Evaluating intervention to reduce risky driving behaviours: Taking the fear out of Virtual Reality

Clara Alida Cutello[1], Michaela Gummerum[2], Elizabeth Hellier[1], Yaniv Hanoch[3]

[1]School of Psychology, University of Plymouth, UK

[2]Department of Psychology, University of Warwick, UK

[3]Southampton Business School, University of Southampton, UK

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Abstract

Educational programs are the most common type of intervention to reduce risky driving behaviour. Their success, however, depends on the content of the material used and the mode of delivery. In the present study, we examined the impact of fear vs positively-framed road safety films and traditional technologies (2D) vs emerging technologies (VR) on young drivers' self-reported risky driving behaviours. One hundred and forty-six university students completed a similar set of questionnaires pre-intervention and post-intervention, two weeks later. In addition, they were randomly assigned to one of the four experimental conditions (VR versus 2D; positive versus negative). In the VR conditions the film was presented using an HTC VIVE Virtual Reality headset. In the 2D conditions the film was presented on a computer screen. Measures evaluating attitudes towards risky driving behaviour were completed at both time frames, questions regarding the participants' emotional arousal were asked at pre-intervention as a manipulation check, and questions regarding willingness to take risks in potentially dangerous driving situations were asked at follow-up. The findings indicate that the positively-framed films significantly decreased self-reported risky driving behaviours in both modalities, but especially when viewed in VR format. In contrast, the fear appeal film, when shown in VR, failed to reduce risky driving behaviours, and in fact, increased young drivers' self-reported risky driving behaviours. Theoretical frameworks regarding the strengths and weaknesses of fear appeals and positively-framed appeals are discussed to aid future research to reduce risky driving. Practical implications on the future usage of VR are also considered.

***Keywords**:* fear appeals, positively-framed appeals, risky driving, virtual reality, young drivers

1. Introduction

With over 1 million people dying in road traffic collisions globally, and young novice drivers (aged 15–25 years) accounting for 48% of road deaths worldwide (World Health Organization, 2019), finding a means of reducing risky driving and improving young drivers' safety is of vital importance. While there are a plethora of safe driving interventions targeted at reducing young drivers' risky driving behaviours, their success has varied (Peck, 2011; Raftery & Wundersitz, 2011). Here, we examined the impact of fear versus positively-framed appeals as well as traditional technologies (2D) versus emerging technologies (VR) on young drivers' (self-reported) risky driving behaviours. Ultimately, examining the impact of these variables on the effectiveness of safe driving interventions could impact their development and employment across the globe.

Most safe driving interventions have utilised fear-based materials and films, which portray a crash scene in a graphically explicit manner (Dejong & Atkin, 1995; Tannenbaum et al., 2015; Tay & Watson, 2002). The assumption governing this approach is that arousing a sense of fear, by depicting an extremely aversive consequence, such as death, will persuade drivers to alter their risk attitudes, intentions, and behaviours and, thereafter, drive more safely (Lewis, Watson & White, 2008; Witte & Allen, 2000). Indeed, when placed in the right context, fear appeals have been found to lead to behavioural change and reduced risky driving (see Tannenbaum et al., 2015; Witte & Allen, 2000; Xu et al., 2015). Fear appeals might work because they raise viewers' awareness of potential risks, attract and hold attention to protective information, and provide enough motivation to avoid engaging in unsafe behaviours (Tay, 2002; Thompson, Barnett & Pearce, 2008). Consistent with this notion, drivers perceived fear road safety messages as relatively more 'attention-grabbing' and 'attention-retaining' than other approaches, making them more memorable (Lewis, Watson, White, & Tay, 2007; Tay & de Barros, 2010).

While fear-based programs are the most common educational interventions used in road safety, mixed findings have led researchers to suggest that fear appeals could generate counterproductive results, increasing rather than decreasing risky behaviours (see Blondé & Girandola, 2019; Carey, McDermott, & Sarma, 2013; Jessop et al., 2008; Kok, Peters, Kessels, Hoor & Ruiter, 2018). For example, fear appeals have been shown to enhance defensive reactions, which are characterized by avoidance of relevant threatening information and message rejection (Brown & Locker. 2009; Cohn, 1998; Hastings & McFayden, 2002; Kempf & Harmon, 2006).

A parallel line of research has championed the use of positive appeals (e.g., humor, empathy, role-modeling, compassion) in road safety interventions (Monahan, 1995; Nabi, 2002). Lewis et al. (2008a) showed that positive, rather than fear, appeals were more effective in reducing risky driving behaviours (see also Zhao, Roditis & Alexander, 2019) and that positive appeals might have a particular advantage for individuals at high risk of collisions, namely, young drivers. Santa and Cochran (2008) examined the effectiveness of empathy, fear and informational appeals used in anti-drink driving interventions in a sample of young drivers. They found that the empathy approach (i.e., highlighting the consequences of one's behaviour for others) was perceived by the participants as the most effective appeal and elicited the most negative affect. Hope has also been found to be a suitable substitution to fear appeals in the promotion of safer behaviours (Nabi & Myrick, 2018). Positive appeals may help draw new attention to an overly familiar issue (Nabi, 2002), and reframe and reconsider issues that individuals may feel as not being particularly relevant to them (Nabi & Myrick, 2018). Overall, these results provide evidence that positive appeals might serve as more effective alternatives to fear ones. In addition, given that positive appeals are seldom used in road safety context, to the best of our knowledge this is the first study that investigates the role of positive appeals on risky driving behaviours.

Road safety interventions have not only varied the content of messages but have also capitalized on emerging technologies to vary the mode of presentation. Since 2016, the Fire and Rescue service in the United Kingdom (UK) – one of the main organisation[s] providing driver safety interventions[1] - has used Virtual Reality (VR) to give thousands of young drivers a realistic experience of a road traffic collision. Likewise, Ford Motor Company has implemented VR technologies to help European cyclists and drivers learn to detect road hazards from another's perspective – in the hope of reducing collisions in the process (e.g. WheelSwap, Forbes 2018). Specifically, VR headsets are being designed for cinematic purposes using HD small cameras (GoPro[TM]) that allow 360° videos. The videos created with VR headsets allow spectators to be able to look at any direction of the scene, from their individual point of view, with a 360° angle. These features enable the viewers to experience a more immersive environment compared to standard videos shown on a television or a computer screen (Dorta, Pierini & Boudhraâ, 2016). Furthermore, as VR technology offers a sense of "being there" (Slater, 2004), and provides the illusion that the events occurring are authentic (Rizzo & Kim, 2005) its usage has grown dramatically in the entertainment industries (Morris, 2015), and in clinical applications (e.g., Anderson et al., 2013; Shiban et al., 2015; Smith et al., 2015).

While VR has shown some success with clinical trials, it does have limitations. Firstly, there can be a lack of transfer of learning from VR to real life environments, perhaps because people treat VR as if it were entertainment (Lin, 2017). Secondly, some studies report a high number of dropout rates, partially due to cyber-sickness, nausea, and dizziness induced by using VR headsets (Valmaggia et al., 2016). Thirdly, there is little to no data on the impact of VR usage in extreme fear appeals, as currently used by the Fire and Rescue Service in the UK. In addition, there is concern that

[1] Additional providers include UKROEd/NDORs, who deliver National Speed Awareness Courses to over 1.2. million UK drivers each year.

VR's ability to provide realism might backfire. That is, experiencing fear appeals (such as car crashes) via VR might aggravate already existing defensive mechanics, such as disengagement, "not-real" strategies, avoidance (Lin, 2017), message rejection and consequent risk-taking (Harre et al., 2005). Finally, to our knowledge, VR's effectiveness in road safety programmes has simply not been tested. To address these gaps in the literature, the present study investigated the effect of Film Content (fear versus positive) and Delivery Mode (2D versus VR) on the effectiveness of a road safety educational film.

We measured participants' risky driving behaviours in two ways. First, a self-report measure of risky driving, the Driver Behaviour Questionnaire (DBQ; Reason et al., 1990) was administered pre-intervention and at the two-week follow-up. Self-reported risky driving measured by the DBQ has been shown to correlate with collision liability (Parker, Reason, Manstead, & Stradling, 1995) and self-reported crashes (Wåhlberg, Dorn, & Kline, 2009). Second, two weeks later, at follow-up participants completed both the DBQ and the Vienna Risk-Taking Test-Traffic (Hergovich, Bognar, Arendasy, & Sommer, 2007), a standardized and widely accepted behavioural measure of risky driving. The Vienna Risk-Taking Test-Traffic is based on Wilde's (1994) theory of risk homeostasis in risky driving. This model argues that people accept a certain degree of risk (target risk value) if they achieve an expected gain (e.g., arriving at a location earlier) in exchange. The target risk value is subjective and differs between individuals. If in a specific traffic situation, the perceived danger exceeds this subjective risk target value, the person will reduce risky driving behaviours. If the perceived danger is seen as less risky than the risk target value, drivers continue to carry out risky activities. In the Vienna Risk-Taking Test, participants are presented with video clips of driving situations that require a situation-contingent reaction (e.g., considering whether to overtake another car in icy conditions) and are asked to indicate if and when they regard the situation as too risky to carry out the behaviour. Thus, the Vienna Risk-Taking Test-Traffic uses a person's reaction time as the prime indicator of their willingness to engage in risky driving activity—the longer they take to abort the situation-contingent behaviour, the more willing they are to take risks.

Several studies have previously used the Vienna Risk-Taking Test to directly measure risk taking behaviour in various traffic situations (Fisher, Kastenmüller & Asal, 2012), have linked risky driving measured by the Vienna Risk-Taking Test to variables that are known to increase risky road traffic behaviour (e.g., voluntary sleep loss; Rusnac, Spitzenstetter, & Tassi, 2016), and have used it to evaluate the effectiveness of road traffic intervention programmes (Chraif, Anitai, & Alex, 2013). Indeed, the German Federal Highway Research Institute recommends dynamic reaction-time exercises, such as the Vienna Risk-Taking Test, as a possible measure to improve the theoretical driving test that all German drivers needs to pass to obtain a driving licence (Malone, Biermann, Brünken, & Buch, 2012). This is because reaction-time measures for risky driving allow for assessing drivers' hazard perception and in how far they can anticipate and react to risky driving situations.

Based on the literature reviewed above, the present investigation had several guiding hypotheses. First, as fear appeals tend to lead to reduced engagement with the risky information and its related outcome, we hypothesised that viewing fear appeals would increase self-reported risky driving in the DBQ and reaction times to risky driving situations in the Vienna Risk-Taking Test. Conversely, viewing positive appeals should reduce risk taking intentions and reaction times, since positive appeals have been shown to increase the relevance of and engagement with risky information. The effect of positive and fear appeals on risky driving should be more pronounced in the VR than 2D conditions, because of the hyper-reality in the depiction of events in VR compared to 2D formats. Finally, as previous research has shown that VR increases the sense of immediacy, of immersion and it provides the illusion that the events occurring are authentic, we were measuring emotional arousal as a manipulation check for the implementation of the VR and 2D condition. Specifically, we expected participants in the VR conditions to report higher emotion arousal (both after the negative and positive appeals) than participants in the 2D conditions.

2. Method

2.1. Participants

One hundred and forty-six participants (F= 102; M= 44) took part in the study. They were all University students from the School of Psychology, aged 18-25 (M = 20.97; SD = 2.14). The only inclusion criterion was a valid driver's license for less than 5 years (M = 3.25, SD = 1.23) – participants could therefore be classified as young novice drivers. Participants were allocated randomly to one of the four experimental conditions: a) Fear VR (n= 39); b) Positive VR (n= 36); c) Fear 2D (n= 37) and d) Positive 2D (n= 34). An a priori power analysis showed that 32 participants per condition should have 80% power to detect an effect size of d= 0.50. Previous interventions on risky driving behaviours have found effects ranging from 0.40 to 0.60 (Hardeman et al., 2002; Vassallo et al., 2007). Therefore, we decided to use an effect size of d= 0.50.

2.2. Measures

Road Safety Films. The road safety films, both negative and positive, were developed specifically for, and used by, the Fire and Rescue Service across the UK. Both films were 6 minutes long, with the same three professional actors playing the parts of young adults driving in a car. A male actor was the driver, and two female actors were the backseat passengers. The participants saw the film from the point of view of the front passenger and were able to see the other passengers interact with the driver. In the fear-based film, one back seat passenger was not wearing a seatbelt and both passengers were distracting the driver, while he was speeding along a narrow road. As a result of the driver's speeding and distracted driving the car was involved in a road traffic collision. The crash and its aftermath are shocking, and the participant witness the backseat passenger's death, the other passenger's severe injuries, and how the Fire and Rescue Service and the paramedics deal with the situations and the bodies.

In the positively-framed film, the same three friends are driving, and again a backseat passenger is not wearing a seatbelt. The driver immediately slows down and encourages her to wear the seatbelt. The backseat passengers are also asked to stop distracting the driver and the passengers caution the driver to be more careful while driving on a narrow road. Unlike the fear-based film, at the end of the positively-framed film, the driver and his passengers arrived safely at a house party, and the film ends with the three friends being welcomed by other guests at the party.

Driver Behaviour Questionnaire (DBQ; Reason et al, 1990). The 50-item version of the DBQ was used to measure participants' self-reported engagement in risky driving behaviours. Each item belongs to one of three subscales: "violations", "errors", or "lapses". Violations are defined as behaviours that deliberately break the law (e.g. "deliberately disregard the speed limits late at night or very early in the morning"). Errors indicate potentially dangerous failures in observation or judgment (e.g. "turn left on to a main road into the path of an oncoming vehicle that you hadn't seen, or whose speed you had misjudged"). Lapses are errors that cause embarrassment and inconvenience rather than risk (e.g. Lock yourself out of your car with the keys still inside). Participants were asked to indicate how often they committed each of the 50 behaviours on a five-point scale (1 = never, 5 = almost always), where higher score indicated higher risk-taking tendencies. Cronbach's alphas for each of the DBQ subscales [violations, errors and lapses] ranged from .61 to .93, across the data collection points, indicating good and very good reliability for all measures. The DBQ was administered at baseline (pre-intervention) and at the 2 weeks follow-up.

Emotional Arousal (Keller & Block, 1996). The 21-item Emotional Arousal Scale measured the level of emotional arousal that participants experienced while watching the films. Participants were asked to rate their emotional arousal on a five-point scale (1= *strongly disagree*, 5= *strongly agree*), where higher scores indicated higher emotional arousal response (e.g. “The safety message makes me feel very afraid”). Cronbach's alphas for the Emotional Arousal was .90, indicating very good reliability.

The Vienna Risk-Taking Test Traffic (Hergovich, Bognar, Arendasy, & Sommer, 2007; Hergovich et al., 2005). The Vienna Risk-Taking Test Traffic was used to assess the participants’ willingness to take risks in potentially dangerous driving situations. The test consisted of 24 videotaped dangerous traffic situations presented from the driver’s perspective on a computer screen. The videos were filmed from the inside of the car, enabling participants to easily picture themselves as the driver of the car. The traffic situations can be categorised into (1) speed choice and overtaking situations and (2) decisions at intersections. Participants view each traffic scene twice: the first time to observe the scene, and the second to indicate at which point the intended driving manoeuvre would be too risky to carry out. Weather conditions also vary between scenes. Participants viewed one practice trial and then completed 23 experimental trials. Response latency (in seconds) was recorded as a measure of the participant’s propensity for risky driving. The time that elapsed between the start of the sequence and the participant’s decision to abandon it was employed as a dependent measure of risk-taking inclination in critical road traffic situations (i.e. the longer participants wait to press the button in order to abandon the critical situation, the higher the risk-taking). We checked for outliers, and three participants' scores were 3SD above or below the mean, hence were removed from the main analysis.

2.3. Procedure

The study received ethical approval from the Human Ethics Committee of the first author's institution (ref. 18/19-999), and participants provided informed consent before participating. The participants were recruited through the University's point system, according to which they were allowed to receive credit points for their participation in the study. The participants were invited to come to the experimental lab at the University. After completing an online version of the DBQ (Reason et al., 1990), participants were assigned randomly to one of the four experimental conditions. In the VR conditions the film was presented using a HTC VIVE Virtual Reality headset. In the 2D conditions the film was presented on a computer screen. After watching the films, the participants were asked to complete an online version of the Emotional Arousal Scale (Wauters & Bregman, 2013). At follow-up, 2 weeks later, participants were invited to come back to the experimental lab at the University. They were asked to completed an online version the DBQ (Reason et al., 1990) again as well as the Vienna Risk-Taking Test-Traffic on the computer (Hergovich, Bognar, Arendasy, & Sommer, 2005).

3. Results

3.1. Statistical Analysis

The internal consistency of the DBQ and Emotional arousal questionnaire was determined by calculating the Cronbach's α scores for the items of each domain. A manipulation check was performed on participants' scores in the DBQ at pre-test to assess whether there were any differences between conditions at the start of the experiment. To ensure that the films content did not impact arousal differently, we conducted a Friedman's analysis of variance (ANOVA) on participants' emotional arousal after viewing the road safety films.

To test the effectiveness of Film Content and Delivery Mode, we conducted a Friedman's analysis of variance (ANOVA) on participants' DBQ, with Delivery Mode (VR or 2D) and Film Content (positive versus fear) as the between-subject factors and the Time of testing (pre-test, follow-up) as within-subject factor. Tukey HSD post hoc comparison was then used to gain further insight on the differences between Delivery Mode, Film Content and Time of the intervention on participants' DBQ scores. Finally, to test the effectiveness of Film Content and Delivery Mode on participants' reaction times in the Vienna Risk-Taking Test Traffic, we conducted a Friedman's analysis of variance (ANOVA) on participants' reaction time scores. We used an α level of .05 for all our analyses. All analyses were performed in R version 2.15.3.

3.2. Manipulation check

We examined participants' scores in the DBQ at pre-test to assess whether there were any differences in risky driving between conditions at the start of the experiment. We performed a 2x2 ANOVA to investigate the effect of Delivery Mode (VR or 2D) and Film Content (positive vs fear) on the mean DBQ scores at pre-test. There were no significant differences between conditions at pre-test (all *p*s > .09; see Figure 1).

We also examined participants' emotional arousal after viewing the road safety films. A 2x2 ANOVA with the independent variables Delivery Mode (VR or 2D) and Film Content (positive or fear) showed a main effect of Delivery Mode $F(1,137) = 102.571$, $p<0.01$. Participants' in both the positive and fear VR conditions displayed a higher emotional arousal response compared to the positive and fear 2D conditions (see table 1.1.). The main effect of Film Content (p=0.9) and the interaction effect did not reach statistical significance (p=0.7).

Variable	VR		2D	
	Fear	**Positive**	**Fear**	**Positive**
Emotional Arousal	77.7 (4.1)	76.9 (4.3)	65.6 (8.1)	70.5 (4.2)

Table 1.1. Participants' means Emotional Arousal scores, by Delivery Mode and Film Content

Finally, preliminary analyses checked gender differences, but no significant main or interaction effects of gender emerged. Hence, analyses reported here collapsed across gender.

3.3. The effect of Film Content and Delivery Mode on the effectiveness of the road safety film

Concerning self-reported engagement in risky driving (DBQ scores), a 2x2x2 mixed ANOVA with the between-subject factors Delivery Mode (VR or 2D) and Film Content (positive versus fear) and the within-subject factor Time of testing (pre-test, follow-up) revealed a significant three-way interaction of Time x Delivery Mode x Film Content. There were also significant two-way interactions of Time x Film Content, and Film Content x Delivery Mode (See Table 1.2.).

Response DBQ	**Df**	**Sum SQ**	**Mean SQ**	**F Value**	**PR(>F)**
Time: Delivery Mode: Film Content	1	1009	1008.8	4.3034	0.001896***
Time: Film Content	1	9833	9833.2	41.9487	0.001977***
Film Content: Delivery Mode	1	868	868.0	3.7028	0.01535**
Residuals	276	64697	234.4		

** p <.01
*** p<.001

Table 1.2. Mixed ANOVA table.

Tukey HSD post-hoc comparison revealed a significant pre-to-post decrease in participants' self-reported engagement in risky driving behaviours in the positive VR condition (*p*<.001) and in the positive 2D condition (*p*<.05). Moreover, there was a significant pre-to-post increase of participants' engagement in risky driving behaviours in the fear VR condition (*p*<.05). No difference was found pre-to-post in the fear 2D condition (*p*=.09). Tukey HSD post-hoc comparison also revealed that the fear VR follow-up condition significantly differed from the fear 2D follow-up (*p*<.001), the fear 2D follow-up significantly differed from the positive 2D follow-up (*p*<.001), and the positive 2D follow-up significantly differed from the positive VR follow-up (*p*<.001; see Figure 1 and Table 1.3.).

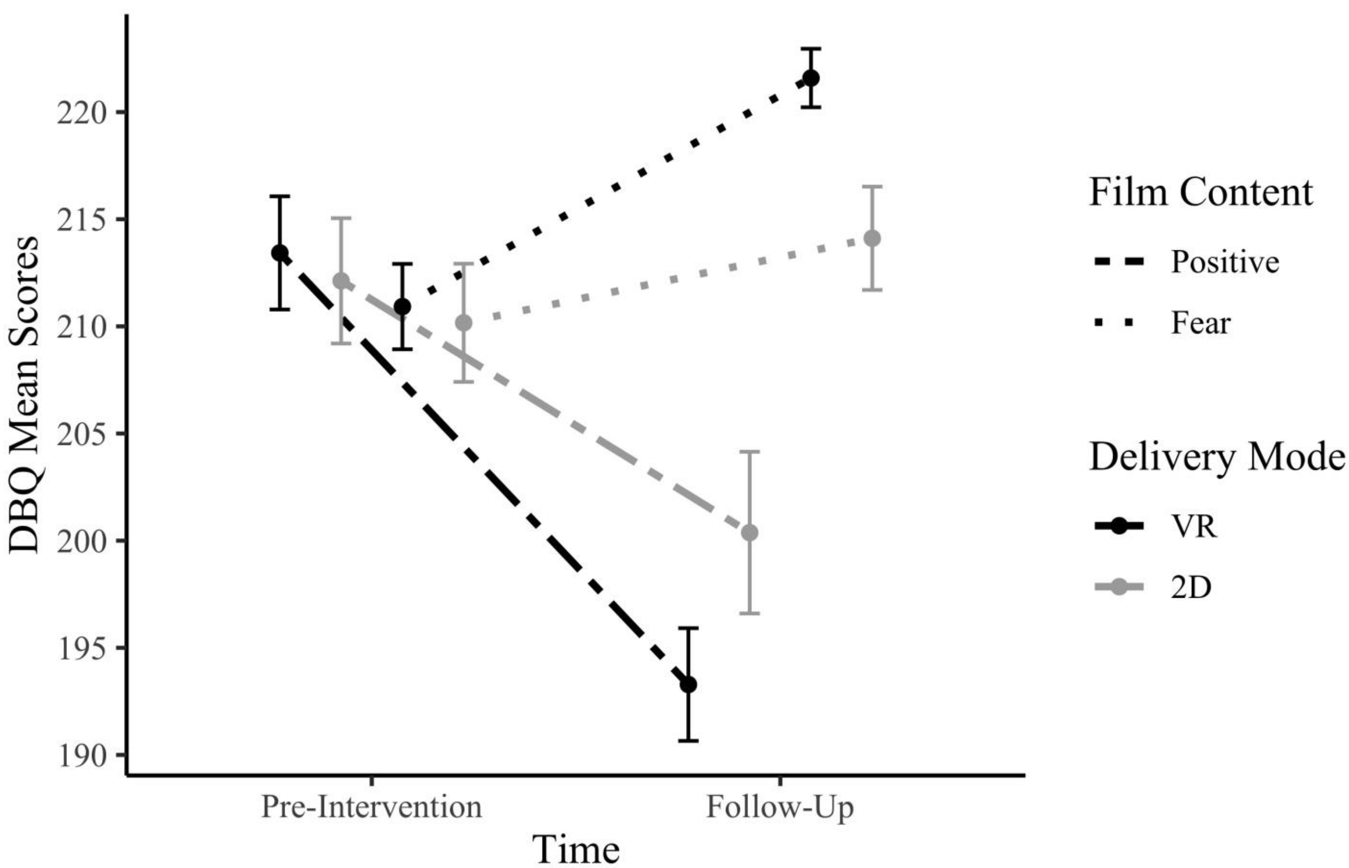

Figure 1. Participants' mean DBQ scores, by Film Content and Delivery Mode. Error bars represent Standard Errors.

	Pre-Test				**Follow-Up**			
Variable	**VR**		**2D**		**VR**		**2D**	
	Fear	**Positive**	**Fear**	**Positive**	**Fear**	**Positive**	**Fear**	**Positive**
DBQ	210.9 (12.44)	231.4 (15.6)	210.1 (16.5)	212.1 (16.5)	221.5 (18.5)	193.2 (15.5)	214.1 (14.4)	200.3 (21.3)

Table 1.3. Participants' sum means DBQ scores, by Delivery Mode and Film Content

3.4. Vienna Risk-Taking Test

A 2x2 ANOVA with the between-subject factors Delivery Mode (VR or 2D) and Film Content (positive versus fear) and the dependent variable Mean Reaction Time revealed a significant main effect of Film Content, $F(1, 134) = 3.958$, $p<.05$. Participants in the fear conditions showed higher RTs, thus indicating more risky driving behaviours, than participants in the positive conditions (see Figure 2). No differences were found between the VR and 2D delivery mode ($p= 0.9$; See table 1.4.).

Response Vienna Risk-Taking Test	**Df**	**Sum SQ**	**Mean SQ**	**F Value**	**PR(>F)**
Film Content	1	14.21	14.2128	3.9584	0.04876*
Delivery Mode	1	3.42	3.4152	0.9500	0.93143
Film Content: Delivery Mode	1	0.07	0.0678	0.0189	0.79098
Residuals	138	496.12	3.5951		

** p <.05

Table 1.4. Mixed ANOVA table.

Finally, a Pearson correlation was computed to explore the interrelations between the implicit (i.e. Vienna Risk-Taking Test) and the explicit (DBQ mean scores) measures of risky driving, taking into account Delivery Mode (VR and 2D) and Film Content (positive versus fear). Because the Vienna

Risk-Taking Test was only administered at follow-up, scores on this test were correlated with the DBQ assessment at follow-up. The Pearson correlation did not revealed any relationship between the two measures of risky driving behaviours (r(140)= -.04, *p*=.09).

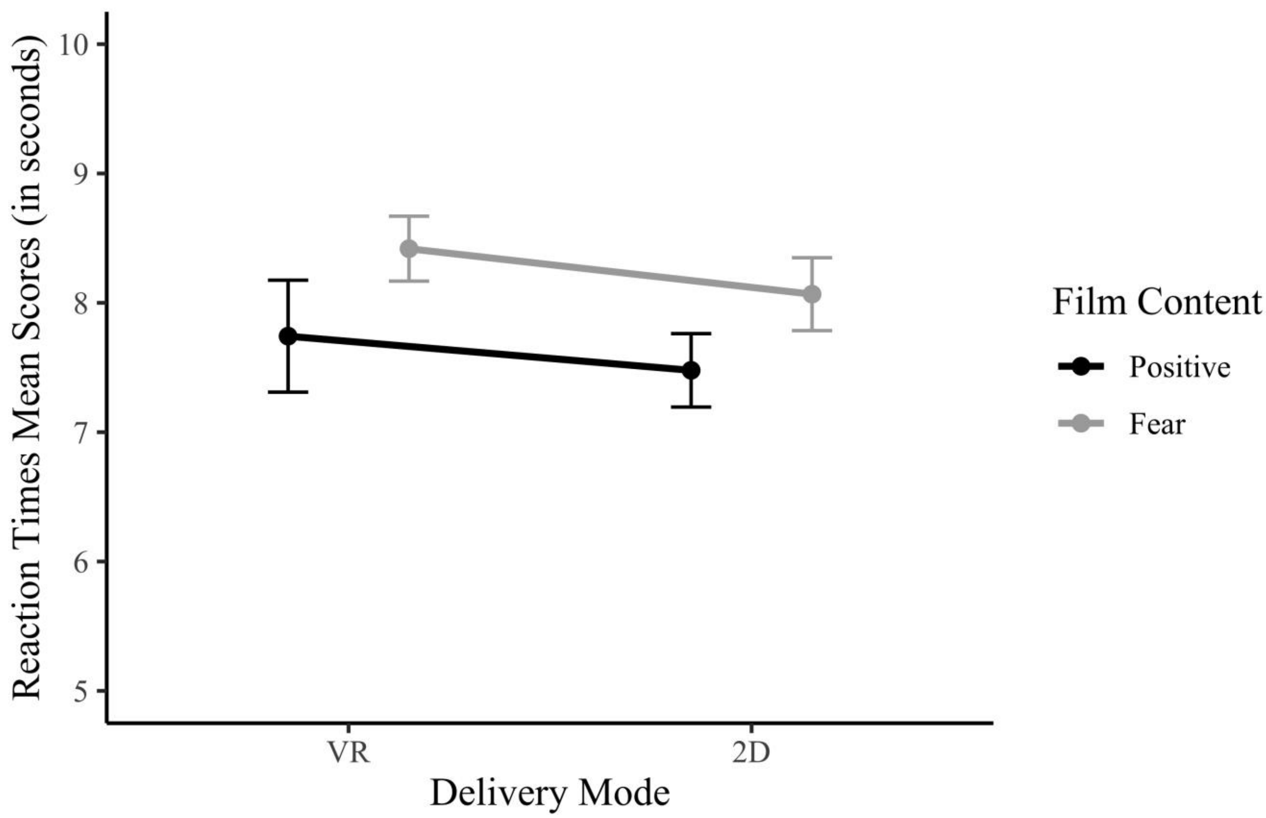

Figure 2. Participants' Reaction Time mean scores, by Film Content and Delivery Mode. The error bars represent the Standard Errors

4. Discussion

According to the World Health Organization (2019), road traffic collisions are the leading cause of death among young adults. Finding the best means to tackle this issue, is thus of paramount importance. Studying currently-used driver safety interventions employed by the Fire and Rescue service across the UK, this research provides the first examination of the effects of both message content (fear versus positive) and mode of delivery (2D versus VR) on risky driving behaviour among young drivers.

Results showed that fear appeals failed to decrease young drivers' risky driving behaviours, measured by both self-reported and objective measures of risky driving. Specifically, participants who viewed the fear VR film reported riskier driving behaviours at follow-up as and exhibited heightened risky driving behaviour. Our results, thus, lend further support to a growing body of evidence showing that fear appeals are not effective in reducing risky driving behaviours. In fact, fear appeals seem to have the opposite effect increasing risky driving behaviours over time (de Hoog, Stoebe & de Wit, 2008; Jessop & Wade, 2008). Exposing participants to an extreme and graphic collision tends to activate defensive mechanisms, such as paying attention to threatening messages for a shorter time (Brown and Locker 2009), disengagement, message rejection (Cohn, 1998; Hastings & MacFadyen, 2002) and an increase in risky behaviours (Harre et al, 2005). Using fear appeals in driver safety interventions might, paradoxically, lead to increase in risky behaviour rather than a decrease. Our results, coupled with others (see Lin, 2017), cast serious doubt on the effectiveness and extensive utilization of fear appeals.

As the first study to examine the usage of VR in driver safety programs, our results caution against the usage of VR in driver safety programs, when combined with fear appeals. As VR is designed to provide a more realistic experience of driving collisions (Lin, 2017; Parsons & Rizzo, 2008), it is likely that participants' experience of the collision in the fear condition was more vivid than those viewing it in 2D. Indeed, in the 2D films the participants experienced the events as spectators, creating a distance between themselves and the avatars (Klimmt et al., 2009; Lin, 2013b). Arguably, VR's capacity to deliver a more realistic experience, might heighten participants' emotional arousal and exacerbate participants' tendency to disregard and dismiss the message, rendering the fear appeal even less effective (Witte, 1992, 1996).

Conversely, our study reveals that positively-framed messages led to a reduction in risky behaviour. In contrast to the fear appeals condition, using VR in combination with a positive message further reduced participants' risky behaviour compared to the positive 2D condition. Hence, while participants who viewed the positive messages showed a decrease in self-reported and objectively-measured risky driving, participants who viewed the positive VR film exhibited the biggest decrease in self-reported risky driving behaviours. Consequently, using VR in intervention strategies can be useful, but only when coupled with positive appeals.

Our results, thus, provide key insights about the role of positive vs fear framed messages in tackling risky driving behaviour among young drivers. On the one hand, they extend previous work regarding the effectiveness of positively framed messages in promoting road safety (Lewis, 2008; Delhomme, 2002), through the portrayal and modelling of "safe" driving behaviours and the positive consequences of adhering to that behaviour (Hoekstra & Wegman, 2011; Lewis, 2007). In addition, they contend that allowing the participants to experience what proactive behaviours can lead to and giving them the illusions that the events occurring are authentic through VR (Rizzo & Kim, 2005) can encourage the creation of positive role models and strategies to be safer on the roads, which in turn decreased risky driving behaviours (Zhao, Roditis & Alexander, 2019). Taken together, our data question the usage of fear appeals and promote the employment of positively-framed messages. Importantly, it shows that the effectiveness of novel technologies, such as VR, depends on the type of messages employed.

Additionally, we used emotional arousal as a manipulation check to gauge the success of the VR intervention. The results are in line with our hypotheses that VR creates a sense of immersion, and it provides the illusion that the events occurring are authentic (Rizzo & Kim, 2005). However, the triggering of emotional arousal is not necessarily just linked to fear, as other emotions can also activate high arousal (e.g. happiness; Russell, 1980). Moreover, many fear appeals may evoke emotions in addition to fear (e.g., disgust, anger), and these emotions may trigger an additional emotional response to the fear appeals message (Tannenbaum et al., 2015). Future research should examine more closely the impact of emotional arousal, message framing and risky driving behaviours.

While this study is the first to examine the impact of VR vs 2D and fear vs positively-framed appeals in driver safety programs, it does have several limitations. Firstly, our sample was not balanced according to gender. Previous research has consistently reported gender differences in responses to interventions and in driving behaviours (Scott-Parker et al., 2014; Watson-Brown, Scott-Parker & Senserrick, 2019). For example, research has found that females are more likely to accept the recommendation of fear appeal messages compared to males (Goldenbeld, Twisk & Houwing, 2008; Tay & Ozanne, 2002), and males are more likely to report riskier driving behaviours compared to females (Brown, Senserrick & Bilston, 2014). Consequently, the results of our study might actually underestimate the effects of fear- and positive appeals on risky driving and its relationship with gender. Hence, future work should focus on gender differences in the implementation of fear vs positively-framed appeals and VR technologies. Secondly, we did not measure actual driving behaviour. Thirdly, young drivers' behaviour is influenced by a multitude of systemic determinants (i.e. legislations, peers, education, technology etc.). The road safety films that were used in this study, were created for and used by the Fire and Rescue Service across the UK, and they tackled some of these determinants, specifically the role of education and peer influence. However, these films did not portray all the multiple of determinants that can influence young drivers, and this research did not control for all the factors that are involved in young drivers' risky behaviours. The results of the present study largely raise concerns about the use of VR and fear appeals. Whether these results are robust enough to be applicable to other films is an important empirical question. In the present study we focused on two important variables (VR and fear), and future work should focus on exploring the impact that other determinants may have.

Despite these limitations, our results have clear implications for risk research. As indicated in the introduction, fear appeals have been extensively used in many domains (see de Boer, Botzen, & Toepstra, 2015; Greenberg & Truelove, 2010; Jackson, 2006; Yang, Dillard & Lin, 2018). Our results cast doubt on the use of fear appeals to change human behaviour, at least within the driving domain. Whether they are also applicable to other risky behaviours is an empirical question that would need further investigation. Moreover, our study provides important insights about the utilization of new technology to alter risky driving behaviour. The literature is rife with work on the role of risk and risk perception on accepting or rejecting new technology (e.g. Siegrist, 2002). There is far less work on how new technology—such as VR—can be utilized to impact risk perception as well as behaviour. The present investigation provides, thus, methodological insights about the use of VR technology in impacting risky behaviour in the driving domain. Future research should extend the present study to other domains, such as online risk-taking, which has gained much attention in the last years (see White, Gummerum & Hanoch, 2015).

Safe driving interventions are largely focused on and targeted towards young drivers. Reducing risky driving behaviour, and thus collisions, offers not only the opportunity to save lives, but also to reduce injuries and financial cost. With millions of young adults being exposed to different driving interventions, it is vital that these programs are designed in the best possible way. This research provides the first examination of the effects of both message content (fear versus positive) and mode of delivery (2D versus VR) on risky driving behaviour among young drivers. The present results caution against further use of fear appeals, especially when delivered via VR technologies. Rather, using positively-framed messages, regardless of the delivery mode (2D or VR), seem to alter driving behaviour in the intended direction. While we focused solely on driver safety, it is important that future studies extend our results to other domains.

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