Effect of speed on flow and enjoyment for driving and rollercoasters

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Highlights

- Psychological flow is achieved when situational challenge is matched to personal skill
- We theorised that driver speed choice is influenced by flow seeking
- Supporting our theory, flow and enjoyment ratings were increased at faster speeds
- Promoting flow via means independent of speed may help reduce speeding behaviour

Data statement

The data for this study are available for download here: https://osf.io/q2f63/

Abstract

Worldwide, road traffic injuries are the eighth highest cause of death, and campaigns targeting excessive speed are a common approach to tackling this issue. Yet one element missing from these campaigns is acknowledgment that speed is inherently enjoyable. This study of UK road users was designed to assess whether flow theory predicts the enjoyment of the sensation of speed in the contexts of road driving and riding a rollercoaster. In a repeated measures experimental design participants viewed 5 first-person videos from a car-driver perspective under the conditions: congested traffic, 20 mph, 25 mph, 30 mph, 35 mph. As a counterpoint to road driving, comprising an experience designed for enjoyment of rapid speed, they also viewed 3 rollercoaster videos under the conditions: 0.5x normal speed, normal speed and 1.5x normal speed. Participants rated experience of flow and enjoyment after each video. Flow and enjoyment ratings were increased at faster speeds compared with slower speeds for the road and rollercoaster contexts. Sensation seeking moderated flow scores for road driving such that higher sensation seekers rated higher levels of flow at 20-35 mph, but not in congestion, compared with lower sensation seekers. Findings are consistent with a flow explanation of speeding, such that increased speed leads to increased flow experience. Sensation seekers may be more prone to such motivation to speed, although further research is needed to verify this. We recommend for enjoyment and flow to be considered in anti-speeding campaigns and for driving to be re-designed to facilitate flow at slower speeds.

Keywords: Speed, flow, enjoyment, driving, rollercoaster

1. Introduction

Worldwide, road traffic injuries are the eighth highest cause of death, and the leading cause of death for those aged 5-29 years (WHO, 2018). Due to societal inequalities, road death rates are three times higher in low-income countries compared with high-income countries (WHO, 2018), suggesting that many of the 1.35 million road deaths per year worldwide (WHO, 2018) are avoidable. With 28 road deaths per million inhabitants in 2019, roads in Great Britain are among the safest in Europe (Murphy, 2020), yet still latest estimates indicate approximately 150,000 road traffic accident casualties per year reported to the police in Great Britain with numerous others unreported (Murphy, 2020). Furthermore, road traffic accidents carry high social and economic harms with lost output, medical, ambulance, police, insurance and human costs, meaning that road accidents in Great Britain cost the economy around £33bn per year (Murphy, 2020, p26).

Human error is the leading cause of road accidents (Iqbal, ur Rehman, Ali, Ullah & Ghani, 2020) and excessive speed is a well-recognised contributory factor. Speeding is one of the "fatal four" unsafe driving practices alongside drink and drug driving, failing to use seat belts and mobile phone use while driving (Norbury, 2020). It has been estimated that a 1% increase in mean speed produces a 4% increase in fatal crash risk, while a 5% reduction in mean speed can reduce fatalities by 30% (WHO, 2018). With these statistics in mind, the WHO has set a target, by 2030, to halve the proportion of vehicles travelling over the posted speed limit and achieve a reduction in speed-related injuries and fatalities (WHO, 2018). Vehicle speed does not only increase accident risk but also increases fuel consumption, as well as levels of exhaust emissions and traffic noise, negatively impacting quality of life for nearby residents (European Commission, 2018). As cars make up approximately 80% of traffic on British roads (Murphy, 2020) there is a clear rationale to research antecedents of speed choice by car drivers.

Curbing excessive speed has long been a target of UK road safety campaigns, from the “Speed Kills/ Kill Your Speed” campaign in the early 1990s to the “Be the Mate who won’t Speed” campaign launched in January 2021 by the UK Department for Transport (Anon, 2021). Arguably one element missing from these campaigns is an acknowledgment that experiencing speed may be inherently enjoyable. For example, soon after mastering how to walk, children will naturally tend to run, for the apparent reason that running is more fun than walking. Few, if any, cyclists would disagree that great pleasure is afforded by coasting downhill. Funfairs and theme parks have packaged and monetised the thrill of speed in the form of rollercoasters and other kinetic attractions, while there is a large industry around car culture and motorsport, the outputs of which are laden with references to the joy of automotive speed.

Duffy (2009) writing in his book “The Speed Handbook: Velocity, Pleasure, Modernism” reflects on Aldous Huxley’s (1931) assertion that “Speed… provides the one genuinely modern pleasure”, arguing that experiencing speed in a car is a pleasure that “feeds our sensations, our senses, working on our bodies to produce physical as well as psychic and psychological effects” (p18), and that speed is “a force of nature” (p105). Duffy (2009) argues that speed pleasure is “polymorphous and resists being pinned down” (p5) as well as being “irreducible” (p169). It seems reasonable, on this evidence, to make enquiries as to whether and how enjoyment may be linked to speed choices of motorists.

The influential Flow Theory of the psychology of enjoyment (Csikszentmihalyi & LeFevre, 1989; Šimleša, Guegan, Blanchard, Tarpin-Bernard & Buisine, 2018) has at its core the relationship between challenge and ability. According to the theory, the flow state is achieved when there is a good match between the challenges presented by a situation and the skills a person possesses that are available to meet such challenges. A good match is conducive to producing flow, which is synonymous with subjective enjoyment. On the other hand, challenges that are too easy or difficult, are not likely to produce a flow state or to be perceived as enjoyable.

Driving is a task that has often been linked to the flow state with research finding that participants regularly report driving in moments coinciding with flow states (Csikszentmihalyi & LeFevre, 1989). From the theoretical perspective of flow, choosing a faster road speed may be the manifestation of a driver combatting boredom. Ramping up the degree of challenge to better match their perceived ability, by increasing speed, may achieve a more flow-inducing and enjoyable driving experience. This reflects a likelihood that, at faster speeds, the driver is more challenged because she must respond to the road environment with greater urgency. Links between speed choice and flow are echoed by Duffy (2009) when he discusses how people "derive pleasure from speeding up the rate of one's responses" (p196). Such a notion is consistent with Fuller's (2005) task-capability interface model of driver behaviour which posits that a key determinant of vehicle speed choice is the balance between task difficulty and driver capability.

The results of several surveys support flow theory explanations of speed choice. Chen and Chen (2011) found that motorcycle riders who rated enjoyment of riding at speed, and the tendency to become absorbed in the experience of riding at speed, were also more likely to report having exceeded the speed limit in the previous six months. Atombo, Wu, Zhang and Wemegah (2017) surveyed an international sample of 354 drivers using the same flow measures as Chen and Chen (2011). Structural equation modelling indicated that perceived enjoyment predicted intention to speed and self-reported speed violation. It should be noted, however, that while both of these studies explicitly set out to assess flow as a predictor of speeding behaviour, they did not use a previously validated flow measure. Broughton, Fuller, Stradling, Gormley, Kinnear, O'Dolan and Hannigan (2009) surveyed UK motorcyclists and car drivers on their views and behaviours with respect to adhering to speed limits. They found that 60% of motorcyclists and 23% of car drivers agreed with a statement that they would "really enjoy driving/ riding fast", that 25% and 24% in each category reported that they found it difficult to keep down to the speed limit, while 28% and 26% in each category agreed that they might break the speed limit where they thought that it was set too low. These data suggest that seeking enjoyment (via flow) might motivate breaking the speed limit, although no behavioural data was collected, and it is acknowledged that inaccuracies associated with self-report survey methodology such as poor recall or socially acceptable responding may be exerting influence in this dataset.

The only experimental data linking driving speed to flow employed a driving simulator set at differing levels of driving difficulty to manipulate flow (Tozman, Magdas, MacDougall & Vollmeyer, 2015). A low flow, anxiety-promoting condition, consisted of racing as fast as possible against 8 highly expert robot drivers on a technically challenging race circuit. This was compared with an optimal flow condition consisting of racing at more moderate speed against one's own previous lap times, on a less demanding race circuit with no other traffic. An additional low flow, boredom-promoting condition consisted of 6-minutes of easy driving on a straight country road with no bends or other traffic, although no instructions regarding speed choice were reported. Flow, assessed using the Engeser Short Flow scale, was found to differ significantly across these conditions, and was highest in the optimal flow condition compared with the other two conditions. This study illustrates that altering demands of a simulated driving experience, via speed cues, can alter flow experience. However, these effects on high-speed race circuit simulations may not generalise to the moderate speeds associated with road driving. In summary, previous research suggests that faster speeds and flow experience are linked but, as the evidence is correlational or based on racing, there is as yet insufficient evidence to build the case that speed choices of road drivers may be influenced by flow seeking. Further research adopting an experimental approach and appraising realistic road speeds is needed to assess whether flow experience is related to speed.

Here we report a study with UK road users, the purpose of which was to assess whether flow theory can predict the enjoyment of the sensation of speeds encountered during moderate road driving. Taking an experimental approach, participants viewed first-person videos shot from the driver seat perspective while progressing along a typical 30 mph road. There were five conditions: congested traffic (<10 mph), 20 mph, 25 mph, 30 mph, 35 mph. Participants rated experience of flow and enjoyment after each video. It was predicted based on flow theory that flow and enjoyment would be greatest for the 35mph video, and least for the 20mph and congestion videos. As a means of tracking the extent to which participants engaged with the videos, an immersion rating was also taken after each video.

Flow theory predicts an influence of driving skill on the relation between speed and challenge, with more skilful drivers predicted to perceive lower levels of flow, all other things being equal. This is based on the notion that a greater degree of challenge would be required to match the superior skill set of better drivers. However, it is known that most drivers, paradoxically, rate themselves as better than the average driver (e.g. Sundström, 2008). This raises an interesting question as to whether the speed-enjoyment relation depends on actual or perceived skill level. Self-reported driving skill was measured to assess this, with the prediction that driving skill would moderate the experience of flow and enjoyment in the road driving context. A further factor that might influence the relation between speed and enjoyment is on-road driving hassle, that is, the extent to which drivers feel compelled to speed up to keep up with the traffic, as is commonly experienced (European Commission, 2018). Under the flow model one would predict that drivers reporting higher levels of on-road driving hassle naturally prefer lower speeds, and thus these drivers would report less flow at higher speeds than drivers reporting lower levels of on-road driving hassle.

As a counterpoint to road driving, based on Duffy's (2009) observation that a rollercoaster travelling at speed provides an instinctive downhill thrill (p105-7), the study also included a rollercoaster condition. The experience of speed while riding a rollercoaster may be different to that for moderate road driving. With a rollercoaster, a more extreme speed experience is on offer. From a flow perspective, it is likely that the experience of fast speeds on a rollercoaster is such that the level of challenge is perceived as overwhelming the skills available to cope. This might lead to a degree of anxiety, negatively impinging on the flow experience. While it has been theorised that the experience of fear and anxiety in a controlled environment of a rollercoaster can be perceived as enjoyable (Stephens, 2018), nevertheless, flow theory would predict decreasing levels of flow as a rollercoaster reaches and goes beyond full operating speed. To test this, participants viewed a series of first-person videos, from the perspective of being a passenger on a rollercoaster. The videos depicted a rollercoaster progressing at different speeds, as follows: slow (half normal speed), realistic (normal speed) and rapid (one-and-a-half times faster than normal speed). Participants rated flow, enjoyment and immersion after each one. It was predicted that flow would decrease as the rollercoaster video speeds increased.

Sensation seeking is often assessed in studies of speeding, recognising the common finding that sensation seekers are more likely to break speed limits (e.g. Jonah, 1997). Sensation seeking is defined as “the seeking of varied, novel, complex, and intense sensations and experiences and the willingness to take physical, social, legal, and financial risks for the sake of such experiences” (Zuckerman, 1994, as cited by Jonah, 1997). Therefore, sensation seeking was also assessed but no effect of sensation seeking was predicted at moderate road speeds. For rollercoasters it is likely that sensation seeking would moderate the experience of flow and enjoyment such that the levels of flow and enjoyment experienced at higher speeds would be greater for individuals with higher levels, compared with lower levels, of the sensation seeking trait.

For the present study it was hypothesised that, in the context of road driving at moderate speeds up to 35 mph: (i) the faster the speed the more flow and enjoyment would be experienced; (ii) sensation seeking would not moderate the experience of flow and enjoyment; (iii) driving skill would moderate the experience of flow and enjoyment; (iv) ratings of on-road hassle would moderate the experience of flow and enjoyment. It was further hypothesised that, in the context of the rapid speed of a rollercoaster: (v) the faster the speed the less flow would be experienced, (vi) the faster the speed the more enjoyment would be experienced, and (vii) sensation seeking would moderate the experience of flow and enjoyment. Hypotheses were pre-registered here: https://aspredicted.org/mp8sr.pdf.

2. Methods

2.1. Participants

A total of 239 participants clicked the link to participate in the study. Data were excluded for 35 participants due to: incomplete data (*n*=26); completion times of under 8-minutes or more than one-hour suggesting sub-optimal engagement with the materials (*n*=7); and failing the attention check (*n*=2). This left a final sample put forward for analysis of *N*=204. The age range was 18-67 years, with a mean of 20.7 years (SD=5.4). The gender distribution comprised 148 females, 52 males and 4 non-binary individuals. The majority of participants were undergraduate psychology students completing the study for course credit. A power calculation indicated that a minimum $N = 73$ participants would be required to detect small-to-medium sized differences ($f > 0.15$) across the three speed conditions of the rapid speed rollercoaster task in one-way repeated measures ANOVA, with alpha set to 0.05, power set to 0.80 and assuming a correlation across conditions of r=0.50.

2.2. Design

A repeated measures design was applied. The moderate speed road driving task had five conditions, determined by the speed of the car in the video: congested traffic (<10 mph), 20 mph, 25 mph, 30 mph, 35 mph. The rapid speed rollercoaster task had three conditions, determined by the speed of the rollercoaster carriage in the video: slow (half normal speed), realistic (normal speed) and rapid (one-and-a-half times faster than normal speed). Dependent variables were flow and enjoyment. Immersion was assessed as a manipulation check. Sensation seeking, driving skill and hassle were employed as moderators. The order of presentation of road and rollercoaster videos was block-randomised such that some participants experienced the five driving videos followed by the three rollercoaster videos, and some vice versa. Condition order was randomised within blocks. There were two versions of each video, which was also randomised.

2.3. Materials

2.3.1. Driving videos There were two versions of each video. The congested driving videos depicted driving on the inside lane of two lanes on a dual carriageway (21s) or driving in the central lane of three lanes on a triple carriageway (19s) with cars moving slowly in front and to the side in each. There were two versions of the free-flowing driving context videos. Both depicted driving along single carriageway roads with clear road immediately ahead and oncoming traffic in the other lane. One was semi-rural with houses on one side and a hedge on the other (20mph version 35s). The other was suburban with houses on both sides (20mph version 30s). Screen grabs of the videos are presented in Figure 1 (a-d). These videos were presented multiple times with their playing speeds adjusted to simulate travelling at the different road speeds. Consequently, the duration of the videos was shorter for faster speeds.

2.3.2. Rollercoaster videos There were two versions of each video. One was shot from a rollercoaster carriage, the track for which was carried on a green scaffold featuring 360 degree loops lasting for 14s at normal speed, while the other, on a red scaffold, did not feature 360 degree loops and lasted 29s at normal speed. Screen grabs of the videos are presented in Figure 1 (e-f). Again, these were presented multiple times with their playing speeds adjusted to simulate travelling at the different speeds, such that the duration of the videos was shorter for faster speeds.

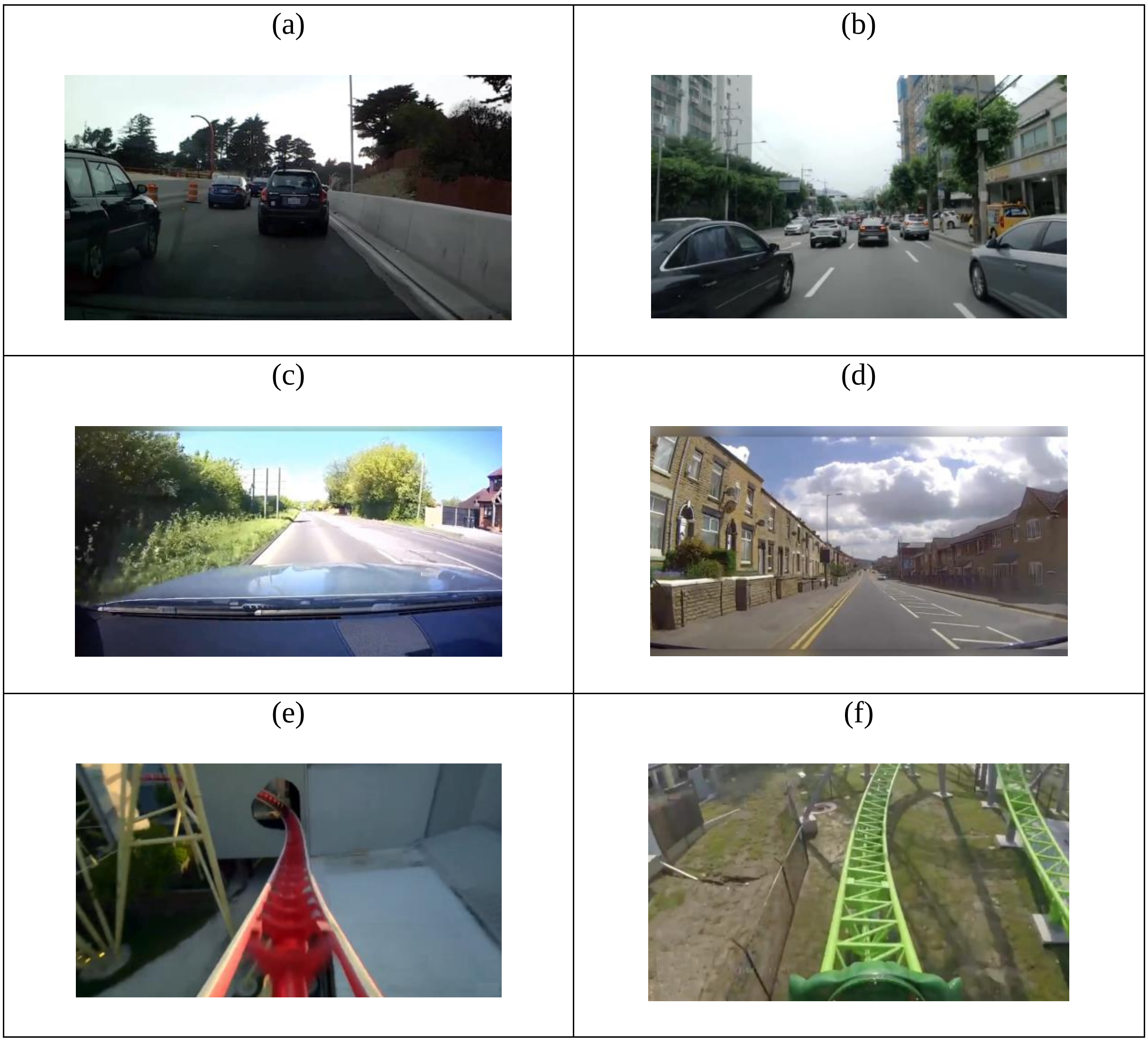

Figure 1: Screen grabs of videos. Key: (a) Congested road version 1; (b) Congested road version 2; (c) Free flowing road version 1; (d) Free flowing road version 2; (e) Rollercoaster version 1; (f) Rollercoaster version 2.

2.3.3. Flow measures: Flow was assessed using the 10-item Engeser Short Flow Scale (Engeser & Baumann, 2016), and also the 3-item flow index used by Ulrich, Keller, Hoenig, Waller and Grön (2014). Participants respond to the Engeser Flow scale (items "I feel just the right amount of challenge"; "My thoughts/activities run fluidly and smoothly"; "I don't notice time passing"; "I have no difficulty concentrating"; "My mind is completely clear"; "I am totally absorbed in what I am doing"; "The right thoughts/movements occur of their own accord"; "I know what I have to do each step of the way"; "I feel that I have everything under control"; "I am completely lost in thought") on a 7-point Likert scale anchored "Not at all', scored 1, and "Very much", scored 7. The final score is the mean across all 10 items, with a range of 1 to 7, where a high score indicates higher levels of flow. This questionnaire has good reliability, Cronbach's α = 0.85 (Engeser & Baumann, 2016). In the present study Cronbach's α ranged from 0.83 to 0.87. The Ulrich flow index, included in order to capture enjoyment aspects of flow that are omitted by the Engeser Short Flow Scale, comprises three items: "I would love to repeat it again"; "I was thrilled"; "Task demands were well matched to my ability". Response is also via a 7-point Likert scale anchored "I do not agree at all', scored 1, and "I completely agree", scored 7. The final score is the sum across the 3 items, with a range of 3-21, where a high score indicates higher levels of flow. This questionnaire has excellent validity, with increased ratings observed for each item under experimentally manipulated flow compared with boredom and overload conditions (Ulrich, Keller, Hoenig, Waller & Grön, 2014). In the present study Cronbach's α ranged from 0.63 to 0.83.

2.3.4. Enjoyment Visual Analogue Scale (VAS): Participants rated each video for enjoyment ("I enjoyed watching the video"). Ratings were made on a Visual Analogue Scale (VAS), consisting of a horizontal line anchored at its left side with "Not at all" and at its right side "Very much". Participants moved a graphic slider yielding a score from 0-100. Although not specifically validated to assess enjoyment, using a VAS has been found to be a reliable and valid psychometric method in the context of quality of life (de Boer, van Lanschot, Stalmeier, van Sandick, Hulscher, de Haes & Sprangers, 2004).

2.3.5. Sensation seeking: This was assessed using the 8-item Brief Sensation Seeking Scale (Hoyle, Stephenson, Palmgreen, Lorch & Donohew, 2002). An example item is "I'd rather have exciting and unpredictable friends", to which response is via a 5-point Likert scale anchored "Strongly disagree', scored 1, and "Strongly agree", scored 5. The final score is the mean across the 8 items, with a range of 1-8, where a high score indicates higher levels of sensation seeking. This questionnaire has acceptable reliability, Cronbach's α = 0.68-0.85 (Hoyle, Stephenson, Palmgreen, Lorch & Donohew, 2002).

2.3.6. Driving skill VAS: Drivers were asked "Please rate your skill as a driver" on a VAS anchored at its left side with "Very poor" and at its right side "Excellent". Participants moved a graphic slider yielding a score from 0-100.

2.3.7. On-Road Hassle VAS: Participants were asked to rate "When you are driving how often do you feel compelled to speed up due to the behaviour of other drivers?" on a VAS anchored at its left side with "Never" and at its right side "Always". Participants moved a graphic slider yielding a "score from 0-100.

2.3.8. Immersion VAS: After watching each video participants were asked, "How immersed did you feel in the video?". Response was via a VAS anchored at its left side with "Not at all" and at its right side "Fully". Participants moved a graphic slider yielding a score from 0-100.

2.4. Procedure

The study, carried out online via Qualtrics, was advertised with the title "Experiences of movement in cars and rollercoasters". Participants began by reading through an information sheet and providing informed consent. Next a short music video was presented to check videos were accessible to participants on the device they were using; if not they were automatically taken to the end of the study and asked to try again using a different device. The initial block of questions included gender, age, type of driving licence (full or provisional) and whether this licence was restricted to Type A, for motorbikes and scooters. Next, participants were asked to complete the driving skills VAS, the on-road hassles VAS and the Brief Sensation Seeking Scale. After this information was collected, participants viewed the 8 videos, one for each speed of driving and rollercoaster. Each video was followed by the measurement scales in the order: Enjoyment VAS, Immersion VAS, Engeser Short Flow Scale, Ulrich Flow Scale and finally an additional VAS asking participants how long they felt the preceding phase lasted ranging from 'Very short' to 'Very long'. Participants were asked to complete the questionnaires for the road context as if they were the driver, and for the rollercoaster context as if they were on the rollercoaster. Finally, participants were thanked and debriefed.

2.5. Analyses

Hypothesis (i) was assessed using one-way repeated measures ANOVA with the independent variable Speed (congested traffic v. 20 mph v. 25 mph v. 30 mph v. 35 mph). Hypotheses (ii), (iii) and (iv) were assessed using separate general linear models with the categorical predictor variable Speed (congested traffic v. 20 mph v. 25 mph v. 30 mph v. 35 mph; categorical variable) and each moderator variable entered as a continuous variable. Each model included speed and the pertinent moderator as main effects and the 2-way interaction. Hypotheses (v) and (vi) were assessed using one-way repeated measures ANOVA with the independent variable Speed (0.5x speed v. 1.0x speed v. 1.5x speed). Hypothesis (vii) was assessed using a general linear model with the categorical predictor variable Speed (0.5x speed v. 1.0x speed

v. 1.5x speed) and the continuous predictor sensation seeking. The model included speed and sensation seeking as main effects and the 2-way interaction.

3. Results

Outliers, defined at the upper end as scores more than 3 times the interquartile range above the 75th percentile value, and at the lower end as scores more than 3 times the interquartile range below the 25th percentile value, were identified for several variables. As it was not possible to eliminate outliers with loss of fewer than 10 cases, these were dealt with by winsorising as indicated in tables 1-3. Upon completion of this process, skewness coefficients across all variables ranged from -0.629 to +1.108, while kurtosis coefficients ranged from -1.02 to +0.291. As these values were in the normal range, planned parametric analyses proceeded.

Table 1: Means, SDs and Winsorisation percentile for sensation seeking scale score, driving skill rating and on-road hassle rating

	M	*SD*	Winsorisation percentile
Sensation seeking scale score	3.31	0.78	-
Driving skill rating	64.80	22.17	99.5
On-road hassle rating	40.08	25.05	-

Table 2: Means (SDs) and Winsorisation percentiles for immersion rating, Engeser and Ulrich flow scales, and enjoyment rating for the road driving videos

	Congested	20 mph	25 mph	30 mph	35 mph	Winsorisation percentiles
Flow Engeser	4.08	4.37	4.32	4.28	4.36	96.1-99.5
	(1.1)	(1.11)	(1.17)	(1.13)	(1.12)	
Flow Ulrich	7.09	7.63	7.64	7.59	8.11	98.0-99.5
	(3.35)	(3.82)	(3.84)	(3.56)	(3.71)	
Enjoyment	17.43	19.19	21.25	22.03	24.04	96.6-98.5
	(18.32)	(19.44)	(21.99)	(22.39)	(22.98)	
Immersion	30.66	29.29	28.71	31.18	31.83	-
	(27.77)	(26.97)	(26.48)	(26.93)	(27.55)	

Table 3: Means (SDs) and Winsorisation percentiles for immersion rating, Engeser and Ulrich flow scales, and enjoyment rating for the rollercoaster videos

	Half speed	Normal speed	1.5 speed	Winsorisation percentiles
Flow Engeser	4.1	4.25	4.26	98.0-99.5
	(1.04)	(1.15)	(1.19)	
Flow Ulrich	11.46	12.22	12.76	-
	(4.76)	(4.82)	(4.99)	
Enjoyment	45.88	49.52	53.27	-
	(28.04)	(27.27)	(28.7)	
Immersion	45.74	49	53.37	-
	(27.73)	(26.57)	(28.4)	

3.1. Road Driving

A series of one-way repeated measures ANOVAs were carried out for the Engeser Flow Scale scores, the Ulrich Flow Scale scores, the Enjoyment VAS scores and the Immersion VAS scores across the five road speeds: congested, 20 mph, 25 mph, 30 mph and 35 mph. Significant effects were found for Engeser Flow Scale scores, $F(4, 812) = 7.192$, MSe = 0.414, $p < 0.001$, partial eta squared = 0.034, Ulrich Flow Scale scores, $F(4, 812) = 5.561$, MSe = 4.740, $p < 0.001$, partial eta squared = 0.027, and Enjoyment VAS scores, $F(4, 812) = 9.044$, MSe = 147.616, $p < 0.001$, partial eta squared = 0.043. There was no effect for Immersion VAS scores, $F(4, 812) = 1.660$, MSe = 208.171, $p = 0.157$, partial eta squared = 0.008. These data are illustrated in Figure 2.

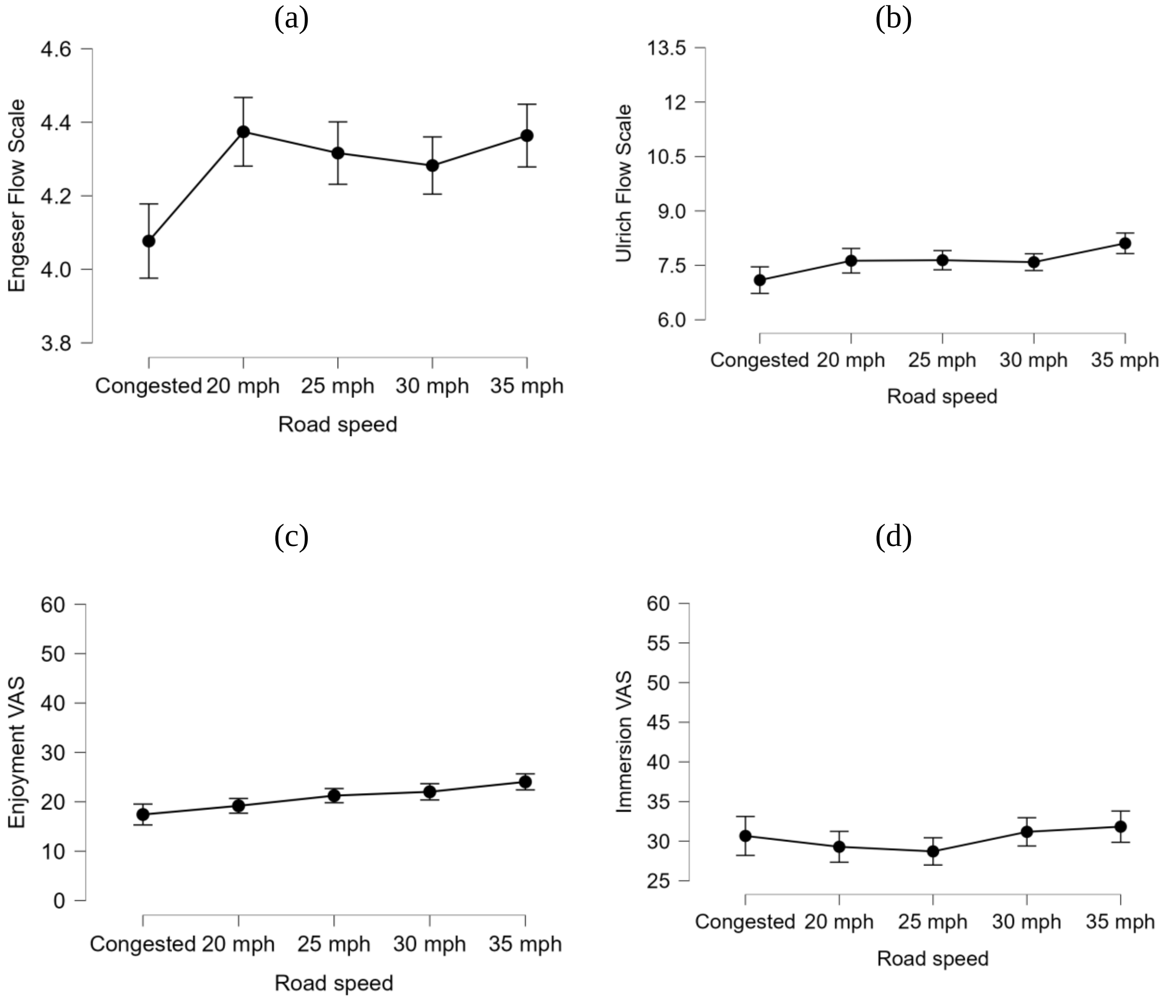

Figure 2: Engeser Flow Scale scores (a), Ulrich Flow Scale scores (b), Enjoyment VAS scores (c) and Immersion VAS scores (d) for the road driving context across the congested, 20 mph, 25 mph, 30 mph and 35 mph conditions.

Planned contrasts for the Engeser Flow Scale scores indicated that flow was increased in the 20 mph, 25 mph, 30 mph and 35 mph videos compared to the congested video (p<.001 in each case). However, there was no difference in means across the four videos 20mph, 25 mph, 30 mph and 35 mph, $F(3, 609) < 1.0$, partial eta squared = 0.005. Planned contrasts for Ulrich Flow Scale scores indicated that flow was increased in the 20 mph, 25 mph, 30 mph and 35 mph videos compared to the congested video (p<.022). There was also a significant increase in flow for the 35mph condition compared with the 25mph condition, $p = 0.016$. Planned contrasts for the Enjoyment VAS scores indicated that enjoyment was increased in the 25 mph, 30 mph and 35 mph videos compared to the congested video ($p<.002$), and that enjoyment was increased in the 35mph video relative to 20mph ($p<.001$) and 25mph ($p=.021$) videos.

The predicted absence of moderating effects of sensation seeking on flow and enjoyment was assessed by examining the interaction effects in a series of general linear models with the within-subjects factor speed (congested, 20 mph, 25 mph, 30 mph and 35 mph), the between-subjects continuous predictor sensation seeking scale score, and the dependent variables the Engeser Flow Scale scores, the Ulrich Flow Scale scores and the Enjoyment VAS scores. The interaction was not significant for Ulrich Flow, $F(4, 808) < 1.0$, partial eta squared = 0.003, and neither was it for Enjoyment VAS scores, $F(4, 808) < 1.0$, partial eta squared = 0.001. However there was a significant interaction for Engeser Flow, $F(4, 808) = 2.394$, MSe = 0.411, $p = 0.049$, partial eta squared = 0.012. The interaction was such that higher sensation seekers rated higher levels of flow at 20 mph, 25 mph, 30 mph and 35 mph compared with lower sensation seekers, but there was no moderating effect of sensation seeking for the congested condition. These data are illustrated in Figure 3a.

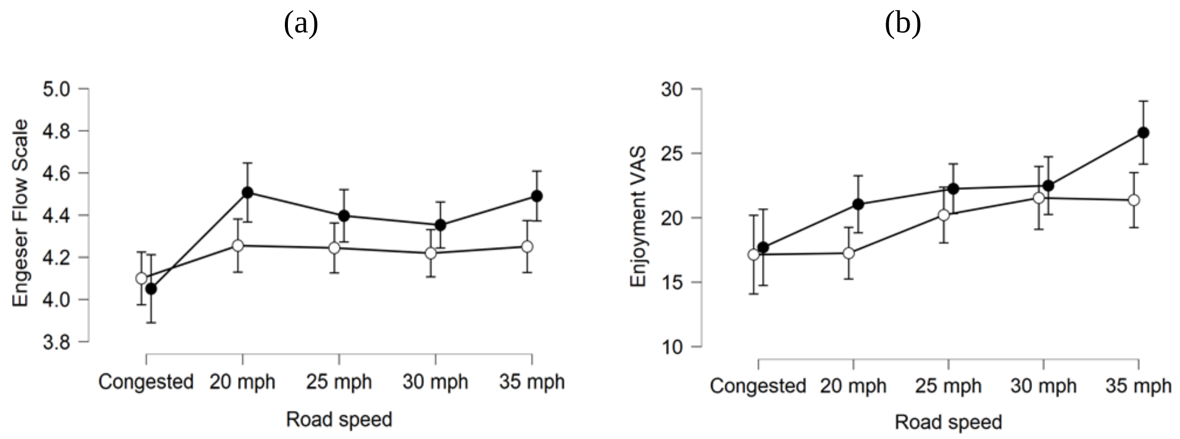

Figure 3: Engeser Flow Scale scores moderated by sensation seeking (a) and Enjoyment VAS scores moderated by on-road hassle rating (b), across the congested, 20 mph, 25 mph, 30 mph and 35 mph conditions. While continuous variables were employed in the analyses, a median split was applied to each moderator variable for illustration purposes; black circles denote higher scores on the moderator variable.

The predicted moderating effects of driving skill on flow and enjoyment were also assessed by examining the interaction effects in a series of general linear models with the within-subjects factor speed, the between-subjects continuous predictor driving skill rating, and the dependent variables the Engeser Flow Scale scores, the Ulrich Flow Scale scores and the Enjoyment VAS scores. None of these were significant with no interaction between driving skill and speed for Engeser Flow, $F(4, 808) < 1.0$, partial eta squared = 0.004, nor for Ulrich Flow, $F(4, 808) = 1.512$, MSe = 7.148, $p = 0.197$, partial eta squared = 0.007, and nor for enjoyment, $F(4, 808) = 1.291$, MSe = 147.405, $p = 0.272$, partial eta squared = 0.006.

Similarly, the predicted moderating effects of on-road hassle rating on flow and enjoyment were assessed by examining the interaction effects in a series of general linear models with the within-subjects factor speed, the between-subjects continuous predictor hassle rating, and the dependent variables the Engeser Flow Scale scores, the Ulrich Flow Scale scores and the Enjoyment VAS scores. There was no interaction between hassle rating and speed for either of the Engeser or Ulrich flow measures, $F(4, 808) < 1.0$, partial eta squared < 0.002. There was an interaction between hassle rating and speed for enjoyment, $F(4, 808) = 2.508$, MSe = 146.528, $p = 0.012$, partial eta squared = 0.012. Participants that reported more often feeling hassled rated more enjoyment at 35 mph than those reporting less often feeling hassled. However, this was not the predicted direction for this interaction effect. These data are illustrated in Figure 3b.

3.2. Rollercoaster

A series of one-way repeated measures ANOVAs were carried out for the Engeser Flow Scale scores, the Ulrich Flow Scale scores, the Enjoyment VAS scores and the Immersion VAS scores across the three rollercoaster speeds, half speed (0.5x), normal speed (1.0x) and 1.5 speed (1.5x). All of these showed significant effects: Engeser Flow Scale scores, $F(2, 406) = 4.743$, MSe = 0.353, $p = 0.009$, partial eta squared = 0.023; Ulrich Flow Scale, $F(2, 406) = 12.747$, MSe = 6.810, $p < 0.001$, partial eta squared = 0.059; Enjoyment VAS scores, $F(2, 406) = 10.737$, MSe = 258.885, $p < 0.001$, partial eta squared = 0.050; Immersion VAS scores, $F(2, 406) = 10.964$, MSe = 273.229, $p < 0.001$, partial eta squared = 0.051. These data are illustrated in Figure 4.

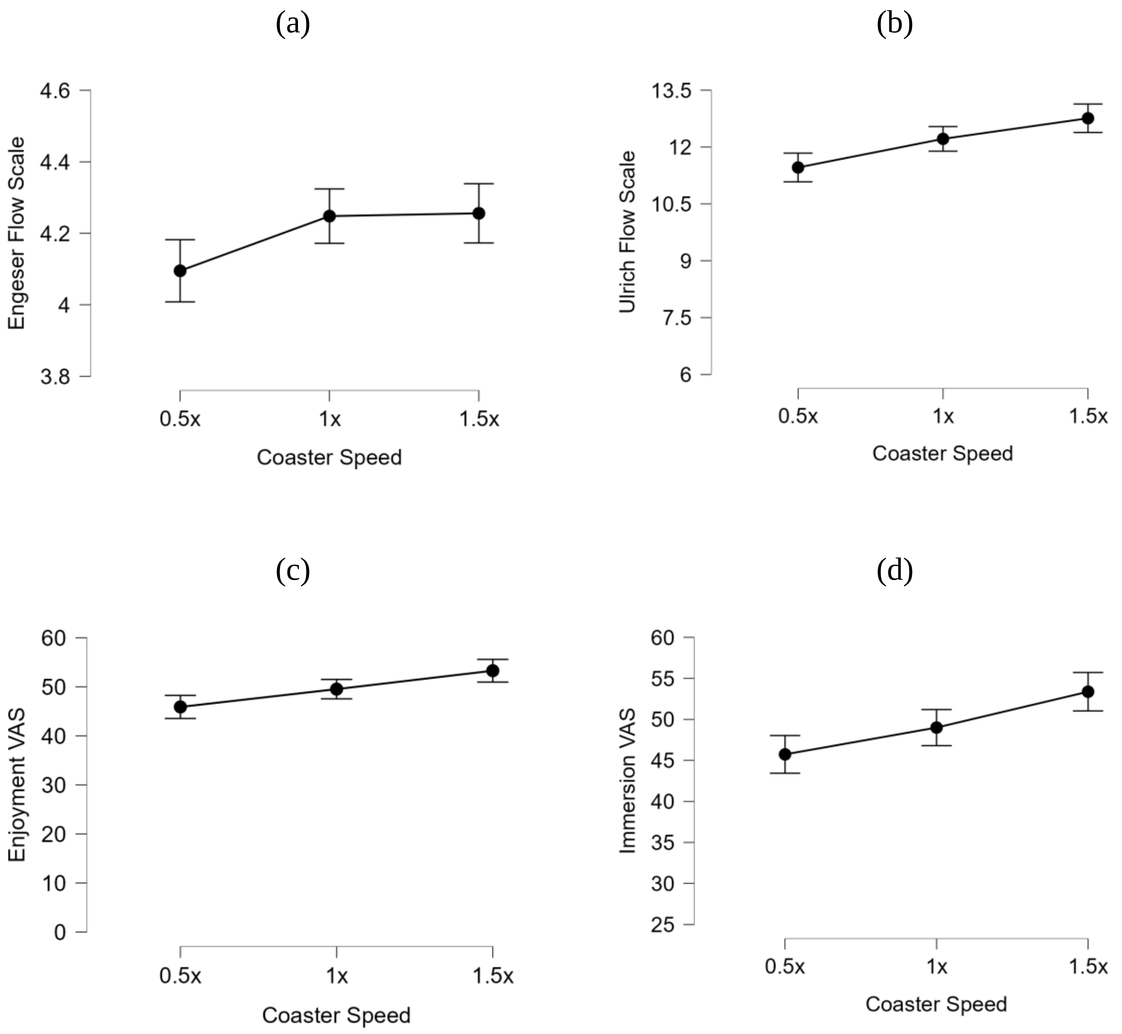

Figure 4: Engeser Flow Scale scores (a), Ulrich Flow Scale scores (b), Enjoyment VAS scores (c) and Immersion VAS scores (d) for the rollercoaster context across the half speed (0.5x), normal speed (1.0x) and 1.5 speed (1.5x) conditions.

Planned contrasts for Engeser Flow ratings indicated that flow was increased for 1.0x compared with 0.5x speed ($p = 0.010$), but not for 1.5x compared with 1.0x ($p = 0.894$). Planned contrasts for the Ulrich Flow Scale scores indicated that flow was increased for 1.0x compared with 0.5x speed ($p = 0.004$), and for 1.5x compared with 1.0x speed ($p = 0.036$).

Planned contrasts for the Enjoyment VAS scores indicated that enjoyment was increased for 1.0x compared with 0.5x speed ($p = 0.023$), and for 1.5x compared with 1.0x speed ($p = 0.019$). Planned contrasts for the Immersion VAS scores indicated increased ratings for 1.0x speed compared with 0.5x speed ($p = 0.047$), and for 1.5x speed compared with 1.0x speed ($p = 0.008$).

The predicted moderating effects of sensation seeking on flow and enjoyment were assessed by examining the interaction effects in a series of general linear models with the within-subjects factor speed, half speed (0.5x), normal speed (1.0x) and 1.5 speed (1.5x), the between-subjects continuous predictor sensation seeking scale score, and the dependent variables Engeser Flow Scale scores, Ulrich Flow Scale scores and Enjoyment VAS scores. None of these interaction effects were significant: Engeser Flow, $F(2, 404) = 1.620$, MSe = 0.352, $p = 0.199$, partial eta squared = 0.008; Ulrich Flow, $F(2, 404) < 1.0$, partial eta squared = 0.001; Enjoyment VAS scores, $F(2, 404) = 1.037$, MSe = 258.837, $p = 0.355$, partial eta squared = 0.005.

4. Discussion

We hypothesised (i) that flow would increase with speed in the road context but (v) not in rollercoaster context, and that greater enjoyment would be reported at higher speeds in both contexts (i; vi). In fact, both flow and enjoyment were increased with higher speeds in the road driving and the rollercoaster contexts. These findings are consistent with a flow explanation of speeding, which rests on the theoretical prediction that increased speed would lead to increased experience of flow by increasing the degree of challenge posed by the task of driving a car or riding a rollercoaster. Thus, these findings are consistent with understanding certain aspects of speeding behaviour when driving as an expression of seeking flow and enjoyment. It is notable that while relative enjoyment increased with speed for the driving videos, still enjoyment scores were relatively low given that the scale measured from 1-100, and driving enjoyment scores were considerably lower than for the rollercoaster. Still, even if at a low absolute level, a higher enjoyment level is likely to be a more pleasant experience than a lower enjoyment level.

We hypothesised (v) absence of increased flow with faster speed in the rollercoaster context assuming a fear-as-fun aspect of rollercoaster riding would over-ride a flow-as-fun explanation. This was with the expectation that the faster speeds would lead to a mismatch between demands of the task and ability to fulfil the task. However, we found that both flow and enjoyment were increased with faster rollercoaster speeds. These findings favour a flow explanation for understanding enjoyment of rollercoasters, possibly reflecting an assumed high level of safety of rollercoasters, such that no matter how rapidly they run, safety assurance overrides speed-related anxiety such that the challenge is not perceived as over-whelming, enabling flow and enjoyment to be experienced (Stephens, 2018).

We did not make predictions with respect to immersion ratings but note the findings that these did not differ across the different speeds in the driving context but that reported immersion increased with increasing speed for the rollercoaster context. This may reflect a floor effect for the driving context, noting that the immersion ratings were noticeably lower for the driving context compared with the rollercoaster context. The higher rollercoaster ratings may reflect that participants were more positively inclined towards these videos than the driving videos. If so, the greater immersion reported for faster rollercoaster videos may be an expression of a generally more positive inclination for the rollercoaster videos compared with the more mundane in-car videos.

We hypothesised (ii) that sensation seeking would not moderate the experience of flow and enjoyment for driving but (vii) would exert a moderating effect for the rollercoaster context. These hypotheses were largely unsupported as analysis showed no moderating effects of sensation seeking in the rollercoaster context and limited evidence of a moderating effect of sensation seeking in the road driving context – for flow but not for enjoyment ratings. A moderating effect of sensation seeking on flow in the road driving context was observed such that, above congested road speed, higher sensation seekers experienced more flow compared with lower sensation seekers. This suggests that sensation seekers may be more prone to basing road driving speed choice on flow experience, although given the mixed findings here, further research would be needed to verify this.

We hypothesised (iii) that driving skill would moderate the experience of flow and enjoyment in the road driving context, however, this hypothesis was not supported as no moderation effects were found. Our reasoning in making this prediction was that, for more skilful drivers, faster speeds would be required for optimal matching of challenge to skills compared with less skilful drivers. In explaining the absence of this predicted moderation effect it is likely that the self-ratings of driving skill did not accurately assess real world driving skill, but rather were inaccurate self-perceptions of driving skill as reported elsewhere (e.g. Sundström, 2008). It is also possible that participants did not understand this question sufficiently as we did not define clearly the construct “driving skill”. We acknowledge this limitation of the study design.

Finally, we hypothesised (iv) that ratings of frequency of on-road driving hassle would moderate the experience of flow and enjoyment in the road driving context. This was assuming that drivers reporting higher levels of on-road driving hassle naturally prefer lower speeds, and thus the flow model predicts that these drivers would report less flow at higher speeds than drivers reporting lower levels of on-road driving hassle. While there was no effect for flow, we did show a moderation effect for enjoyment such that individuals reporting more frequent on-road hassles rated more enjoyment at 35 mph than those reporting less frequent hassles, which was not the predicted direction for this interaction effect. We interpret this effect as likely to be spurious, such that the hypothesised relation between on-road hassle and flow experience as a function of speed remains unsupported.

We suggested earlier the notion that enjoyment of speed is an inherent and irreducible human characteristic, as suggested by Duffy (2009). In finding that speed has an effect on flow experience and enjoyment for road driving up to 35 mph and for riding on a rollercoaster moving more rapidly, these data support this notion. Indeed, such a view has been put forward by the philosopher Glezos (2017) who argued that "speed lies in the heart of the human", based on observations concerning the oldest known human tool, the Acheulean axe. At 1.5 million years old this axe was invented around the same time that history records the first evidence of *Homo Sapiens*. Either by throwing or other usages, the axe would have sped up the time required for various tasks to be accomplished. Glezos suggests that this tool may not have been merely a consequence of human neocortical expansion, rather as humans adjusted to the increased velocity it afforded, it may have contributed to this expansion. Glezos suggests, therefore, our relationship with velocity may be one that is fundamental, or has he puts it, velocity may well have been "generative of the human". This line of thinking reinforces the importance of factoring in enjoyment of the sensation of speed when designing interventions for encouraging road driving at safe speeds.

The present study builds on previous research showing a link between flow, enjoyment and speed choice in drivers and motorcyclists, however, the present study expands knowledge by using experimental methods as opposed to surveys (Atombo, Wu, Zhang & Wemegah, 2017; Broughton, Fuller, Stradling, Gormley, Kinnear, O'Dolan & Hannigan, 2008; Chen & Chen, 2011), and by assessing flow and enjoyment at moderate road speeds rather than for racing (Tozman, Magdas, MacDougall & Vollmeyer, 2015). One implication of this study is for flow experience and enjoyment of speed to be considered when planning anti-speeding campaigns for road safety. Given the present study's support for our theory that speed choice is influenced by seeking flow experience, we recommend driving interventions that facilitate flow at slower speeds. For example, greater focus on those aspects of driving taught and examined by the UK charity, IAM RoadSmart, formerly the Institute of Advanced Motorists, including observation, timing, and optimum road positioning (IAM RoadSmart, 2021), would increase the level of challenge of the driving task independent of speed choice. Furthermore, encouraging greater use of graphic displays found in modern cars that provide feedback on driving performance with respect to fuel efficiency would similarly increase the challenge of moderate speed driving, in theory, offering opportunities to experience flow independent of speed. Alternatively, a campaign raising awareness of tendencies, possibly unconscious, to speed up in the pursuit of flow might be designed; this could be tagged as "mindful driving". Further research might usefully assess whether drivers are aware that they may be speeding up in the pursuit of flow. Our flow theory of vehicle speed choice is compatible with traditional road safety campaigns that highlight risks of speeding since making risks salient would be predicted to limit flow experiences, as processing of risk would interrupt unconscious flow experience. The flow theory of vehicle speed choice is also compatible with Fuller's (2005) task-capability interface model of driver behaviour, highlighting the specific example of speed choice as an important factor contributing to driving task difficulty.

One limitation of this study is that it was based on participants watching first person videos of driving and riding rollercoasters and not behavioural data. Of course, there is no guarantee that flow and enjoyment experienced while watching videos would be equivalent to that experienced in real life. One issue is that, because participants accessed videos on their own devices, field of view would have varied across participants, a factor previously shown to affect speed perception (Lidestam, Eriksson & Eriksson, 2019). On the other hand, as this was a within-subjects design, participants would have watched all videos with the same field of view and therefore this factor would not have biased any one condition. Still, an obvious further study would be to assess flow and enjoyment in real life driving and rollercoaster scenarios. There was also a confound between video speed and duration such that the faster the speed the slower the duration of the video. Therefore, we cannot rule out that people experience more flow and report greater enjoyment for shorter length videos, although this seems unlikely. The alternative would have been to cut the faster speed videos to a standard duration but then there would have been a confound between distance travelled and speed condition. A compromise would be necessary one way or the other, and we note that this applies for research conducted through videos or in real life.

In conclusion this study has demonstrated, in the contexts of road driving at moderate speed, and riding a rollercoaster at more rapid velocity, that the faster the depicted speed, the more flow and enjoyment were experienced. This is the first time that an effect of speed on flow and enjoyment of driving at moderate road speed has been demonstrated in an experiment. These observed effects are consistent with our flow theory of vehicle speed choice which posits that speed choice when driving may be an expression of flow-seeking, increasing the challenge of driving at moderate speeds to better match perceived driving skill. Hence this research opens the door to considering whether substituting alternative routes to flow experience can moderate vehicle speed choices and increase adherence to speed limits.

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