

Evaluating an Intervention to Reduce Risky Driving Behaviors: Taking the Fear Out of Virtual Reality

Clara Alida Cutello ^{1,*}, Michaela Gummerum,² Yaniv Hanoch ³ and Elizabeth Hellier¹

Educational programs are the most common type of intervention to reduce risky driving behavior. 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 versus positively framed road safety films and traditional technologies (2D) versus emerging technologies (VR) on young drivers' self-reported risky driving behaviors. 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 vs. 2D; positive vs. 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 toward risky driving behavior 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 behaviors 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 behaviors, and in fact, increased young drivers' self-reported risky driving behaviors. 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.

KEY WORDS: 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 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 behaviors, 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 behaviors. 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 utilized 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

¹School of Psychology, University of Plymouth, Plymouth, PL4 8AA, UK.

²School of Psychology, University of Warwick, Coventry, CV4 7AL, UK.

³Business School, University of Southampton, Southampton, SO17 1BJ, UK.

*Address correspondence to Clara Alida Cutello, School of Psychology, University of Plymouth, Plymouth, UK; clara.cutello@plymouth.ac.uk.

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 behaviors and, thereafter, drive more safely (Lewis, Watson, & White, 2008b; Witte & Allen, 2000). Indeed, when placed in the right context, fear appeals have been found to lead to behavioral change and reduced risky driving (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 behaviors (Tay & Watson, 2002; Thompson, Barnett, & Pearce, 2009). 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 behaviors (Blondé & Girandola, 2019; Carey, McDermott, & Sarma, 2013; Jessop, Albery, Rutter, & Garrod, 2008; Kok, Peters, Kessels, Ten 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, and compassion) in road safety interventions (Monahan, 1995; Nabi, 2002). Lewis, Watson, and White (2008a) showed that positive, rather than fear, appeals were more effective in reducing risky driving behaviors (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 behavior for others) was perceived by the participants as the most effective appeal and elicited the most positive affect. Hope has also been found to be a suitable substitution to fear appeals in

the promotion of safer behaviors (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 behaviors.

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—one of the main organization[s] providing driver safety interventions¹—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™) 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, 2009), 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, Pauli, & Muhlberger, 2013; Smith *et al.*, 2015).

While VR has shown some success with clinical trials, it does have limitations. First, 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). Second, some studies report a high number of dropout rates, partially

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

due to cyber-sickness, nausea, and dizziness induced by using VR headsets (Valmaggia, Latif, Kempton, & Rus-Calafell, 2016). Third, 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 United Kingdom. In addition, there is a concern that VR's ability to provide realism might backfire. That is, experiencing fear appeals (such as car crashes) via VR might aggravate already existing defensive mechanisms, 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 programs has simply not been tested. To address these gaps in the literature, the present study investigated the effect of Film Content (fear vs. positive) and Delivery Mode (2D vs. VR) on the effectiveness of a road safety educational film.

We measured participants' risky driving behaviors in two ways. First, a self-report measure of risky driving, the Driver Behavior Questionnaire (DBQ; Reason, Manstead, Stradling, Baxter, & Campbell, 1990) was administered at 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 (Wählberg, Dorn, & Kline, 2010). 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 behavioral 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 behaviors. If the perceived danger is seen as less risky than the risk target value, the person will 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 behavior. 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 behavior, the more willing they are to take risks.

Several studies have previously used the Vienna Risk-Taking Test to directly measure risk-taking behavior 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 behavior (e.g., voluntary sleep loss; Rusnac, Spitzenstetter, & Tassi, 2016), and have used it to evaluate the effectiveness of road traffic intervention programs (Chraif, Anitei, & 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 need to pass to obtain a driving license (Malone, Biermann, Brünken, & Buch, 2012). This is because reaction-time measures for risky driving allow the assessment of drivers' hazard perception and 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 hypothesized 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 the previous research has shown that VR increases the sense of immediacy and immersion and provides the illusion that the events occurring are authentic, we measured 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: (1) Fear VR ($n = 39$); (2) Positive VR ($n = 36$); (3) Fear 2D ($n = 37$) and (4) 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 behaviors have found effects ranging from 0.40 to 0.60 (Harde- man, Johnston, Johnston, Bonetti, & Wareham, 2002; Vassallo et al., 2007). Therefore, we decided to use an effect size of $d = 0.50$.

2.2. Measures

2.2.1. 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 United Kingdom. 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.

2.2.2. Driver Behavior Questionnaire

The 50-item version of the DBQ was used to measure participants' self-reported engagement in risky driving behaviors (Reason et al., 1990). Each item belongs to one of the three subscales: "violations," "errors," or "lapses." Violations are defined as behaviors 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 behaviors on a 5-point scale (1 = never, 5 = almost always), where higher score indicated higher risk-taking tendencies. Cronbach's α for each of the DBQ subscales (violations, errors, and lapses) ranged from 0.61 to 0.93, across the data collection points, indicating good and very good reliability for all measures. The DBQ was administered at baseline (preintervention) and at the 2 weeks follow-up.

2.2.3. Emotional Arousal

The 21-item Emotional Arousal Scale measured the level of emotional arousal that participants experienced while watching the films (Keller & Block, 1996; Wauters & Bregman, 2013). Participants were asked to rate their emotional arousal on a 5-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 α for the Emotional Arousal was 0.90, indicating very good reliability.

2.2.4. The Vienna Risk-Taking Test Traffic

The Vienna Risk-Taking Test Traffic was used to assess the participants' willingness to take risks in potentially dangerous driving situations (Hergovich,

Bognar, Arendasy, & Sommer, 2007). 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 categorized 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 time 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 laboratory 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 an 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 (Keller & Block, 1996; Wauters & Bregman, 2013). At follow-up, two weeks later, participants were invited to come back to the experimental laboratory at the University. They were asked to complete an online version of the DBQ (Reason et al., 1990) again, as well as the Vienna Risk-Taking Test-Traffic on the computer (Hergovich, Bognar, Arendasy, & Sommer, 2007).

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 pretest 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 vs. fear) as the between-subject factors and the Time of testing (pretest, 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 0.05 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 pretest to assess whether there were any differences in risky driving between conditions at the start of the experiment. We performed a 2×2 ANOVA to investigate the effect of Delivery Mode (VR or 2D) and Film Content (positive vs. fear) on the mean DBQ scores at pretest. There were no significant differences between conditions at pretest (all $ps > 0.09$; Fig. 1).

We also examined participants' emotional arousal after viewing the road safety films. A 2×2 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

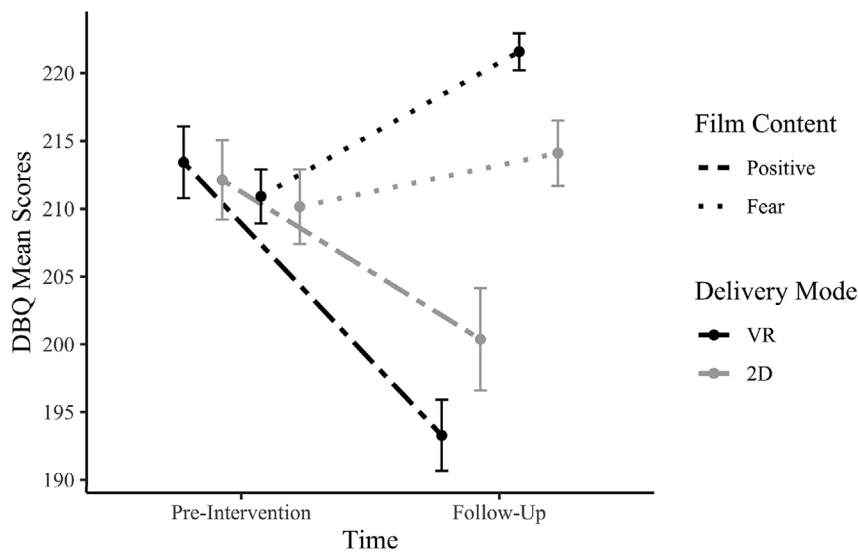


Fig 1. Participants' mean DBQ scores, by Film Content and Delivery Mode. Note: The error bars represent Standard Errors.

Table I. Participants' Mean Emotional Arousal Scores by Delivery Mode and Film Content

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 II. Mixed ANOVA Table

Response DBQ	Df	Sum SQ	Mean SQ	F Value	PR(>F)
Time: Delivery Mode: Film Content	1	1,009	1,008.8	4.3034	0.001896***
Time: Film Content	1	9,833	9,833.2	41.9487	0.001977***
Film Content: Delivery Mode	1	868	868.0	3.7028	0.01535**
Residuals	276	64,697	234.4		

** $p < 0.01$.

*** $p < 0.001$.

and fear 2D conditions (Table I). The main effect of Film Content ($p = 0.9$) and the interaction effect did not reach statistical significance ($p = 0.7$).

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

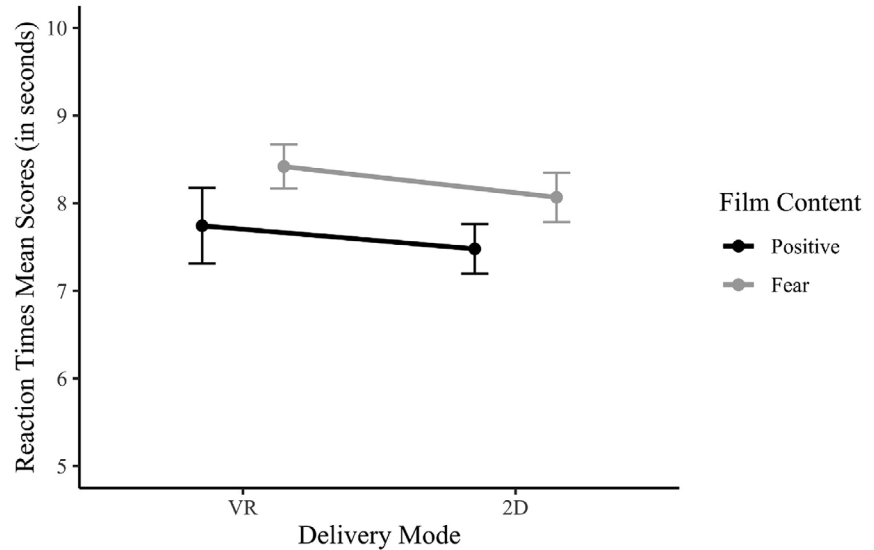
Concerning self-reported engagement in risky driving (DBQ scores), a $2 \times 2 \times 2$ mixed ANOVA with the between-subject factors Delivery Mode (VR

or 2D) and Film Content (positive vs. fear) and the within-subject factor Time of testing (pretest, follow-up) revealed a significant three-way interaction of Time \times Delivery Mode \times Film Content. There were also significant two-way interactions of Time \times Film Content, and Film Content \times Delivery Mode (Table II).

Tukey HSD post-hoc comparison revealed a significant pre-to-post decrease in participants' self-reported engagement in risky driving behaviors in the positive VR condition ($p < 0.001$) and in the positive 2D condition ($p < 0.05$). Moreover, there was a significant pre-to-post increase of participants' engagement in risky driving behaviors in the fear VR condition ($p < 0.05$). No difference was found pre-to-post in the fear 2D condition ($p = 0.09$). Tukey

Table III. Participants' Sum Mean DBQ Scores by Delivery Mode and Film Content

Variable	Pretest				Follow-Up			
	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)

Fig 2. Participants' Reaction Time mean scores, by Film Content and Delivery Mode. Note: The error bars represent Standard Errors.**Table IV.** Mixed ANOVA Table

Response	Vienna Risk-Taking Test	<i>Df</i>	Sum SQ	Mean SQ	<i>F</i> Value	PR(> <i>F</i>)
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		

** $p < 0.05$.

HSD post-hoc comparison also revealed that the fear VR follow-up condition significantly differed from the fear 2D follow-up ($p < 0.001$), the fear 2D follow-up significantly differed from the positive 2D follow-up ($p < 0.001$), and the positive 2D follow-up significantly differed from the positive VR follow-up ($p < 0.001$; Fig. 1 and Table III).

3.4. Vienna Risk-Taking Test

A 2×2 ANOVA with the between-subject factors Delivery Mode (VR or 2D) and Film Content (positive vs. fear) and the dependent variable Mean Reaction Time revealed a significant main effect of

Film Content, $F(1,134) = 3.958$, $p < 0.05$. Participants in the fear conditions showed higher Reaction Times, thus indicating more risky driving behaviors than participants in the positive conditions (Fig. 2). No differences were found between the VR and 2D delivery mode ($p = 0.9$; Table IV).

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 vs. 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 reveal any relationship between the two measures of risky driving behaviors ($r(140) = -0.04$, $p = 0.09$).

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. By studying currently used driver safety interventions employed by the Fire and Rescue service across the United Kingdom, this research provides the first examination of the effects of both message content (fear vs. positive) and mode of delivery (2D vs. VR) on risky driving behavior among young drivers.

Results showed that fear appeals failed to decrease young drivers' risky driving behaviors, measured by both self-reported and objective measures of risky driving. Specifically, participants who viewed the fear VR film reported riskier driving behaviors at follow-up and exhibited heightened risky driving behavior. Our results, thus, lend further support to a growing body of evidence showing that fear appeals are not effective in reducing risky driving behaviors. In fact, fear appeals seem to have the opposite effect increasing risky driving behaviors over time (Cutello *et al.*, 2020; De Hoog, Stroebe, & 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 & Locker, 2009), disengagement, message rejection (Cohn, 1998; Hastings & MacFadyen, 2002), and an increase in risky behaviors (Harre *et al.*, 2005). Using fear appeals in driver safety interventions might, paradoxically, lead to increase in risky behavior rather than a decrease. Our results, coupled with others (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 viewing 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 be-

tween themselves and the avatars (Klimmt, Hefner, & Vorderer, 2009; Lin, 2013). 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 behavior. In contrast to the fear appeals condition, using VR in combination with a positive message further reduced participants' risky behavior 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 behaviors. 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 versus fear-framed messages in tackling risky driving behavior among young drivers. On the one hand, they extend the previous work regarding the effectiveness of positively framed messages in promoting road safety (Chaurand, Bossart & Delhomme, 2015; Lewis, 2008b), through the portrayal and modeling of "safe" driving behaviors and the positive consequences of adhering to that behavior (Hoekstra & Wegman, 2011; Lewis, Watson, & Tay *et al.*, 2007). In addition, they contend that allowing the participants to experience what proactive behaviors 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 behaviors (Zhao *et al.*, 2019). Taken together, our data questions 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 and 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 behaviors.

While this study is the first to examine the impact of VR versus 2D and fear versus positively framed appeals in driver safety programs, it does have several limitations. First, our sample was not balanced according to gender. Previous research has consistently reported gender differences in responses to interventions and driving behaviors (Scott-Parker, Watson, King, & Hyde, 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 behaviors compared to females (Brown, Senserrick, & Bilston, 2014). Consequently, the results of our study might actually underestimate the effects of fear appeals, and positive appeals on risky driving and its relationship with gender. Hence, future work should focus on gender differences in the implementation of fear versus positively framed appeals and VR technologies. Second, we did not measure actual driving behavior. Third, young drivers' behavior 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 United Kingdom, 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 behaviors. 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 (de Boer, Botzen, & Terpstra, 2015; Greenberg & Truelove, 2011; Jackson, 2006; Yang, Dillard,

& Lin, 2018). Our results cast doubt on the use of fear appeals to change human behavior, at least within the driving domain. Whether they are also applicable to other risky behaviors 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 behavior. The literature is rife with work on the role of risk and risk perception on accepting or rejecting new technology (e.g., Siegrist, 2000). There is far less work on how new technology—such as VR—can be utilized to impact risk perception as well as behavior. The present investigation thus provides methodological insights about how the use of VR technology is impacting risky behavior 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 (White, Gummerum, & Hanoach, 2015).

Safe driving interventions are largely focused on and targeted toward young drivers. Reducing risky driving behavior, 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 vs. positive) and mode of delivery (2D vs. VR) on risky driving behavior 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 behavior in the intended direction. While we focused solely on driver safety, it is important that future studies extend our results to other domains.

ACKNOWLEDGMENTS

We would like to thank the Devon and Somerset Fire and Rescue Service and the participants for their support and co-operation.

REFERENCES

- Anderson, P. L., Price, M., Edwards, S. M., Obasaju, M. A., Schmertz, S. K., Zimand, E., & Calamaras, M. R. (2013). Virtual reality exposure therapy for social anxiety disorder: A randomized controlled trial. *Journal of Consulting and Clinical Psychology, 81*(5), 751–760. <https://doi.org/10.1037/a0033559>
- Blondé J., & Girandola, F. (2019). When Defensive Reactions Contribute to the Acceptance of Fear-Arousing

- Communications. *Current Psychology*, 38(1), 75–83. <https://doi.org/10.1007/s12144-017-9590-z>.
- Brown, J., Senserrich, T., & Bilston, L. E. (2014). Gender differences in crash characteristics among young drivers admitted to hospitals in NSW. Proceedings of the 2014 Australasian Road Safety Research, Policing & Education Conference 12–14 November, Grand Hyatt Melbourne.
- Brown, S., & Locker, E. (2009). Defensive responses to an emotive anti-alcohol message. *Psychology & Health*, 24(5), 517–528. <https://doi.org/10.1080/08870440801911130>.
- Carey, R. N., McDermott, D. T., & Sarma, K. M. (2013). The impact of threat appeals on fear arousal and driver behavior: A meta-analysis of experimental research 1990–2011. *PLoS One*, 8(5), e62821. <https://doi.org/10.1371/journal.pone.0062821>
- Chaurand N., Bossart F., & Delhomme, P., (2015). A naturalistic study of the impact of message framing on highway speeding. *Transportation Research Part F: Traffic Psychology and Behaviour*, 35, 37–44. <https://doi.org/10.1016/j.trf.2015.09.001>.
- Chraif, N., Anitei, M., & Alex, S. (2013). The effects of exposure to the publicity campaign “Stop the Accidents” on the willingness to take risks in traffic situations. *Social & Behavioral Sciences*, 78, 562–566. <https://doi.org/10.1016/j.sbspro.2013.04.351>
- Cohn, J. (1998). Don't just say no—Berkeley research Dr. Joel Brown questions effectiveness of the federal government's anti-drug education program, San Francisco Bay Guardian, August 5, 1998. Retrieved from www.cerd.org/press/press03.html
- Cutello C.A., Hellier E., Stander J., & Hanoch, Y., (2020). Evaluating the effectiveness of a young driver-education intervention: Learn2Live. *Transportation Research Part F: Traffic Psychology and Behaviour*, 69, 375–384. <https://doi.org/10.1016/j.trf.2020.02.009>.
- de Boer, J., Botzen, W. J. W., & Terpstra, T. (2015). More than fear induction: Toward an understanding of people's motivation to be well-prepared for emergencies in flood-prone areas. *Risk Analysis*, 35(3), 518–535. <https://doi.org/10.1111/risa.12289>
- De Hoog, N., Stroebe, W., & de Wit, J. B. F. (2008). The processing of fear-arousing communications: How biased processing leads to persuasion. *Social Influence*, 3(2), 84–113. <https://doi.org/10.1080/15534510802185836>
- Dejong, W., & Atkin, C. K. (1995). A review of national television PSA campaigns for preventing alcohol impaired driving, 1987–1992. *Journal of Public Health Policy*, 16, 59–80.
- Dorta, T., Pierini, D., & Boudhraâ, S. (2016). Why 360° and VR headsets for movies? Exploratory study of social VR via Hyve-3D. IHM'16: Contextes et domaines applicatifs. <https://doi.org/10.1145/3004107.3004117>
- Fisher, P., Kastenmüller, A., & Asal, K. (2012). Ego depletion increases risk-taking. *Journal of Social Psychology*, 152(5), 623–638. <https://doi.org/10.1080/00224545.2012.683894>
- Forbes. (2018). Ford uses VR to let cyclists and motorists see the road from the other's point of view. Retrieved from <https://www.forbes.com/sites/kevinmurnane/2018/05/31/ford-uses-vr-to-let-cyclists-and-motorists-see-the-road-from-the-others-point-of-view/#4c853e9b484b>
- Goldenbeld C., Twisk D., & Houwing, S. (2008). Effects of persuasive communication and group discussions on acceptability of anti-speeding policies for male and female drivers. *Transportation Research Part F: Traffic Psychology and Behaviour*, 11(3), 207–220. <https://doi.org/10.1016/j.trf.2007.11.001>.
- Greenberg, M., & Truelove, H. B. (2011). Energy choices and risk beliefs: Is it just global warming and fear of a nuclear power plant accident? *Risk Analysis*, 31(5), 819–831. <https://doi.org/10.1111/j.1539-6924.2010.01535.x>
- Hardeman, W., Johnston, M., Johnston, D., Bonetti, D., & Wareham, N. (2002). Application of the theory of planned behaviour in behaviour change interventions: A systematic review. *Psychology and Health*, 17(2), 123–158. <https://doi.org/10.1080/08870440290013644>
- Hastings, G., & MacFadyen, L. (2002). The limitations of fear messages. *Tobacco Control*, 11(1), 73–75. <https://doi.org/10.1136/tc.11.1.73>
- Harré N., Foster S., & O'Neill, M., (2005). Self-enhancement, crash-risk optimism and the impact of safety advertisements on young drivers. *British Journal of Psychology*, 96(2), 215–230. <https://doi.org/10.1348/000712605x36019>.
- Hergovich A., Arendasy M.E., Sommer M., & Bognar, B., (2007). The Vienna Risk-Taking Test - Traffic. *Journal of Individual Differences*, 28(4), 198–204. <https://doi.org/10.1027/1614-0001.28.4.198>.
- Hoekstra T., & Wegman, F., (2011). Improving the effectiveness of road safety campaigns: Current and new practices. *IATSS Research*, 34(2), 80–86. <https://doi.org/10.1016/j.iatssr.2011.01.003>.
- Jackson, J. (2006). Introducing fear of crime to risk research. *Risk Analysis*, 26(1), 253–264. <https://doi.org/10.1111/j.1539-6924.2006.00715.x>
- Jessop, D. C., Albery, I. P., Rutter, J., & Garrod, H. (2008). Understanding the impact of mortality related health-risk information: A terror management theory perspective. *Personality and Social Psychology Bulletin*, 34, 951–964.
- Jessop D.C., & Wade, J., (2008). Fear appeals and binge drinking: A terror management theory perspective. *British Journal of Health Psychology*, 13(4), 773–788. <https://doi.org/10.1348/135910707x272790>.
- Keller, P. A., & Block, L. G. (1996). Increasing the persuasiveness of fear appeals: The effect of arousal and elaboration. *Journal of Consumer Research*, 22(4), 448–459. <https://doi.org/10.1086/209461>
- Kempf, D. S., & Harmon, S. K. (2006). Examining the effectiveness of proposed cigarette package warning labels with graphic images among U.S. college students. *Academy of Marketing Studies Journal*, 10(2), 77–93.
- Klimmt, C., Hefner, D., & Vorderer, P. (2009). The video game experience as “true” identification: A theory of enjoyable alterations of players' self-perception. *Communication Theory*, 19, 351–373. <https://doi.org/10.1111/j.1468-2885.2009.01347.x>
- Kok, G., Peters, G. Y., Kessels, L. T. E., Ten Hoor, G. A., & Ruiter, R. A. C. (2018). Ignoring theory and misinterpreting evidence: The false belief in fear appeals. *Health Psychology Review*, 12(2), 111–125. <https://doi.org/10.1080/17437199.2017.1415767>.
- Lewis, I., Watson, B., & Tay, R. (2007). Examining the effectiveness of physical threats in road safety advertising: The role of the third-person effect, gender, and age. *Transportation Research Part F: Traffic Psychology and Behaviour*, 10, 48–60. <https://doi.org/10.1016/j.trf.2006.05.001>
- Lewis, I., Watson, B., & White, K. (2008a). Predicting future speeding behaviour: The appeal of positive emotional appeals for high risk road users. Proceedings of the Australasian College of Road Safety and the Travelsafe National Conference, Brisbane.
- Lewis, I., Watson, B., & White, K. (2008b). An examination of message-relevant affect in-road safety messages: Should road safety advertisements aim to make us feel good or bad? *Transportation Research Part F: Traffic Psychology and Behaviour*, 11(6), 403–417.
- Lewis, I. M., Watson, B., White, K. M., & Tay, R. (2007). Promoting public health messages: Should we move beyond fear-evoking appeals in road safety? *Qualitative Research Health*, 17(1), 61–74. <https://doi.org/10.1177/1049732306296395>
- Lin, J. H. T. (2017). Fear in Virtual Reality (VR): Fear elements, coping reactions, immediate and next-day fright responses toward a survival horror zombie virtual reality game. *Computers in Human Behavior*, 72, 350–361. <https://doi.org/10.1016/j.chb.2017.02.057>
- Lin, J.-H. (2013). Identification matters: A moderated mediation model of media interactivity, character identification, and video game violence on aggression. *Journal of Communication*, 63, 682–702. <https://doi.org/10.1111/jcom.12044>

- Malone, S., Biermann, A., Brünken, R., & Buch, S. (2012). *Neue Aufgabenformate in der Theoretischen Fahrerlaubnisprüfung*. Bergisch Gladbach, Germany: Bundesanstalt für Straßenwesen.
- Monahan, J. L. (1995). Thinking positively: Using positive affect when designing health messages. In E. Maibach & R. L. Parrott (Eds.), *Designing health messages: Approaches from communication theory and public health practice* (pp. 81–98). Sage Publications, Inc.
- Morris, C. (2015). Is 2016 the year of virtual reality? *Fortune*. Retrieved from <http://fortune.com/2015/12/04/2016-the-year-of-virtual-reality/>
- Nabi, R. L., & Myrick, J. G. (2018). Uplifting fear appeals: Considering the role of hope in fear-based persuasive messages. *Health Communication, 34*(4), 463–474. <https://doi.org/10.1080/10410236.2017.1422847>
- Nabi R.L. (2002). The theoretical versus the lay meaning of disgust: Implications for emotion research. *Cognition & Emotion, 16*(5), 695–703. <https://doi.org/10.1080/02699930143000437>.
- Parker, D., Reason, J. T., Manstead, A. S., & Stradling, S. G. (1995). Driving errors, driving violations and accident involvement. *Ergonomics, 38*(5), 1036–1048. <https://doi.org/10.1080/00140139508925170>
- Parsons T.D., & Rizzo, A.A., (2008). Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: A meta-analysis. *Journal of Behavior Therapy and Experimental Psychiatry, 39*(3), 250–261. <https://doi.org/10.1016/j.jbtep.2007.07.007>.
- Peck, R. (2011). Do driver training programs reduce crashes and traffic violations? — A critical examination of the literature. *International Association of Traffic and Safety Science, 34*(2), 63–71. <https://doi.org/10.1016/j.iatssr.2011.01.001>
- Rafferty, S., & Wundersitz, L. (2011). *The efficacy of road safety education in schools: A review of current approaches*.
- Reason, J., Manstead, A., Stradling, S., Baxter, J., & Campbell, K. (1990). Errors and violations: A real distinction? *Ergonomics, 33*, 1315–1332.
- Rizzo, A., & Kim, J. (2005). A SWOT analysis of the field of virtual reality rehabilitation and therapy. *Presence: Teleoperators and Virtual Environments, 14*(2), 119–146. <https://doi.org/10.1162/1054746053967094>
- Rusnac, N., Spitzenstetter, F., & Tassi, P. (2016). Eveningness is associated with higher risk-taking in dangerous driving situations. *Chronobiology International, 33*(7), 937–941. <https://doi.org/10.3109/07420528.2016.1170027>
- Russell, J. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39*, 1161–1178. <https://doi.org/10.1037/h0077714>.
- Santa, A. F., & Cochran, B. N. (2008). Does the impact of anti-drinking and driving public service announcements differ based on message type and viewer characteristics? *Journal of Drug Education, 38*(2), 109–129. <https://doi.org/10.2190/DE.38.2.b>
- Scott-Parker, B., Watson, B., King, M. J., & Hyde, M. K. (2014). “I drove after drinking alcohol” and other risky driving behaviours reported by young novice drivers. *Accident Analysis and Prevention, 70*, 65–73. <https://doi.org/10.1016/j.aap.2014.03.002>
- Shiban, Y., Pauli, P., & Muhlberger, A. (2013). Effect of multiple context exposure on renewal in spider phobia. *Behaviour Research and Therapy, 51*(2), 68–74. <https://doi.org/10.1016/j.brat.2012.10.007>
- Siegrist M. (2000). The Influence of Trust and Perceptions of Risks and Benefits on the Acceptance of Gene Technology. *Risk Analysis, 20*(2), 195–204. <https://doi.org/10.1111/0272-4332.202020>.
- Slater M., (2009). Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*(1535), 3549–3557. <https://doi.org/10.1098/rstb.2009.0138>.
- Smith, M. J., Fleming, M. F., Wright, M. A., Losh, M., Humm, L. B., Olsen, D., & Bell, M. D. (2015). Brief report: Vocational outcomes for young adults with autism spectrum disorders at six months after virtual reality job interview training. *Journal of Autism and Developmental Disorders, 45*(10), 3364–3369. <https://doi.org/10.1007/s10803-015-2470-1>
- Tannenbaum, M. B., Hepler, J., Zimmerman, R. S., Saul, L., Jacobs, S., Wilson, K., & Albarracin, D. (2015). Appealing to fear: A meta-analysis of fear appeal effectiveness and theories. *Psychological Bulletin, 141*(6), 1178–1204.
- Tay R., & Ozanne, L. K. (2002). Who are we scaring with high fear road safety campaigns? *Journal of Asia-Pacific Business, 4*(2), 1–2. https://doi.org/10.1300/j098v04n02_01.
- Tay, R., & de Barros, A. (2010). Public perceptions of the use of dynamic message signs. *Journal of Advanced Transportation, 42*(1), 95–110. <https://doi.org/10.1002/atr.5670420107>
- Tay, R., & Watson, B. (2002). Changing drivers’ intentions and behaviours using fear-based driver fatigue advertisements. *Health Marketing Quarterly, 19*(4), 55–68. <https://doi.org/10.1300/J026v19n0405>.
- Thompson, L. E., Barnett, J. R., & Pearce, J. R. (2009). Scared straight? Fear-appeal anti-smoking campaigns, risk, self-efficacy and addiction. *Health, Risk & Society, 11*, 181–196. <https://doi.org/10.1080/13698570902784281>
- Valmaggia, L. R., Latif, L., Kempton, M. J., & Rus-Calafell, M. (2016). Virtual reality in the psychological treatment for mental health problems: A systematic review of recent evidence. *Psychiatry Research, 236*, 189–195. <https://doi.org/10.1016/j.psychres.2016.01.015>
- Vassallo, S., Smart, D., Sanson, A., Harrison, W., Harris, A., Cockfield, S., & McIntyre, A. (2007). Risky driving among young Australian drivers: Trends, precursors and correlates. *Accident Analysis and Prevention, 39*(3), 444–458. <https://doi.org/10.1016/j.aap.2006.04.011>
- Wählberg A.E. af, Dorn L., & Kline, T., (2010). The effect of social desirability on self reported and recorded road traffic accidents. *Transportation Research Part F: Traffic Psychology and Behaviour, 13*(2), 106–114. <https://doi.org/10.1016/j.trf.2009.11.004>.
- Watson-Brown, N., Scott-Parker, B., & Senserrick, T. (2019). Association between higher-order driving instruction and risky driving behaviours: Exploring the mediating effects of a self-regulated safety orientation. *Accident Analysis and Prevention, 131*, 275–283. <https://doi.org/10.1016/j.aap.2019.07.005>
- White, C. M., Gummerum, M., & Hanoch, Y. (2015). Adolescents’ and young adults’ online risk taking: The role of gist and verbatim representations. *Risk Analysis, 35*(8), 1407–1422. <https://doi.org/10.1111/risa.12369>
- Wilde, G. J. S. (1994). *Target risk: Dealing with the danger of death, disease, and damage in everyday decisions*. Toronto: PDE.
- Witte, K. (1992). Putting the fear back into fear appeals: The extended parallel process model. *Communications Monographs, 59*(4), 329–349. <https://doi.org/10.1080/03637759209376276>
- Witte, K. (1996). Predicting risk behaviors: Development and validation of a diagnostic scale. *Journal of Health Communication, 1*(4), 317–342. <https://doi.org/10.1080/108107396127988>
- Witte, K., & Allen, M. (2000). A meta-analysis of fear appeals: Implications for effective public health campaigns. *Health Education and Behaviour, 27*(5), 608–632.
- World Health Organization. (2019). Road traffic injury report. Retrieved from <https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries>
- Wauters Birgit, & Brengman, M., (2013). The Effect of Priming on the Effectiveness of Threat Appeals. *Contemporary Management Research, 9*(1), 47–66. <https://doi.org/10.7903/cmr.11036>.
- Xu, X., Alexander, R. L., Jr., Simpson, S. A., Goates, S., Nonemaker, J. M., Davis, K. C., & McAfee, T. (2015). A cost-effectiveness analysis of the first federally funded anti-smoking

- campaign. *American Journal of Preventive Medicine*, 48, 318–325. <https://doi.org/10.1016/j.amepre.2014.10.011>
- Yang, C., Dillard, J. P., & Lin, R. (2018). Understanding fear of Zika: Personal, interpersonal, and media influences. *Risk Analysis*, 38(12), 2535–2545. <https://doi.org/10.1111/risa.12973>
- Zhao, X., Roodis, M. L., & Alexander, T. N. (2019). Fear and humor appeals in “The Real Cost” Campaign: Evidence of potential effectiveness in message pretesting. *American Journal of Preventive Medicine*, 56(2), 31–39. <https://doi.org/10.1016/j.amepre.2018.07.033>