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Exploring the Perception of Additional Information Content in 360° 3D VR Video for Teaching and Learning

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Abstract: 360° 3D virtual reality (VR) video is used in education to bring immersive environments into a teaching space for learners to experience in a safe and controlled way. Within 360° 3D VR video, informational elements such as additional text, labelling and directions can be easily incorporated to augment such content. Despite this, the usefulness of this information for learners has not yet been determined. This article presents a study which aims to explore the usefulness of labelling and text within 360° stereoscopic 3D VR video content and how this contributes to the user experience. Postgraduate students from a university in the UK (n = 30) were invited to take part in the study to evaluate VR video content augmented with labels and summary text or neither of these elements. Interconnected themes associated with the user experience were identified from semi-structured interviews. From this, it was established that the incorporation of informational elements resulted in the expansion of the field of view experienced by participants. This "augmented signposting" may facilitate a greater spatial awareness of the virtual environment. Four recommendations for educators developing 360° stereoscopic 3D VR video content are presented.

Keywords: virtual reality; 360° 3D VR video; multimedia; perception; higher education; cognitive loading

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1. Introduction

The term Virtual Reality (VR) was first described by Jaron Lanier as "conceived of as an expansion of reality, the provision of alternate realities for people *en masse* in which to share experiences" [1]. Winn and Bricken later described VR as a "computer-generated, multidimensional, inclusive environment which can be accepted by the participant as cognitively valid" [2]. Such environments can be deployed using a range of technologies to facilitate user autonomy, interaction, a feeling of presence and ultimately facilitate learning [3]. VR experiences are commonly delivered via a head mounted display (HMD), enabling a user to view or move around within a virtual space whilst observing or interacting with this environment [4]. Although HMD use has become an increasingly common method to deploy VR content (driven at least in part by the development of stand-alone, untethered systems where a headset is not directly connected to a separate computer interface), it should be noted that the use of HMDs is not an absolute requirement for an experience to be considered VR.

Experiences based upon immersing the learner in an artificial representation of a real environment are widely employed to facilitate education and training in public [5] and commercial [6] organisations. These experiences allow learners to access practice-relevant locations outside the traditional classroom, particularly those where physical access may present logistical challenges and ethical or safety concerns. Interactive VR content has the additional advantage that learners can develop skills in a safe environment. Such approaches have seen application in medicine [7] and industry [8] where the execution of complex procedures or the operation of equipment has the potential to present a risk to the person involved. In addition, VR training has also been employed to enhance learner confidence [9] and to support wellbeing [10].

A VR environment can be constructed using a variety of different techniques. These include 3D static images [11], stereoscopic 3D 360° video [12] or game engines such as Unity® or Unreal Engine 4® to produce 3D interactive worlds populated with objects or environments co-populated with geometric constructs [13]. Alongside the presentation of any virtual environment (be it artificially created or derived from a real image), all VR formats provide the opportunity to embed information in ways which would not be possible in the real world. This can include the incorporation of labels, summary text or the highlighting of key items and areas. Features such as these are usually incorporated with the aim of directing the attention of the learner, providing additional context or highlighting areas of importance (Figure 1). As such, VR experiences can be developed to contain additional rich sources of information beyond the environment itself, further augmenting the virtual experience.

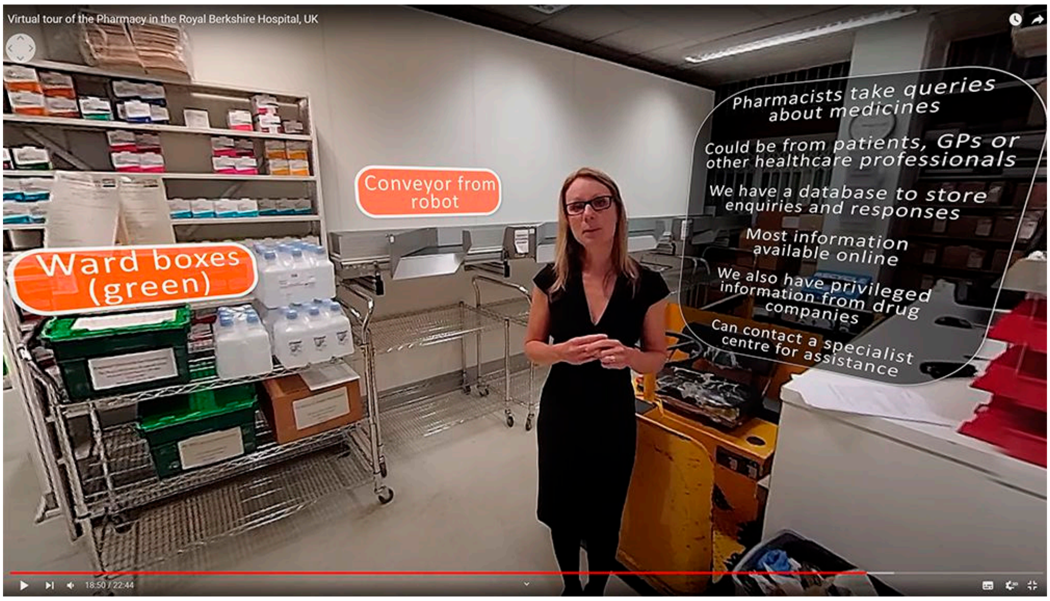

Figure 1. A still image from a 360° 3D VR video giving examples of labels (orange ellipse) and summary text (white text on a black shape).

2. Previous Research

In 2019, 79% of UK Further Education and 96% of Higher Education institutions reported using VR or augmented reality (AR) [14]. The use of VR is often associated with experiential learning, where learners learn through reflection on doing [15], with the VR environment acting as a user-accepted proxy for a real-world experience. VR is used to provide the concrete experience in Kolb's cycle of learning [16], although in fully interactive experiences it can also be used to address active experimentation simultaneously, as learners can plan and address additional scenarios within the same VR experience. There is therefore significant interest in deploying VR within practice-orientated subjects (such as medicine and allied health disciplines) where learners require exposure to practice environments to develop their professional skills in preparation for the workplace [17,18].

Several factors can affect the VR experience. These include those related to the virtual environment (such as the level of immersion and presence felt by the user and the level of interactivity incorporated into the virtual environment). Additionally, factors related to the "real" physical element of the experience (such as the characteristics and quality of the media and the comfort of a user when interacting with the facilitative technology) can also impact engagement. These points are explored in detail below:

1. Immersion and presence—a sense of "being" within an environment has been highlighted as particularly important for spatial learning [19], whilst exploration of the content at the learner's own pace facilitates a constructivist approach to learning.
2. Interactivity—increased interactivity can result in increased engagement, attentiveness [20] and attainment [21], but with greater interactivity comes increased development complexity.
3. Media characteristics—VR headsets are available at different price points [22], but high-quality experiences can be delivered using low-quality devices with minimal impact on learning [23]. However, high fidelity video and audio quality have been associated with greater immersion [24].
4. Comfort—discomfort has been associated with learner disengagement [25]. VR delivered by HMDs is often associated with motion sickness (often termed cybersickness in this context [26]). VR content can be designed to mitigate this risk, such as allowing the user to control all movement [27] to reduce sensory disconnect.

Whilst fully interactive "game-like" VR content is widely known, 360° 3D video content deployed via VR HMDs has received comparatively less attention. Compared to fully interactive game-like VR experiences (the production of which most often requires a team of specialist developers) [28], the development of immersive video and image-based content requires moderate to advanced skills in videography and photo editing. The barrier to content creation for video-based material may therefore be lower for educators compared to that for fully interactive experiences, particularly with the shift towards digital modes of instruction and concomitant technological upskilling necessitated by the COVID-19 pandemic [29].

For learners, video-focused content is less complex to navigate than fully interactive material. Interaction with video-focused content takes place using an interface similar to streaming video, and as such is more likely to be familiar to the general user than a game-style interface. If filmed correctly [30], motion sickness can be reduced or avoided. Using 360° 3D VR video also makes video-focused content more accessible. Content can be rapidly disseminated using streaming platforms to facilitate sharing and post-session review, either using a conventional desktop display or in a personally owned HMD. As such, the development of immersive VR 360° video experiences presents less complexity than fully interactive content, can be delivered to learners with less expensive hardware and can still allow learners to explore the environment around them by presenting a realistic representation of the space.

A scoping review on the use of educational 360° VR videos from 2020 highlighted that the area was "not well understood at the present time" [31]. Within a higher education context, Lee et al. [32] examined the effectiveness of VR-based video compared to on-screen delivery for the same instructional content. The study reported higher levels of enjoyment, interest and learning achievement when content was delivered via HMD [32]. Within English language education, VR delivery was similarly compared to traditional 2D delivery for training aimed at enhancing the writing performance of university students. Whilst learners who experienced conventional 2D video displayed a greater increase in their English language writing performance, VR video promoted an increase in long-term retention [33]. VR video has also been used in education training for reflection activities. In a 2019 study, 360° video of teaching sessions were reviewed by the learners who undertook reflection activities relating to their pedagogical practice [34]. Using 360° video, learners were able to observe all aspects of the classroom rather than the space within a defined camera area, giving them greater scope for observation and reflection.

Whilst design principles for educational 360° 3D VR video content have not yet been widely discussed in the literature [35,36], the use of multimedia in a non-VR setting (including video) has been described in the context of cognitive theory. Within this framework, Mayer et al. [37] present a model for learning from multimedia content which relies on the learner having two streams of information—from the eyes (pictures, video or text) and ears (sounds and narration). Design principles which aim to reduce cognitive overload, manage essential processing and foster generative processing were developed [37,38], and it is recommended that efforts are made to manage information content via both streams. The authors identify including redundancy in the video (such as including text containing the same information presented verbally) as one factor which increases extraneous processing. This could contribute to cognitive overload, which may be expected to lead to a decrease in learning and retention.

It has been described how this framework can be applied to interactive 360° video content [39] delivered by means other than VR HMD. The authors comment that additional augmented elements should "be a stimulus for the reader to promote cognitive engagement" [39]. Within our study, participants similarly identified that the inclusion of summary text within the VR environment—for the purpose of elaboration and contextualisation—allowed them to select visual or auditory cognitive streams. It should be noted that although redundancy is considered to complicate the user experience of multimedia, the inclusion of additional elements may not necessarily result in an increase in complexity. Augmented elements offer a means to simplify cognitive streams, thereby shifting the burden of redundancy between streams depending on user preference. Whilst it is not clear as to whether this will lead to increased attainment [40,41], learning via a preferred learning style has been proposed to directly correlate to comprehension and learning [42].

The production of VR video content for education has not received significant attention in terms of recommendations or guidelines for its development. Moreover, the contribution and usefulness of augmented elements (such as additional text and labelling) is rarely considered. This qualitative study aims to explore user perceptions of the usefulness of labelling and text within 360° 3D VR video content and aspects of the learner experience regarding the incorporation of such additional supporting content.

3. Materials and Methods

The 360° stereoscopic 3D VR video content in this study was recorded at the Royal Berkshire Hospital (Reading, UK) and the Hugh Sinclair Unit of Human Nutrition. Video clips featuring a hospital pharmacist explaining the layout and working practices of the pharmacy were recorded using Vuze+ and Vuze XR cameras (human·eyes™) in 360° (4 K) and 180° 3D (5.7 K), respectively. Additional visual elements, including labelling and summary text were incorporated using Adobe Premiere Pro™. The final video was uploaded to the headset and presented to participants using Oculus Go™ VR headsets (60 Hz refresh rate and resolution of 1280 × 1440 per eye) using the Oculus Gallery software, which enables users to play, pause, rewind and fast forward the video during playback using an on-screen video control panel, operated by using the Oculus Go™ controller. The video was presented with a full-sphere resolution of 3840 × 1920 per eye and frame rate of 30 frames per second, with a length of 22 min and 45 s. 12 different locations within the pharmacy were shown during the video and the order in which they were displayed mirrored the order that locations would have been visited during an analogous in-person tour. Locations visited included the main dispensary, aseptic medicine preparation suite, storage area and dispensary robotics facility. To minimize the potential for motion sickness, all video was recorded using a camera in a static location and users were "teleported" between locations using a fade-to-white transition.

Additional visual elements were timed to appear whilst the speaker was giving the presentation. The additional video elements were as follows:

1. 13 labels highlighting the name of the functional spaces within the pharmacy (one per space presented at the start of each new location; white text on a black background)
2. 41 labels for key objects or areas within the video (2–7 on-screen simultaneously; white text with an orange background)
3. 23 summary text boxes adjacent to the presenter summarising the spoken content (one on-screen at any time; white text on a black background)

Three separate videos were generated, each of which incorporated a different level of additional text and labelling (Figure 2). Additional examples can be found in Figure S1 in the supplementary information. These were as follows:

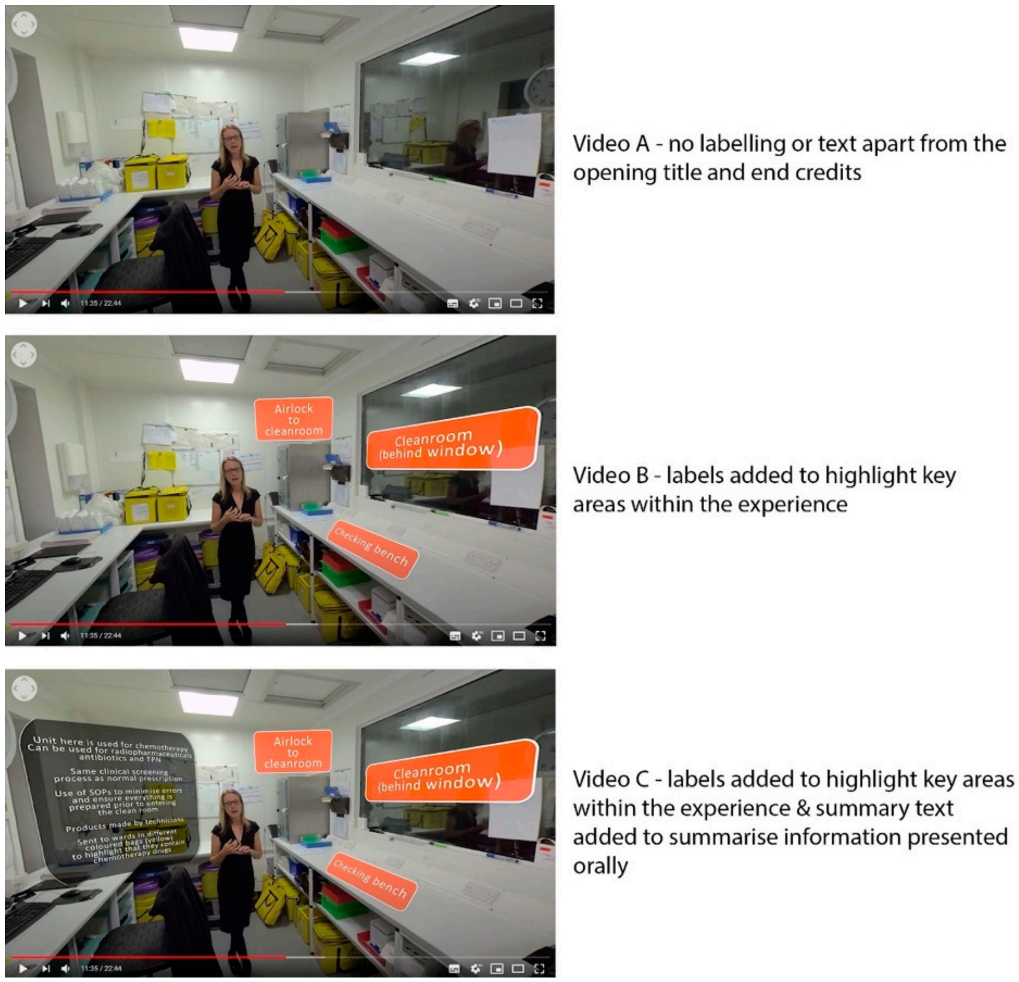

Figure 2. A screenshot from each of the **Videos A**–**C**, used in the study illustrating the difference in the level of labelling and summary text provided to the viewer; **Video A**: No labelling or text apart from the opening title and end credits; **Video B**: Labels to highlight functional spaces and key areas within the experience (orange boxes); **Video C**: Labels to highlight functional spaces and key areas within the experience (orange boxes) and summary text boxes to summarise information presented orally (black boxes).

3.1. Participants

Thirty postgraduate students at a university in the UK were recruited for this study. Students who had previously studied for a pharmacy degree, are currently studying for a pharmacy degree or had previously worked in a pharmacy practice environment were excluded to reduce the chance of subject bias related to prior knowledge of the environment. Participants were recruited as a random sample from open advertisement disseminated via university email lists. Participation was voluntary and participants were reimbursed reasonable expenses.

3.2. Study Design

Consent to participate in the study and for the interview to be recorded was established prior to watching videos and re-established prior to the commencement of the interview. Participants were provided with an Oculus Go™ VR headset and were randomly assigned to watch one of three videos (A, B or C), ensuring ten participants in each group. Semi-structured interviews (up to 30 min in duration) were conducted via Microsoft Teams within 48 h of the participant viewing the experience and followed a general interview guide approach [43]. Questions were designed to collect factual information, sensory information, information regarding, behaviors, opinions/values and feelings [44]. Factual/knowledge prompts (related to prior experience of VR HMDs) were used to open the interview to put the participant at ease before progressing to longer and open-ended questions [45]. Participants were first asked to describe prior experience and confidence in using VR systems, comfort and enjoyment. Open-ended questions were then used to explore participant experience and how this related to their confidence and ability to understand and take in the information presented, along with a comparison between the VR experience and an equivalent hypothetical in-person tour. A list of interview prompts and the interview schedule is presented in the supplementary information. Within the virtual continuum, this study sits wholly within the virtual reality regime. However, video A is a virtual representation of an unmodified real-life space, whilst videos B and C are virtual representations of a real-life space which have then been modified or augmented with additional virtual informational elements.

3.3. Thematic Analysis

Interviews were transcribed by J.P.H. Cross-checking of transcription accuracy undertaken by S.A.A. Data were analysed by using thematic analysis, as described by Braun and Clarke [46]. The analysis consisted of six stages: familiarisation with the data, developing an initial coding scheme, searching for themes, theme review, naming and defining themes, followed by describing the themes in this manuscript. Codes and theme development followed an inductive approach where development is directed by the content of the data. The analysis was performed across all participants simultaneously to ensure consistency in themes across all three groups (A, B or C) and themes were agreed upon by J.P.H. and S.A.A.

4. Results

Thematic analysis of participant interviews (n = 30) revealed three emergent broad themes with sub-themes which are presented, along with definitions derived from the scope of each theme based on participant responses (Table 1). The interconnectivity between themes and sub-themes is shown in Figure 3. An expanded theme and sub-theme table—with example quotations for each theme—is presented in Table S1 (supplementary information).

Table 1. Emergent themes, sub themes and associated definitions.

Theme & Definition	Sub-theme & Definition
Interaction with the virtual "real" environment *Perceptions around the experience and learning related to the simulated environment with no additional augmentation; i.e., the virtual representation of the environment as it would be in the real world*	**Exploration of content in the virtual real environment** *Factors affecting the extent to which learners explore the virtual real environment within the experience*
	Learning in the virtual real environment *Perceptions around learning in the virtual real environment*
Interaction with the virtual "augmented" environment *Perceptions around the experience of learning and content within a simulated real environment which has then been augmented with elements not found within the real environment; in this case text, labels and sounds*	**Labelling** *Perceptions of usefulness and optimal placement of labels within the virtual augmented environment*
	Summary text *Perceptions of usefulness and optimal placement of summary text within the virtual augmented environment*
	Learning in the virtual augmented environment *Perceptions around learning in the virtual augmented environment*
	Exploration of content in the virtual augmented environment *Factors affecting the extent to which learners explore the virtual augmented environment within the experience*
	Adding augmentation features *Requests to add features which would not have been possible in a real-life environment*

Table 1. *Cont.*

Theme & Definition	Sub-theme & Definition
Usability *Physical factors which affect the learning experience related to the physical learning environment and delivery method*	**Comfort and discomfort** *Factors influencing learner comfort and discomfort during the experience*
	Factors affecting enjoyment *Physical elements which positively or negatively affect the enjoyment of the experience by the learner*
	Experience of headset use *Perceptions of the overall experience of using the headset, such as ease of use*
	Video length *Perceived parity or disparity between the actual video length and that viewed as ideal by learners*

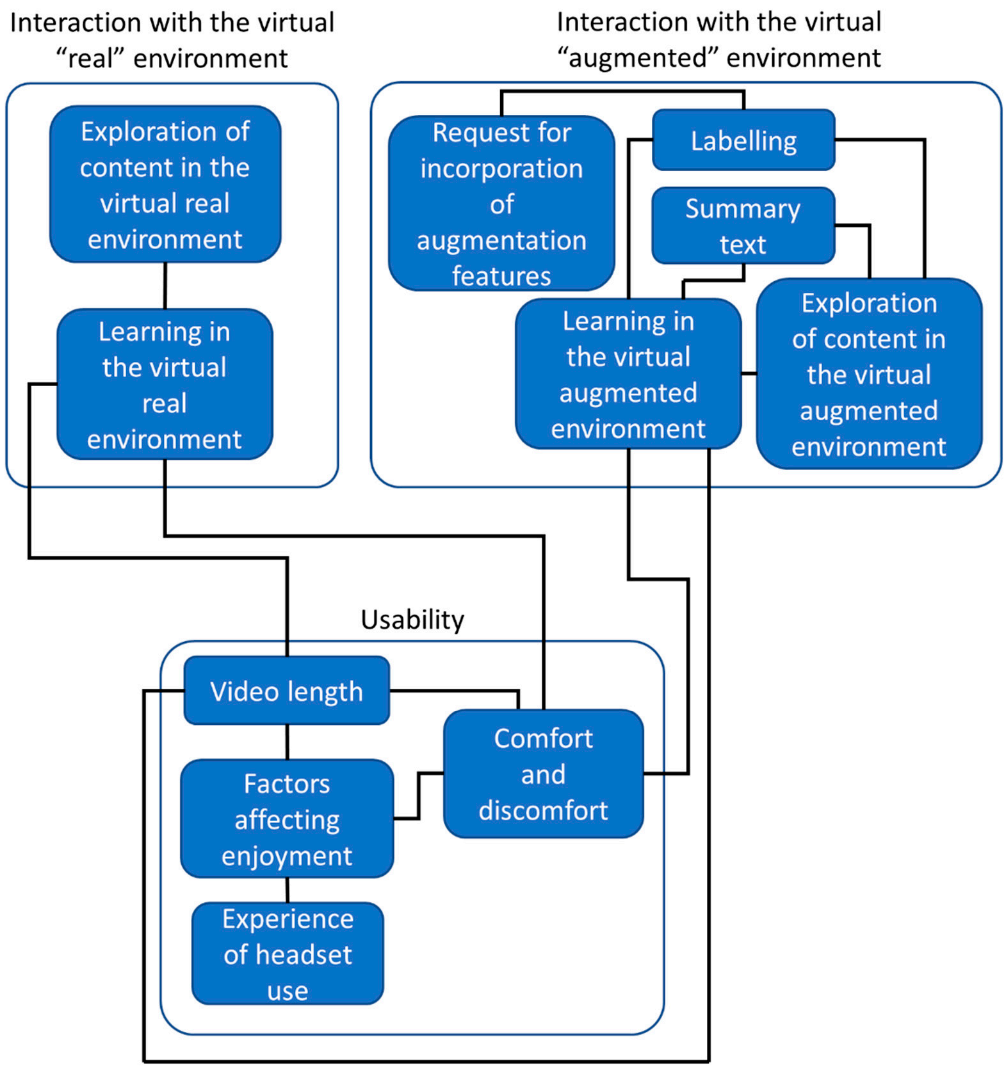

Figure 3. The connectivity between themes and sub-themes identified in this study.

4.1. Interaction with the Virtual "Real" Environment

One emergent theme focused on the participant interaction with the virtual "real" environment. The virtual "real" environment is defined in this context as: perceptions around the experience and learning related to the simulated environment with no additional augmentation; i.e., the representation of the environment as it would be in the real world. Within this theme, the sub-themes relating to the exploration of content and learning were identified.

4.1.1. Exploration of Content in the Virtual "Real" Environment

Participants discussed how they explored the content and their motivation for doing so. When viewing the video, most participants explored the full environment. Participants identified that key motivators for the exploration of the virtual real environment were factors which could have been expected in a real-world visit—curiosity and novelty of the experience.

> *"Curiosity, to see what everything was there just to get all of it in. It's not usual where you get to see a film, you just get to have a look around and see the rest of the scenery as well but yeah its interesting being able to see everything in the room as opposed to what's right in front of you."*

They also reported being able to explore the environment without feeling obligated to make eye contact or maintain focus on the presenter. The use of VR in this context therefore allowed them to forgo established social norms in favour of their own exploration and interaction with the environment. As a result, they were free to look around without feeling that they were being rude to the staff member giving the tour.

> *"Usually when you're here in person, you expect it to be like looking at the person talking and to show you are actually listening to, but I didn't feel that need there and I just listened to what happened and I was looking at all the things around me."*

Participants also reported that exploration gave them greater insight into the environment and processes that may take place within it, positively affecting how they learn.

> *"Looking around gave me a better idea of what it would be like to work in person."*

However, at times, exploration could also have a negative impact on learning.

> *"I was so distracted by the fact I could look around and explore that I didn't necessarily take in the information. I was aware she was talking, and I was trying to pay attention but then I was like, oh, what's that over there?"*

4.1.2. Learning in the Virtual "Real" Environment

Participants described multiple factors about their experience that either complimented or conflicted with their preferred learning style. Some aspects discussed had a positive effect on their learning experience. For example, participants reported that using VR videos would enable them to take part in the experience at their own pace and review the content multiple times, which would help with understanding and retention. This would be advantageous over an in-person experience which could not be reviewed again at a later date; at least not in the same format.

> *"So I think it does definitely have sort of those advantages to VR so you can see more almost you can go back and review it, you can take your time with it"*

> *"The issue with going in person is that you don't get to do it again if you forget something."*

Participants reported that audio in the headset was likely to be better than an in-person experience, particularly if that session were being undertaken as part of a group.

> *"I think it was better because if you are in a big group you aren't standing behind someone, you aren't trying to listen to someone and its focussed on you, that's a positive for the VR."*

However, participants described how several aspects of learning could not be accommodated if teaching of a topic *only* used VR. This included an inability to take notes whilst wearing a VR headset of the type employed in this study. It is noted, however, that this can be addressed by using a headset with video passthrough to enable learners to see a section of the environment in front of them, such as a notebook.

> *"I think one downside of the VR headset is I couldn't take notes, so I wouldn't have been able to recall that information."*

Participants also highlighted that it was not possible to ask the presenter questions during the experience.

"You wouldn't be able to ask questions in a VR environment."

Participants also requested interactive features, such as quizzes, to consolidate and test their knowledge.

" . . . if there was maybe a short quiz after each clip or like if you had maybe split it into two or something then that might work as well."

4.2. Interaction with the Virtual "Augmented" Environment

The second theme identified focused on the virtual "augmented" environment (defined in this context as perceptions around the experience of learning and content within a simulated real environment which has then been augmented with elements not found within the real environment).

4.2.1. Labelling

Video A contained no labelling or text. A majority of group A participants specifically requested labelling be added, either in general or to particular areas of importance within the video, linking this to the theme of requests for the incorporation of augmentation features.

"I think it would have been very useful to have little labels pop up as things were being explained to explain which segments she was referring to."

"If you could see labels above different doors to other places that would potentially help there. So I think labels and the text would certainly be useful, absolutely."

"Smaller rooms its not that hard to figure out where she is pointing but then the largest rooms that might actually yeah be helpful."

Participants in groups B and C reported that they liked the labelling and indicated that the inclusion of labels prompted them to look around the environment to a greater extent, linking this theme to that of the exploration of content in the virtual augmented environment.

"There were the orange text markers, so I was looking around to see if there were any of those in the clip anywhere other than straight forward."

Whilst participants requested more labels, it was also identified that labelling could have a negative effect on participant attention, as reading the labels distracted them from listening to the information from the presenter, reducing their ability to take in information and limiting learning.

"Sometimes I got distracted from what she was talking about and focused on reading" (Group B participant)

4.2.2. Summary Text

Summary text was presented as white text on a black background. Annotations of this type were present in videos viewed by participants in Group C but not those in Group B (where videos contained labels only) or Group A (where videos contained neither summary text nor labels).

Group C participants reported that the inclusion of information elements of this type helped to clarify important points and to assist with the volume of information presented.

"I liked the pop-ups which summarised what she was saying, I thought they were really good and because they covered sort of the really important parts of what she was saying."

They also reported that if they missed important points, they could then use the summary boxes instead. The participants identified that the inclusion of summary text was useful, as it allowed them to choose between listening and reading when assimilating information.

> *"I don't think I took in everything that [presenter] said but from the summaries that kept popping up I think that I got all of that information."*

Participants reported that the labels (orange boxes) were easier to read than the summary text (black boxes) and, as with labelling, reported that reading the text distracted them from listening to the presenter.

> *"The orange ones were easier, I think they were shorter as well."*

Group B participants requested additional summary text. It was considered particularly useful when the presenter listed information (such as the list of staff who work in the pharmacy department).

> *"So asking about whose role was what, I struggled a bit more with and again perhaps that's because I have less familiarity with the area but perhaps not if this is intended for students who are coming in kind of a baseline as well, then I think understanding which role applied to which room and which scenario. Maybe that could have been, you know, better signposted visually maybe with text."*

4.2.3. Request for Incorporation of Augmentation Features

As previously described in the discussion of the labelling and summary text subthemes, participants from Group A requested labelling to be added to their experience. However, participants across all groups also requested other features be added to the augmented environment. This included interactive features such as quizzes and a map or walkthrough of the environment to enable participants to increase their awareness of the connectivity of the spaces within the virtual environment. In some cases, requests were made specifically to address perceived limitations of the VR video experience compared to face-to-face delivery of a similar tour.

> *"You're kind of teleported there, so perhaps a video of just someone walking through those spaces at the beginning, or an embedded video or even a floor plan might be something that can help you picture where you are."*

4.2.4. Learning in the Virtual "Augmented" Environment

Participants identified that augmented features within the virtual experience benefited either their learning or learning processes. For example, the inclusion of summary text was viewed as a positive aspect of the VR experience.

> *"If it were one on one I don't think from the information delivered so much it would be much different. You would lose the summaries which I found really valuable because they gave you the really important information, so I think that would be a loss. However, an in person conversation you can do dialogue so if there is a query or you have something you don't understand, you can ask and she will explain it better, which is something you can't get using videos. But if the opportunity of questions weren't there and she was just delivering the same talk, but I were in the same room rather than watching on VR, I think VR is better because of the popups in the summaries."*

Learners were also able to use augmented features to compensate for the loss of attention or to shift focus to reading information rather than to listening to the presenter.

> *"I think I liked having the little pop-ups on screen, that gave you a little more information, I think they were good. There might have been a case where one stayed on screen for a bit of time and I found myself reading that instead of listening."*

The inclusion of augmented elements also provided learners with an opportunity to review the information during the experience, which may assist those who prefer to learn by reading rather than listening, or to offer opportunities for consolidation.

> *"I need to read something two to three times for it to solidify in my head"*

4.2.5. Exploration of Content in the Virtual "Augmented" Environment

Although summary text and labelling were viewed as a motivator for exploration, the most reported reasons for exploring the virtual space were curiosity and a desire to learn about the environment.

> *"I wanted to look around and see the space."*

> *"It's interesting being able to see everything in the room as opposed to what's right in front of you."*

However, within this context, the inclusion of augmented features helped to direct learner attention to key points of interest within the environment, helping them to identify what was important.

> *"There was one where there's the patient bed, but then it became clear when she spoke why the medicine cabinet next to it was labelled, because she referenced that in terms of that's where you keep the patient's own medicine."*

4.3. Usability

The third emergent theme focused on usability considerations of the experience. This theme relates to the physical process of viewing the experience in a VR headset. Four sub-themes were identified; those relating to comfort and discomfort, factors affecting enjoyment, experience of headset use and video length.

4.3.1. Video Length

The video viewed by participants was 22 min and 45 s in length (for comparison purposes, the equivalent face-to-face version of this experience is delivered as a one-hour in-person session). Irrespective of which version of the video the participants watched, the majority stated that the video was too long as a single VR experience.

> *"I thought it was too long, I wasn't able to focus for the length of the video."*

Observations relating to video length are linked to the theme of learning in the virtual "real" environment, as loss of focus by participants may negatively affect learning. Participants also requested quizzes in the experience to both improve their learning but to also provide a break in the video, suggesting that the introduction of quizzes could serve a dual purpose.

Participants indicated that the volume of information was appropriate to the experience, and so the majority did not say that the video should be shorter. Instead, they indicated the video should be cut into individual clips which would provide clear opportunities for breaks. Participants associated the length of the experience with discomfort and expressed a preference for the experience to be split into at least two sections of approximately 10–15 min in duration.

> *"It could work well if there were a break in the middle to just give yourself a bit of a break and acknowledge that you feel that discomfort and that its ok to pause the video and have that break."*

For some participants, video length was directly related to the theme of comfort, with some indicating that the video was too long because of discomfort with the headset, suggesting that had the headset been more comfortable, a longer video could be tolerated.

> *"I think it was a little bit too long, but that might have just been again because I was a bit uncomfortable towards the end, maybe a bit of motion sickness and by the end I wanted to take the headset off."*

4.3.2. Comfort and Discomfort

Most participants found the VR experience to be generally comfortable.

> *"So that specific headset was very comfortable inside."*

However, some participants reported minor to moderate discomfort when participating in the experience. None of the reported factors were significant enough to cause a participant to discontinue the VR experience. Factors included the headset being perceived by some as heavy and/or bulky, which led to facial discomfort. Not all agreed with this assessment, with some reporting the headset as being both comfortable and light. Others reported the headset to be initially uncomfortable, but claimed that this was addressed by adjusting the headset straps.

"it's obviously quite bulky and a little bit heavy."

Some factors were more significant. Two participants experienced mild motion sickness, (a well-documented side-effect of VR HMDs [26]). A minority of participants reported eye discomfort, which they attributed to the perceived quality of the video. Some participants, but not all, who wore glasses found the headset to be uncomfortable.

"If I have head bobbing on in a video game, this will cause me motion sickness. I found a similar experience if I moved my head too quickly. If I sat still it wasn't too bad but if I move my head too quickly to the right or left I would get a bit of motion sickness or disorientation."

"I think worst part was the quality of the video. My eyes get really tired after a while."

" … it's a bit uncomfortable with glasses on … "

4.3.3. Experience of Headset Use

Participants spoke about how they found the experience of using the headset. Most participants reported the headset and controller used in this study were intuitive and easy to use.

"I found that it was very intuitive with the controller, like to point and click."

None reported that they found the headset so difficult to use that they were unable to proceed with the VR experience, but some stated that it took time to familiarise themselves with the headset and its operation.

"Initially it was a bit difficult but within a few minutes, I understand how to use it easily now..."

Some participants reported that the graphical interface of the headset was similar to that used in other devices primarily used to play games, including games consoles.

"You know, just hold the button down to sort of bring up the menu and then from there it's just like using, I don't know, say another games console or controller of some kind."

This theme was linked to comfort and discomfort, as those new to VR took some additional time to adjust the straps to ensure an optimal fit.

"It took time to get it like it actually fitted … "

4.3.4. Factors Affecting Enjoyment

Participants reported a variety of factors which either had a positive or negative effect on their enjoyment of the VR experience. All participants described the experience as enjoyable and attributed enjoyment to factors including the novelty of the experience, immersion (with high sound quality and a 360° FOV positively affecting the perception of immersion) and perception of the experience as fun.

"I quite liked the novelty of it at least and I quite liked the different format and I found it quite fascinating, actually being able to look at it from a 360 degree point of view."

"I had fun and it was something new to try."

However, there were some factors which negatively affected the positive sense of enjoyment by participants. Participants were more likely to cite less enjoyment if they experienced discomfort during the experience.

"It was immersive, I was interested in finding out what was happening in the video but some of the discomfort elements were negative."

Additionally, poor video quality (such as perceived low resolution) was cited by some as reducing immersion, which also had a negative impact on the sense of enjoyment by participants, reinforcing that content fidelity is a key factor in the immersion level of VR content.

"The video quality wasn't perfect, it was pixelated, so it didn't feel like I was completely in but it was still enough that I was able to see what the room was like."

5. Discussion

The aim of this qualitative study was to explore the user perceptions of the usefulness of labelling and text within 360° stereoscopic 3D VR video content, and how the incorporation of additional elements influences the user experience. From the results, it was possible to identify interconnected themes relating to user experiences in the virtual "real" environment, virtual "augmented" environment and usability. It is particularly notable that users accepted, expected or requested the presence of augmented elements within the virtual experience, demonstrating a willingness to engage fluidly with information streams which would not normally present within a real environment or representation thereof.

Smith et al. describes design considerations regarding the placement of text in VR exploratory experiences delivered via HMD [47]. It is notable from this study that the placement of labels, ensuring that they do not obscure key visual elements, is considered a key design principle. The separate placement of text in this manner ensures that visual streams complement, reinforce and highlight rather than interfere or clash.

Segmentation is identified as one strategy for managing essential processing [37]. Aligned with this, the majority of participants within this study (all of whom watched the full 22-min experience), reported that shorter segmented video experiences were preferable. This can be attributed to the richness of information content, ability to remain focussed and comfort factors relating to the use of HMDs. This observation is consistent with a previous study which examined the effect of adding interactive elements to video lectures. In this study, for videos of greater than 11 min in length, the average viewing time was 10 min and 48 s, compared to 8 min and 48 s when no interactive elements were provided [48]. Segmentation of content also provides the opportunity to embed tasks allowing learners to evaluate their learning and retention outside of the VR environment, providing a means to purposefully blend VR and traditional teaching modalities [49].

Whilst labelling and text may have the potential to increase fatigue, it may also provide benefits for learners, including being a motivator for the exploration of the environment (as identified by the participants during the study). Greater exploration may lead to increased 3D spatial awareness of the local environment, although in experiences which employ "teleporting" to move between locations, learners may experience less understanding of the connectivity of spaces [50].

Placement of information outside of a typical participant field of view may necessitate the use of signalling. Akin to a presenter in a real-life experience gesturing or pointing to direct attention, non-informational elements, such as sound or arrows, can be incorporated into video to direct attention without increasing cognitive load. Appropriate signalling has been shown to increase learner motivation to interact with the content [51]. Signalling also allows the user to maintain control over their viewing area [52]. This ensures that the viewpoint within the video does not change independently of the user, thus reducing the likelihood of motion sickness [53].

It is also noted that the inclusion of labelling and text also has implications for accessibility. The inclusion of audio–visual cues and information may help to facilitate access to content for those with hearing or visual impairments. This is an important consideration, as there is currently no standard format for subtitles in 360° stereoscopic 3D VR content [54,55], with app developers and streaming platforms taking their own unique approaches. Where text is included, it should be checked using a reading speed calculator to ensure that it can be read during the allotted time. The use of video-based content may also facilitate a standardised experience across different HMD hardware. Whilst HMD hardware is constantly improving, video files often require little to no modification to allow them to be viewed using different HMDs, especially if streaming from a platform which can transcode on-the-fly to a format suitable for the end user device, such as YouTube [56]. Improvements in hardware may positively affect visual fidelity but would not fundamentally change a video-based experience. In contrast, the quality of 3D experiences rendered "on-demand" is highly dependent on both HMD and computing hardware and, in some cases, may be exclusive or restricted to individual platforms. The outcomes reported here suggest that improvements in fidelity or other physical factors, such as size and shape of the HMD, may increase user comfort and enjoyment.

This study also highlighted factors which lead to an increase in learner enjoyment and comfort. Whilst some of these are an inherent weakness or limitation of current VR delivery methods (such as difficulty in notetaking whilst wearing an HMD), other factors such as visual and audio fidelity can be directly controlled by those developing the VR content. Visual quality was perceived by participants as one factor which can detract from the comfort, enjoyment and immersiveness of VR experiences. Ensuring that content is produced with the highest fidelity possible should therefore be a priority during development.

6. Conclusions

This qualitative study sought to evaluate the perception of the usefulness of labels and text within 360° 3D video delivered via a VR HMD to establish the contribution of augmented elements (such as additional text and labelling) to the user experience of learning environments presented in virtual reality. From participant responses, three themes with 11 sub-themes were identified. The themes related to how users interacted with the virtual "real" environment, the virtual "augmented" environment and factors related to usability of the headset and experience.

This work has identified that the inclusion of labelling, to highlight key and important features, can help motivate learners to explore a virtual environment. The inclusion of summary text enables learners to select which cognitive stream they prefer using to learn presented information. However, participants also identified that shorter experiences were preferred, and that poor audio and/or visual fidelity were associated with discomfort and a reduction in enjoyment of the experience.

The following recommendations are proposed for educators seeking to develop 360° stereoscopic 3D video content for deployment in HMDs:

1. Labelling may lead to additional exploration and 3D awareness by the learner and incorporation can help direct the learner's attention to notable features. Where 3D spatial awareness is a key learning outcome, the incorporation of labelling may then assist the learner.
2. Summary text may be useful to learners, particularly where text overlaps with information provided orally. This may allow learners to select which cognitive stream they prefer to use to learn, helping the learner to focus.
3. The principle of segmentation within the framework for cognitive learning should be applied to 360° 3D VR video to reduce cognitive overload and maximise user comfort. Participants in this study suggested 10 min as the optimal length of the experience. Elements to evaluate student learning could be included between segments for learner self-evaluation outside of the VR environment.
4. Video-based experiences should be recorded to maximize fidelity. This may increase both enjoyment and immersion, whereas low fidelity contributes to feelings of discomfort and a reduction in enjoyment.

Following on from this work, we believe there is considerable scope to examine other design features within an educational context. Although our study focused on textual artifacts, it is important to note that signaling can also include auditory and directional elements/signposting. Future work could encompass examining the effectiveness of different signaling types on the user experience. We also intend to examine the placement of varied informational elements in the context of learning gain and retention, using qualitative, quantitative and mixed research methods. This may include the use of eye-tracking technology to establish the optimal placement for visual elements within educational media. It is considered that a framework for the design and implementation of 360° 3D VR video within an educational setting could be developed through further studies.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/virtualworlds1010001/s1, Interview prompts, Interview Schedule, Figure S1: screenshots from the virtual video experience, Table S1: Themes and sub-themes identified in this study with example quotes for each sub-theme.

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