding the viewer through the information, often appearing as a "talking head", possibly interspersed with clips of other subject matter, using standard film making techniques of framing, zooming, panning and cutaways etc. In 360 videos, we have found that viewers often feel obliged to look at the presenter, as they would in real life when someone is talking to them, which can detract from the usefulness of being able to look around. This can be contrasted with the ease with which viewers can ignore presenters who are talking to them on ordinary TV. Perhaps viewers will habituate to presenters in 360 video as they have with regular TV. At the other end of the spectrum are 360 degree videos that just give vicarious experiences without explanation. Often these experiences are uninformative and rather lonely, most VR simulated roller coaster experiences are typically taken solo. In this study we explored having a presenter/companion on the roller coaster to talk to the viewer, but who then screamed along interactively with the ride when it got going. Only two of the riders had misgivings about the presenter, he was seen positively by all the others. Analysis of interviews enabled us to investigate this in depth and in summary, the presenter helped riders feel safer, feel light hearted and as if they were having fun, his enthusiasm and excitement were infectious, he became a companion on the ride, he gave them something to focus on and helped to direct their attention.

7.5. Digital Archiving of Motion Experiences

The cultural heritage industry is undergoing a significant challenge right now as society produces more "born-digital" artifacts. Various strategies exist for archiving these, for example, web pages. Creating digital archives of existing artifacts - especially visual ones such as paintings has also had significant research. Recently, 3D scanning has been used in museums to capture and represent objects that could not be physically archived [?]. There has also been work on developing haptic ways to experience digital recreations of museum objects, e.g. [?]. Many of these current archival strategies are concerned with individual artifacts rather than experience. 360 video is a relatively new technology that offers a nice strategy for capturing experiences and allowing viewers to look around and experience the visual 'feel' of being in a space, however questions as to best practices in 360 video (e.g. regarding embodiment and presenters) have yet to be established. It is for this reason that we chose to develop the V-Armchair system with 360 video rather than with a 3D generated world, which is perhaps more familiar for virtual roller coasters.

Video however, even 360 video, can only take a user so far in terms of recreating an experience. Much of the 'feel' of an experience, particularly in the case of something like a roller coaster, is related to other senses (in this case kinesthesia). As such, it may be desirable to also capture other sensory aspects. Motion is arguably a low-hanging fruit in terms of sensory capture, with high quality accelerometers being fairly ubiquitous. The V-Armchair platform serves as a method of playing back such recorded experiences - albeit one with a limited movement range being based on a Stewart Platform, while the software allows a general purpose coupling of 360 video with synchronised motion data. Critically, the ability to 'tone down' the movements allows such recordings to be experienced by user-groups who may be unable to have the real experience, such as frail or elderly users, which makes it a desirable tool for making experiences accessible to wider audiences.

It should be noted that the ability to capture and playback motion experiences are only two of the three necessary parts of a 'real world' archiving system. The critical aspect of curating such recordings is not addressed in this work.

8. Conclusions

In this paper we have described the design and implementation of the V-Armchair 4D motion experience and have described a user study focusing particularly on the user experience of older riders. However, the Younger Group of riders were found to have a similar response. Riders overwhelmingly responded positively to the experience, demonstrating high engagement through scores on the GEQ. Riders' enthusiasm was also echoed in the thematic analysis of interviews which, allowed us to explore the role of the well-received presenter/companion in the 360 video in some detail. The analysis also allowed us to tease out components affecting presence and immersion and consider how the experience could be improved. In future work we are planning to extend the study to older riders, and further investigate the role of the presenter, and the effects of motion, in virtual thrill rides.

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