

Virtual Reality Human Factors

Immersive video as a behaviour change tool in road safety

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Introduction

Virtual reality has existed in various forms since the early 1980s, however with advances in technology, in both hardware and quality of graphics, the variables have changed so much that it calls into question some of the validity of older research when considering contemporary society. Furthermore, overall media exposure has greatly increased with the introduction of mobile technology and widespread use of the internet, so not only has society become more technologically savvy as innovations have become more integrated into everyday life, but expectations have also increased in its quality and capability.

Only recently has virtual reality technology advanced to such a point where it has become both affordable and compact enough for a wider market. As such its popularity has grown exponentially and its market is expected to grow tenfold over the next five years.

Traditionally Virtual Reality has primarily been used as a tool for training as it offers a number of benefits over training in the real world. It offers a level of complete control over the environment and level of difficulty meaning that all users will have an identical experience and level of training. It allows the user to be safely placed in an environment or situation which would otherwise be hazardous in the real world. This has been heavily capitalised on by the military and in particular the Royal Air Force, who use it to train inexperienced pilots before placing them into planes, which in turn also offers them a large long term cost benefit.

There are relatively few examples to date where virtual reality has been used as a tool for behaviour change, and as such its application in road safety is untouched ground. Therefore, it is the purpose of this research to take a broad perspective of its potential for application by these means, and to lay the foundations for future studies into its viability and success.

This report outlines a study commissioned by Safer Roads Humber to ultimately determine the viability virtual reality has when compared to other traditional media delivery mechanisms as a tool for promoting positive behaviour change among young adults aged between 15 and 19. Through primary and secondary research, it takes current behaviour change theory into consideration and addresses concerns voiced by the road safety community regarding unintended effects.

Background

Terminology

There is a variety of terminology that has emerged over the years when discussing virtual reality, however, more recently, standards on terminology and their definitions have been recognised. The following defines the most commonly associated terminology:

1. **Presence:** The term used to describe the psychological state of the user whilst inside the virtual world. This includes both higher and lower conscious and unconscious functions. This includes the higher conscious sense of being present and accepting the virtual world as a reality, and the lower unconscious functions such as autonomic responses, which suggest a true physical presence within the environment.
2. **Immersion:** A simplification describing virtual content surrounding the user and 'immersing' them into media. It doesn't go as far as to include any presence the user may experience, but is more of a reference to the technical capability of the environment itself.
3. **Involvement:** Further to Immersion, it describes the level of interaction that a user may have with the virtual environment.
4. **Virtual Reality (VR):** This has become somewhat of an all-encompassing term for immersive video and true virtual reality. True Virtual reality by definition; must allow the user to control and interact with the perceived environment, and be as close to a reality as is technically possible.
5. **Virtual Environment (VE):** A computer generated environment. Not necessarily as viewed in Virtual Reality. It describes any environment which is generated by computer graphics, so also includes other media such as computer games.
6. **Augmented Reality:** This is a step between reality and virtual reality. Computer generated graphics are laid over live images from the real world. These may be viewed through a mobile phone utilising its built-in camera, or through specialist glasses. Therefore, interactive computer generated objects can pop out of other static objects, or be placed in locations within a real room. This will likely begin as more of an everyday utility tool for the mass market in comparison to the entertainment aspect of full virtual reality.
7. **VR Headset:** This may describe any headset which allows the user to experience a form of virtual reality. May also be commonly referred to as a 360 headset as in the case with mobile phone adapted headsets.
8. **Immersive Video:** May specifically describe 360-degree video that does not have a fully interactive element.

Existing Research Summary

As has been stated, virtual reality is a relatively new domain, and as a result there is not currently a comprehensive set of research into its full effects on the user, or indeed its potential benefits. To

determine the latter, there needs to be an understanding as to what viewing content in this way does to the user so that it can be capitalised on in the right ways to encourage positive behaviour change.

The review of existing evidence only takes into consideration papers published since 1999; anything published before this date has been considered to no longer be relevant unless it has been cited more recently as a current understanding or convention.

It is important to note that there is a distinct difference between training and behaviour change. While training is teaching someone a new skill, behaviour change is altering attitudes, and a much more complex process.

Evidence predominantly comes from research into virtual reality as a technology and its use in some examples as a tool for behaviour change. Other research looks at technology and the digital domain, whose findings may be transferable to the virtual reality research domain.

Author	Date	Title	Design	Results Summary
Anderson et al	2008	Assessing craving in young adult smokers using virtual reality	Participants were subjected to a number of smoking cues, and asked to rate their levels of craving, and then how long it takes them to return to a baseline	Participants responded strongly to these cues, and did not return to baseline craving following exposure compared to other smokers
Bailey et al	2011	Presence and Memory: Immersive virtual reality effects on cued recall		A strong correlation between levels of reported presence and level of cued information recall
BAÑOS et al	2008	Presence and Emotions in Virtual Environments: The Influence of Stereoscopy	Stereoscopy and non-stereoscopy groups, two different films - one centred on relaxation, one on joy. Questionnaires were used to assess emotional impact.	Stereoscopy (3D) had no influence on increasing a sense of presence or emotional reaction to content. However, an increase in presence had a stronger positive emotional response.
Baren and Jsselsteijn	2004		Compendium of presence research to date	Defines various approaches and developing standardised measures, however most research focuses on different types of emotion and behaviour using differing measures to provide a converging

				perspective on this area of research.
Chittaro & Zangrando	2008	The Persuasive Power of Virtual Reality: Effects of simulated human distress on attitudes towards fire safety	Participants split into two groups, LowEmo, HighEmo (Both negative framed anxiety) Questionnaires on anxiety levels and attitudes towards the dangers of smoke and fires	The HighEmo group showed more positive changes with regards to their reported attitudes towards fire safety.
Ekeh et al	2013	Pilot evaluation of the short-term effect of driving simulation on novice adolescent drivers	40 students split into two groups: Control and Experimental. The experimental group underwent 12 modules of driver training using a virtual reality system. (6 hours split over 2 or 3 days) Driver records reviewed at 6, 12 and 18 months' post intervention.	Exceptional results. Driver records were reviewed for speeding and other offences, and collisions. Twice as many in the control group had received an offence as the experimental group. The control group experienced 4 times as many collisions as the experimental group.
Omaki et al	2016	A systematic review of technology-based interventions for unintentional injury prevention education and behaviour change	Compendium of technology based interventions (11 highlighted as virtual reality)	All but one VR tool has been used for pedestrian skills training to children. The results have been positive in each instance, with all but one of them using observed behaviour as their method of evaluation.
Plancher et al	2007	Virtual reality for the study of true and false memory	Two groups - One active - One passive. Active group navigates through a 'new' town while the passive group are passengers.	Little difference between active and passive participation verses false memory.
Schuemie et al	2001	Research on presence in virtual reality: A survey	Various	Defines different concepts of presence theory and empirical evidence linking this to task performance, emotional response and memory recall.

Sivunen & Hakonen	2011	Review of virtual environment studies on social and group phenomena	Compendium of Presence research to date	Highlights the relationship between behaviour in VEs and real life (RL) based on empirical evidence. The following, through previous research studies in 2003,2007 and 2008 have proven to be the same in RL and VE in: Interpersonal distance; discrimination; the presence of others; and reactions to persons in need.
Slater	2009	Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments		States new definitions for sense of presence to PI and Psl: The physical sense verses the psychological sense. The relationship between the psychological presence (Psl) and mimicking real world behaviour correlate.
Slater	2015	Changing bodies changes minds: owning another body affects social cognition		Ownership of an outgroup body has been found to be associated with a significant reduction in implicit biases against that outgroup, hence reducing social biases
Slater & Sanchez	2014	Transcending the self in immersive virtual reality	Observational Study	Participants were presented with different sized and skin coloured virtual avatars in virtual reality. They behaved differently depending on their shape, size and skin tone.
Uhrig et al	2016	Emotion Elicitation: A Comparison of Pictures and Films	Positive or Negative images or video clips were displayed for 6 seconds, and questionnaires were used to assess emotional stimulus.	Film clips were more effective at eliciting positive emotions than pictorial images, whereas pictures were more effective at

				eliciting negative emotions than film.
Witmer & Singer	1998	Measuring Presence in Virtual environments: A presence Questionnaire	cited	Defining the qualities needed for presence as immersion in a psychological sense: Involvement; having an active role within the world. The greater the sense of presence, the less likely to have reported simulator sickness.
Yee et al	2009	The proteus effect: Implications of transformed digital self-representation on online and offline behaviour	Participants were entered into a virtual environment and their avatars' behaviour was monitored for 15 minutes	Differing visual characteristics in the online avatar had a profound influence on behaviour in face to face interactions within the Virtual Environment. Taller avatars were more aggressive. Similarities in characteristics between an avatar and a user were seen as more favourable and a powerful cue at coercing.

Witmer and Singer define the necessary conditions needed for presence and state that there are a number of contributing factors involved. Control factors, sensory factors, distraction factors and realism factors are all major components. While *Barfield and Hendrix* (1995) noted that frame rate and refresh rate (the rate at which movement is updated) have an influential part.

While presence is a subjective sensation, it is considered the single most important measure in the effectiveness of virtual reality, and is the focus or at the least the inclusion of almost all research in the domain. Many of these studies have proven a direct relationship between emotion and levels of reported presence and stated that there is actually interplay between the two; that both high levels of emotion cause a higher sense of presence, and a higher sense of presence causes a higher emotional state.

Arguably a commonly accepted paradigm around exactly what presence is, and how to measure it has yet to emerge. However, the use of a variety of different measures and directions have added complimentary perspectives on the matter.

Schloerb (1995) treats the concept of presence as binary, either telepresent or not-telepresent, however the general consensus among other authors is that the concept is much more of a continuous scale. This thinking takes into account that on an individual basis there are other contributing factors. While the technology may contain all of the key ingredients for the physical world, it is still subject to the participant's own internal mental world, such as memory or day dreams.

Dr Mel Slater is considered one of the leading minds in this area, and has been working on virtual reality research since the 1990s. His work is often cited by others and some of his latest work has sought to draw in these other perspectives and establish more of a consensus towards the concept.

In some of his latest research he has redefined presence into two sub categories, PI - Physical presence (the sense of physically being within the environment) and Psl - Psychological Presence (The psycho-emotional sense of being within the environment.) (Slater *et al* 2009).

Perhaps important to note is that virtual reality as it exists today can only fool two of the basic senses, sight and hearing. A real environment will include far greater sensory information such as that which the body is accustomed to. Two of the clearest examples are the sense of smell and touch. Until such a time that technology has advanced to replicate or fake this other sensory information, it would be expected that there is a certain level of cognitive dissonance experienced, and the level of physical presence will only be able to progress so far.

While the majority of research is from a psychological perspective, more recently neurological studies have been able to add a further dimension to the understanding.

A study published in Nature Neuroscience describes studies into the hippocampus, the region of the brain which assists with memory and creating mental maps for space. For example, when a person explores a room, neurons in the hippocampus will become selectively active, helping to provide a cognitive map of the space. A further study which inserted rats into a virtual environment, showed that despite their observed behaviour and movement around a space being comparable to the real world, neurons in the hippocampus were firing at random, disrupting normal operation in the brain.

Often used as a comparison with road safety risk behaviour are behaviours associated with health, and in particular smoking. While smoking is arguably a more complex behaviour due to an element relying on chemical addiction, there is an element of transferable knowledge with relation to the study into virtual reality.

One study in particular focused on using a virtual reality environment to establish cues to cravings. In a randomised control trial, adolescent participants were exposed to either cued or neutral environments in virtual reality. The groups exposed to the smoking cues reported higher levels of craving, thus establishing virtual reality as a viable medium for controlling cue exposure (Traylor *et al*; 2008). Interestingly, these adolescents did not return to their baseline levels as their adult counterparts did in a similar experiment, perhaps suggesting that the effects of virtual reality on adolescents is somewhat different to that on adults.

Virtual reality has previously been suggested as an effective tool at increasing rates of anxiety and fear (Baas *et al*; 2004) which was the basis for a study whose aim was to increase awareness and attitudes of risks associated with smoke in evacuating buildings (Chittaro & Zangrando; 2015). This study tested two techniques: the first technique simulated the damaging effects of smoke on the user through a visualisation that should not evoke strong emotions. The second aimed at partially reproducing the anxiety of an emergency situation.

This study used a gamified environment with sound and imagery to simulate harm from the smoke-filled room. Participants in this group reportedly had improved responses to attitudes towards the dangers of smoke, and showed increased levels of anxiety. However, the authors note that *studies of negatively-framed messages that appeal to fear (and the resulting anxiety) have shown induction of mild fear to be an effective strategy, while induction of greater levels of fear can backfire and result in less rather than more persuasion, due to the trigger of defensive reactions.*

In qualitative data collection following the experiment, participants described their disappointment at dying within the game, and wanted to try again to win. This may highlight an area for consideration in any gamified environments.

An area which may prove of concern is using this technology with an inappropriate goal for the age group. *Segovia and Bailenson (2009)* placed children into an immersive virtual reality simulation and then interviewed them after the experience. Children in the virtual reality condition reported more false memories, confusing the virtual experience as having happened in the real world earlier in their lives. This effect lasted several days after treatment.

Memory recall in virtual reality is complex, however, it was identified very early on in the technology's development. Various studies suggested that it is possible that after experiencing a highly vivid and sensory experience, participants had limited cognitive resources to dedicate to memory task, and went on to explain that this may be associated also with the increased emotional stimulus.

The reasons as to why there is increased emotional stimuli is not yet fully understood. It may be the case that because the technology is still in its infancy there is a novelty to the experience which may diminish over time as it becomes more mainstream. However neurological science research would suggest that it is perhaps due to unexplained neural-activity.

Overview of Behavioural Science

While it is often the go-to example for road safety, the threat and fear appeal message comes under great criticism from research. *Lewis et al (2007)* explain there is "a large body of literature characterised by issues of long standing debate and inconsistent findings". *Wundersitz et al (2010)* cite studies which have demonstrated that: *"exposure to fear appeals can elicit maladaptive responses, that is, responses that do not try to control or remove the threat implied by the fear message but attempt to cope with unpleasant feelings that result from the advertisement. Such maladaptive responses might include defensively avoiding or ignoring the message, failing to process the threatening part of the message and denying the personal relevance of the message. It may also promote reactance against a message such that individuals view the message as a challenge and increase the undesired behaviour. In other words, the message is rejected or regarded as ineffective. All of these responses are dangerous because they can reduce the threat without reducing the actual level of risk."*

Another area which should be lighted upon bears particular relevance to the adolescent age group. Young adults traditionally place a large importance on their social context. Social identity theory states that *despite certain differences [...] individuals define themselves in terms of their social group memberships and that group-defined self-perception produces distinctive effects on behaviour and intergroup relationships (Hogg & Abrams 1988; Turner 1999).*

While this is by no means new thinking, it is worth bearing in mind when researching the digital domain. Social Identity theory, Deindividualisation theory and the Proteus effect (the observed effect of individuals taking on other behaviour characteristics based on the appearance of their avatar) will all influence outcomes whether exposed in a group setting or on an individual basis.

Design

Given the limited pool of current research into the viability of VR as a behaviour change tool, the purpose was to design an experiment that will assist intervention designers in understanding how viewing content through a VR headset affects the user both psychologically and physiologically, and how this might be best utilised to frame and deliver targeted messaging.

The starting point for this was to understand the relationship between user and technology. Existing research states that there is a strong correlation between emotional level and reported presence, and since presence is the primary goal of virtual reality technology, this was one of the main avenues of investigation.

Additionally, the emotional state of a participant will have an influence over their receptiveness to messaging. Therefore, understanding what influential effect the content itself has, and how it is augmented by viewing it in a VR headset is important.

Aim

1. A controlled trial (without randomisation) VR experiment to provide measures of:
 - a. psychological effect: reported emotional state
 - b. physiological effect: Change in heart rate over time, and return to baseline
 - c. behavioural elements: indications on social norms, willingness and intentions
 - d. users' level of reported presence
 - e. how these results differ between standard screen viewing and VR headset viewing.

Objectives

The purpose of the experiment is three-fold:

1. To measure any change in elicited emotion (Including levels of stress) when viewing content through a VR headset compared to watching the same content on a standard screen.
2. To determine the level of 'presence' achieved through viewing content on a VR headset.
3. To further understand the relationship between types of emotion and levels of presence.

Selection & Blinding

Recruitment for studies is always a difficult task, however for the purposes of this experiment, Safer Roads Humber were able to recruit directly from schools and colleges in the Humber area to take part. However, the experiment took place outside of lab conditions in the field and entirely at the college's pleasure.

With the lack of control that is otherwise offered in lab experimentation, potential issues were identified and mitigated against where possible. Students were made available by the college a class at a time, with classes randomly assigned to one of the four experimental groups.

The decision was made for the experiment to be blinded, so that the participants did not know what type of content they would be viewing, or that those who were running the experiment were road safety professionals. The reasons for blinding were two-fold:

1. As one road safety video and one non-road safety video were being used, the knowledge of it being a road safety experiment could immediately bias the results. By describing the experiment as market research and not identifying in any way that it is linked to road safety should remove bias and lead to more accurate results.
2. Previous findings from qualitative data gathering with the target age group, place an importance on context. This adolescent age group are very compliant and prone to exhibit demand characteristics. Perhaps as a result of the way the education system is structured, they perceive things to be more like a test and will provide what they think is the *correct* answer, rather than answering honestly.

This is something that has been carefully considered in the questionnaire design. Once again because only half of the content can easily be identified as being linked to road safety issues, the questionnaire cannot directly ask questions on purely road safety matters. Therefore, proxy questions that identify social norms, willingness and intentions on several other risk related behaviours were included. These have been guided by a government report on perceptions of young people (2011).

Ethics

Due to the blinding of the experiment, ethical considerations needed to be made for participants. Participants were unable to give informed consent before taking part because the true nature of the experiment hasn't been disclosed in full.

Participants were told that it is simply market research and that they were going to watch one of four videos, and then be asked to fill out another questionnaire. Once all final questionnaires had been collected, the true reason for the experiment was disclosed and time was given to answer any questions or concerns that they may have had.

Scales

The following established scales have been included or adapted for measurements of changes in Emotion, Stress and Presence.

Hospital Anxiety and Depression Scale (HADS)

This self-assessment scale has a series of 14 statements that the user has to identify to what level they agree with on a numerological scale of 0 to 3. (*Zigmond, A. S. and Snaith, R. P. 1983*) Designed to assess both levels of anxiety and depression, the overall scores for both parts give an indication of mental health concerns and exclude other contributing factors such as fatigue or physical discomfort.

In this study, the questions relating to depression have been omitted and the number scale has been adjusted to 1 to 4, to make it more user friendly.

Positive and Negative Affect Scale (PANAS)

The PANAS scale (Watson et al, 1988) consists of a series of 20 words describing different feelings and emotions. These have been grouped into being either positive or negative (10 of each). The user is required to indicate the level that they feel each emotion at that point in time. In this study, this has been scored on a scale of 1 to 10 (1 being not at all, and 10 being extremely), rather than the standard scale of 1 to 5. The order that the emotions are listed in is randomised.

Presence

Slater, Steed and Usoh (1993) established a framework for assessing the levels of presence which has been replicated in other studies in various ways; however, the concept remains the same in all. It states that there are 3 concepts that need to be assessed.

- *The subject's sense of 'being there' – a direct attempt to record the overall psychological state with respect to an environment.*
- *The extent to which, while immersed, it becomes more 'real or present' than everyday reality.*
- *The 'locality' that is the extent to which the virtual environment is thought of as a 'place' that was visited rather than just as a set of images.*

Questionnaire Design

All questionnaires in this study have a simple and neutral design and are all printed in black and white as not to influence any answers with colour choice [See Appendix 1].

The questionnaire was separated into 5 different sections. In the first section participants were asked to rate, on a scale of 1 to 10, the levels of 20 different emotions that they were experiencing at that time as per the PANAS test (*Watson et al, 1988*).

Interested	Distressed
Excited	Upset
Strong	Guilty
Scared	Hostile
Enthusiastic	Proud
Irritable	Alert
Ashamed	Inspired
Nervous	Determined
Attentive	Jittery
Active	Afraid

The following section administers an adapted version of the HADS test (*Zigmond, A. S. and Snaith, R. P. 1983*) where participants were asked to rate their level agreement with 7 statements relating to anxiety.

I feel tense or 'wound up'
I still enjoy the things I used to enjoy
I get sort of frightened feeling as if something awful is about to happen
I can laugh and see the funny side of things
Worrying thoughts go through my mind
I feel Cheerful
I can sit at ease and feel relaxed

Section three, the final section in the pre-intervention questionnaire, listed 7 statements relating to social norms, willingness and intentions. Participants were asked to rate how much they agree with the statements.

Having unprotected sex just once is unlikely to result in catching a sexually transmitted infection (STI)
My friends would disapprove if they knew I had money troubles
I feel optimistic about my future
I would be willing to cross a busy road, away from a proper crossing
My friends would approve if I drank alcohol
My friends are likely to help out a classmate being bullied
I can speak openly with my friends about any subject

The post questionnaire included two further sections in addition to the same three answered in the pre-questionnaire. The fourth asked them to complete the test for presence (*Slater, Steed and Usoh 1993*) - three questions which asked participants to rate their sense of being present within the film, and a free text box for the third and final question.

Rate your sense of being inside the film
To what extent were there times during the experience where you forgot that you were in a classroom?
When you think back to the film, do you think of it more as images that you saw, or more as something you experienced?

Finally, there was a section asking participants for personal data on their gender, year of birth and postcode. This data was used for matching participants; filtering by year of birth; and looking further at participants by Index of Multiple Deprivation.

Experimental Process

Convenience samples were obtained through colleges by class. Each class was assigned to one of the four experimental groups. Class sizes consisted of 10 students.

Participants were given a brief introduction explaining that they were taking part in a survey and were asked to complete a questionnaire individually before watching a short film, and completing another questionnaire. They were also told that they would be fitted with a watch to monitor their heart rate.

Participants were fitted with a heart rate monitoring watch before being issued the pre-questionnaires. Participants were asked to keep these on throughout, until they were specifically

requested to remove them at the end of the monitoring period. Participants were also politely requested not to fiddle with the units.

Once all pre-questionnaires were completed, participants were exposed to the chosen film and chosen method of delivery. In the case of the headsets, they were each individually fitted and the film set to role as the next participant was being fitted. In the case of the standard screen delivery, they all watched the film collectively as a class.

The content was as follows:

- Group 1: Road Safety content (VF4) through a VR headset
- Group 2: Road Safety content (VF4) on a standard screen
- Group 3: Positively framed non-road-safety content (Always) through a VR headset
- Group 4: Positively framed non-road-safety content (Always) on a standard screen

Once they had finished viewing the content, they were asked to remove their headsets (if in the relevant group) and complete a post experiment questionnaire.

Once the questionnaires were completed and collected, they were told that they can remove their heart rate watches. Once this was done, all participants were thanked and the purpose of the experiment explained in full, and they were given an opportunity to ask any questions that they may have had.

Results

All results (pre-to post) underwent a paired-T test. This is a statistical test to determine whether any changes in results are statistically significant to a confidence level of 95%. *Any results marked with a small circle in charts are identified as not statistically significant.*

Sample sizes obtained within each group are;

- VF4 Standard n=26
- VF4 VR n=31
- Always Standard n=26
- Always VR n=29

Because of unknown factors involved with the subjective nature of many of the measures, the two weeks' post results have only been included with relation to the behaviour questionnaires.

Emotion

Emotion	% Change VF4S	% Change VF4VR	%Change ALWS	% Change ALWVR
Interested	-13%	-7%	-21%	-7%
Distressed	+103%	+129%	-29%	-15%
Excited	-56%	-34%	-6%	+5%
Upset	+65%	+163%	-2%	+2%
Strong	-12%	-14%	-11%	+6%
Guilty	+23%	+105%	-23%	-8%
Scared	+98%	+111%	-4%	-7%
Hostile	+22%	+57%	-19%	-11%
Enthusiastic	-32%	-38%	-6%	+3%
Proud	-60%	-30%	-12%	+7%
Irritable	-12%	+60%	-36%	-19%
Alert	+31%	+30%	-14%	-11%
Ashamed	+9%	+67%	-4%	+11%
Inspired	-29%	-6%	+21%	+5%
Nervous	+22%	+34%	-31%	-30%
Determined	-39%	-12%	-7%	+5%
Attentive	-15%	-1%	-25%	-16%
Jittery	+32%	+67%	-42%	-14%
Active	-28%	-9%	-16%	+1%
Afraid	+64%	+138%	-23%	-14%

Figures in bold signify that they are statistically significant.

Grouping the emotional change by positive and negative emotional types:

Combined Positive Emotional Change			
Version	Change Score	% Change	T-test
VF4 Standard	-10.6	-25%	Significant
VF4 VR	-7.7	-15%	Significant
Always Standard	-5.0	-11%	Significant
Always VR	-0.7	-1%	Not significant

Higher score = Increased Positive Emotions

Combined Negative Emotional Change			
Version	Change Score	% Change	T-test
VF4 Standard	+8.2	+37%	Significant
VF4 VR	+14.7	+83%	Significant
Always Standard	-5.2	-26%	Significant
Always VR	-2.7	-13%	Not Significant

Higher score = Increased Negative Emotions

Stress

A single stress score has been calculated by matching individual responses between pre-and post questionnaires by adding together contributing and mitigating answers to create a combined score.

The change between combined pre-and combined post scores has been averaged across each of the samples.

Version	Change Score	% Change	T-test
VF4 Standard	+2.7	+43%	Significant
VF4 VR	+3.5	+59%	Significant
Always Standard	-0.6	-16%	Not Significant
Always VR	-0.8	-8%	Not Significant

Higher score = Increased stress

Behaviour

Individual scoring has been matched between pre-& post questionnaires. An average score for change by group has been taken.

Having unprotected sex just once is unlikely to result in catching a sexually transmitted infection (STI)			
Version	Change Score	% Change	T-test
VF4 Standard	+0.1	+3%	Not Significant
VF4 VR	-0.2	-4%	Not Significant
Always Standard	+0.2	+4%	Not Significant
Always VR	-0.4	-11%	Significant

Lower score = improved attitudes

My friends would disapprove if they knew I had money troubles			
Version	Change Score	% Change	T-test
VF4 Standard	+0.1	+5%	Not Significant
VF4 VR	+0.6	+24%	Not Significant
Always Standard	+0.1	+7%	Not Significant
Always VR	+0.3	+16%	Not Significant

Higher score = improved attitudes

I feel optimistic about my future			
Version	Change Score	% Change	T-test
VF4 Standard	0	-1%	Not Significant
VF4 VR	-0.2	-2%	Not Significant
Always Standard	+0.2	+4%	Not Significant
Always VR	+0.4	+6%	Significant

Higher score = improved attitudes

I would be willing to cross a busy road, away from a proper crossing			
Version	Change Score	% Change	T-test
VF4 Standard	-0.7	-14%	Significant
VF4 VR	-1.6	-26%	Significant
Always Standard	+0.3	+5%	Not Significant
Always VR	-0.5	-8%	Significant

Lower score = improved attitudes

My friends would approve if I drank alcohol			
Version	Change Score	% Change	T-test
VF4 Standard	-0.5	-9%	Not Significant
VF4 VR	-1.5	-19%	Significant
Always Standard	-0.2	-2%	Not Significant
Always VR	+0.2	+3%	Not Significant

Lower score = improved attitudes

My friends are likely to help out a classmate being bullied			
Version	Change Score	% Change	T-test
VF4 Standard	+0.3	+4%	Not Significant
VF4 VR	-0.6	-7%	Significant
Always Standard	+0.2	+3%	Not Significant
Always VR	-0.6	-7%	Not Significant

Higher score = improved attitudes

I can speak openly with my friends about any subject			
Version	Change Score	% Change	T-test
VF4 Standard	+0.3	3%	Not Significant
VF4 VR	-0.1	-10%	Significant
Always Standard	+0.2	-2%	Not Significant
Always VR	-0.8	-1%	Not Significant

Higher score = improved attitudes

Presence

Presence has been described as a sliding scale and not something that is just experienced within Virtual Reality; therefore, scores have been included from both the standard format and virtual reality groups. This also helps draw comparison between the two different types of film (VF4 and Always).

Overall scoring for presence has been calculated to take into account differences in physical presence and psychological presence using the following;

$$\text{Average}(PIQ + PIPsIQ \times PsIQ)$$

Of the three questions asked relating to presence, to assess the overall experience the first has been classed as relating to physical presence, the second classed as relating to both, and the final question psychological presence. Scoring is out of a possible 40.

Version	Score
VF4 Standard	9.9
VF4 VR	18.9
Always Standard	6.8
Always VR	21.5

Discussion

Viewing content within a VR headset has had a clear influential effect on change of levels of emotion over and above viewing the content in a standard format. Prior to experimentation, the Always film was chosen as a comparative film which we had considered to focus more on positive emotions, however when looking at the results of the standard and VR film, it appears to have a much more neutral trend. Many of the results are statistically insignificant, and for the most part levels of movement are small. It would suggest that this film is emotionally neutral overall, rather than positive as was originally assumed.

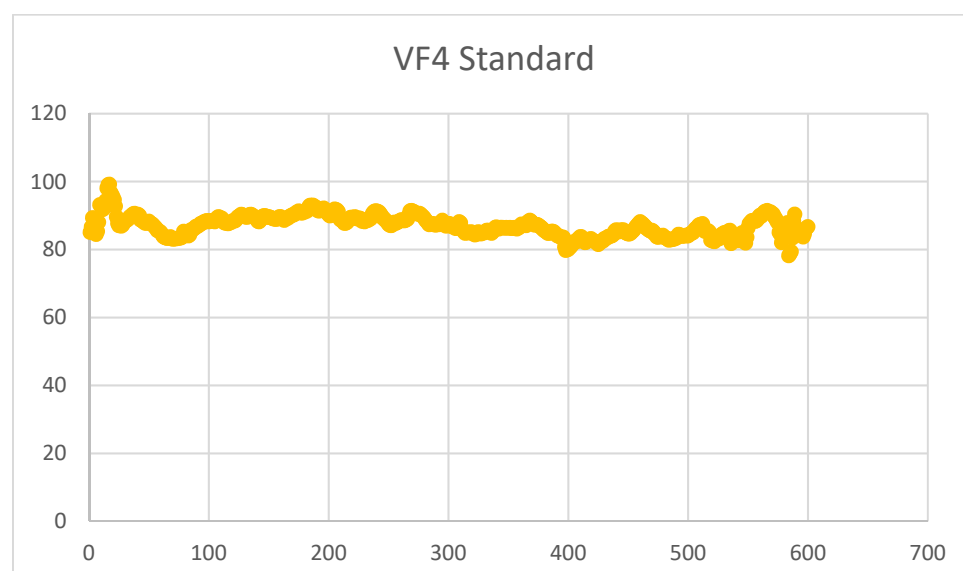
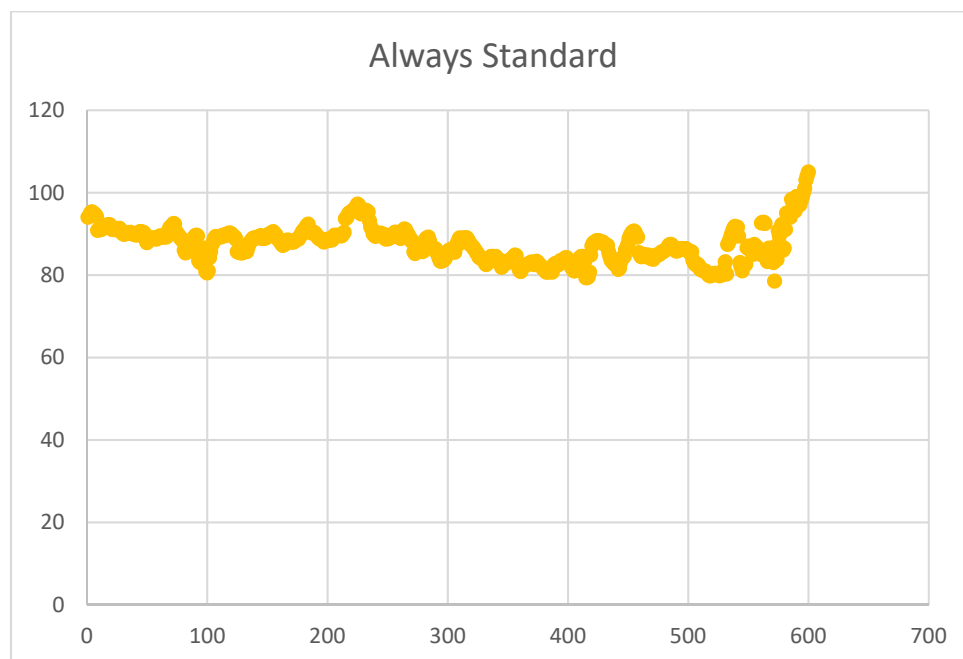
The lack of statistically significant results when considering the emotions individually means that responses cannot be compared between the standard viewing group of Always and the VR viewing group. However, taking a broader perspective when combining all 20 emotions into their positive or negative groupings it gives a slightly clearer picture.

Once again, the results of emotional change from the Always virtual reality group prove inconclusive as to whether any of the movement was significant, however there is significant movement for the standard group. This showed an overall reduction in positive emotions by 11% and a reduction in negative emotions by 26%. The fact that there is an overall reduction in emotion would suggest that the film itself is not very emotive, and even perhaps that participants were bored.

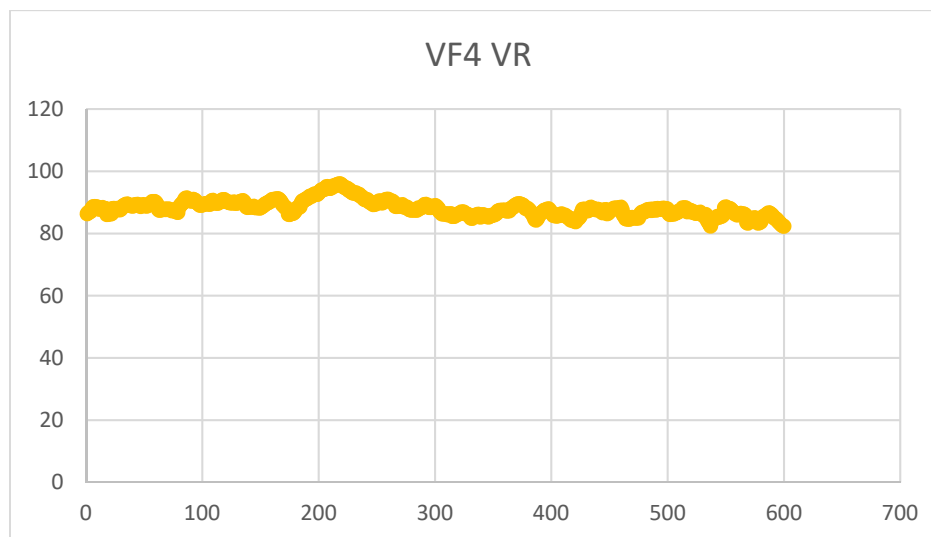
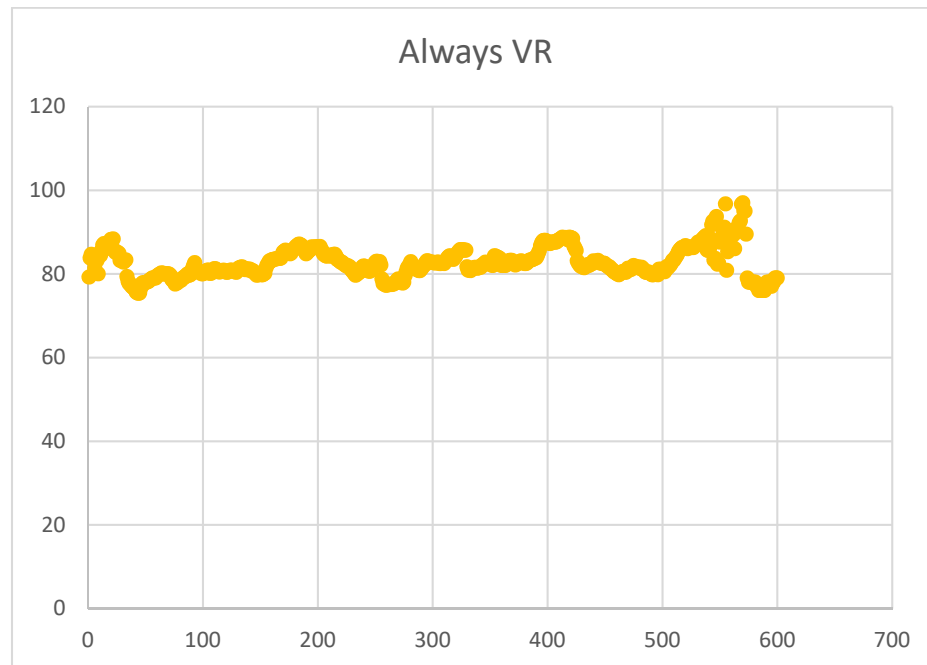
Comparing this to the VF4 groups, there is a significant difference between the standard and virtual reality groups. Virtual reality has a substantially increased effect on reducing positive emotions and substantially increasing negative emotion according to these results.

Interestingly when this data is matched with the biometric data obtained from participants' heart rate', it suggests that something much more complex is taking place.

The comparison between the two standard groups doesn't seem to indicate that very much is taking place. To begin, the Always Standard readings show a small but steady decline in average heart rate among participants over time, and a sharp increase at the end. Whereas the VF4 standard film shows a slight increase in average heart rate throughout the duration of the film, with lower average readings either side. Looking at these readings alone, it would suggest that the Always group experienced a mild calming effect throughout the duration of the experiment, and became emotionally stimulated at the very end, whereas the VF4 group experienced mild emotional stimulus for the duration of the film, and then a return to normal.



In comparison with these, the two virtual reality groups experienced a difference in readings. Beginning with the VF4 Group, they would appear to have a momentary spike in emotional stimulus when they are entered into the virtual world, which returns back to normal over time and experience no further arousal. Where in clear contrast the Always Virtual Reality group experience a series of moderate peaks and troughs suggesting a much more stimulating experience overall.



There are substantial differences in trends when splitting emotional change by gender group. Emotional movement in all experimental groups appeared much greater among females than males. However, this reduces sample sizes by around half so statistical testing has not been run on these individual results.

The change in the levels of reported stress were small in real terms, so small in fact with both of the Always groups that they were statistically insignificant. However, both of the VF4 groups showed a marked increase in the levels of reported stress, enhanced by viewing content in virtual reality with an influence of approximately 30% increased effect. The results from the questionnaires relating to

emotion would seem to support this with the content itself having a remarkable influence on their reported feelings of distress, once again showing an increased effect through virtual reality.

Movement on any of the questions related to behaviour was very small and much of that was determined to be statistically insignificant. Areas of interest to highlight are in relation to the VF4 virtual reality group. There is a small improvement in relation to alcohol with a 19% reduction in score on perceived approval among friends. However, comparing this to the final two questions from this section and their perception of their friends shows a decrease in how willing they would be to help a classmate who is being bullied (-7%), and also their ability to speak openly with their friends (-10%). There is certainly more to investigate in this area. One explanation for this may be the idea that for every situation individuals have an immediately accessible associated reference. The message 'don't drink drive' has become incredibly ingrained within society and in particular with this age group (whether adhered to or not) and therefore anything related to road safety is immediately associated with this message whether it actually contains it or not. This may explain their improved perception of friends in one area, and a reduction in others.

Lastly, on their levels of presence experienced. This is a score that determines how effective the immersive video is at fooling the user into thinking that they are *really there*, which is the primary objective of virtual reality.

The Always film (in VR) scored a presence score 63% higher than the VF4-360 film (in VR). Comparing this with the biometric results shows a correlation between emotional stimulation and presence. Couple this with the results from specific emotions defined in the questionnaire and it would strongly suggest that the negative emotions associated with the VF4-360 may have had an adverse effect on the users' sense of presence, which would support the findings from other research papers.

Using both of the standard groups' reported levels of presence within the film as a baseline to compare content to content, viewing the Always film had a three times increased effect on presence compared to only a two times increase with the VF4 film.

Recommendations

This study has further demonstrated that there is a relationship between emotion and levels of presence. Presence is the most important measure when considering the effectiveness of virtual reality technology. The results from this study would appear to suggest that negative emotion weakens the sense of presence in participants. Therefore, if the decision is made to push forward with virtual reality as a platform for delivery of messages, it should elicit positive emotions in the user in order for the delivery mechanism to provide a sense of presence.

There is a clear difference between viewing content in a standard format and viewing it in a virtual reality headset and this would suggest that virtual reality has the potential to be a beneficial way to deliver certain content and messaging. However, there are a number of other factors that must be involved within the process.

There are many effects which apply in the real world as well as the virtual. Based on the existing evidence, it is strongly suggested that fear appeal is not a very effective method of delivering long lasting behaviour change and that instead positively framed messaging should be used to influence social norms and encourage a change.

However, the two films that were used as part of this study were between 6 and 7 minutes in length meaning that total exposure time is rather short, especially as a one off. Without having a series of doses of the messaging over an extended period, there is very little that will be achievable or sustainable simply from having participants watch through a short film.

It is the recommendation of this report that virtual reality is not used in isolation to modify behaviour, as the amount of exposure is simply too short. In order to have a chance at meeting any objectives, it must only be used as part of a larger and wider spanning intervention.

With that in mind, if virtual reality is to be used as a single element of a larger intervention, then it would be most effective if it were to elicit positive emotions for two specific reasons.

First of all positive emotions increase the levels of presence, meaning that the technology itself becomes a more effective delivery mechanism but reciprocally, positive emotions should be enhanced by the use of a VR headset, meaning that it will make the users much more receptive to any messaging or activities which follow its use.

This might be the single most useful tool at delivering positive change through positive messaging, not because it is effective at delivering any messaging by itself, but that it creates an atmosphere among the participants that will create the right headspace for them to be receptive to the messaging that can be delivered perhaps by other means.

Further study will need to investigate virtual reality as a training tool and likewise whether it performs differently with different age groups. This study found no real concern for levels of stress based on the two examples that were available however further qualitative data collection is recommended to further discuss with participants.

Finally, it is worth noting that the concept of top shelf thinking should be given further exploration. If any recorded movement on alcohol was as a result of participants reaching for the most common road safety message they know (*'don't drink and drive'*), then this could help steer further messaging to support or reinforce interventions.

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Appendices

Appendix 1: Questionnaire

We need your help! We are interested in finding out your thoughts and feelings, so please take a few minutes to answer the questions in this survey.

There are no right or wrong answers, it's simply about how you feel.

We will not find out who you are or share your answers with anyone else so please answer all the questions on your own and as honestly as possible.

Please read each question carefully and if you don't understand any of them, please ask your tutor.

1

On a scale of 1 to 10, rate how much of the following emotions you are feeling at this very moment. (Where 10 means a lot, and 1 means none)

1

None

A lot

10

	1-10
Interested	
Distressed	
Excited	
Upset	
Strong	
Guilty	
Scared	
Hostile	
Enthusiastic	
Proud	

	1-10
Irritable	
Alert	
Ashamed	
Inspired	
Nervous	
Determined	
Attentive	
Jittery	
Active	
Afraid	

2

On a scale of 1 to 4, rate how much you agree with the following statements about how you feel now. (Where 4 means Strongly Agree, and 1 means Strongly Disagree)

1

Strongly Disagree

Strongly Agree

4

	1-4
I feel tense or 'wound up'	☐
I still enjoy the things I used to enjoy	☐
I get a sort of frightened feeling as if something awful is about to happen	☐
I can laugh and see the funny side of things	☐
Worrying thoughts go through my mind	☐
I feel cheerful	☐
I can sit at ease and feel relaxed	☐

3

On a scale of 1 to 10, please rate how much you agree with the following statements. (Where 10 means Strongly Agree, and 1 means Strongly Disagree)

1

Strongly Disagree

Strongly Agree

10

	1 - 10
Having unprotected sex just once is unlikely to result in catching a sexually transmitted infection (STI)	☐
My friends would disapprove if they knew I had money troubles	☐
I feel optimistic about my future	☐
I would be willing to cross a busy road, away from a proper crossing	☐
My friends would approve if I drank alcohol	☐
My friends are likely to help out a classmate being bullied	☐
I can speak openly with my friends about any subject	☐

4

On a scale of 1 to 10, please rate the following.

(Where 10 means Completely, and 1 means Not at all)

1

Not at all

Completely

10

	1-10
Rate your sense of being inside the film	☐
To what extent were there times during the experience where you forgot that you were in a classroom?	☐

5

When you think back to the film, do you think of it more as images that you saw, or more as something you experienced?

6

About you:

This data will only be used to pair questionnaires. All data will be confidential and remain anonymous.

I am:

Female

☐

Male

☐

Year of birth:

Day of birth:

Postcode

