Protected Cycle Lanes and Cyclists' Behaviour and Perceptions of Safety

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ALEXANDRA KNIGHT

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Abstract

Due to the climate crisis, and many other benefits associated with cycling, governments worldwide have been advised to increase their country's cycling mode share. However, in many places, including New Zealand, cycling rates are still low. Research has determined that a central barrier to cycling in countries with low cycling rates is the perception cycling is unsafe. Unfortunately, this perception is accurate in many places, including New Zealand. Protected cycle lanes (PCLs) are a possible solution to both problems; research shows that people tend to feel safer in them, and, in many places, they improve crash rates for cyclists. However, some studies have found conflicting results regarding PCLs' safety benefits. A possible reason crash rates increase in some places is that cyclists travel faster in them due to either a decreased mental workload or from feeling safer. The theories underpinning the hypothesis were Fuller's Task-Capability Interface model of driving behaviour and Summala's Zero-Risk Theory. Two studies were performed to see if PCLs improve measures related to use (like perceptions of safety) in New Zealand and if bicyclists' speeds increase relative to painted cycle lanes. These studies were an online questionnaire and an on-road experiment with a post-ride questionnaire. The studies found that cyclists in New Zealand felt safer on PCLs, were more willing to allow their children to bike on them, showed less concern towards hazards, and believed they would experience less dread in coming up to them than on painted bike lanes. Additionally, a relationship between physical separation and increased speed was not found. In terms of theory, a consistent relationship between feeling safe or having a lower mental workload and speed was not observed either. Further research is required to reassess the latter two findings as this study was the first of its kind, and environmental factors may have affected the results. However, so far, the findings are promising that PCLs are a good (and safe) intervention to increase cycling rates in New Zealand.

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1. Introduction

The benefits of cycling as a form of transport are many. For example, higher cycling rates can reduce local sound and carbon pollution, reduce traffic congestion and improve the physical, mental and economic welfare of those who commute by bike (Pape, 2016). Moreover, due to the climate crisis, policymakers worldwide have been advised to set goals to increase cycling rates, New Zealand included (He Pou a Rangi, 2021). Unfortunately, between 2015 to 2018, only 1.36% of trips in New Zealand were completed by bicycle, and 0.6% of all kilometres travelled were completed by bike compared with 64.42% and 64.6% respectively for driving a car or van (Ministry of Transport, n.d.). Considering cycling's lower mode share, it's unlikely that New Zealand is near where it needs to be to meet our targets. Additionally, those who once made up a considerable percentage of cyclists, children, have significantly reduced in numbers over the last couple of decades (Mackie, 2009).

Considering the benefits of cycling and the pressing need to shift towards sustainable transport, it is worth understanding why people are not cycling more. Many researchers have asked this question, and international and local research points to the same barrier; people believe cycling is unsafe (Cycling Safety Panel, 2014; Waka Kotahi, 2021; Wang et al., 2011). As well as being the most cited concern from adults which stops them from biking (in countries with low cycling rates), safety is also what stops children from cycling, as concerned adults do not allow or encourage them to (Cycling Safety Panel, 2014; Lorenc et al., 2008). Therefore, increasing adults' perceptions of safety seem important to increasing cycling rates for everyone.

Unfortunately, concerns around safety are not unfounded. In a study conducted using travel and injury data from 2007 and prior, in New Zealand, cyclists had the second-highest injury rates per kilometre travelled following motorcyclists (Tin Tin et al., 2010). Ethically, it is questionable to try and increase cycling rates without reducing risk, and pragmatically, it would be unlikely to work in the long run anyway. As Macmillan et al. (2014) point out, although peoples' subjective risk ratings do not always match objective risk, hearing of accidents and experiencing close calls increases perceptions of risk. So, suppose the current levels of risk did not change, but the number of cyclists did. In that case, it's likely more accidents and close calls would undo whatever positive impact an intervention had on peoples' perceptions of safety, thus decreasing willingness to cycle. Therefore, it's crucial for increasing safety and use that interventions reduce both objective and subjective risk.

Much research has investigated what interventions potential cyclists believe would encourage them to bike more and what factors make them feel unsafe. Often, answers to these questions converge, suggesting people think they would cycle more if there were bike lanes separated from cars for them to use (as being next to motorised traffic is what leads many to feel unsafe) (Bowie et al., 2019; Wang et al., 2011). Additionally, evidence suggests parents would allow their children to bike more if cycle lanes were separated from the road (Ghekiere et al., 2015).

Interventions that go to these ends include building cycle lanes completely off the road (like a footpath reserved for cyclists), off-road shared paths or building a physical separator between a kerbside bike lane and traffic. However, restrictive factors related to budgets and land use make it impossible to have lanes constructed off the road everywhere cyclists need to go. Sharing a path with pedestrians can also act as a deterrent for some cyclists. Many cyclists state that pedestrians are unpredictable, and several studies suggest some cyclists will choose to bike in mixed traffic instead of shared paths as they reach their destinations faster (Bowie et al., 2019; Mantuano et al., 2017). Bike lanes with physical separation ("protected cycle lanes" or "PCLs") are a solution that bypasses both these issues and provides separation from traffic.

Excitingly, many PCLs have met the goals of increasing safety (Ling et al., 2020; Lusk et al., 2011; Teschke et al., 2012; Wall et al., 2016) and usage (Ling et al., 2020; Lusk et al., 2011) in the locations they are installed. However, neither finding is universal.

To expand, PCLs do not always increase cycling rates, and in some cases where cycling rates have increased, it's unclear whether PCLs were the cause or if it was because of multiple interventions happening at once (Pucher et al., 2010). However, this finding may not be an issue, as the lack of effectiveness probably only means that other problems need to be addressed as well. As Macmillan and Woodcock (2017) suggest, perceptions of safety are not the only barrier to cycling; however, they are a central one, especially for areas with fewer cyclists. In other words, infrastructure that makes people feel safe is necessary but may not always be sufficient to increase cycling rates.

What is more concerning is that some PCLs may not be as safe as they appear. For example, a study published in 2020 that analysed injury rates between PCLs, painted bike lanes and sharrows in three different U.S. towns found conflicting results. The authors found that high continuous separation that wasn't broken frequently for driveways and intersections had the highest protection results. However, one-way PCLs with 'lighter' protection, such as intermittent, thin bollards or low curbs showed no difference in protection against injury compared to painted bike lanes, and two-way light PCLs increased cycling injuries (Cicchino et al., 2020).

Another study in the U.S. by Wall et al. (2016) found that whilst PCLs decreased crash and injury rates at intersections compared with roads without bicycling infrastructure (23%), they tended to be more severe when they did occur. Interestingly, the same study found that the effectiveness of PCLs was heterogeneous, with some reducing injury rates to zero. Unfortunately, the authors did not go into detail about whether the more effective PCLs in the study were one or two-way.

In a report from Bowie et al. (2019) for Waka Kotahi, the New Zealand Transport Agency, the authors asked 63 cyclists to complete pre-determined rides in Wellington, Auckland and Christchurch containing different types of cycling infrastructure. Participants were asked to give ratings on several 6-point scales (ranging from very poor to very good) during the rides, including one for traffic safety. Video recordings from the cyclists' point of view were also taken of the trips to contextualise participants' answers. While the authors found that PCLs were generally favoured above all other infrastructure, some participants gave unfavourable safety ratings. These negative ratings were usually associated with cars suddenly intercepting the PCLs at driveways and side street intersections. One of the reasons given was that participants did not feel like they had enough space to react to sudden hazards.

Several other studies have observed increases in crashes where PCLs have been installed, especially at intersections (Garder et al., 1994). A common finding is that this is especially so for two-way PCLs, although there is some evidence some one-way PCLs might increase crash rates as well (Thomas & DeRobertis, 2013).

Some hypotheses have been shared to explain the findings listed above. For example, some researchers have argued that PCLs have been falsely blamed for increasing injury rates by not accounting for increases in cycling rates. The argument is that the absolute number of injuries increased, but if the higher cycling rates were considered, the rate of injury per cyclist would be lower (Thomas & DeRobertis, 2013). Others have suggested PCLs increase injury severity or rates at intersections because they are installed in dangerous places (Garder et al., 1994; Wall et al., 2016). However, neither the original interpretations of the studies nor the arguments against them are unequivocally supported by data. So, it is possible injury rates could have risen. Additionally, the research showing two-way PCLs as being more dangerous than, at least, unidirectional PCLs have more acceptance (Methorst et al., 2017).

The above crash data were often based on post-accident questionnaires, information retrieved from police and hospital reports. One factor that cannot be gleaned from examining injury data associated with PCLs is how this infrastructure affects the behaviour of road users. In the study of human factors in transport, it is generally accepted that many factors, including the design of the road and other road users' behaviour, affect drivers' behaviour. For example, drivers tend to go faster on wider roads and slower on narrow roads (Charlton & Starkey, 2016). These changes in perception and behaviour are presumed causes behind a lot of crashes. It is possible something similar could be happening at these sites for either the cyclists or the drivers.

Some researchers have looked into what infrastructure-human interaction could be increasing crash rates at some of these sites. For example, several studies have assessed the impact double-laned PCLs and separated bike lanes have on drivers' mental workload and expectations (when trying to turn when cycling traffic is bidirectional) (Methorst et al., 2017; Räsänen & Summala, 1998). However, these studies have generally had an emphasis on driving behaviour without considering cyclists' behaviour. In fact, most research that has looked at crashes between bicyclists and car drivers, in general, have focused on drivers. A key assumption behind this focus is that car-bike collisions are usually drivers' faults, so understanding why drivers 'fail-to-see' cyclists take precedence. The logic is that if we can increase drivers' awareness of cyclists, fewer crashes would occur (Hezaveh et al., 2018).

The argument behind focusing on drivers undoubtedly makes sense. However, car-bicycle crashes involve cyclists too, and there may be something about PCLs that change how cyclists interact with them. Summala and Räsänen (2000) give a good argument for why cyclists' behaviour is also important for understanding crashes. In an on-road observational study they conducted, Räsänen and Summala (1998) found that 68% of bicyclists saw drivers while coming up to a roundabout, compared to 11% of drivers who saw cyclists. However, at the roundabout in question, cyclists had the right-of-way, so 92% of cyclists believed cars would stop for them based on right-of-way rules. In a follow-up discussion, Summala and Räsänen (2000) argued, if car drivers are inattentive towards cyclists, it follows that many crashes are probably avoided because cyclists adapt to close calls becoming gatekeepers to their safety. Therefore, if it was found that cyclists change their expectations or behaviour on PCLs, then it may also explain the crash statistics found in some locations.

In looking at the literature, few studies investigate whether cyclists change their behaviour on PCLs. Furthermore, most studies that have investigated cyclists' behavioural changes relied on methods that were unable to discern why or if behavioural changes were attributable to the infrastructure. However, several different groups of research exist which, together, point toward a hypothesis of how PCLs may be affecting cyclists' behaviour. These groups include 1) research that indicates cyclists may travel faster on PCLs; 2) other research that has explained speed changes in drivers; 3) research that suggests these factors might occur in PCLs and 4) research that indicates similar factors might influence cyclists too. Ultimately, if it is found that cyclists travel faster on lanes with separation, knowing this can help create safe and attractive design.

1.1. Cyclists' speed choices in lanes separated from traffic

As mentioned, some research suggests cyclists bike faster on lanes separated from traffic; however, most of this research has not investigated the phenomena closely. For example, El-Geneidy et al. (2007) conducted a study where eight cyclists were asked to cycle around Minneapolis with a GPS on their handlebars for three weeks. The authors found that when participants rode on different facilities ranging from wholly separated from traffic to no separation at all (mixed traffic), they tended to bike the fastest on paths physically separated from traffic. Additionally, Strauss and Miranda-Moreno (2017) and Clarry et al. (2019) conducted similar studies to one another using disaggregate data from popular cycling apps in Montreal and Toronto, to see what road characteristics were associated with higher cycling speeds. Again, both found that cyclists travel faster when they are separated from traffic than on unseparated facilities.

Lastly, and locally, a levels of service project was carried out for Waka Kotahi The New Zealand Transport Agency by Bowie et al. (2019). The report included the results from both an on-road experiment and an online questionnaire. In the former, 63 cyclists were asked to complete pre-determined rides in Wellington, Auckland and Christchurch, all of which included different types of cycling infrastructure. In addition, participants' speeds were measured using GPS during the experiment, and they were asked to rate the roads they just rode on several scales. The authors found that cyclists' speeds were the highest on a PCL in a residential area in Christchurch. These speeds were high compared to other PCLs, shared paths and painted bike lanes. However, more information about infrastructure's effects on speed choices regarding PCLs, or how they, in general, compared to other road types was absent.

Unfortunately, one of the studies only assessed paths completely off the road (El-Geneidy et al., 2007). Additionally, Clarry et al. (2019) put both PCLs and off-road bike paths in the same category when interpreting their results. Because of these designs, the results from both studies cannot be used as evidence PCLs are specifically related to higher speeds; instead, they are evidence that cyclists travel faster on some lanes separated from traffic. What is also unclear from this data is why cyclists travel faster on these facilities and if increased speed is an inherent consequence of physical separation from traffic. For example, the PCLs may have been installed on roads with fewer driveways, influencing the cyclists' speeds. Conversely, a strength of the study from Bowie et al. (2019) is the questions asked of the participants on the different roads. Differences in answers to these may help explain the speed changes. For example, cyclists underestimated the risk on the road they went quickly in and mainly discussed enjoying themselves.

Ultimately, determining if (and how), PCLs affect cyclists' speeds is crucial to creating safe and attractive interventions. For example, increased speed reduces the time drivers and cyclists have to react to hazards. So, designers may use this knowledge to slow down cyclists or intercepting traffic at higher risk points. Conversely, creating environments that foster higher cycling speeds can make cycling a competitive form of transport (Clarry et al., 2019; Strauss & Miranda-Moreno, 2017). So, if PCLs do cause higher cycling speeds, it may provide more cause to install them or things like them to create a modal shift.

Before drawing a link between these findings and participants' speed choices, research conducted on drivers' speed choices will be explored. Exploring similar results and existing theories that explain them will help formulate a grounded hypothesis to explain the findings from Bowie et al. (2019) and to test if the same generally occurs in PCLs.

1.2. Infrastructure, driving and speed choice

There is not a large body of research investigating the role of infrastructure in cyclists' speed choices to explain the above findings. However, there is plenty that has investigated this relationship with car drivers. Therefore, the second group of studies investigate infrastructure's role in driving speeds to start forming a hypothesis as to why cyclists might bike faster in PCLs. Some commonly found relationships between infrastructure and speed are related to road width and environmental complexity.

For example, Charlton and Starkey (2016) examined the effects of centrelines and road width on speed choice and risk perception in a simulator study. The authors found that narrower roads and denser traffic increased risk ratings and lowered speed choices, respectively. Additionally, it was found that when wire rope was used as a centreline, it mitigated the effects of traffic density. To expand, risk ratings and speed choices were similar on the same roads when the wire was used regardless of busyness. The hypothesis from this is that the physical separation is what caused this effect to occur. Another key finding is the authors found perceptions of risk and speed choice were highly correlated regardless of road condition.

In another simulator study, Edquist et al. (2012) investigated how the environmental complexity of a driving environment affected speed choices, mental workload and reaction time to unexpected hazards. The authors found that adding adjacent environmental complexity (buildings and parked cars) to the driving task reduced chosen speeds and altered lateral lane position towards the centreline. Edquist et al. (2012) also found that environmental complexity increased drivers' mental workloads. Lastly, it was also found that participants' subjective mental workload and speed choice correlated highly with one another.

Enmeshed and separate from the literature on the effects of road design on speed choice, theories have been posed to explain why drivers' speeds change depending on infrastructure. Two popular ideas is that perceptions of risk (as reflected in Charlton and Starkey's 2016 study) and mental workload (Edquist et al., 2012) affects speed choice. Two theories that argue for such relationships are Fuller's Task-Capability Interface (TCI) model of driving behaviour and Summala's Zero-Risk Theory. Both theories are based on the premise that drivers are likely to slow down when feeling undesirable levels of risk. However, the theories diverge when discussing what an undesirable level of risk is and where this feeling comes from.

The Zero-Risk Theory argues that drivers generally operate in a subjective state of no risk, and any feelings of risk are undesirable. This lack of feeling risk comes from operating within safety margins. The idea is that when people learn to drive, they experience a lot of anxiety. Eventually, drivers learn the speeds and following distances that will keep them safe in various circumstances. Drivers learn these margins by their continued survival while performing these behaviours; therefore, the safety margins created from this process are a sort of heuristic reinforced by survival and a lack of frightening situations. After drivers develop these margins, their fear response turns off as long as they follow their own rules of appropriate behaviour in different traffic circumstances and nothing dangerous happens (Summala, 1988).

However, suppose drivers behave beyond these safety margins by driving too quickly or following someone too closely? In that case, it is thought drivers will experience anxiety again, which prompts them to change their behaviour to get back to feeling no risk. The underlying premise for this feeling-action model is that the function of fear is to motivate humans to move away from it. I.e., fear is uncomfortable, and its presence in us indicates a threat, so it pushes us to change our circumstances to no longer experience it. To emphasise, under the Zero-Risk Theory, feelings of risk come from acting in a way the drivers assume increases the likelihood of a crash or injury (Summala, 1988).

Sometimes, drivers may push themselves out of safety margins for different motivations; for example, they have a shorter time to get somewhere or to show off to peers. Additionally, safety margins can change over time by drivers taking more subjective risks and continuing to experience no consequences, thereby including higher speeds or shorter following distances into something felt as safe (Summala, 1988).

Therefore, the Zero-Risk theory of driving behaviour (and other risk-compensation ideas) assumes infrastructure affects drivers insofar as it creates a perceptual space that co-creates drivers' safety margins, which dictates their speed. In the case of wide, obstruction-free motorways, the argument is that the environment feels safe enough to travel at high speeds without risk, while in a clustered culdesac with traffic calming measures, a drivers' safety margins for speed are lower.

Conversely, the TCI model presumes drivers have an ideal level of risk they choose to feel and experience risk on a continuum. Fuller et al. (2008) also argue that feelings of risk do not come from perceptions of safety but from the difficulty of the driving task and how close this is to the driver's capacity to meet it. Task demand comes from how difficult it is to get to a destination without experiencing a collision. The general idea is that as a driver starts driving, their risk of a collision is certain unless they make adjustments to avoid it. So, the act of driving, getting to a destination and avoiding collision then becomes a 'task' that has a difficulty level.

Task demand is strongly related to the complexity of a situation and a person's current biological ability, knowledge and skill to navigate it (capability). Whilst both constructs are usually discussed as distinct, Fuller (2005) explains, task demand affects capability as too little may cause a driver to become inattentive and too much overwhelmed. This last point is based on the idea that humans function best at a moderate level of arousal, and when tasks increase or decrease mental workload, this shifts our arousal level. Simplistically, if a task is difficult, it increases mental workload, which increases arousal levels, while the opposite happens if a task is easy. So, for example, if a task becomes too difficult, it may overload the drivers' workload, which increases their arousal levels beyond optimum functioning, making the task even more difficult as their capacity to deal with a task lessens.

The explanation of traffic calming measures under the TCI model is similar to that of risk-compensation hypotheses, except the reason is due to workload. For example, in a crowded area, with more curves in the design, the drivers' have more things to focus on and navigate, which increases task demand. To account for the added demand, drivers slow down to navigate the circumstance effectively.

The tension between the theories concerning what an undesirable level of risk is, is an interesting theoretical question that other authors have discussed since both publications (Lewis-Evans & Rothengatter, 2009). However, the tension between the cause of feelings of risk, and therefore speed, is a more immediate practical conversation to have, especially regarding cyclists' behaviour. If it is understood what motivates speed changes more in cyclists, we are closer to tweaking and creating designs that foster different speed levels where desired. Therefore, this aspect of the theories was what was investigated when reviewing research in the following sections.

1.3. Cyclists' Mental Workloads and Perceptions of Safety In PCLs

1.3.1. Cyclists feel safer in PCLs

Thirdly, the literature on whether cyclists feel safer in PCLs or have lower mental workloads within them have been addressed by stated preference studies and on-road studies. In these studies, cyclists and potential cyclists commonly state they feel safer in cycling facilities that are physically separated from traffic. If this finding is reliable, it provides implications to increasing use and safety if perceptions/feelings of risk change cyclists' behaviour.

For example, Winters et al. (2010) analysed survey results from 1,402 people in Metro Vancouver to determine what factors motivate and deters people from cycling. Participants' experience levels ranged from potential (did not cycle but were willing to cycle more) to regular cyclists in the sample. However, regardless of experience level, having interactions with cars was one of the main deterrents. Additionally, people said they were much more willing to cycle on routes separated from traffic.

In 2012, a stated preference study was conducted in Dublin to determine which characteristics of cycle lanes were more attractive to cyclists of varying experience levels (Caulfield et al., 2012). While PCLs were not the most favoured type of intervention in the study, off-road cycle lanes (PCLs with a grass verge separator) were preferred to painted bike lanes or no cycling facilities. This finding was especially so for the inexperienced cyclists, who also showed an aversion to cycling in heavy traffic.

In New Zealand, Wang et al. (2011) conducted a similar stated preference study, where a questionnaire was given to 140 staff members and students at the University of Auckland. The biggest concern and barrier to cycling all participants cited in the questionnaire was that cycling was unsafe. Again, regardless of experience, the authors found that all participants found interacting with motor vehicles and parallel traffic volume undesirable. Following this, the most preferred intervention that would encourage cycling for participants was a cycleway separated from traffic for the entirety of their route. A hundred percent of regular cyclists cited this, alongside 80 percent of infrequent, potential and non-cyclists. A limitation with these findings is that participants do not directly vote on what seems safer – just preferable. However, the results together, alongside other findings in the literature, suggest at least part of what attracted the participants to PCLs was probably safety.

In an on-road experiment, Caviedes and Figliozzi (2018) investigated where cyclists felt the most stress directly. The authors investigated this by sending cyclists out on the same route, twice a day, for five days. During this time, video footage, GPS data and GSR (galvanic skin response) data were obtained. Participants were also asked to locate where they felt the most stress on a map after each ride. Only GSR ratings that were two standard deviations away from participants' baseline were taken to be stress responses, and care was taken to ensure that temperature and physical exertion did not interfere with GSR readings.

The authors found that GSR responses and self-reported stress ratings were positively correlated, particularly in mixed traffic and points of interception with motorised traffic. Most importantly, the authors found one of the lowest stress recordings was in a PCL, which was physically separated from parked and moving traffic. In fact, generally, separated facilities (both off and on-road) resulted in lower stress levels for participants. This finding was still present after the stress of intersections was removed, which suggests the separation during midblocks lowered stress responses. However, whilst the authors argued that stress in this instance was fear due to safety concerns, 'stress' could be feelings of risk that either come through perceptions of risk or higher mental workloads as no effort was taken to distinguish them (Caviedes & Figliozzi, 2018).

Finally, the levels of service project carried out by Bowie et al. (2019) also measured participants' perceptions of safety. Safety ratings were taken from on-road participants, and additional data was collected via an online survey. The survey was released after the on-road experiment and used footage retrieved by the participants in the on-road study. In the questionnaire, respondents were shown short clips of a range of cycling infrastructure, including PCLs. Seventy-seven videos were used overall, but participants were only shown 11 each, which were randomly assigned. After viewing each video, they were asked how comfortable they would have been riding in the area shown and were asked if they would cycle there.

In the on-road study, the authors found riders rated PCLs higher than all other types of infrastructure, including shared paths. The mean safety rating was five for PCLs compared to 4.7 on painted bike lanes on collector roads and residential streets, and 3.7 in central city and suburban business areas. As mentioned already, the authors noted that when ratings were low for PCLs, cyclists encountered a vehicle at a side street intersection or a driveway. Lastly, the online results found that participants were the most willing to cycle in PCLs than all other road types.

1.3.2. Physical separation, workload and gaze behaviour in cyclists

Although infrastructure's effects on mental workload for cyclists have not been explicitly investigated, a couple of on-road studies investigate how physical separation affects cyclists' visual attention. The reason why these studies are relevant is that visual complexity affects mental workload (Mantuano et al., 2017). So, if participants are scanning an environment more, it may indicate an increased visual load, and therefore workload. Like the relationship between cyclists' feelings of safety and PCLs, if it's found that workload is smaller for cyclists in PCLs, this provides further reason to suspect speed differences might reliably occur in them.

The first study conducted by Mantuano et al. (2017), looked at how visual behaviour in cyclists changed when cycle lanes were physically separated from pedestrians. The authors analysed the visual behaviour of cyclists on two different sections of an off-road cycling track. The first section had a painted line separating cyclists from pedestrians, and the second had a large concrete portico over the pedestrians' walkway, physically and visually separating the two lanes. In analysing participants' gaze behaviour, the authors compared where they fixated relative to an area of interest determined to be the optimum focal point to survey risk within. Gaze behaviour differed between the routes insofar as a greater percentage of fixations and fixation duration were in areas outside of the target zone when there was no physical separation between the cyclists and the pedestrians. Generally, cyclists focused on pedestrians when they were present and more when there was no physical separation between them. This observation was used to explain the differences in gaze behaviour between the conditions.

Similarly, a study was conducted by Jang and Kim (2019), which analysed the differences in eye movement and fixation in different cycle lanes, two of which were bike lanes physically separated from traffic. While no significant differences were found in the number of fixations given to different points of interest, the researchers found that cyclists did not look as widely horizontally.

The authors explained the cyclists' change in gaze width to a reduced concern of vehicle collision (to the left), so they were not scanning in this direction as much.

Again, whilst neither study looked at mental workload specifically, what is suggested by these two studies is physical separation prompts cyclists to fixate directly ahead of themselves instead of on horizontal hazards. This finding may indicate that physical separation lowers cyclists' concern towards lateral hazards, thus reducing mental workload. Taken together with research that found cyclists' performances on PDTs went down when they were right next to drivers, it may be the case that physical separation reduces mental workload in addition to perceptions of risk.

1.4. The Relationships Between Cyclists' Perceptions of Safety and Mental Workload and Their Speeds

1.4.1. The perceptions of safety on cyclists' speeds

Lastly, the few studies that examine the effects of risk perception and mental workload on cyclists' speed choices are summarised. If there is a relationship between these variables and cyclists experience lower perceptions of risk and mental workload on PCLs, it follows PCLs may encourage higher speed rates.

Unfortunately, the literature investigating the impact of feeling safer on cyclists' speeds appears to have predominantly investigated helmet use instead of infrastructure. As will be discussed, this literature is inadequate to prove or disprove a general risk-compensation effect in cyclists. Still, the studies are valuable to assess to determine appropriate methodologies for testing a Zero-Risk hypothesis in cyclists.

A Zero-Risk or risk compensation hypothesis applied to helmet use is that those who wear helmets may 'undo' some or all the benefits wearing a helmet may give them by cycling more recklessly as they feel safe enough to. Overall, the research for a risk-compensation effect from helmet use is unsupportive of the hypothesis, but some findings are mixed. Additionally, most of the studies' methods cannot create any causal claims about how helmet use affects speed choices (Esmaeilikia et al., 2019).

For example, Høye et al. (2020) investigated whether helmet use (and other safety apparel) leads to riskier behaviour via a questionnaire sent out over three years; 2015, 2016 and 2017. The authors found that helmet and other safety apparel, while negatively associated with other risky behaviour, were positively associated with speed. Also, safety apparel use had mixed results across time for crash involvement and the type of crash. For example, bike light use consistently reduced crash involvement in darkness but showed mixed results in general crash involvement, and helmet use was negatively associated with crash involvement between 2015 – 2016 but was positively related to a $p < .05$ significance level between 2016 – 2017. Altogether, the results are mixed, and murky as to if there was a relationship between helmet use and behaviour. Moreover, the questionnaire only picked up correlational data.

Another naturalistic study by Schleinitz et al. (2018) analysed behaviour from 76 cyclists who had their bicycles set up with a data acquisition system (DAS). The DAS recorded whether they wore a helmet and how fast they rode. After four weeks of riding where the participants wanted to ride, the data was collected and analysed. The authors found that while speed was associated with helmet use, this finding was not significant. Additionally, two factors (pedelec use and longer trips) were significantly correlated with higher speeds, which also correlated with helmet use, thereby weakening any causal claim the authors might want to make about helmet use leading to higher speeds.

The above lack of clarity is likely due to the naturalistic conditions the studies were in, which, unfortunately, is how a lot of the literature about this subject has been explored (Esmaeilikia et al., 2019). As mentioned by Esmaeilikia et al. (2019), to decipher any change in behaviour from helmets, studies need to be designed in a way to record changes in behaviour from a baseline of participants not wearing a helmet to after they wear one, to see if changes in speed behaviour occur.

Fortunately, three studies that fit this description more were conducted by the same group of authors in 2011, 2013 and 2018. The first couple of studies were very similar to one another in design. In them, the authors measured heart rate and speed after participants cycled down a short hill strip once with a helmet and again without one. Out of both samples, some were frequent wearers of helmets, and the rest were not. The authors replicated the same findings in both; namely, the only group who increased their speed in the helmet wearing condition were the routine wearers and no change in heart rate was observed in any condition. In both groups, the speeds in the non-helmet wearing condition were similar, whilst the speeds in the helmet wearing condition were higher for the frequent users. Additionally, in the first study, the authors also asked participants which condition they found riskier. Both groups' risk ratings were similar in the helmet wearing condition, yet ratings were a lot lower in the non-wearing condition for frequent users (Fyhri & Phillips, 2013; Phillips et al., 2011).

In the 2011 study, the authors suggested the findings supported a risk compensation effect (Phillips et al., 2011). However, as the authors point out in their limitations section and in future publications, if this was true, they might have seen the effect occur in the infrequent user group too. The authors also argued this critique could not prove there was no risk compensation effect, as sometimes, risk compensation occurs after habituating to something new.

Therefore, Fyhri et al. (2018) conducted a follow-up study that recruited cyclists who did not usually wear bicycle helmets to see if they went slower when not wearing them after habituating to wearing them. The authors found no significant differences in speed between the conditions where they were wearing or not wearing them, and this did not change after they habituated to wearing them.

The lack of hard evidence in the studies listed is not anomalous. For example, Esmaeilikia et al. (2019) synthesised 27 studies that assessed risk compensation in cyclists using helmets. Overall, 18 papers were unsupportive of the risk compensation hypothesis, three had mixed results, and two studies supported it. Additionally, those supporting the theory did not employ methodological designs to measure differences before and after helmet use; instead, the results were based on retrospective data from cyclists.

The lack of clear evidence of the risk compensation effect occurring with helmet use could be used as proof risk compensation does not occur at all for cyclists, yet it should not be. For example, bike lanes and helmet use differ similarly to self-explaining road design and seat belt use, which differ in their effects on speed. The former has been shown to have significant impacts on drivers' speed choices and behaviours, while little evidence exists for the latter (Housten & Richardson, 2007; Rock, 1993; Shannon & Szatmari, 1994). Reasons for this may include the element of personal choice which goes into wearing a helmet or a seatbelt and the differences in people who make these choices. However, this would suggest that increases in crashes/speed may be seen in places that mandate wearing them, which were not observed in the studies mentioned above. Instead, the impact physical space and factors relating to vision has on our perceptions of safety may be more influential than an idea safety has been increased by wearing something. These questions are outside the scope of this study; however, the central point is that the two have different effects on drivers, and the same may be found for cyclists.

What can be gleaned from the studies looking at helmet use and risk compensation is that relying purely on retroactive data from naturalistic settings to infer causal effects contains too much noise to discern relationships between variables. Therefore, research investigating infrastructure's impact on behaviour should include studies with control groups or repeated measures design.

1.4.2. The effect of mental workload on cyclists' speeds.

In contrast to the research on risk compensation, research investigating how mental workload or environmental complexity affects cyclists' speed has varied more. Additionally, the following studies have used better methods to analyse the relationships between different phenomena, mental workload and speed than most of those investigating risk compensation in section 1.4.1. However, as will be discussed, some results attributed to mental workload in the following studies may have been caused by perceptions of safety instead.

An example of a study like this was conducted by Vlakveld et al. (2015), examining the relationship between speed and cyclists' mental workload in real-world cycling conditions. The central aim of the study was to determine how older people using e-bikes might affect their safety. In driving research, speed increases mental workload, and older people have a lower workload capacity. Therefore, the authors hypothesised that the extra speed that comes from using an e-bike might increase older cyclists' mental workload, affecting their ability to react to transport situations effectively. Because of these aims, one of the study's main findings was the relationship between speed and workload.

The experiment was an on-road study, which got two groups of cyclists (middle-aged or elderly) to cycle a 3.5 km loop. In one part of the loop (in both directions), there was a simple traffic condition and a complex traffic condition in another. These road conditions were chosen to increase task demand/workload for the participants to provide the conditions to measure the interaction between increased workload and speed. An off-road bike path was provided as the simple task, and four unsignalised intersections in a residential area where the cyclists had to turn across traffic made up the complex task. Altogether, the study had eight conditions (2x2x2). The variables which made up these conditions were: bike type (conventional bike or e-bike), age group (middle-aged (30-45) or elderly (65+)), and traffic condition (simple or complex). Speed was measured by GPS, speedometer, and a rotation sensor in the bottom bracket, while mental workload was measured via participants' performances of a peripheral detection task (PDT) (Vlakveld et al., 2015).

Unsurprisingly, the traffic condition that caused increased mental workloads was the complex task. Additionally, all participants tended to slow down in the complex situations and bike faster in the e-bike condition. The only difference between the age groups was an interaction effect found for the older cyclists and not the other participants. Namely, older cyclists tended to slow down more in the complex situation on an e-bike, relative to how much they slowed down on a conventional bicycle in the same condition (Vlakveld et al., 2015).

Some may conclude that these results prove that higher workloads cause cyclists to slow down. Before reaching this conclusion, a reminder needs to be made that these situations were turns that require slowing down beyond the need to counterbalance workload demands. For example, the turns crossed both directions of traffic. Slowing down in this instance could have been a pre-emptive action in case participants needed to come to a stop or wait for traffic to pass. Turning on a bicycle itself also requires greater physical effort in steering and balance than that required of a driver, which could have impacted speed choice, which may have also been harder for older cyclists. Lastly, turning is generally conducted at lower speeds due to the need to reduce the impact centrifugal force has on completing them successfully. Altogether, the reduction in speed in the complex situations for both age groups was likely impacted by these other factors. The last two could have also contributed to how much more older cyclists slowed down in the e-bike x complex condition.

Furthermore, the relationship was negative when the participants' speeds and performance on the PDTs were correlated. So, the higher a participant's speed, the better they tended to perform on the PDT. This relationship was found in all conditions (simple + conventional bike, complex + conventional bike, simple + e-bike, and complex + e-bike). This relationship is surprising given the opposite is found in drivers. The authors hypothesised that the extra exercise behind the higher speeds may have decreased the workload for participants by improving arousal. It is also plausible that when participants cycled faster, it was because their mental workloads were lighter. However, it is to be noted that the relationships were weak and were only statistically significant when both the age groups' data were merged.

Another on-road study conducted by Pejhan et al. (2021) investigated where cyclists' anxiety levels and mental workloads spiked in an on-road situation and looked at the corresponding relationship speed had with these variables. The authors investigated these relationships by measuring how heart rate, hit rate scores in a PDT, speed, and balance changed on roads with different conditions. These conditions included when participants had to share the road with cars, cycle on roads with wider shoulders, when they were being overtaken by different sized vehicles and going past long lines of traffic. Participants were also asked to rate how safe they felt in various traffic scenarios to expand on the results found in the on-road experiment.

The authors found that when participants were overtaken by vehicles within a 2 m radius, their speeds were significantly slower than overtaking distances greater than 2 m or no over-taking. The authors also found that when they compared the effects of "…type of an overtaking vehicle with minimum lateral distance, speed, age, sex, and skill level…" for participants' heart rate, large vehicles showed the strongest effect (Pejhan et al., 2021, p. 7). Similarly, speeds were significantly lower when participants went past a line of traffic or came up to an intersection. In these situations, participants performed the worst in the PDT, and their heart rate was the fastest (Pejhan et al., 2021).

Due to the previously mentioned relationship between high-density traffic or approaching an intersection, speed and heart rate, participants' heart rates were the highest while they were going between 5 – 10 km/h. This increase was unlikely to be caused by the slower speeds, but because both occurred in traffic scenarios with higher complexity/more contact with motorised vehicles. Additionally, results from the questionnaire found that participants, irrespective of age, sex or skill level, tended to say they felt less safe sharing the road with other vehicles than on roads with a wider shoulder (Pejhan et al., 2021).

The results from this study suggest that feeling anxious or experiencing a higher mental workload may slow cyclists down, as seen with car drivers. The study also indicates that the places where these factors increase the most are when the separation between cyclists and vehicles is lower. What is undiscernible from this study is whether perceptions of safety were the cause of the anxiety and increased heart rate, mental workload was, or if these factors were enmeshed. For example, it’s unlikely many would argue that fear would increase heart rate. Yet, an early study by Szabo et al. (1994) was also able to show in a controlled setting that cyclists’ heart rate increased above their current heart rate while cycling as their mental workload did. The authors were able to do this by recording participants’ heart rates before, during and after a mental arithmetic (MA) challenge. MA challenges were given during cycling at both low and moderate exercise intensities and at rest prior to and post cycling. The results were clear: in every condition, participants’ heart rates increased while trying to solve an arithmetic problem compared with the time around it.

In Szabo et al.’s (1994) study, the interference of fear was seemingly absent, which shows that workload can increase cyclists’ nervous response. These findings are incredibly relevant, as they provide support for Fuller’s argument that task demand may create ‘feelings of risk’, even with cyclists. The results also have implications for research that measures either mental workload or fear through cyclists’ heart rates as both tend to increase heart rate.

However, it must be noted that just because increased workload can increase heart rates in cyclists, it does not mean this was the cause, as increased heart rate is a well-known symptom of fear. Additionally, if in Pejhan et al.’s (2021) study, anxiety symptoms were caused by perceptions of danger, this relationship could still explain participants’ reduced performance on the PDT. To expand, if people do have an optimum level of arousal where exceeded their mental capacity diminishes, and fear causes spikes in this arousal, it follows people could perform worse on a task measuring mental workload when perceptions of risk are higher.

Finally, a study was conducted by de Waard et al. (2010), which came close to discerning the effects of perceptions of safety and workload on cyclists' speed. This study aimed to determine the added risk using a phone posed on cyclists' likelihood of crash involvement. In the paper mentioned, three studies were conducted. In the first, the authors investigated how many recently recorded cycling injuries occurred while cyclists' were on their phones by contacting cyclists who had recently been in an accident. In the second, the authors observed how normal cycling and using a mobile phone was by conducting a street observational study in the same area participants in study one was recruited in. Contrary to expectations, the authors found that a smaller proportion of cyclists were using a mobile phone in their accident than the proportion who were using a phone in the second study. So, the authors designed a third study to see how talking on a mobile phone affected cyclists' behaviour to help explain their findings from studies one and two.

In the third study, the authors directed 24 participants to cycle the same stretch of cycle path in six different conditions. These conditions included two control conditions (where participants had two hands on the handlebar, and then only one), two phone conditions (where an easy and a difficult MA task was administered over the phone), a texting condition (where they had to continuously write out a Dutch Happy Birthday song on their phone), and an MP3 condition (where they listened to music). Several measurements were taken during these different conditions, with three being more relevant to the discussion at hand. Namely, these variables were participants' speed, self-reported risk ratings and effort ratings (de Waard et al., 2010).

Out of the experimental conditions listed above, de Waard et al. (2010) found that participants cycled the slowest in the texting condition, followed by the difficult-phone condition, the easier-phone condition, the control conditions, and then the MP3 condition. In both cases, the authors found that risk and effort ratings were higher for the three phone-related conditions than the control conditions and the MP3 condition, which mirrored participants' speed ratings.

Interestingly, participants' risk ratings aligned more with the observed speed changes. For example, most of the risk and effort ratings mirrored each other; however, the condition with the lowest speed and highest risk rating was the texting condition, when the most effortful was the difficult phone condition. Additionally, for the texting condition (slowest speed), the F and partial eta-squared values were higher for risk ratings than effort ratings when comparing the two between the one-hand control and texting conditions. Finally, participants' effort ratings were validated by a PDT, as the lowest scores were in the high-difficulty phone conversation condition, suggesting vision tunnelling, which occurs in high workload situations. Unfortunately, the authors did not focus on these differences in ratings much. However, it does provide some evidence that feelings of risk and workload may be independent of one another in cyclists and that perceptions of risk may have more explanatory power over cyclists' speed choices.

1.5. The current research

As a recap, policymakers in New Zealand and abroad have made it clear they want to increase cycling rates due to its many benefits. However, to increase cycling rates effectively and ethically, we need infrastructural designs that attract usage by feeling safer and being safer. PCLs potentially fill this need as research has shown they improve subjective risk ratings and have been associated with lowered objective risk. However, in some areas, the findings on safety have been mixed.

Altogether, some evidence suggests cyclists travel faster in lanes separated by traffic, which could explain some of the troubling crash and injury statistics. For example, GPS studies show cyclists travel faster in lanes separated from traffic in some places; however, it is left unknown by this data if the observations are due to PCLs or something else. Furthermore, other research suggests that mental workload and risk perceptions may be lower in PCLs compared with lanes without physical separation. Both variables have been associated with higher speed choices in drivers and cyclists. However, a lack of research tests whether cyclists have lower mental workloads in PCLs or if their speeds change reliably.

If cycling speeds reliably increase in PCLs, this carries implications for cycling safety and attractiveness. Safety, because higher speeds may reduce the reaction time available to cyclists when they encounter hazards; attractiveness, because higher speeds mean faster arrival times, making cycling a competitive form of transport.

Discovering if PCLs increase cyclists' speeds and increase measures relating to attractiveness is important to encouraging cycling rates. Therefore, this study attempts to answer these two questions:

1. Are PCLs rated higher than painted bike lanes in measures likely to increase cycling rates?
2. Do cyclists behave differently in PCLs than painted bike lanes?

As a secondary focus, effort was given to identify patterns in the data that could help explain findings related to speed changes. Namely, the role perceived safety and mental workload had on cyclists' speed choices was investigated. Two studies took place to answer all of the above: an online questionnaire and an on-road study.

An on-road repeated-measures experiment was considered the best way to answer the questions above. In this study, two routes would be sought that contained different types of separation (painted vs physically separated) to see how cyclists' behaviours and ratings related to use differed between them. Designing the experiment in this way was thought to be the best option based on the rationale cited by Esmaeilikia et al. (2019). I.e., repeated measures designs where an intervention is present then absent (or vice versa) is the best way to measure the effects of that intervention.

However, when this project began, New Zealand went into level 4 lockdown in response to the Covid-19 virus outbreak, which made the possibility of an on-road experiment uncertain. Because of the uncertainty, an online questionnaire was created to attain some initial data if a later on-road experiment could not happen. The questionnaire showed short videos of cycling footage to participants, followed by questions about the footage they saw. It was decided that videos were an ideal way to prompt participants to think about cycling on roads with different (or no) bike lanes in lieu of being able to bike on them themselves.

Being in lockdown meant that domestic travel was restricted, so existing videos were sought instead of recording some for the experiment. Luckily, several videos with first-person cycling footage had already been taken in New Zealand to conduct the New Zealand bicycling levels of service project by Bowie et al. (2019) mentioned earlier. After contacting one of the lead researchers, the project's videos were shared electronically. All videos contained first-person footage of a person cycling in Christchurch, Wellington or Auckland, which were attained through a go pro attached to their helmet, taken by 63 participants. In total, 77 videos were reviewed before the final videos for the questionnaire were chosen. For more information on the initial project, see (Bowie et al., 2019).

Videos from the project were then organised into different types of cycling infrastructure; bike lanes with physical separation (Protected), bike lanes with painted separators (Unprotected) and everything else (Control). Further categories were created to group the roads by general function, i.e., residential, town centre, industrial, and connector roads. Within these latter sub-groups, videos were then compared between the PCLs and the painted bike lanes to determine pairs of videos similar in landscape, surrounding infrastructure, traffic pace, and busyness. The videos were then divided into pairs to find a range of road settings where each pair's primary difference is the type of separation from traffic. This grouping was done so differences in answers could be attributed to infrastructure. However, exact couples could not be found due to the lack of control in how the videos were taken. I.e., the videos were taken in a natural transport environment by participants who were not trying to manufacture transport interactions. Additionally, some parts of the permanent physical environment could not be matched, like the presence or type of intersecting access ways.

Significant limitations were associated with this lack of control; for example, there were substantial differences in the hazards present in some video pairs, such as cars or pedestrians pulling out in front of the camera. Additionally, only a proxy for behaviour could be obtained from the questionnaire through self-report items thereby creating limitations to answering the second main research question. Finally, it was also uncertain if participants' answers were what they would have been in an on-road experiment where they rode on the roads themselves.

Fortunately, circumstances allowed an on-road study to take place as well. As mentioned, this study's design was an on-road repeated measures study. The route was found using the New Zealand Google search engine (google.co.nz) to determine which major North Island cities (Tauranga, Wellington, Hamilton and Auckland) had separated cycle lanes. Search terms used were: separated cycle lanes, cycle lanes, protected cycle lanes, and the cities' names. Several PCLs across the North Island in Tauranga, Wellington and Auckland were found via various governmental and cycle-related websites. Each location and its surrounding infrastructure were assessed using images from Google Earth. The goal was to find an area that contained several protected and unprotected cycle lanes with similar characteristics like speed limit, traffic flow, bicycle flow (i.e. one-way or two-way), presence or absence of adjacent parking spots and gradient. Risk ratings from Motorcyclist risk statistics from the Roadsafety Risk website were also considered (KiwiRap, n.d.). No road with a risk rating of moderate or severe was included.

Two routes in Māngere best fit the criteria (see figures 9 and 10). Other locations considered either had issues with connectivity (they were separated in location) or uniformity of design. For example, some of the streets found in Wellington had several PCLs present but did not have surrounding painted cycle lanes. Other locations had an isolated street with a PCL that had connected painted cycle lanes but no nearby protected roads.

Additional information about the area's infrastructure was obtained by some researchers who helped design the PCLs. This information confirmed that before installing the PCLs, those lanes and nearby painted cycle lanes had very similar road and traffic characteristics. However, a significant limitation with the chosen routes was the difference in traffic flow and speed between the bike lane routes during the experiment. To expand, measurements taken post-installation of the PCLs showed a marked decrease in traffic flow and vehicle speed in the streets that contained the concrete separators (Mackie et al., 2018). The assumed reason for this change is that the protectors created a traffic-calming effect in the area, which cannot be separated from their presence. Additionally, for some of the roads with PCLs, additional traffic calming measures were specifically implemented. These differences in speeds are why quiet residential streets were chosen as the control for the experiment, so that the results may pick up differences from separation alone. A more detailed account of the studies' designs and their results are in the sections that follow.

2. Method

2.1. Online Questionnaire

2.1.1. Participants and recruitment

Respondents were recruited online via e-advertisements containing an embedded link which took participants to the questionnaire (see Appendix A). The advertisement was sent to several cycling groups in New Zealand via Facebook.com for administrators to post on their pages. Recruitment took place in July 2020, and the link was kept open until the 19th of March 2021. However, no new responses were collected after the 5th of February, 2021.

Eighty people attempted the questionnaire, 44 gave partial completions where at least one section was completed, and 27 completed the whole survey. Only the 27 fully completed surveys were used for data analysis. Sixteen out of the remaining sample identified as male (59.3%), eight as female (29.6%) and three as Non-binary/third gender (11.1%). The age of the participants ranged between 20 to 76 years of age (*M* = 55.52, *SD* = 14.36), and the majority self-identified as New Zealand European (N = 23; 85.2%). Out of the remaining sample, one respondent identified as 'Other European', two self-described as 'New Zealander/Kiwi' (one of which also identified as New Zealand European and Māori), and another as 'Half Korean' (who also identified as 'Other European'). The sample was not representative of the general New Zealand population, as there was an over-representation of New Zealand Europeans (85.2% compared with 70.2%) and underrepresentation of all other ethnicities, especially Māori (3.7% compared to 16.5%) (Statistics New Zealand, n.d.).

Understanding which people tended to drop out of the survey could have provided more information concerning the demographics this study captured and which it did not. However, the demographics section was at the end; therefore, those who dropped out did not provide the information needed to discern a pattern.

In terms of location, ten participants were from the Waikato; five were from Auckland and Wellington (each); two were from Canterbury, and one from the Bay of Plenty, Northland and Wairarapa (each). The survey respondents tended to cycle frequently in town (21 cycled 3-5 times per week (77.8%); five cycled once per week (18.5%), and one cycled once a month (3.7%). When asked how confident they were cycling, a high level of confidence was reported by most of the participants; 17 selected "I feel confident in my ability to cycle in all road conditions" (63.0%), and eight selected "I feel confident in my ability to cycle in most road conditions but there are some streets/conditions which make me nervous while biking" (29.6.%). The remaining two chose to self-describe. Both participants stated they felt comfortable in many situations but did not feel confident in specific instances like rural areas or during the busy holiday season.

2.1.2. The questionnaire

The online questionnaire items were based on the research questions mentioned in section 1.5. (see Appendix B for the questionnaire). Altogether, participants were asked 15 questions per video, and there were ten videos overall. Participants were shown eight videos taken on PCLs and painted bike lanes (four each), which could be organised into four pairs with similar road functions (see section 1.5. for details). Two control videos were also shown (in a shared bus lane and a shared traffic lane ("sharrow")) (see figures 1 to 5). After participants completed five of these sections, they were encouraged to take a short break to counteract fatigue and boredom. Following the video sections, eight items were given to respondents to capture relevant demographic and cycling-related information.

Questionnaire items differed between open-ended and closed in each video section, with more open-ended questions preceding those that restricted choice. Most of the restricted questionnaire items came in the form of 5-point Likert scales, ranging from a -2 point response (e.g.

"very concerned") to a +2 response (e.g. "very unconcerned"). These responses were then converted to answers ranging from 1 to 5 for data analysis.

The same questionnaire items were provided for each video. Unfortunately, this may have primed participants to answer the open-ended questions differently than they may have otherwise for the videos following the first. Care was taken to randomise the order participants viewed the videos to minimise this effect.

Prior to sending out the questionnaire, Qualtrics estimated the completion time for the survey questions themselves to range between 35 – 45 minutes. However, how long participants took to complete the questionnaire was higher on average and varied more than the estimated completion time window (*M* = 1 hour and 36.25 minutes, *SD* = 2 hours and 39.63 minutes, range = 20.38 minutes – 14 hours and 1.69 minutes). The variability is (primarily) likely due to the break in the middle of the questionnaire. This break was not timed, so participants could take as long as they wanted before returning to the survey.

The items in the questionnaire were created to measure:

1. How safe participants thought they would feel on the different roads (1 item)
2. How willing respondents were to allow a child they knew to ride on each road (1 item)
3. How fast participants thought they would travel along the roads (1 item)
4. If participants expected different risks on the various roads and how threatening they rated these risks (3 items)
5. If participants thought they would prepare themselves to give way to cars at side street intersections (even when they do not have to) (1 item)
6. If participants were more or less concerned about cars passing them, vehicles coming out of driveways, and vehicles coming out of side street intersections on the different roads (4 items)

Some measures answered only one of the above questions, others answered more than one, and some questions had more than one corresponding item to answer them (see Appendix B for full questionnaire). Altogether, the questionnaire items intended to measure differences between how cyclists might behave on PCLs vs painted lanes and if the presence of PCLs improved measurements related to increased usage. Secondary to these aims was to understand why any differences (or lack of differences) occurred and if these could be related to the TCI model or Zero-Risk Theory.

Figure 1

The town roads: Videos 1 (Unprotected) and 2 (Protected)

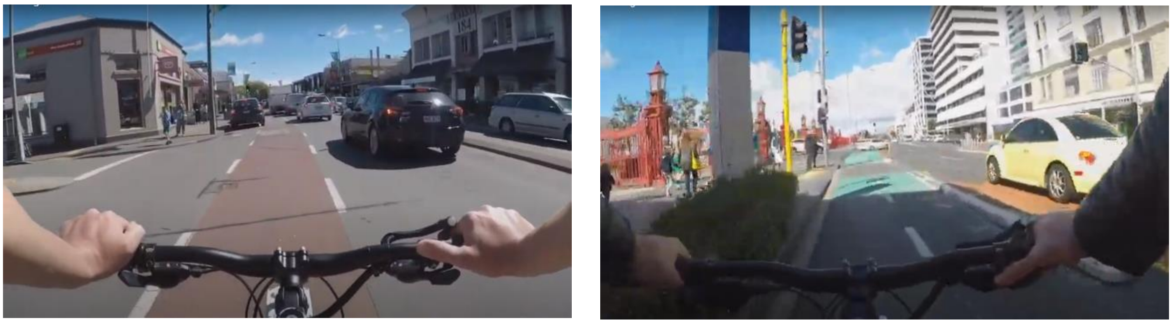


Figure 2

The connector roads: Videos 3 (Unprotected) and 4 (Protected)

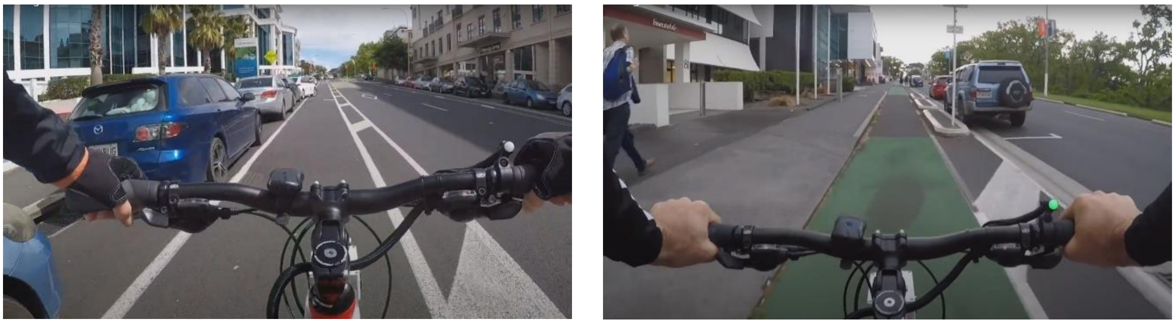


Figure 3

The industrial roads: Videos 6 (Unprotected) and 5 (Protected)

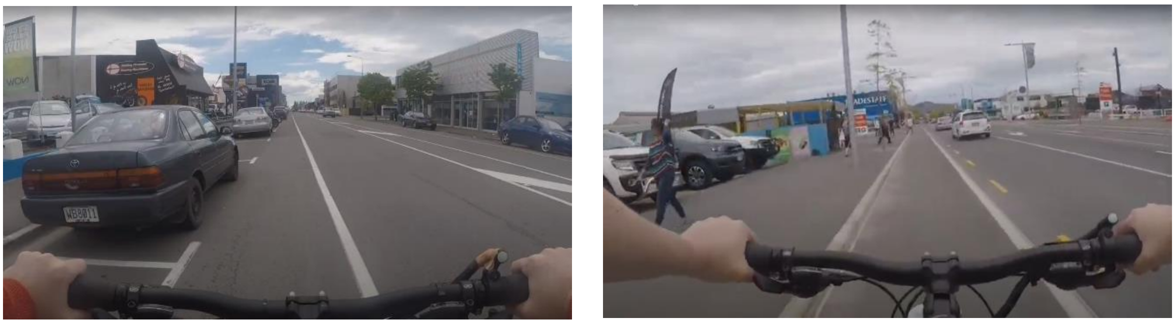


Figure 4

The residential roads: Videos 8 (Unprotected) and 7 (Protected)

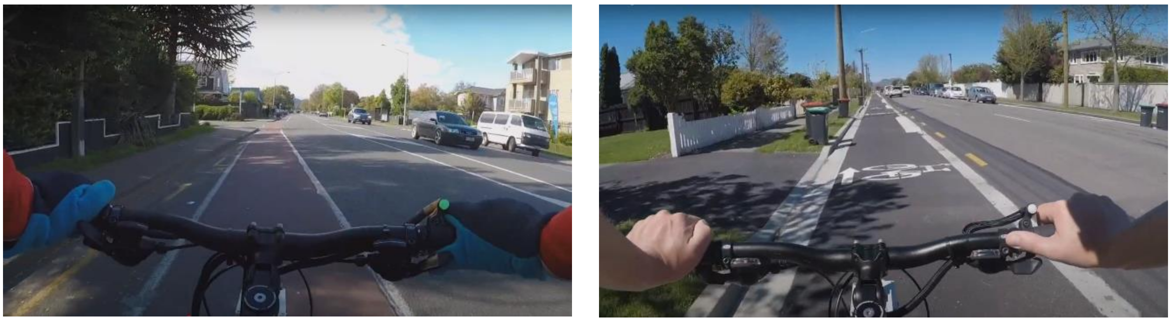


Figure 5

The control roads: Videos 9 (sharrow) and 10 (shared bus lane)

2.1.3. Data and Analysis

The central research questions were answered by comparing participants' answers relating to behavioural changes (for example, self-reported speed changes) and factors relating to increased usage (for example, safety ratings). These measures were compared between road type (PCLs (Protected), painted cycle lanes (Unprotected) and un-laned roads (Control)), and then by individual roads organised by road function pairs (town, connector, industrial and residential). The analyses used to determine these differences were (mostly) repeated measures ANOVAs. However, when the sample size was too small for some questions, or the type of data did not fit an ANOVA's assumptions, either t-tests or a Friedman's ANOVA were used instead.

Following these calculations, several Pearson's correlations were conducted to answer a secondary question: what about the videos best explained the results observed for questions one and two? Several relationships were investigated, with the first few examining if and how safety and hazard-concern related to self-reported speed ratings. Exploring these relationships was done to test the underlying hypothesis of Zero-Risk Theory and the TCI model (i.e., whether feelings of safety or mental workload (lots of hazards) were associated with speed choice). Next, the relationships between participants' total hazard-concern and car-related hazard concern ratings and safety ratings were analysed for each road. The first relationship was examined to see if the correlation found in Fuller et al.'s (2008) study between task difficulty and feelings of risk was replicated between participants' safety and hazard-concern ratings. The other correlations were conducted to see which car-related hazards co-occurred the most with lower ratings of safety. Understanding what factors co-occur with feeling unsafe is of interest as 'feeling unsafe' is one of the most significant barriers to cycling for interested people (Cycling Safety Panel, 2014; Waka Kotahi, 2021; Wang et al., 2011)

Finally, the relationship between willingness and safety ratings was investigated to see if these ratings correlated and whether safety ratings were higher or lower than willingness ratings. By looking at co-occurrence and the average difference in ratings between the two variables, it may imply the level of safety standards needed to increase infrastructure usage from children.

2.2. On-road study

2.2.1. Participants and recruitment

Twenty-five participants were recruited for this study; however, one was excluded from data analysis as they only completed one of the two routes. Out of the remaining sample, 16 identified as male, seven female and one as a transgender man. Participants were between 18 and 65 and had ridden a bicycle on-road at least once within the last twelve months. The mean age was 45.5 years (SD = 11.34). Fourteen of the sample identified as New Zealand European (66.7%), four as Chinese (16.7%), three as Māori (12.5%), two as English/British (8.3%), and one as Pakistani (4.2%). The sample was very similar to the 2018 census data for the wider Auckland region, except Pacific peoples were absent (15.5%), and New Zealand Europeans were over-represented (53.5%) (Statistics New Zealand, n.d.). These differences were more prominent when the sample was compared to the 2018 population statistics for the local area (Māngere); only 11.6% of Māngere Central's population were New Zealand European, and 73.8% were Pacific Peoples (Statistics New Zealand, n.d.). This sample difference could be attributed to cyclists' characteristics in New Zealand, a low up-take of locals for the experiment, and a low level of cyclists in the area. For example, most participants disclosed that they had come from other Auckland areas to take part.

Like the online questionnaire, the sample rated themselves as fairly confident and tended to bike on the road regularly. To expand, all the participants rated their confidence as either 1 "I feel confident in my ability to cycle in all road conditions" (14 participants) or a 2 "I feel confident in my ability to cycle in most road conditions but there are some streets/conditions which make me nervous while biking" (10 participants). Twenty of the sample rode in town at least once per week, i.e., 13 chose "3 – 5 times per week"; seven selected "once a week; two chose "once a month"; and one selected "2 – 4 times per year".

As mentioned, the study was located in Māngere, New Zealand, so printed recruitment posters (Appendix C) were disseminated there and in areas nearby (Papatoetoe, Manukau, and Penrose). Locations posters were placed in included two libraries, several laundromats and cycling related stores, and a local tertiary institution (the Manukau Institute of Technology). Additionally, digital versions of the recruitment posters were sent to administrators of cycling groups within the Auckland region and two Māngere resident community groups via Facebook.com to post on their pages. The posts were then shared by group members to other group and personal pages, creating a snowballing effect. It was hoped that those local to the area and interested in biking would be recruited by targeting these physical and digital spaces. The recruitment posters and study protocol were approved by the Human Research Ethics Committee at the University of Waikato.

2.2.2. Equipment

Participants were asked to bring their own bicycles to the experiment to ensure ease of use and make the ride feel as natural as possible. Only manual bicycles and bicycles with pedal assist were accepted into the study (e.g., no unicycles or scooters were allowed); however, one participant took part with a trailer attached to their bike that contained their dog. This circumstance was accepted as the participant gave assurance that this was part of their typical biking experience.

Helmets with camera mounts were provided to each participant to use during the experiment. After participants were fitted with a helmet, a camera was attached to it to record the environment in front of and aligned with the participant's head. The footage captured by the camera was also used to observe when participants turned their heads, presumably, to look at something. Eye-tracking glasses were also used with some participants; however, no data was gained by this as the sunlight interfered with the near-infrared light beams used to track the wearer's pupils.

A smartphone with an opened app called 'Ride with GPS' was also attached to participants' handlebars during the experiment. Ride with GPS is a navigation app created for cycling which provides audio navigation instructions through the speakers of the phone and displays where the user is on a map in real-time. The exact route, including places where participants were preferred to go off-road or use a pedestrian crossing to cross the road, was created in the app with custom cues. Additionally, Ride with GPS recorded participants' speed during the experiment and where they cycled using GPS coordinates. This data was used to compare participants' speeds between the roads and see whether they followed the route.

2.2.3. The Route

The route contained 3.1 kms of roads with PCLs located on three separate roads (Master's Avenue, Freisian Drive and Thomas Road turned Orly Avenue), and approximately 3.8 kms of road containing painted bike lanes. Two loops were made from the route to create two conditions for the on-road experiment: a loop with several cycle lanes with physical separation ('Protected Loop') and another primarily containing painted separators ('Unprotected Loop'). The roads that had measurements taken from them were Thomas Road and Friesian Drive for the Protected loop (see Figure 6) and Buckland and Massey Road for the Unprotected loop (see Figure 7). These streets had an official road limit of 50 kmph, were relatively flat, were not adjacent to parking spots and went past numerous entrances to driveways and side streets. An exception to this was Thomas Road in the Protected loop, which contained a hill with a moderate incline. Additionally, some of the roads in the Unprotected loop had yellow lines to indicate no parking, which sporadically disappeared. Both loops also included quiet residential streets, which served as a control for the experiment as both the residential streets and the PCLs had low traffic levels. Altogether, there were approximately 1.4 kms of residential roads in the Unprotected loop and 950 ms in the Protected. However, measurements were only taken on (approximately) 700 ms of road, on Duggan Avenue (in the Protected loop) and Lyncroft Street (in the Unprotected loop) (see Figure 8).

Initially, both loops started in the Māngere Town Centre Square (see Figure 9), where the Protected loop was 4.9 kms (left), and the Unprotected was 6 kms (right). However, due to security reasons, both loops were changed to start and end at the Māngere Police station on Bader Drive (see Figure 10). This re-route increased the distance of the Protected loop to 5.7kms (left) and the Unprotected loop to 6.4km (right). Consequently, the first seven participants completed the first versions of the route, whilst the rest completed the later iteration.

Figure 6

The Protected Roads: Thomas Road (left) and Friesian Drive (right)

Figure 7

The Unprotected roads, Buckland Road (left) and Massey Road (right)

Figure 8

The Control roads, Lyncroft Street (left) and Duggan Avenue (right)

Figure 9

Initial Protected and Unprotected routes

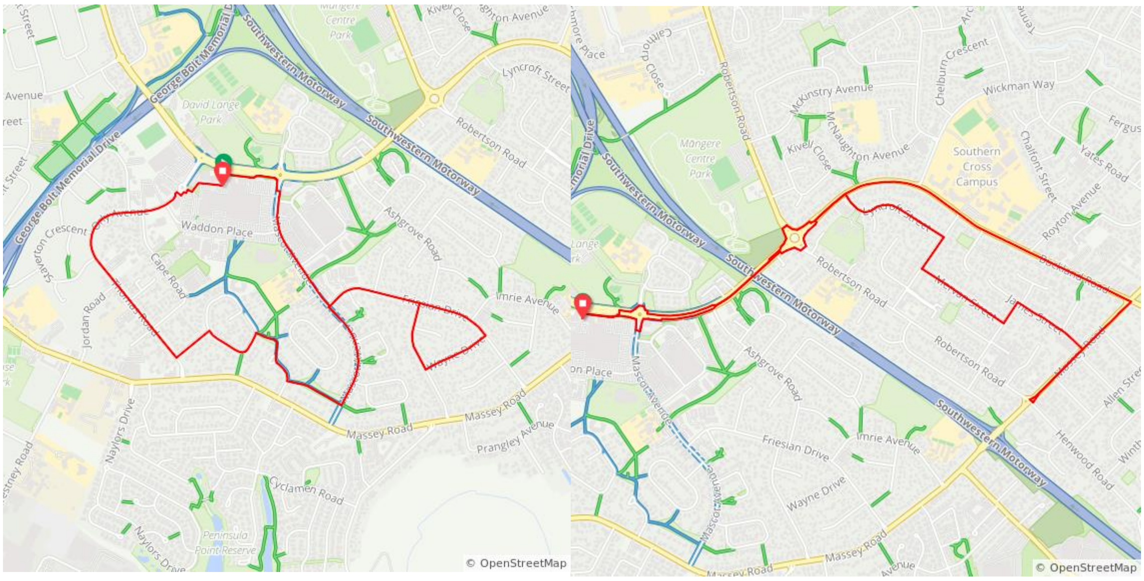
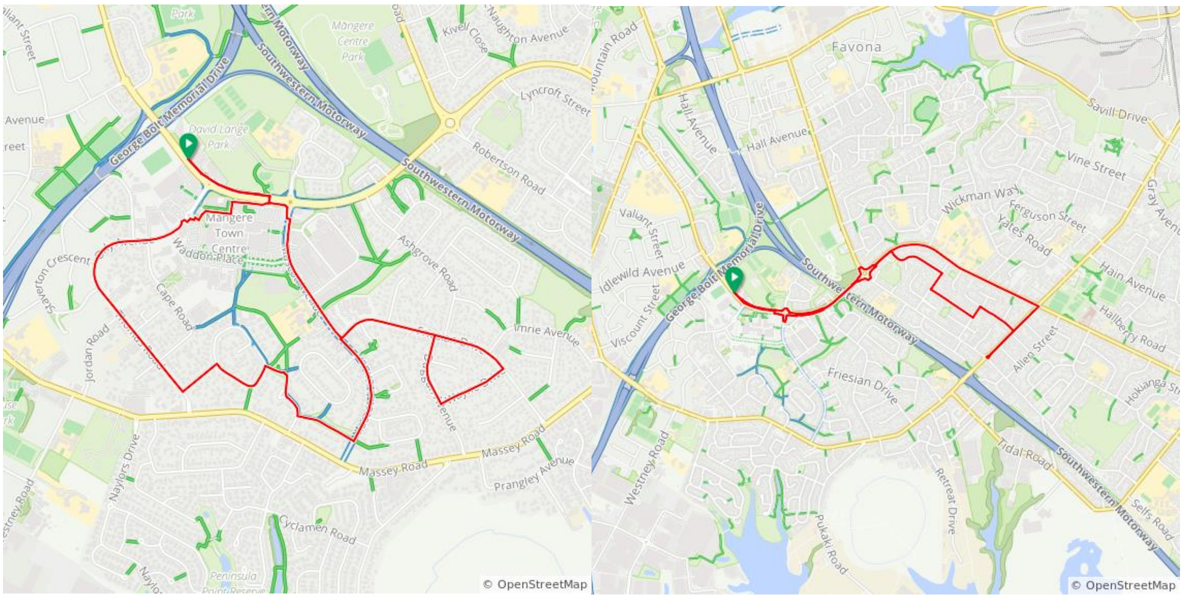


Figure 10

Protected and Unprotected route after re-route



2.2.4. Procedure

The study contained two on-road conditions which alternated in order between the participants. Condition 1 was when a participant would complete the protected loop followed by the unprotected, and condition 2 was the reversed order. Participants were assigned to a condition alternatively, so there was a near-even split between the order conditions (for example, participant 1 was in condition 1, participant 2 was in 2, participant 3 was in 1, and so on). Each route started and ended in the same place.

Participants would arrive at the starting point with their bike and be given the information sheet (see Appendix D) and consent form to read and sign (Appendix E). As the participant read through the sheets, permission was sought to install the cell phone mount onto their handlebars. Once completed, participants would have the protocol explained to them and were invited to ask any questions they had. During the explanation, a map of the first loop the participant would complete was shown and described to them, and participants found the helmet with the best fit.

Once the participant confirmed they were comfortable cycling on the loop, a recording camera was secured on top of their helmet, and the navigation was started in Ride with GPS. Participants would then be encouraged to cycle each loop by (predominantly) following the app's audio cues to reduce the distraction caused by the visual display.

After the first loop, participants returned to the starting point and were given a post-ride questionnaire on a tablet about the ride they just took. The questionnaire was designed so entering the participant's condition would change which set of questions was shown in the first half (Protected for condition 1, Unprotected for condition 2). Halfway through, the questionnaire would instruct the participant to give the tablet back to the researcher. Instructions were then given for the second half of the experiment; the only difference in the second instructions was the loop's directions.

After participants finished the second loop, the second half of the questionnaire was given to them while the researcher stopped the camera recording and uninstalled the cell phone mount. The second half of the questionnaire was like the first (except about the roads in the second loop), with extra items asking about the participant's bicycling habits and their demographics at the end. A Forty-dollar gift voucher for The Warehouse was then given to thank the participant for their time.

2.2.5. The post-ride questionnaire

Overall, the post-ride questionnaire contained 97 items: 15 for each road enquired about and seven in the demographics section (see Appendix F for the questionnaire). Not every participant completed every question, as some only displayed if the answer to a previous question met a specified condition. An average completion time was unable to be measured accurately due to the varying breaks participants had in the middle of the questionnaire for instructions and the second ride. Approximately each half seemed to take participants between 10 to 15 minutes to complete.

The questions contained in the post-ride questionnaire were adopted from the online questionnaire released earlier in 2020. Parallel items were used to compare the participants' data with the online questionnaire and on-road data. Some items were not included in the on-road questionnaire as the information they intended to measure could be retrieved from another item, and another related to the videos specifically. Those not included were two car-specific hazard items (see items 3.11 and 3.16 in Appendix B) and the item asking participants where they would have cycled on the road.

The items included in the questionnaire were intended to measure: what participants were thinking about on the road; their perceptions of safety; whether participants would allow a child to ride on the road; hazards (which ones they remembered, would expect on a road like the one they were cycling on and how concerned they would be about each hazard chosen); how fast participants thought they were going relative to their normal speed (and why); whether they slowed down for a side street on the road, and whether they expected cars to give way to them at that side street. An additional item about anticipation was added to measure any dread participants thought they would have about cycling that road again after doing it in the experiment. Altogether, the measures above were intended to answer this study's two main research questions: Do PCLs rate more favourably in measures likely to increase use? And, do cyclists' behaviours change on PCLs compared to non-separated bike lanes?

2.2.6. Data and Analysis

Speed analyses of each road of interest were taken, save for approximately 40 – 50 metres at each end of each road. Additionally, head turns were counted and analysed to capture participants' visual attention on each road. However, head turn count was only looked at within a midsection of the portions used to measure speed rather than the entire streets. Each section chosen for head turns included one side street intersection.

A working definition for a head turn was initially trialled. However, due to differences in how far away an object was from a participant when they glanced at it or original head position (for example, if they were looking down before glancing), a 'head turn' was challenging to operationalise. So instead, inter-rater reliability was used to ensure the reliability of the counts. Head turn rate was taken from how many head turns a participant took during a section, divided by how long it took them to cycle it.

Several two-way repeated measure ANOVAs were conducted to determine differences in cyclists' feelings, expectations, and behaviours between the roads in the on-road study. However, not every participant answered every question due to skip logic for some items. So, when questions had samples too small for an ANOVA (or resulted in data outside the assumptions of an ANOVA), a t-test or a Friedman's ANOVA was used instead. Altogether, these tests were used to answer the main research questions regarding the impact of physical separation on measures related to increased usage and cyclists' behaviour.

A repeated measures model was used for the above tests as scores from the same participants were compared between roads/road types. The reasons for conducting tests for both individual road and road types were to make sure there weren't statistical differences between the roads within each road type and to see any effects that wouldn't have been picked up if they were clustered. Where possible, order effect (whether participants were in condition 1 or 2) was also added as a between-subjects independent variable. Inclusion of order was to account for the possible impact of fatigue near the end of the experiment and ensure answering questions about one route didn't affect participants' questionnaire answers or behaviour on the second route they cycled.

Finally, Pearson's correlations were conducted between several variables on each road. Like the online study, most of these tests were conducted to supplement the findings for questions one and two. Again, correlations between speed changes and head turns, and safety and hazard-concern ratings were conducted to test the TCI model's and Zero-Risk Theory's hypotheses. Additionally, correlations between safety and hazard-concern ratings and safety and willingness ratings were undertaken again. Lastly, speed ratings were compared with participants' observed speed to test the fidelity between their speed ratings and actual speeds.

3. Results

3.1. Online questionnaire data

The results from the online questionnaire are included below. Generally, the data collected from the online questionnaire answered two central research questions: Are PCLs likely to attract more users than painted bike lanes in New Zealand?; Do cyclists behave differently in them, and if so, how?

To answer whether PCLs are likely to attract more users, safety ratings, how willing participants were to allow their child or a child they knew to bike on them, how hazardous participants believed them to be, and their anticipated interactions with cars were measured.

3.1.1. Safety ratings

Below, Figure 11 shows the mean safety ratings participants gave to the roads by road type. As shown, the Protected roads (roads with on-road lanes with physical separators (P)) were rated the safest on average (M = 3.84, SE = .13), followed by the Control roads (un-laned roads (C)) (M = 3.22, SE = .18) and then the Unprotected roads (roads with painted bike lanes (U)) (M = 2.83, SE = .19). Additionally, the Confidence interval (CI) for the Protected group is smaller than the other two, suggesting the spread in safety ratings for this group was smaller.

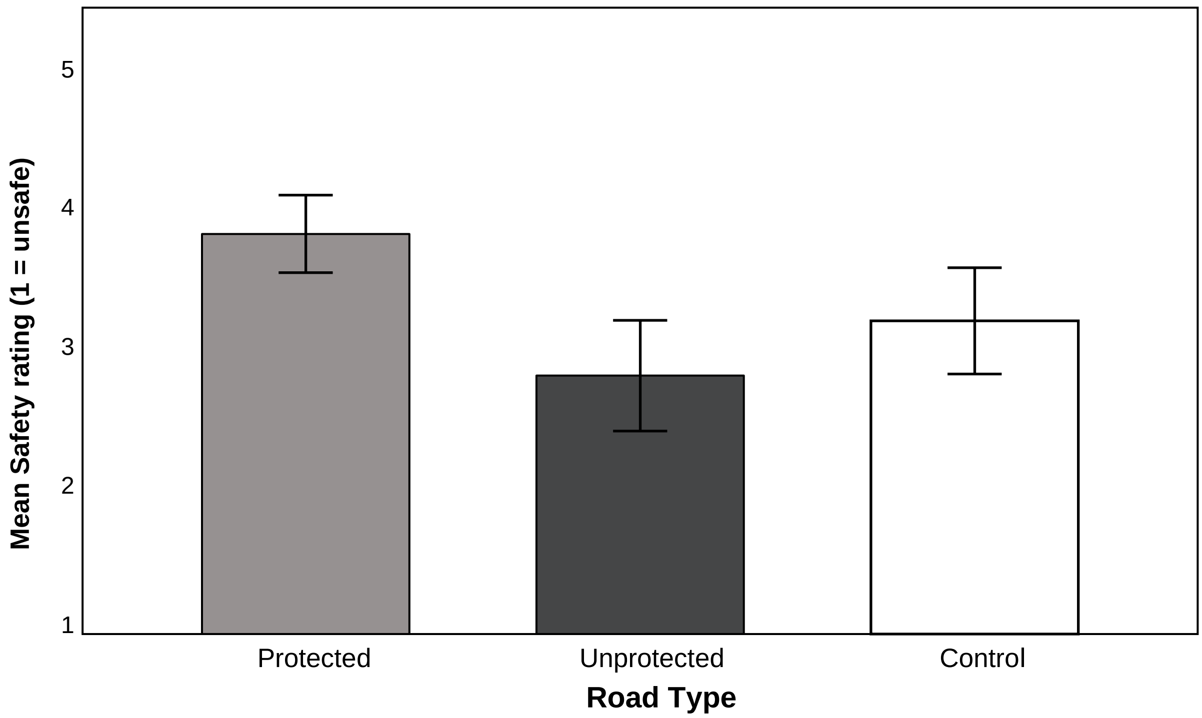
A repeated measures One-Way ANOVA was conducted to see if the differences illustrated in Figure 11 were significant. Results from the ANOVA showed a significant effect between road types for safety ratings ($F(2,52) = 20.83$, $p < .001$, $\eta_p^2 = .45$), confirming that safety ratings were significantly different between road type.

A post-hoc Bonferroni-adjusted pairwise comparison test was used to see which road type pairs had significant differences between them. The results showed the Protected roads had higher safety ratings on average than both the Unprotected ($p < .001$) and Control roads ($p = .003$).

However, no significant difference was observed between the Control and Unprotected roads (p = .065).

Figure 11

Mean safety ratings by road type (whiskers = 95% Confidence Interval)



Safety ratings were then compared between each video to see whether the differences observed between road types may be better explained by individual road; see Figure 12 for a depiction of each road's mean safety rating. As shown, participants tended to rate the Protected roads relatively uniformly and higher than the other roads (*M range* = 3.58 – 4.25). However, two roads in the other groups were rated close to the lower-rated Protected roads. To expand, the highest-rated Unprotected road in Video 8 (*M* = 3.58, *SE* = .23) had the same mean safety rating as the video rated the lowest in the Protected group (Video 4 *M* = 3.58, *SE* = .22); and the highest-rated Control road (Video 10 *M* = 3.67, *SE* = .19) had a higher mean rating than the same Protected road (Video 4).

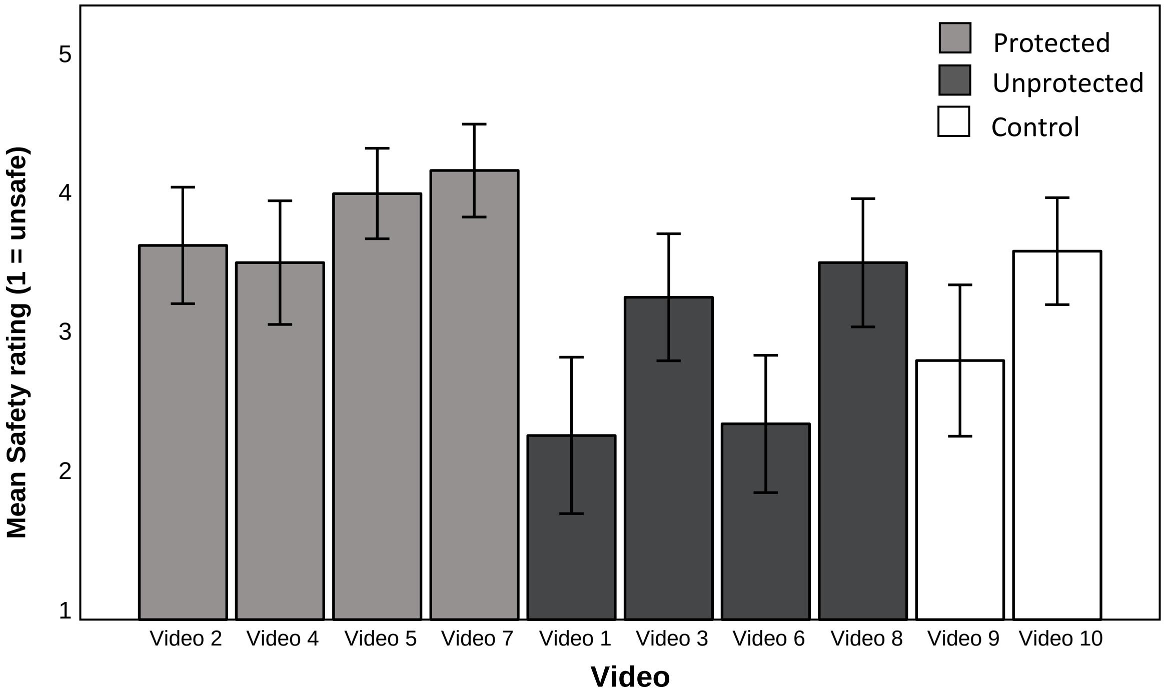
In contrast to the Protected roads, the safety ratings for the Control and Unprotected roads were varied, as illustrated by the differences in mean ratings between roads in each group. For example, the mean safety ratings in videos 1 (*M* = 2.33, *SE* = 0.27) and 6 (*M* = 2.42, *SE* = 0.24) in the Unprotected group are lower than videos 3 (*M* = 3.33, *SE* = 0.22) and 8 (*M* = 3.58, *SE* = .23) (see Figure 12).

Overall, the road with the highest safety ratings was the residential Protected road (Video 7 *M* = 4.25). In comparison, the road which was rated the lowest was the Unprotected road in town (Video 1 *M* = 2.33, *SE* = 0.27) (see Figure 12).

When participants' safety ratings for the videos were compared with a repated measures One-Way ANOVA, a significant within-subjects effect from the videos was found for participants' safety ratings ($F(9,207) = 15.50$, $p < .001$, $\eta_p^2 = .40$). A post-hoc Bonferroni-adjusted pairwise comparison test found no statistical differences in safety ratings within the Protected or Control road types. However, differences were found between the Unprotected roads; videos 1 and 6 were rated significantly lower than videos 3 and 8 to a $p < .01$ level. Moreover, all the roads in the Protected group were rated significantly higher than videos 1 and 6 in the Unprotected group. This finding was to a $p < .001$ level for the Protected roads in videos 2, 5 and 7, while the significance levels between videos 4 (P) and 1 (U) ($p = .007$), and 4 and 6 (U) ($p = .021$) were larger. Other significant differences included: Video 5 (P) was rated significantly safer than 9 (C) (p = .013), Video 7 (P) was rated safer than videos 9 (C) (p = .001) and 3 (U) (p = .040), and Video 10 (C) was rated safer than videos 1 (U) (p < .001) and 6 (U) (p < .001)

Figure 12

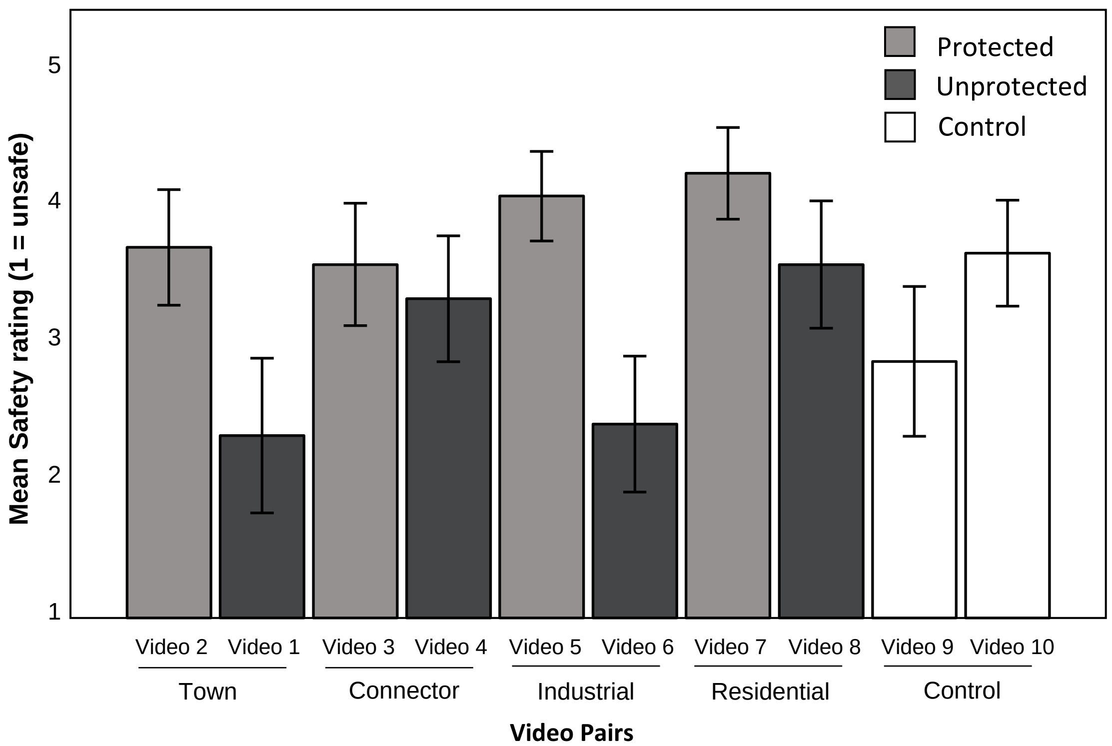
Mean safety ratings by video (whiskers = 95% Confidence Interval)



Another way of observing the differences between the individual roads, is by similar road function. Therefore, Figure 13 shows each Protected road paired with an Unprotected counterpart organised by road function. As shown, the roads with physical separation were rated higher than their Unprotected counterparts. Interestingly, this relationship was more extreme between the videos in town ((P) Video 2 *M* = 3.71, *SE* = .20; (U) Video 1 *M* = 2.33, *SE* = .27) and in industrial areas ((P) Video 5 *M* = 4.08, *SE* = 0.16; (U) Video 6 *M* = 2.42, *SE* = .24) compared to the pairs on connector ((P) Video 4 *M* = 3.58, *SE* = 0.22; (U) Video 3 *M* = 3.33, *SE* = 0.22) or residential roads ((P) Video 7 *M* = 4.25, *SE* = 0.16; (U) Video 8 *M* = 3.58, *SE* = 0.23). The post-hoc Bonferroni adjusted pairwise comparison tests showed the differences in safety within the 'town', 'industrial' and 'residential' pairs were significant (town $p = < .001$; industrial $p < .001$; residential $p = .025$), while those within the 'connector' pair were not (connector $p = 1.00$).

Figure 13

Mean safety ratings between video pairs (whiskers = 95% Confidence Interval)



3.1.2. Willingness to allow children to cycle on the road

Next, how willing participants were to allow their child, or a child they knew, to cycle on the roads was compared. Figure 14 shows the mean willingness ratings participants gave for the roads by road type. Like the safety ratings, respondents were the most willing to allow children on the Protected roads (M = 3.21, SE = .16), followed by the Control roads (M = 2.41, SE = .16) and then the Unprotected roads (M = 2.19, SE = .15). However, willingness ratings tended to be lower on average than safety ratings (see figures 11 and 14 for a comparison).

A One-Way ANOVA was conducted to see if there were significant differences in participants' average willingness ratings between road types. The ANOVA's result was significant ($F(2,52) = 17.33$, $p < .001$, $\eta_p^2 = .47$). Further, a post-hoc pairwise comparison test confirmed the differences between the Protected roads and the Control and Unprotected roads were significant ($p < .001$). However, a significant difference between the Control roads and the Unprotected roads was not observed ($p = .45$).

Figure 14

Mean willingness ratings by road type (whiskers = 95% Confidence Interval)

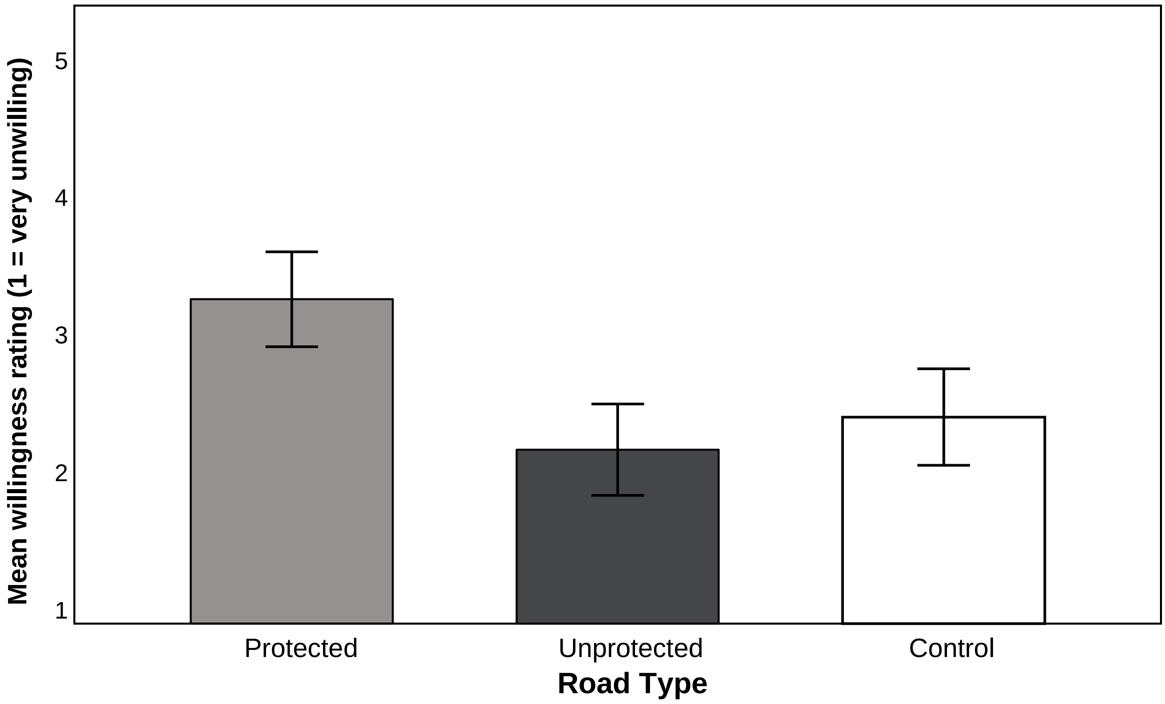


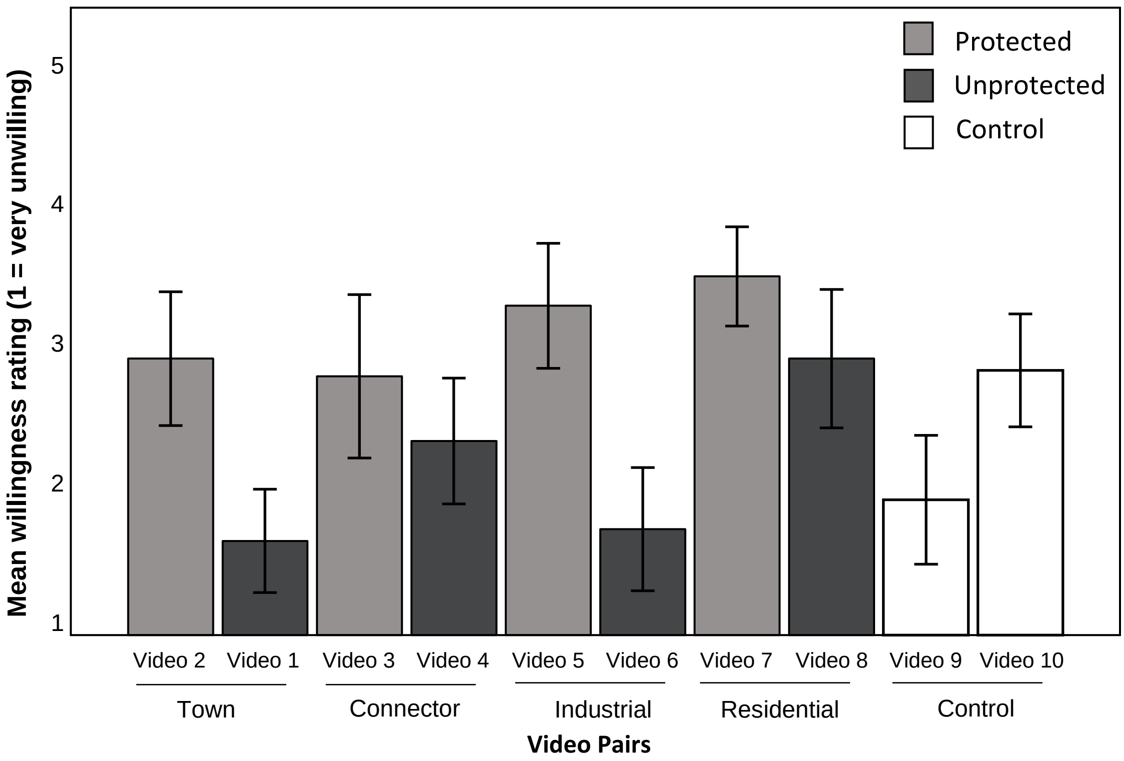
Figure 15 shows participants' mean willingness ratings between the individual roads, organised into pairs with similar road functions. Again, the relationships shown in Figure 15 are very similar to participants' safety ratings (see Figures 13 and 15). Namely, the Protected roads are more homogenous (mean range = 2.83 – 3.54) than the other two groups (Unprotected mean range = 1.67 – 2.96; Control mean range = 1.96 – 2.88). Furthermore, the Protected roads tended to be rated higher than the other roads in general and within each road-function pair. However, the roads in the town and industrial pairs had bigger differences than those in the connector and residential pairs. Overall, the lowest-rated roads were the Unprotected road in the town area (Video 1 M = 1.67, SE = 0.18), and the Unprotected road in the industrial area (Video 6 M = 1.75, SE = 0.21). On average, the highest-rated road for willingness ratings was the Protected road in the residential area (Video 7 M = 3.54, SE = 0.17).

A repeated measures One-Way ANOVA was conducted to see if there were significant differences in participants' willingness ratings between the individual roads; a significant effect was found ($F(9,207) = 14.77$, $p < .001$, $\eta_p^2 = .39$). Results from a post-hoc Bonferroni-adjusted pairwise comparison test found no significant differences within the Protected group. However, there was a significant difference between the Control roads ($p = .014$) and between Video 1 and videos 3 ($p = .012$) and 8 ($p < .001$), and between videos 6 and 8 ($p = .001$) in the Unprotected group.

Additionally, the differences within the Town and Industrial pairs were significant to a $p < .001$ level, while no significant differences were observed in the other pairs (Connector $p = 1.00$; Residential $p = .24$). Moreover, every road in the Protected group had significantly higher willingness ratings than Video 1 in the Unprotected group to a $p < .001$ level, except for Video 2 ($p = .021$), which was still significant. Other significant differences found included: Video 2 (P) was rated higher than 6 (U) ($p = 0.010$); Video 5 (P) was rated higher than videos 6 (U) ($p < .001$) and 9 (C) ($p < .001$); Video 7 (P) was rated higher than videos 6, 1 and 9 (all to $p < .001$).

Figure 15

Mean willingness ratings between video pairs (whiskers = 95% Confidence Interval)



3.1.3. Expected Hazards

For every video, respondents were asked two closed questions about hazards. The first item asked respondents to select every hazard they would expect on a road like the one in the video (see hazard list under ‘hazard’ in Table 1). Then, the second item asked respondents how concerning they would find each of the hazards they selected in the first item for that road.

Table 1 shows both the total number of instances a participant selected a particular hazard as concerning (the rows) in a video (the columns), as well as the median concern rating participants gave to each hazard for each video (in parentheses). The bottom row shows the total number of hazards listed per video. As seen in this row, on average, the Unprotected videos (U) had a higher count of selected hazards and had the smallest range of total hazard counts between them (123 - 130). The Protected roads are different in that three have the same count as one another (videos 2, 5 and 7, count = 101), yet Video 4 has 19 more hazard citations. A similar difference is found between the Control roads, with the lowest number of counts being 104 (Video 10) compared with 125 (Video 9). These discrepancies within the Control and Protected road types suggest participants’ perceptions of hazards may not have been homogenous within them.

Table 1 also shows that, in general, the Unprotected roads and the Control roads had higher counts for “vehicles next to/behind you” than the Protected roads. “Parked cars/open doors” was also rated more often in the Unprotected group on average than in both the Control and Protected groups’ ratings. An exception to this was Video 8 (U), which had relatively fewer selection counts to the Unprotected group for parked cars. Additionally, videos 4 (P) (regarding parked cars) and 9 (C) (regarding both hazards) had high ratings for their respective groups.

Generally, the median ratings shown in Table 1 suggests participants were the least concerned with pedestrians or cyclists and more concerned when they listed something car-related. The hazards with the biggest ranges in concern ratings were ‘parked cars/open doors’ and the ‘other’ category.

Table 1

Count of each hazard chosen as a concern for each road with median concern rating in parentheses

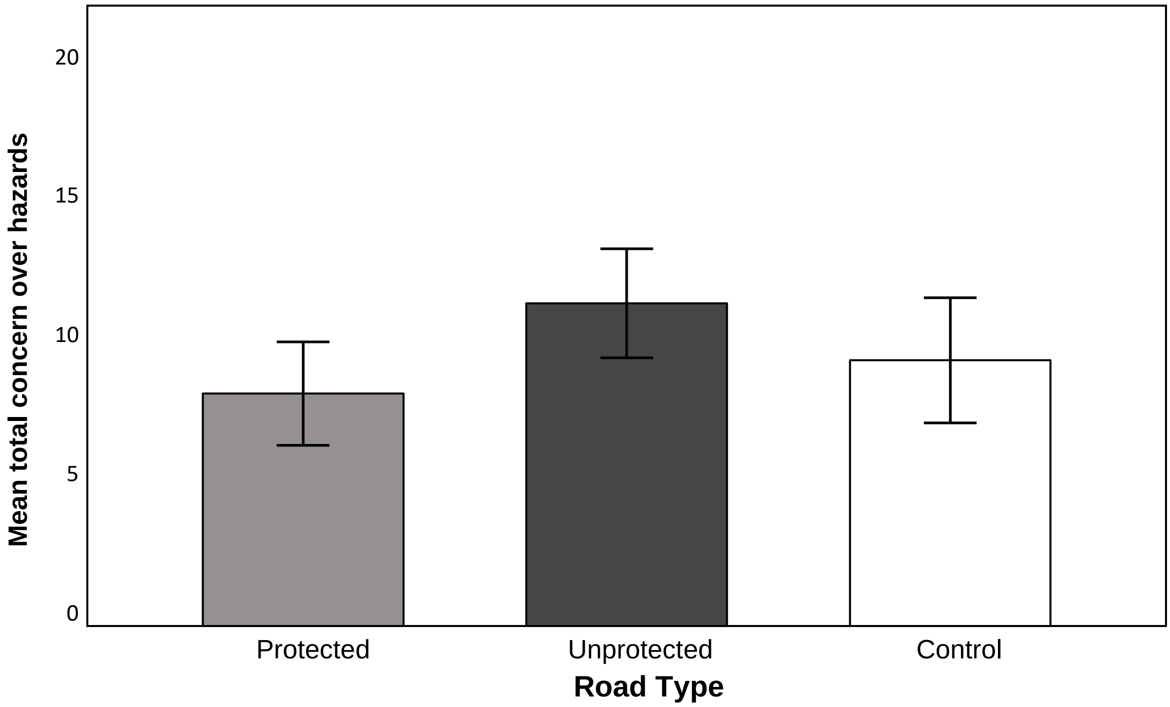
	Protected Roads				Unprotected Roads				Control Roads	
Hazard	**Vid 2**	**Vid 4**	**Vid 5**	**Vid 7**	**Vid 1**	**Vid 3**	**Vid 6**	**Vid 8**	**Vid 9**	**Vid 10**
Pedestrians	24 (2)	27 (2)	26 (2)	14 (1)	24 (2)	20 (1)	18 (1.5)	18 (1)	23 (1)	14 (1)
Other cyclists	19 (1)	15 (1)	13 (1)	12 (1)	14 (1.5)	10 (1)	16 (1)	16 (1)	13 (1)	10 (1)
Vehicles next to/behind you	9 (2)	10 (2)	16 (2)	15 (2)	22 (3)	19 (2.5)	22 (3)	20 (2)	26 (3)	19 (2)
Parked cars/open doors	3 (2.5)	17 (3)	3 (2)	5 (3)	24 (3)	26 (3)	27 (4)	13 (2)	15 (3)	8 (2)
Cars from driveways	24 (3)	27 (2)	20 (2)	24 (2)	12 (3)	23 (3)	24 (3)	24 (2)	16 (3)	16 (3)
Cars from side streets	16 (3)	13 (2)	14 (2)	25 (2)	18 (3)	16 (3)	17 (3)	25 (2.5)	24 (2)	25 (2)
Other	6 (2.5)	11 (2.5)	9 (2)	6 (1)	9 (3)	9 (2)	5 (1)	14 (2)	8 (3)	12 (2)
Total	101	120	101	101	123	123	129	130	125	104

Next, the concern ratings participants gave to the hazards they chose for each road were totalled for each road. This metric was used to compare how concerning participants found the roads in regard to hazards. Figure 16 shows a bar graph comparing the mean ratings of participants' total hazard-concern ratings for each road type. As shown, the Unprotected road type, had the highest mean (*M* = 11.57, *SE* = .95) followed by the Control group (*M* = 9.52, *SE* = 1.09), and then the Protected group (*M* = 8.32, *SE* = .90).

A repeated measures One-Way ANOVA was conducted to see whether participants' total hazard-concern ratings were significantly different between the road types; the result was significant ($F(2,52) = 19.39$, $p < .001$, $\eta_p^2 = .43$). In addition, a post-hoc Bonferroni-adjusted pairwise comparison test showed the total hazard-concern scores participants gave for the Unprotected roads were significantly higher than both the Protected ($p < .001$) and Control groups ($p = .005$). However, no significant difference was observed between the Protected and Control roads ($p = .12$).

Figure 16

Mean of the total Hazard-Concern rating participants had for each road type (whiskers = 95% Confidence Interval)



The next figure (Figure 17) portrays the different mean total hazard-concern scores for each video in the study organised by road function pairs. Overall, the Unprotected roads tended to be rated higher than the Protected and Control roads. This difference is evident in each road function pair, where the Unprotected roads had a higher mean total hazard-concern score than their Protected counterpart. The differences appear a lot larger in the town pair ((P) Vid 2 M = 9.33, SE = .95; (U) Vid 1 M = 13.19, SE = 1.12) and the industrial pair ((P) Vid 5 M = 6.82, SE = 1.03; (U) Vid 6 M = 12.15, SE = 1.03), like the trends found for participants' willingness and safety ratings.

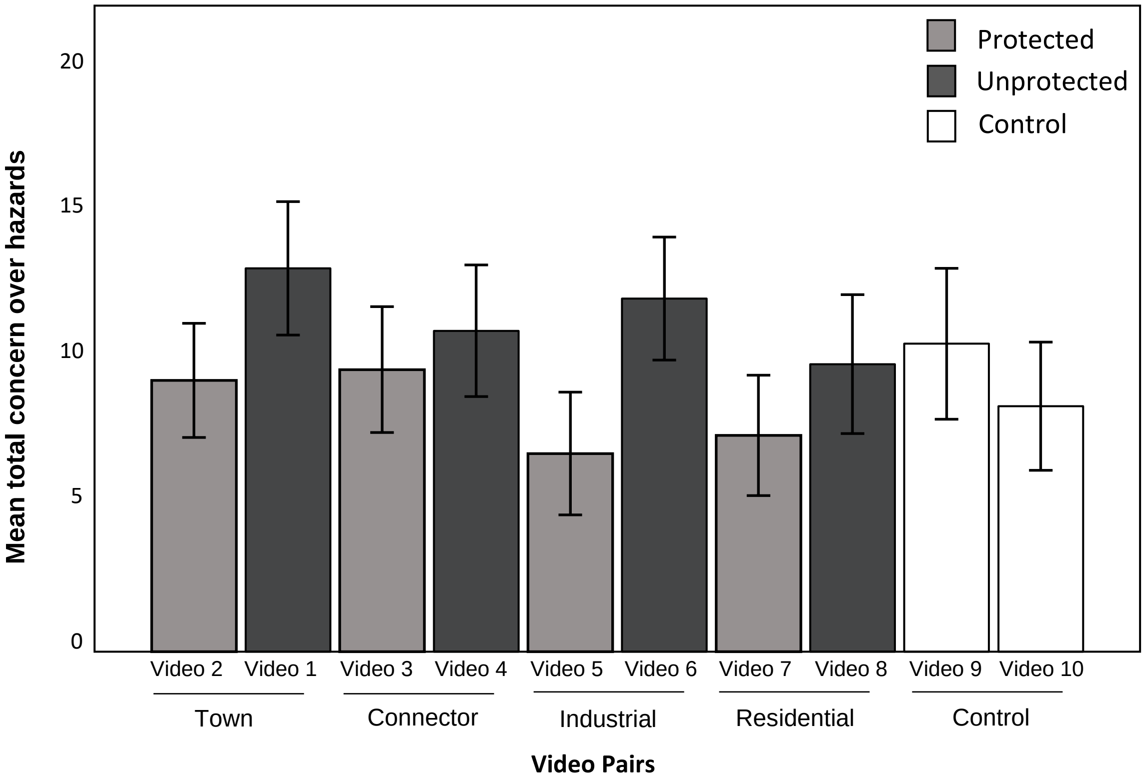
Additionally, Figure 17 shows there were differences in total hazard-concern ratings within the different road types. The most prominent of these differences are between videos 4 (M = 9.70, SE = 1.05) and 5 (M = 6.82, SE = 1.03) in the Protected group and videos 1 (M = 13.19, SE = 1.12) and 8 (M = 9.89, SE = 1.16) in the Unprotected group.

A One-Way ANOVA was conducted to see if, like road type, the individual roads were rated significantly different to one another. Again, a significant difference was found between the individual roads in relation to participants' total hazard-concern ratings ($F(9,234)$, $p < .001$, $\eta_p^2 = .30$).

A post-hoc Bonferroni-adjusted pairwise comparison test was also conducted to determine significant differences between the individual road pairs. The differences within the town ($p = .001$) and industrial ($p < .001$) pairs were significant. Additionally, no significant differences between the videos in the connector ($p = 1.00$) and residential ($p = .45$) pairs were observed. Moreover, the big differences described earlier within the Protected type (videos 4 and 5), and Unprotected type (videos 1 and 8), were significant ($p = .040$; $p = .025$). Additionally, three of the Unprotected roads (1, 3 and 6) had higher mean total hazard-concern scores than videos 5 (P), 7 (P) and 10 (C) to at least a $p < .05$ level; the Unprotected videos 1 and 6 had significantly higher overall scores than Video 2 (P) ($p = .001$; $p = .030$); and the mean score for Video 6 (U) was significantly higher than that of Video 4 (P) ($p = .008$).

Figure 17

Mean of the total Hazard-concern rating participants had for each video by road function (whiskers = 95% Confidence Interval)



3.1.4. Comfort with passing cars

For every video, respondents were asked, "How comfortable would you feel having a vehicle pass you on this road?". Figure 18 shows the mean comfort rating participants gave to this question by road type. As shown, participants tended to say they would feel more comfortable having cars pass them on the roads within the Protected group (M = 4.30, SE = 0.12) compared with the Unprotected (M = 3.28, SE = 0.20) and the Control roads (M = 3.35, SE = 0.18). Moreover, the CI is smaller for the Protected group, suggesting a smaller spread in ratings for this group than the other two.

A One-way ANOVA was carried out to determine if any of the differences shown in Figure 18 were significant; they were ($F(2,52) = 25.32$, $p < .001$, $\eta_p^2 = .49$). Additionally, a post-hoc Bonferroni-adjusted pairwise comparison test found significant differences in the comfort ratings participants gave the Protected roads compared with both the Control ($p < .001$) and Unprotected groups ($p < .001$). No significant difference was found between the Unprotected and Control roads ($p = 1.00$).

Figure 18

Mean comfort ratings participants gave to the question "how comfortable would you feel having a vehicle pass you on this road?" by road type (whiskers = 95% Confidence Interval)

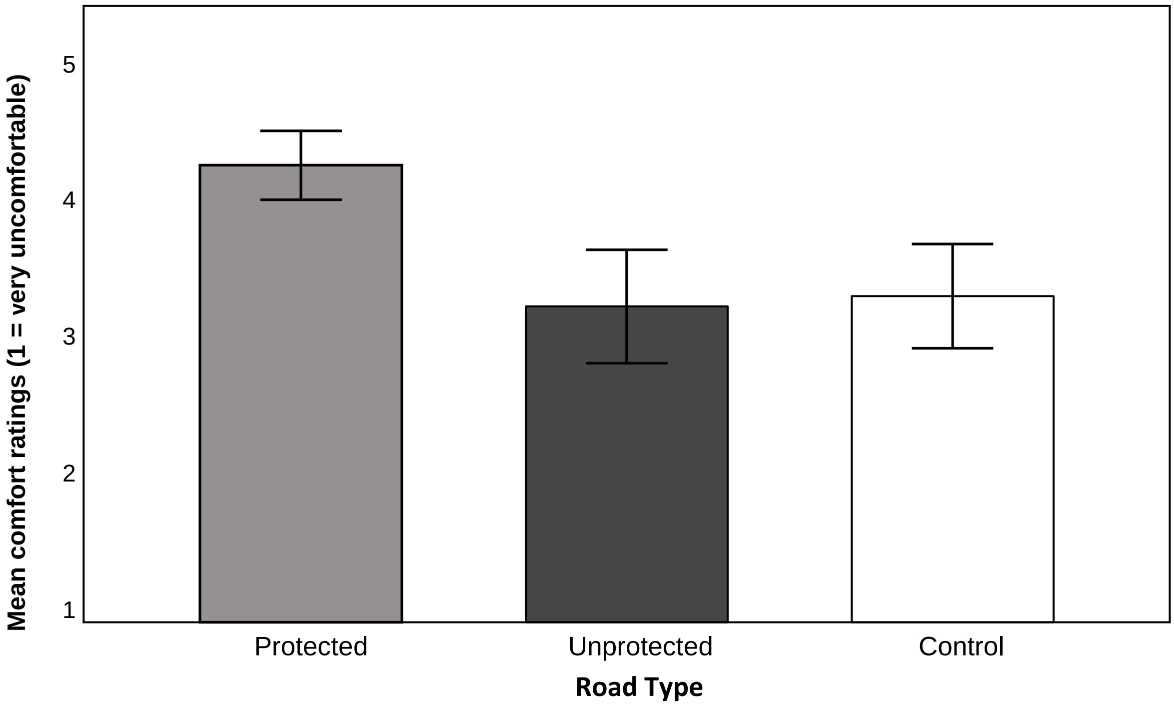


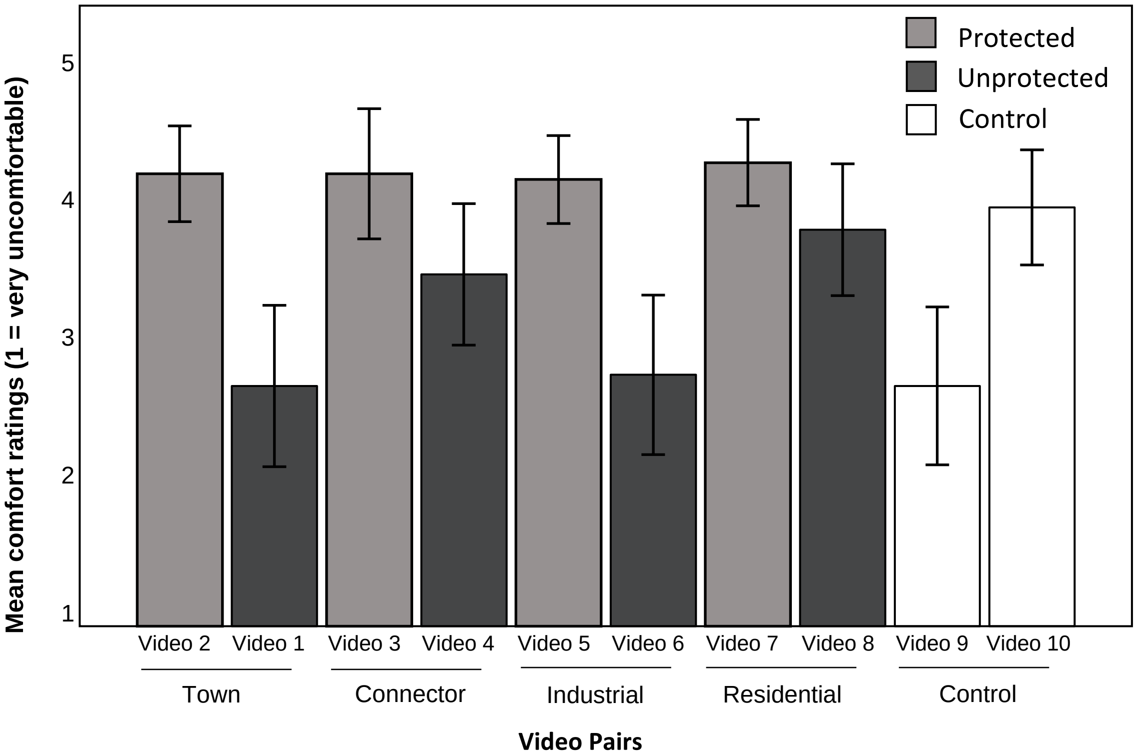
Figure 19 shows the mean comfort-with-cars-passing rating participants gave to each road by road function pair. What is highly noticeable about the figure is that the Protected roads all have similar means (*M* range = 4.20 – 4.32), compared with both the Control and Unprotected roads. To elaborate, videos 1 (*M* = 2.72, *SE* = 0.28) and 6 (*M* = 2.80, *SE* = 0.28) have lower mean comfort ratings than 3 (*M* = 3.52, *SE* = 0.25) and 8 (*M* = 3.84, *SE* = 0.23) in the Unprotected group, and the difference between the mean ratings in videos 9 (*M* = 2.72, *SE* = 0.27) and 10 (*M* = 4.00, *SE* = 0.20) in the Control group is 1.28.

Additionally, the ratings given to the Protected roads tended to be relatively higher than the other roads; however, the gap between videos 8 (U) and 9's (C) means and those in the Protected group was smaller. Consequentially, participants said they were more comfortable having cars pass them on the Protected road out of each road function pair. Figure 19 also shows the most striking differences were within the town (Vid 2 (P) *M* = 4.24, *SE* = .17; Vid 2 (U) *M* = 2.72, *SE* = 0.28) and industrial (Vid 5 (P) *M* = 4.20, *SE* = 0.15; Vid 6 (U) *M* = 2.80, *SE* = 0.27) pairs. Again, similar trends were seen in participants' willingness and safety ratings mentioned earlier (see figures 13 and 15).

Results from a One-way ANOVA confirmed there were significant differences between the comfort ratings given to the different roads ($F(9,216) = 14.76$, $p < .001$, $\eta_p^2 = .38$). A post-hoc Bonferroni-adjusted pairwise comparison test was also conducted. No significant differences between any of the Protected roads ($p = 1.00$) were observed. Additionally, respondents gave the residential Unprotected road in Video 8 significantly higher comfort ratings than two of the other Unprotected roads (Video 1 $p = .004$; Video 6 $p = .048$), as well as the Control road in Video 9 ($p = .006$). Video 10 was rated significantly higher than the other Control road, Video 9 ($p = .004$), as well as videos 1 ($p = .013$) and 6 ($p = .013$) in the Unprotected group. Additionally, the lowest-rated videos in terms of comfort (1 (U), 6 (U) and 9 (C)) were all rated significantly lower than all the roads in the Protected group ($p < .01$) and Video 10 in the Control group ($p < .05$). Video 3 (U) was also rated significantly lower than Video 7 (P) ($p = .015$. Lastly, the post-hoc test confirmed the differences observed in the town (*p* = .001) and industrial (*p* = .002) pairs were significant. No significant differences were found within the connector (*p* = .75) and residential (*p* = .21) pairs.

Figure 19

Mean comfort ratings participants gave to the question "how comfortable would you feel having a vehicle pass you on this road?" for each video, by road function pair (whiskers = 95% Confidence Interval)



3.1.5. Concern over cars coming out of driveways

Participants were also asked how concerned they were about cars coming out of their driveways for each road. The available answers ranged from 1 (very concerned) to 5 (very unconcerned) and included a sixth option, ”I do not remember any driveways”. Some participants selected the last item, so there are under 24 responses for some of the roads. Therefore, pairwise paired-sample t-tests were used to calculate differences in the ratings due to some of the video’s small sample sizes.

Figure 20 shows the differences in mean concern ratings (regarding cars coming out of their driveways) by road type. As visible in the figure, the Control road type (*M* = 2.61, *SD* = 1.08) had a mean close to 3 “neither concerned nor unconcerned”, which was higher than both the Protected (*M* = 2.17, *SD* = 0.69) and Unprotected road types’ means (*M* = 2.13, *SD* = 0.51), which were closer to 2, “somewhat concerned”. Additionally, the Control road type had a larger CI, suggesting it contained a bigger spread in ratings than the other two.

Two pairwise paired-sample t-tests between the Control group and the other two road types were carried out to determine if their differences were significant. There was a significant difference between participants’ concern ratings between the Control and Unprotected road types ($t(22)$ = 2.59, p = .017), but no significant result was observed between the other pair ($t(22)$ = 1.99, p = .059).

Figure 20

Mean concern ratings participants gave to the question "How concerned would you have been about cars coming out of their driveways on this road?" by road type (whiskers = 95% Confidence Interval)

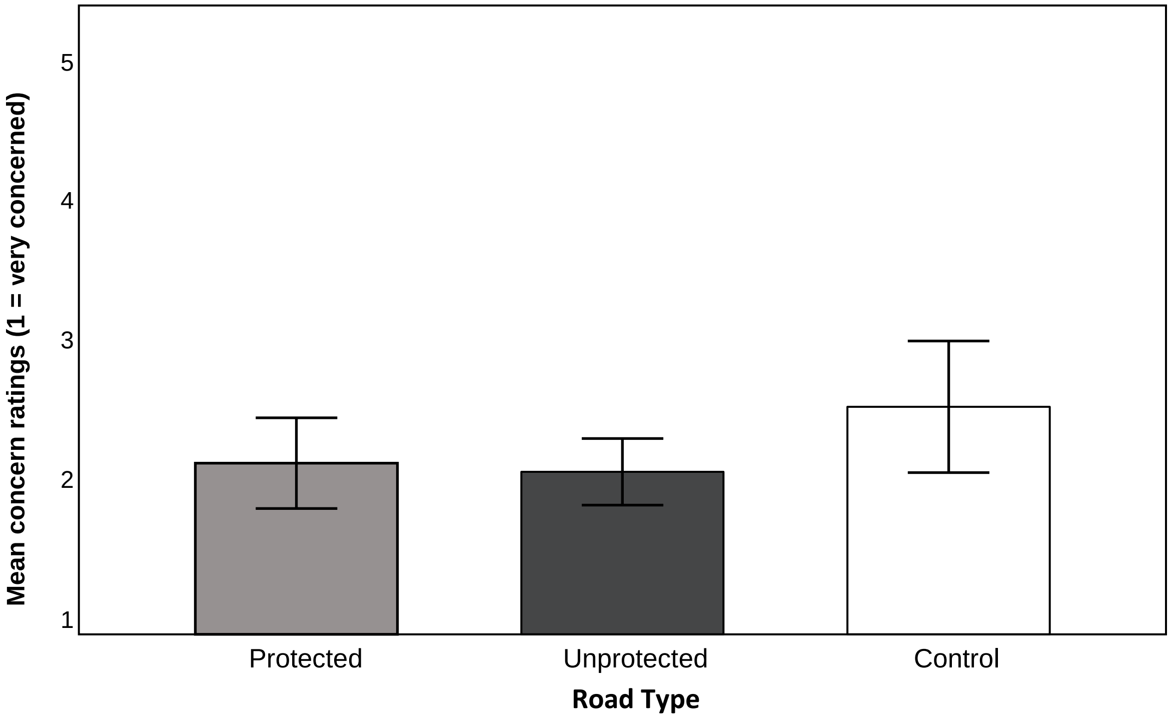


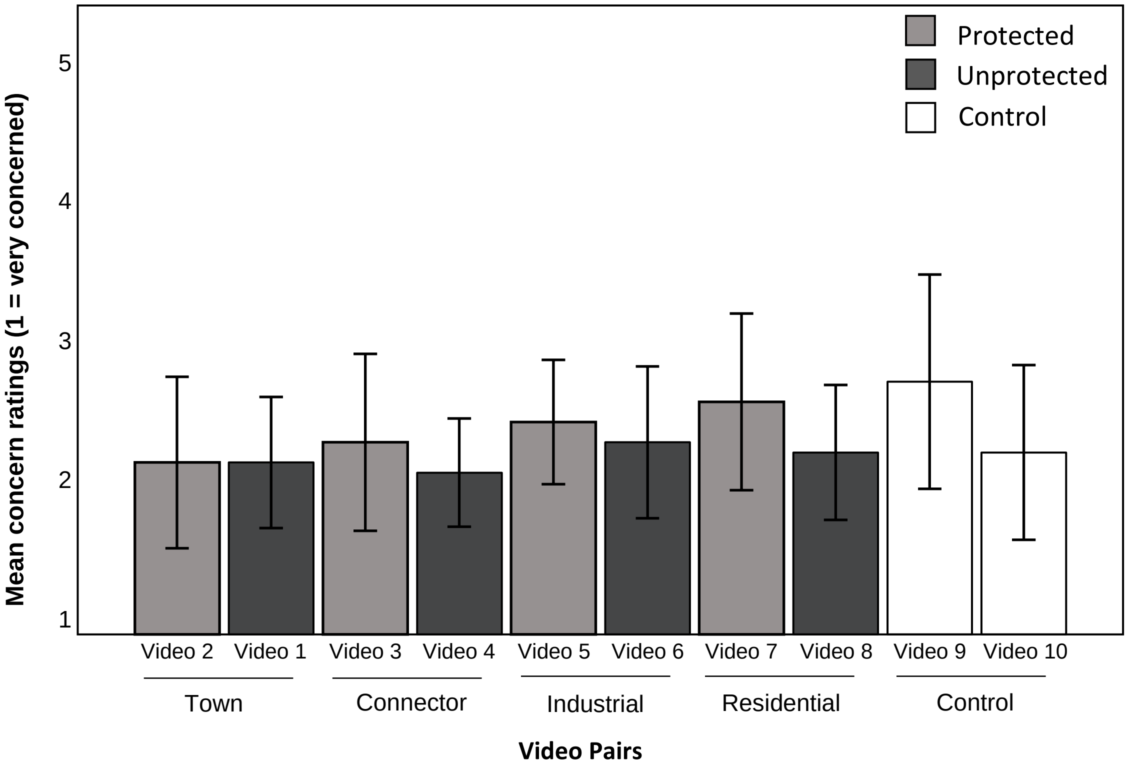
Figure 21 shows how participants' mean concern ratings about cars coming out of driveways differed between the individual roads by road function pair. As visible in both figures, there were not large differences between the ratings for the roads, and they seem to cluster between 2 "somewhat concerned" and 3 "neither concerned or unconcerned".

Two within-road-type pairs, one in the Protected group (Videos 7 ($M = 2.42$, $SD = 0.95$) and 2 ($M = 2.00$, $SD = 1.00$)) and one in the Control (videos 9 ($M = 2.79$, $SD = 1.27$) and 10 ($M = 2.45$, $SD = 1.10$)), appeared to have large differences within them (see Figure 21). Two pairwise paired-sample t-tests were conducted to test the significance between these differences. The results found a significant difference between the roads in the Protected group ($t(24) = 2.30$, $p = .031$), but not between the Control roads ($t(17) = 1.72$, $p = .10$).

The connector, industrial and residential pairs look like they have differences in means between them; however, none of them had large enough differences to investigate (see Figure 21).

Figure 21

Mean concern ratings participants gave to the question "How concerned would you have been about cars coming out of their driveways on this road?" by video pair (whiskers = 95% Confidence Interval)



To address the second research question, participants were asked several questions regarding their expectant behaviour on the roads and at intersections on these roads. Participants' ratings were then compared between each video and road type for each question to uncover differences between them.

3.1.6. Speed (self-reported)

Firstly, participants were asked how fast they thought they would travel on the roads portrayed in each video. When the mean of participants' speed responses were clustered and compared by road type (see Figure 22), speed ratings were noticeably higher in the Control group (M = 3.35, SE = 0.13), than both the Protected group (M = 2.95, SE = 0.08) and the Unprotected group (M = 2.69, SE = .094).

A repeated measures One-Way ANOVA was conducted between road type and speed ratings to see whether any of the above differences were significant; significant differences in speed-ratings between road type were found ($F(2, 52) = 13.73$, $p < .001$, $\eta_p^2 = .35$). A post-hoc Bonferroni-adjusted pairwise comparison test revealed a significant difference between the speed ratings of the Control Group compared with both the Unprotected group (p < .001) and the Protected group ($p = .009$). However, no significant difference was found between the Unprotected and Protected groups ($p = .071$).

Figure 22

Mean self-reported speed ratings by road type (whiskers = 95% Confidence Interval)

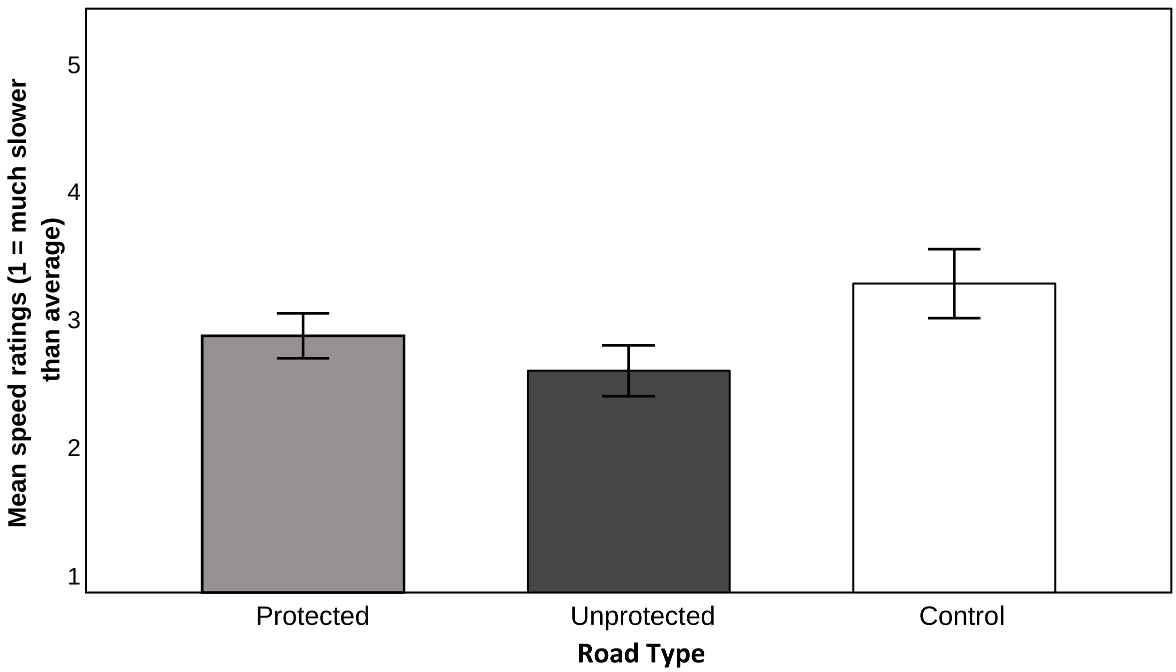


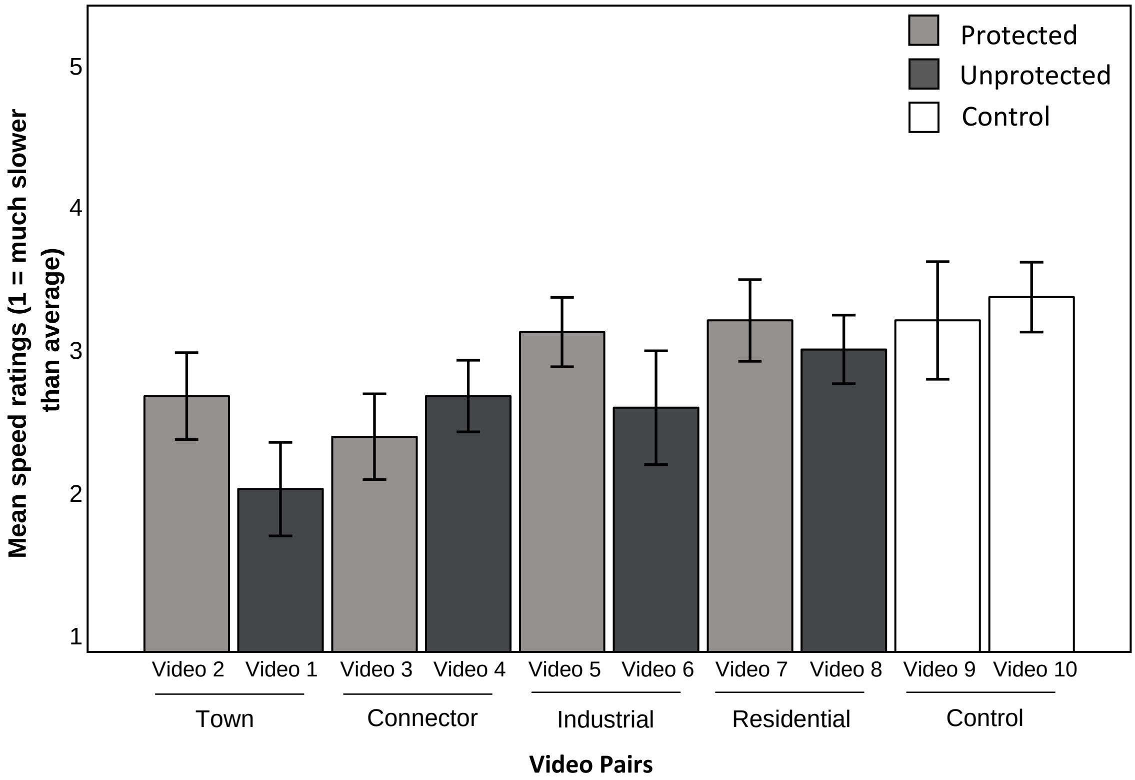
Figure 23 shows how the mean speed ratings compared between the individual roads. As shown, many of the speed ratings for each video were close to 3 ‘No difference (average)’ in relation to participants’ average speed. Additionally, speed ratings did not differ greatly within road type except for Video 4 (M = 2.48, SE = 0.14) in the Protected group and Video 1 (M = 2.12, SE = 0.16) in the Unprotected group, which were lower than the other roads within their groups. The video with the highest self-reported speed ratings was Video 10 in the Control group (M = 3.44, SE = 0.12), and the video with the lowest was Video 1 in the Unprotected group.

Additionally, the road pairs with the biggest differences in average self-reported speed ratings were the town and industrial pairs. The rest of the pairs did not seem to have much of a difference within them. There was also no consistent trend within the pairs as to which type of road was rated higher. In three out of the four pairs, the Protected roads were rated higher than the Unprotected; however, for the connector pair, the reverse was true (see Figure 23).

Results from a repeated measures One-Way ANOVA showed there were significant differences in participants’ self-reported speed ratings between the individual roads (F(9,216) = 9.77, p < .001, η_p^2 = .29). A post-hoc Bonferroni-adjusted pairwise comparison test revealed many significant differences between the video pairs, some of which were in the same road type. Within the Protected group, participants said they would bike significantly slower on average for Video 4 than videos 5 (p = .006) and 7 (p = .005); within the Unprotected group, Video 1 had significantly lower self-reported speed ratings than Video 8 (p = .004); and no significant difference was found within the Control groups’ self-reported speed ratings (p = 1.00). Additionally, Video 9 (C) had significantly higher ratings than videos 1 (P) and 4 (U); Video 10 (C) had significantly higher ratings than videos 1 (p < .001) and 3 (p = .013) (Unprotected) and videos 2 (p = .013) and 4 (p < .001) (Protected); and Video 1 was rated significantly lower than videos 2 (p = .048), 5 (p < .001) and 7 (p < .001) in the Protected group. The post-hoc Bonferroni pairwise comparison test found only one pair with a significant difference between the roads within it: the town pair (p = 0.48).

Figure 23

Mean self-reported speed ratings between video pairs (whiskers = 95% Confidence Interval)



3.1.7. Cycling location

Participants were also asked the question, “Would you have chosen to ride in a different space on the road instead of that chosen in the video?” for each road. Participants had five choices to choose from: “I would have stayed in the same place as the cyclist”, “I would have biked on the footpath”, “I would have biked in the middle of the traffic lane”, “I would not have biked on this road at all” and a text box option for “other”. For context, the cyclists in the videos rode in the cycling space allocated on each road, i.e., in lanes when they were present and sharing with traffic in the sharrow in Video 9.

The most popular answer for most videos, excluding videos 6 (U) and 9 (C), was ‘bike in the same place’. This choice was selected particularly prevalently for all the Protected roads and videos 8 in the Unprotected group (residential) and 10 in the Control group. Conversely, videos 1, 3, 6

(Unprotected), and 9 (Control) had mixed results, with higher levels of responses for the choices “other” and “I would have biked in the middle of the traffic lane”. The latter option was especially popular for videos 6 (U) and 9 (C)

For the videos with the higher counts of ‘other’, what participants’ wrote was investigated. For videos 3 and 6 (Unprotected), when participants selected ‘other’, they tended to say they would bike further to the right of the cycle lane (or on the left-hand side of the traffic lane) to avoid being “doored” by parked cars. In Video 1 (U), a participant said the same thing, but most said they would have been more cautious than the cyclist and would have slowed down. For videos 2 and 4 (P), when participants selected ‘other’, they tended to say they would remain in the cycle lane but not as close to the footpath as the cyclist did. Responses for Video 2 tended to be in relation to a specific hazard; a car was coming out of an accessway. Participants said they would have biked further to the right to avoid the car’s bumper or would have stopped until the car came out.

3.1.8. Self-reported behaviour at intersections

Next, participants were asked: “in approaching the side street the cyclist passed on this road…” if they would have cycled past it at the same speed they were already travelling, increased their speed or slowed down in case they needed to stop. However, there was not a side street present in every video. Therefore, another response, “I do not remember the cyclist passing a side street”, was available to select to account for these absences and for genuine instances of not recalling.

Videos 3, 4, 5, and 6 did not have side streets, and videos 2 and 10 had large accessways that looked like entrances to side streets. Interestingly, although the counts of those who answered with a speed response were smaller on some of these roads (for example, Video 6 (U) had the lowest count remembered (16)), more people gave speed ratings than said they could not remember a side road in the videos. Overall, Video 8 (U) had the highest count of people who remembered a side street (27).

Generally, participants tended to say they would either continue going the same speed they were already going past each intersection on the road or slow down. Very few said they would increase their speed while going past an intersection; the maximum number of people who said this for any given street was 2 for Video 7.

A related sample Friedman's ANOVA was conducted to test if participants' self-reported speed at intersections significantly differed between the videos. No significant difference was found in self-reported speed ratings between the roads ($X^2_F(9) = 11.02$, $p = .27$). Because there was no main effect, no post-hoc pairwise comparison test was conducted.

3.1.9. Expectations of cars at intersections

Participants were also asked to rate how likely it was that a car would give way to them at the side street in the video; they were only asked this if they did not select "I do not remember a side street" for the previous question. Figure 24 shows the mean expectation ratings participants gave the roads by road type. The lower the ratings, the lower participants rated the likelihood that a car would give way to them at the video's side street intersection.

As depicted, participants had the lowest mean expectation rating in the Control group (M = 2.75, SE = 0.20), followed by the Unprotected (M = 2.92, SE = 0.19), then the Protected group (M = 3.14, SE = 0.21). However, the means were all mostly close to 3, which is the neutral response, "I'm not sure whether turning cars would give way or not" (see Figure 24).

Three pairwise comparison paired-sample t-tests were conducted to see whether there were any significant differences in participants' expectation ratings between road types. No significant relationships were assumed, so the alpha level was divided by three to reduce the likelihood of a random significant result occurring (p = .017 compared with p = 0.05). Interestingly, a significant result was found between the Protected road and Control road groups (p = .015). No significant result was found for the other two pairs, however (Unprotected < Protected $p = .08$; Control < Unprotected $p = .15$).

Figure 24

Mean side-street expectation ratings by road type (whiskers = 95% Confidence Interval)

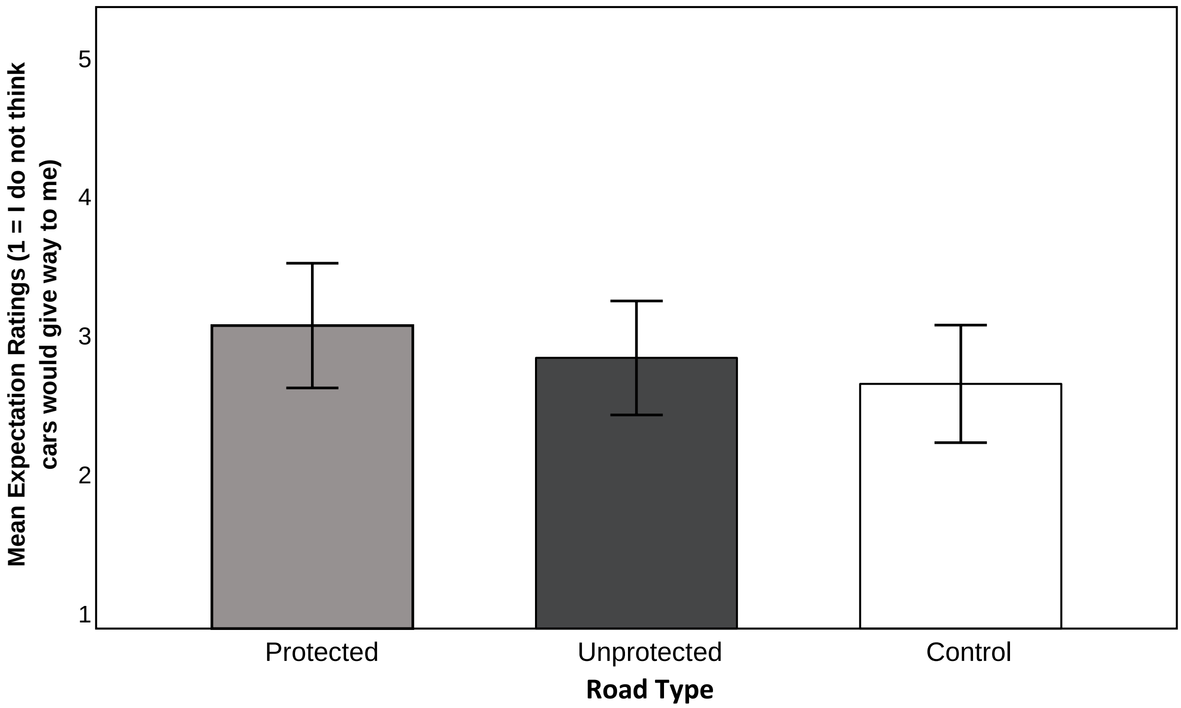


Figure 25 shows participants' mean expectation ratings between the videos, organised by road function. As shown, participants' expectation ratings did not vary much except for videos 7 (P) and 8 (U) (the residential roads), which had slightly bigger means than the other videos. Moreover, the videos' means tended to cluster between 3 and 3.5, suggesting participants tended to give the side street intersections a response close to neutral.

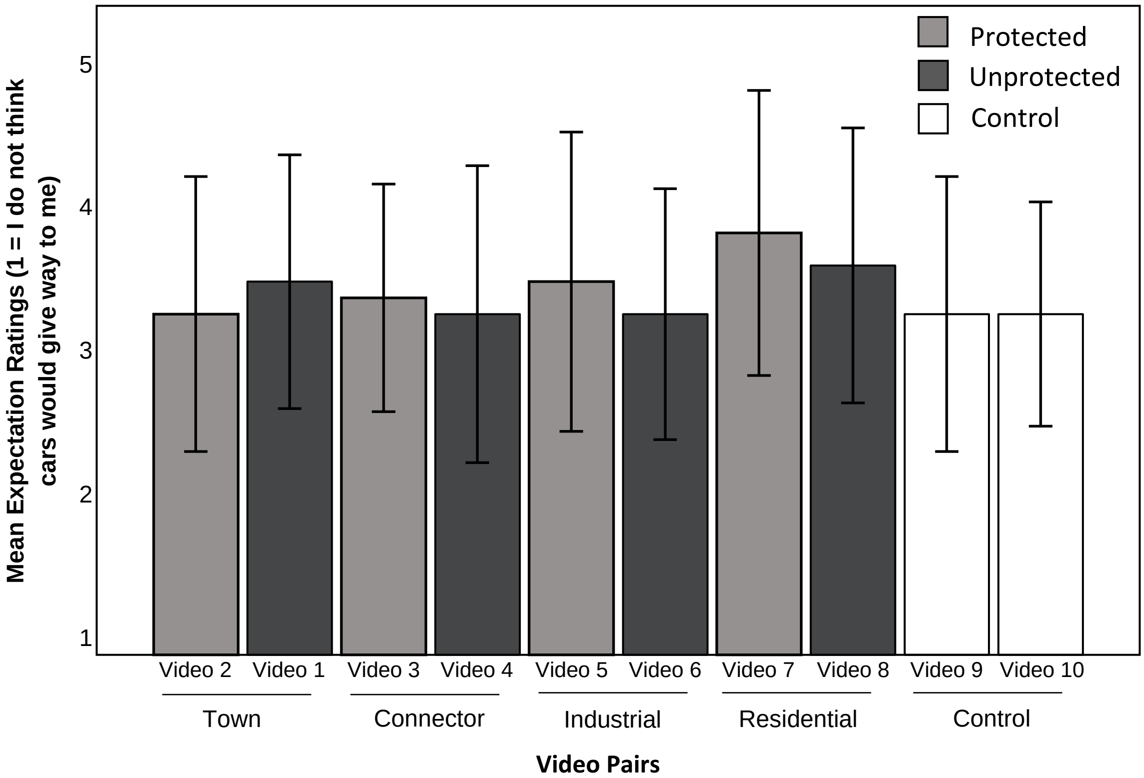
For each road function pair, the means were close in scale, and in three out of four, the Protected roads' mean expectation ratings were slightly higher. However, this trend was not observed for the town pair, as Video 1 (U) (*M* = 2.86, *SD* = 1.11) is rated higher on average than Video 2 (P) (*M* = 2.78, *SD* = 1.09). The greatest mean difference within a pair was also the town pair (*M* difference = .08) (see Figure 25).

Due to the similarities in means, not all the individual pairs were tested for significance. However, a couple of pairs were compared to test the homogeneity within the road types' group expectation ratings, as the differences in means appeared sizable. These pairs were videos 2 (*M* = 2.78, *SD* = 1.09) and 7 (*M* = 3.27, *SD* = 1.28) in the Protected group, and videos 8 (*M* = 3.22, *SD* = 1.15) and 3 (*M* = 2.94, *SD* = 1.20) in the Unprotected group (see Figure 25).

Two pairwise paired-sample t-tests found a significant difference between videos 2 and 7 (Protected) ($t(25) = -2.82$, $p = .009$, *Cohen's d* = -.61); and between videos 3 and 8 (Unprotected) ($t(16) = 2.95$, $p = .009$, *Cohen's d* = .72). These results suggest that the means of one or two roads may explain the differences observed between road types due to driving up the protected and unprotected groups' average ratings.

Figure 25

Mean side-street expectation ratings between video pairs (whiskers = 95% Confidence Interval)



Finally, several correlations were conducted between variables for each road to add to the findings listed above. Specifically, safety and hazard-concern ratings were correlated with speed ratings, hazard related data and safety ratings were correlated with one another, and the relationship between safety and willingness ratings was investigated.

3.1.10. Safety and self-reported speed ratings

Two Pearson's correlations were used to identify any relationship between participants' safety ratings or hazard-concern ratings and how fast they said they would go. This investigation aimed to test the main assumptions for the TCI model and Zero-Risk Theory: people will travel more quickly if they have a lower mental workload or feel safer. Only data from the individual roads were used in the correlations because significant differences were found within road types in all the ratings.

No significant relationship was observed between respondents' safety ratings and self-reported speed ratings for any road (see Table 2). Additionally, only one significant result was observed between hazard-concern and speed (Video 7 (see the result in bold)). For safety ratings, there was no trend for the relationships between the variables: i.e., for three of the roads, respondents' higher speed ratings corresponded with lower safety ratings (see numbers in italics in Table 2), and for the rest (7 videos), higher speed ratings correlated with higher safety ratings. Conversely, all the Pearson's R statistics from the test were negative between hazard-concern ratings and speed.

Table 2

Correlation results between participant's safety and hazard-concern ratings, and their self-reported speed for each road

		Protected				Unprotected				Control	
		Vid2	Vid4	Vid5	Vid7	Vid1	Vid3	Vid6	Vid8	Vid9	Vid10
Safety x Speed	Pearson's R	*-0.024*	0.250	0.191	0.264	0.247	0.336	0.255	0.245	*-0.039*	*-0.037*
	P	0.904	0.209	0.339	0.192	0.214	0.093	0.199	0.229	0.850	0.853
	N	27	27	27	26	27	26	27	26	26	27
Hazards x Speed	Pearson's R	-0.334	-0.182	-0.324	**-0.47**	-0.305	-0.240	-0.108	-0.341	-0.041	-0.095
	P	0.089	0.363	0.099	**0.015**	0.122	0.238	0.592	0.082	0.837	0.636
	N	27	27	27	**26**	27	26	27	27	27	27

3.1.11. Hazards and safety ratings

Next, several correlations were conducted between safety ratings and hazard related variables. The first correlation, between participants' safety ratings and total hazard-concern ratings, was examined to see if more concern over hazards was usually paired with lower safety ratings. The rest were between safety ratings and items which measured concern or expectations towards car-related hazards. The car-related items measured: how comfortable participants were with cars passing them on each of the roads; how confident they were cars would give way to them at side-street intersections; and whether they were concerned about cars coming out of their driveways. All the significant correlations are shown in bold in Table 3.

As shown in Table 3, all the correlation coefficients came back negative between safety and hazard-concern ratings, meaning that higher total hazard-concern ratings were usually paired with lower safety ratings for each video. This relationship was significant for six out of ten videos (see results in bold). Out of the significant correlations, the coefficients ranged between .44 and .62, which indicate moderate to strong relationships.

In terms of the car-related hazards, all the correlations between safety ratings and how comfortable participants were with cars passing them were significant; and all but one were significant between safety ratings and participants' expectations cars would give way at side street intersections. In addition, each relationship was positive for both hazards. So, as participants' comfort levels and their expectations cars would give way increased, their ratings of safety tended to too. For the hazard concerning cars passing, this relationship was strong for every Unprotected road and Video 9 (especially Video 1 (U)) and moderate for the rest of the videos. Conversely, the relationships were strong for videos 5 (P), 3 (U), 8 (U) and 9 (C) and moderate for the rest of the videos for participants' expectations at intersections.

Lastly, Table 3 shows only one significant correlation between safety ratings and how concerned participants were about cars coming out of their driveways between the videos (Video 3 (U)). Additionally, no clear relationship direction was observed; videos 7 (P) and 9 (C) showed negative relationships while the others were positive.

Table 3

Correlation results between participant's safety and hazard-related ratings for each road

		Protected				Unprotected				Control	
		Vid2	Vid4	Vid5	Vid7	Vid1	Vid3	Vid6	Vid8	Vid9	Vid10
Safety x Hazard-concern	Pearson's R	-0.25	-0.33	**-0.57**	-0.29	-0.38	**-0.48**	**-0.62**	**-0.55**	**-0.59**	**-0.44**
	P	0.211	0.098	**0.002**	0.158	0.053	**0.012**	**0.001**	**0.004**	**0.002**	**0.022**
	N	27	27	**27**	26	27	**27**	**27**	**26**	**26**	**27**
Safety x Cars passing	Pearson's R	**0.521**	**0.472**	**0.551**	**0.529**	**0.723**	**0.644**	**0.628**	**0.638**	**0.606**	**0.481**
	P	**0.005**	**0.013**	**0.003**	**0.005**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.011**
	N	**27**	**27**	**27**	**26**	**27**	**26**	**27**	**26**	**26**	**27**
Safety x Intersections	Pearson's R	**0.58**	**0.54**	**0.69**	**0.52**	**0.60**	**0.66**	0.39	**0.64**	**0.64**	**0.58**
	P	**0.004**	**0.015**	**0.003**	**0.006**	**0.004**	**0.004**	0.136	**0.000**	**0.003**	**0.002**
	N	**23**	**20**	**16**	**26**	**21**	**17**	16	**26**	**19**	**26**
Safety x Driveways	Pearson's R	0.000	0.170	0.298	-0.152	0.419	**0.43**	0.162	0.100	0.426	-0.062
	P	1.000	0.406	0.178	0.458	0.074	**0.036**	0.438	0.636	0.078	0.784
	N	26	26	22	26	19	**24**	25	25	18	22

3.1.12. Safety and willingness

Finally, a Pearson's correlation was conducted between participants' safety and willingness ratings (see Table 4). Each coefficient from the correlation was positive, suggesting that as participants gave higher safety ratings, they tended to do the same for willingness ratings. However, this relationship was only significant for six out of the ten roads (see results in bold). Additionally, for one of the roads (Video 7 (P)), Pearson's R was so low as to suggest no relationship between safety and willingness ratings. For those roads which had a significant correlation between safety and willingness ratings, the size was moderate.

Table 4

Correlation results between participant's safety and willingness ratings for each road

		Protected				Unprotected				Control	
		Vid2	Vid4	Vid5	Vid7	Vid1	Vid3	Vid6	Vid8	Vid9	Vid10
Safety x Willingness	Pearson's R	0.261	**0.56**	**0.544**	0.014	**0.525**	**0.509**	**0.572**	0.218	**0.593**	0.312
	P	0.198	**0.002**	**0.004**	0.947	**0.005**	**0.007**	**0.002**	0.286	**0.001**	0.113
	N	26	**27**	**26**	26	**27**	**27**	**27**	26	**26**	27

3.2. Post-ride Questionnaire and On-road Data

Below are the results taken from the post-ride questionnaire and on-road study data. Like the online results, this data answers two central research questions: Are PCLs likely to attract more users than painted bike lanes in New Zealand? Do cyclists behave differently in them, and if so, how?

Again, to answer whether PCLS are likely to attract more users, safety ratings, how willing participants were to allow a child they knew to bike on each road, and how hazardous they believed the roads to be were compared. Additionally, how much anticipatory dread participants thought they would experience coming up each road again if it was part of their commute was measured and compared.

3.2.1. Safety ratings

Below, Figure 26 illustrates the average safety ratings participants gave the different road types. As shown, the average rating for the Unprotected roads (M = 3.29, SE = 0.21) was lower than both the Protected (M = 4.17, SE = 0.14) and Control groups (M = 4.25, SE = 0.17). Whilst the Protected and Control road types were rated similarly in terms of safety.

A 2 (order) x 3 (road type) ANOVA was conducted to determine whether safety ratings were significantly different between the road types, and whether the order participants completed the experiment in affected ratings. The test results showed a significant effect for safety ratings by road type ($F(2,44) = 14.71$, $p < .001$, $\eta_p^2 = .40$). No significant order effect ($F(1,22) = .40$, $p = .55$, $\eta_p^2 = .016$), or interaction between order and road type for safety ratings was observed ($F(2,44) = .27$, $p = .76$, $\eta_p^2 = .012$). A post-hoc, Bonferroni-adjusted pairwise comparison test showed there was a significant difference between participants' safety ratings on the Unprotected and the Protected roads ($p = .002$), and the Unprotected and Control roads ($p < .001$). However, no significant difference was observed between the Control and Protected roads ($p = 1.00$).

Figure 26

Mean safety ratings by road type (whiskers = 95% Confidence Interval)

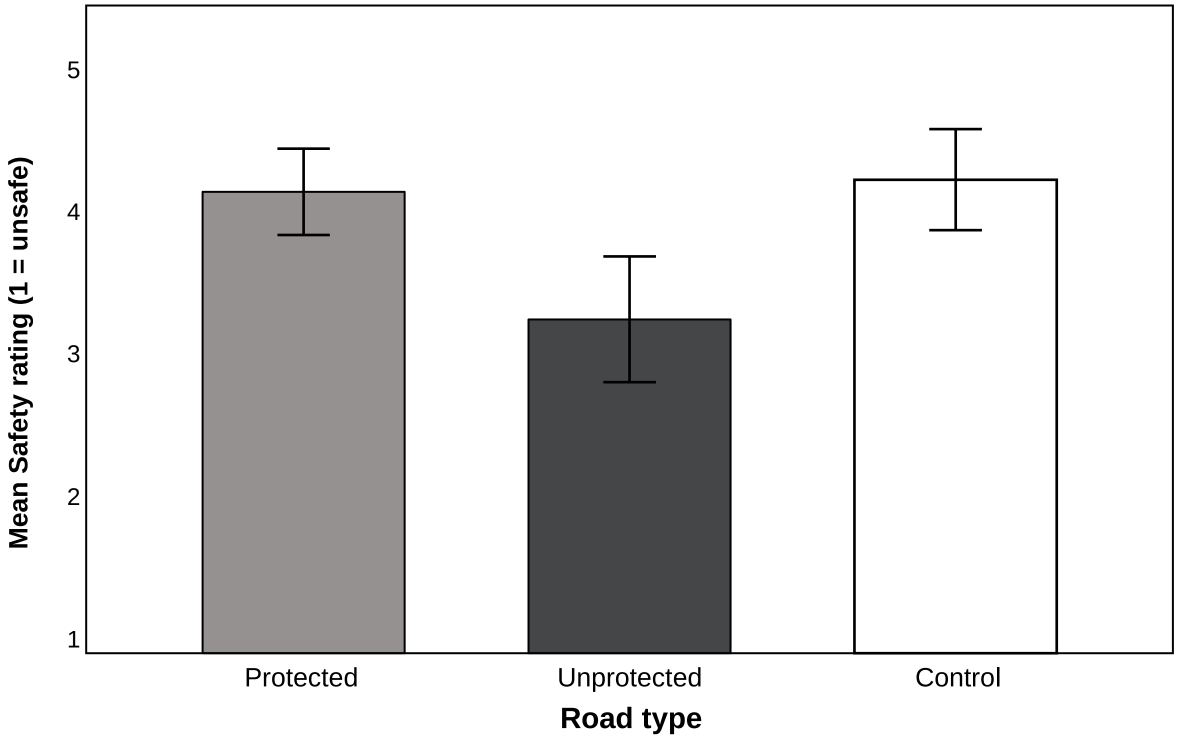


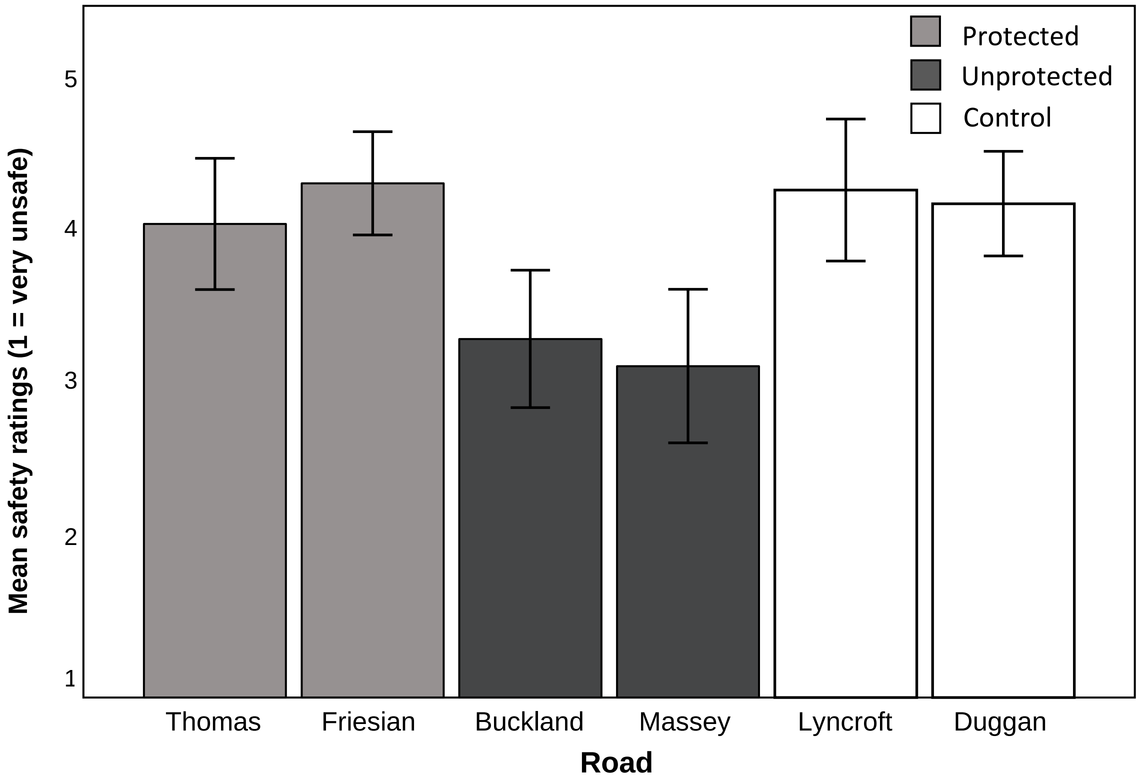
Figure 27 depicts the safety ratings between the individual roads and uses the same colour coding as Figure 26 to illustrate road type. As shown, the roads within each road type had similar ratings, and a similar pattern is seen as in Figure 26 concerning the different road types. Namely, both the Unprotected roads (Buckland $M = 3.31$, $SE = .21$; and Massey $M = 3.13$, $SE = .24$) had lower mean safety ratings than the Protected roads (Thomas *M* = 4.05, *SE* = .21; and Friesian *M* = 4.31, *SE* = .16) and the Control roads (Lyncroft *M* = 4.26, *SE* = .23; and Duggan *M* = 4.18, *SE* = .17).

A repeated measures 2 (order) x 6 (road condition) ANOVA was conducted to see how ratings of safety differed on the roads when they were not grouped by road type. Results from the ANOVA showed a significant within-subjects effect from the individual roads for safety ratings ($F(5,105) = 9.87$, $p < .001$, $\eta_p^2 = .32$). No between-subjects effect (order) ($F(1,21) = .14$, $p = .71$, $\eta_p^2 = .007$), and no significant interaction between order and road condition ($F(5,105) = .44$, $p = .82$, $\eta_p^2 = .020$) was observed for safety ratings.

A post-hoc Bonferroni-adjusted pairwise comparison test showed both Massey (*M* = 3.13, *SE* = 0.24) and Buckland Road (*M* = 3.31, *SE* = 0.21) were rated significantly lower on average than Friesian Drive (*M* = 4.31, *SE* = 0.16), Duggan Avenue (*M* = 4.18, *SE* = 0.17) and Lyncroft Street (*M* = 4.26, *SE* = 0.26), but not with Thomas Road (*M* = 4.05, *SE* = 0.21). These differences all had *p* values below .01 except for the difference between Buckland and Lyncroft, which had a *p* value of .031. No significant differences in mean safety ratings were observed between any of the Protected and Control roads.

Figure 27

Mean safety ratings for each road (whiskers = 95% Confidence Interval)



3.2.2. Willingness to allow children to cycle on the road

Figure 28 depicts the mean ratings participants gave for how willing they were to allow their child or a child they knew to cycle on each road by road type. Like the safety ratings, willingness ratings were lower for the roads in the Unprotected group (M = 2.10, SE = 1.14) than the other groups (Protected M = 3.17, SE = 1.12; Control M = 3.56, SE = 1.15) (see Figure 28). Additionally, the differences in rating between the different road types are larger for willingness ratings than the differences seen in safety ratings. This difference is especially stark when comparing the Control roads and the Unprotected roads. Also, willingness ratings are lower on average than participants' safety ratings (see figures 26 and 28 for a comparison).

Another repeated measures 2 x 3 ANOVA test was carried out to determine if participants' mean willingness ratings significantly differed by road type (3) or order (2). A post-hoc Bonferroni-adjusted pairwise comparison test was also conducted to see which differences between the groups were significant.

The two-way ANOVA results found a significant within-subjects effect from road condition for willingness ratings ($F(2,44) = 21.43$, $p < .001$, $\eta_p^2 = .49$). No significant effect from order ($F(1,22) = 1.05$, $p = .32$, $\eta_p^2 = .046$) and no significant interaction between order and road type ($F(2,44) = .92$, $p = .41$, $\eta_p^2 = .040$) was found for participants' willingness ratings.

The pairwise comparison results showed that both the Control and Protected roads' mean willingness ratings were significantly higher than participants' ratings in the Unprotected condition ($p < .001$). However, no significant difference was found between the Control and Protected groups' mean ratings ($p = .18$).

Figure 28

Mean ratings for "willingness to allow children to bike on the road" by road type (whiskers = 95% Confidence Interval)

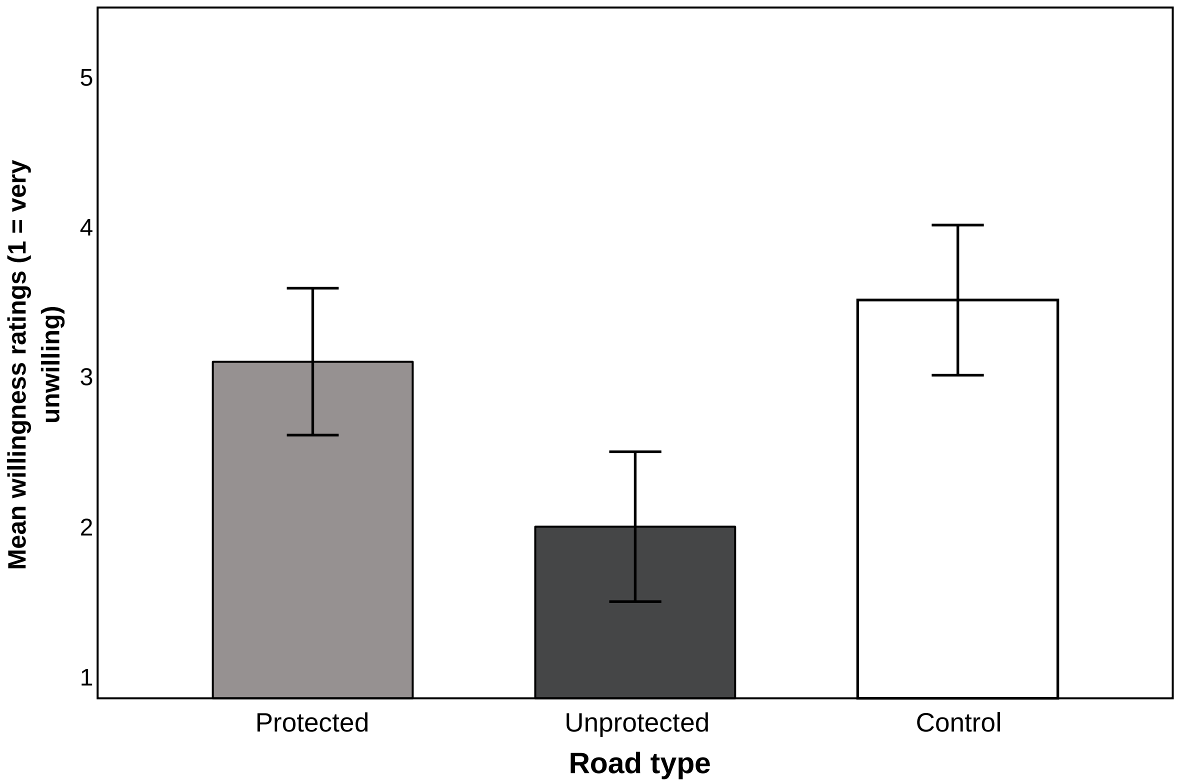


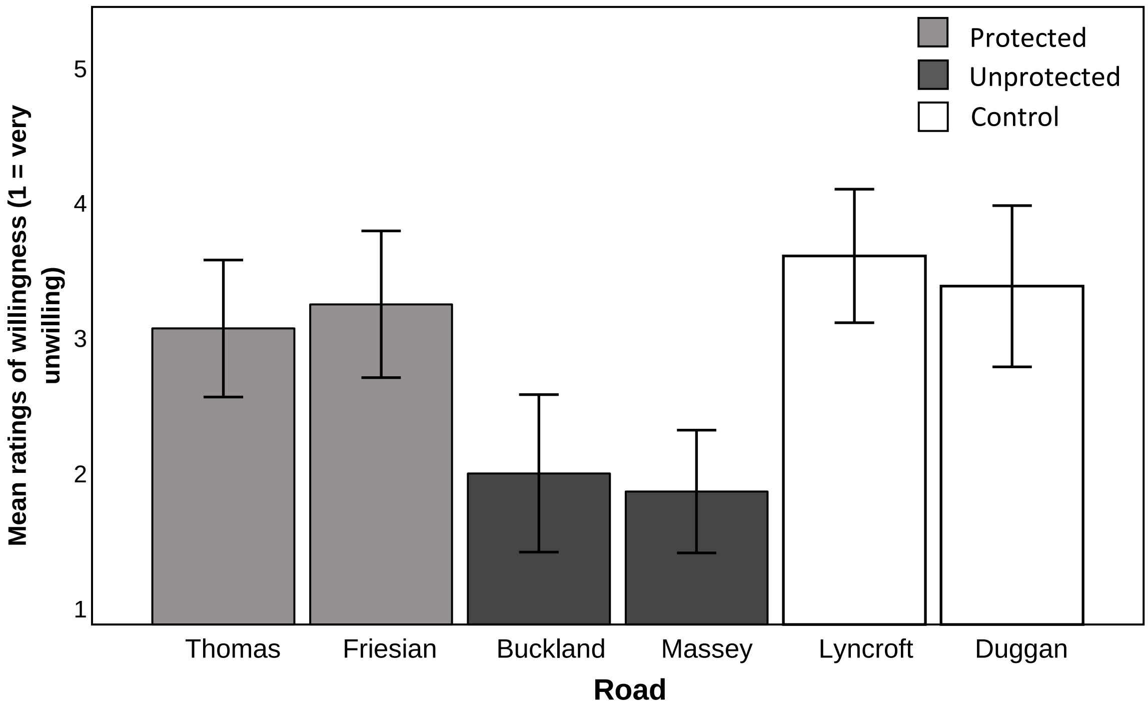
Figure 29 depicts the mean willingness rating participants gave to the individual roads. As shown, the ratings between the roads within each road type had similar ratings to one another. Again, like the safety ratings, the two Unprotected roads (Massey *M* = 1.9, *SE* = 0.21; Buckland *M* = 2.08, *SE* = 0.28) were rated lower than both the Protected (Thomas *M* = 3.11, *SE* = 0.22; Friesian *M* = 3.30, *SE* = 0.26) and the Control roads (Lyncroft *M* = 3.64, *SE* = 0.23, Duggan *M* = 3.42, *SE* = 0.29)

Another repeated measures 2 (order) x 6 (individual road) ANOVA was carried out to see if these differences were significant or if order affected how participants rated the roads. Significant differences were found between the willingness ratings participants gave the roads ($F(5,105) = 18.59$, $p < .001$, $\eta_p^2 = .47$). No significant order effect ($F(1,21) = 1.26$, $p = .27$, $\eta_p^2 = .057$), and no significant interaction between order and road was found for participants' willingness ratings ($F(5,105) = .81$, $p = .54$, $\eta_p^2 = .037$).

A post-hoc Bonferroni-adjusted pairwise comparison test showed that both Unprotected roads were rated significantly lower than every other road to a $p < .001$ level, except for the comparison between Friesian Drive and Buckland Road ($p = .009$). No other significant differences were found between the rest of the pairs ($p > .05$).

Figure 29

Mean ratings for "willingness to allow children to bike on the road" for each road (whiskers = 95% Confidence Interval)



As per the online results and the overlap between willingness and safety ratings, a Pearson's correlation was conducted to determine how related the two were. All of the relationships between safety and willingness ratings were positive, showing that as safety ratings were higher, willingness ratings also tended to be. Surprisingly, this relationship was only significant for Buckland Road (r = 0.54, p = .007)

3.2.3. Anticipation ratings

Anticipation ratings from the question 'would you have any anticipation to cycle on this road if it was part of the most direct route between you and your destination?' for the roads in each road type were also compared using a repeated measures 2 (order) x 3 (road type) ANOVA test. As mentioned, anticipation in this study refers to negative anticipation or 'dread'.

Figure 30 shows participants' mean anticipation ratings by road type. As shown, participants rated their anticipation for every road type lowly, which, for this scale, means low amounts of dread. For example, average scores ranged between close to 1 "No, I would not be concerned about cycling on this road at all" (Protected and Control) to between 1 and 2 "I would feel a little apprehensive before reaching it" (Unprotected). There was a fifth option outside the scale for each road, which was "I would take a detour so I wouldn't have to bike on it". No one selected this option for any road, so no figure has been made to include its counts.

Results from the ANOVA, showed anticipation scores were significantly different between road type (F(2,44) = 8.15, p < .001), however, the observed effect size was small (η_p^2 = .27). No significant effect from order (F(1,22) = 3.15, p = .090, η_p^2 = .13), and no significant interaction between order and road type (F(2,44) = .071, p = .93, η_p^2 = .003) was observed. Results from a post-hoc Bonferroni-adjusted pairwise comparison test showed participants gave higher anticipation ratings for the Unprotected roads (M = 1.60, SE = 0.16), compared with both the Protected (M = 1.21, SE = 0.073, p = .022), and the Control roads (M = 1.23, SE = .094, p = .023). No significant difference was observed for participants' anticipation scores between the Protected and Control roads (p = 1.00).

Figure 30

Mean anticipation ratings by road type (whiskers = 95% Confidence Interval)

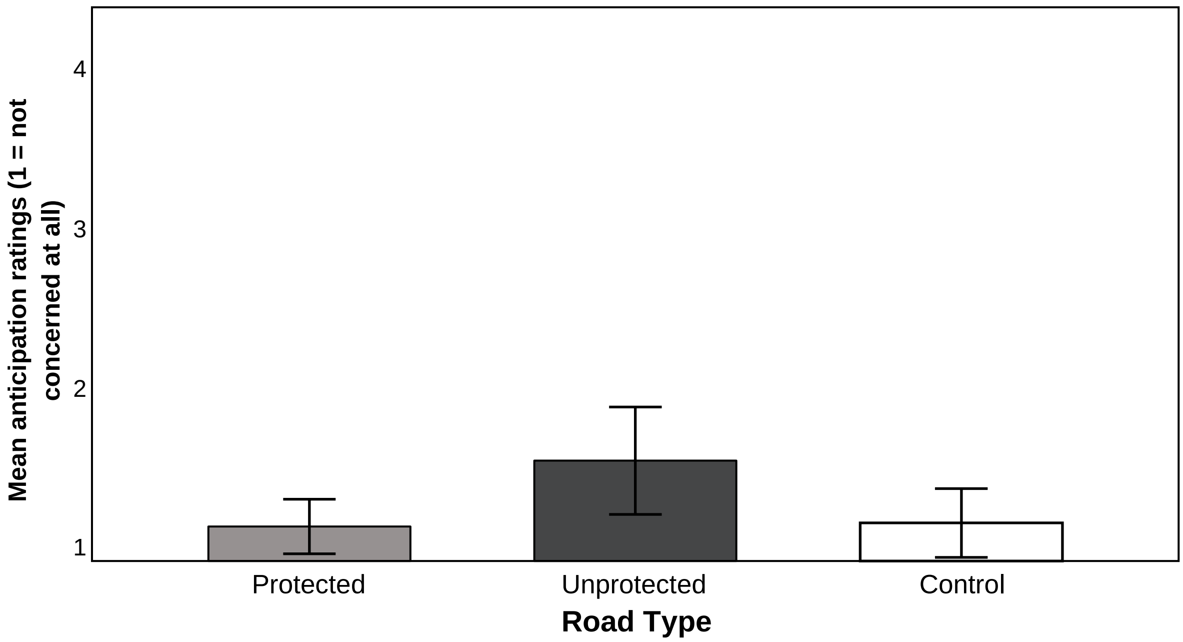
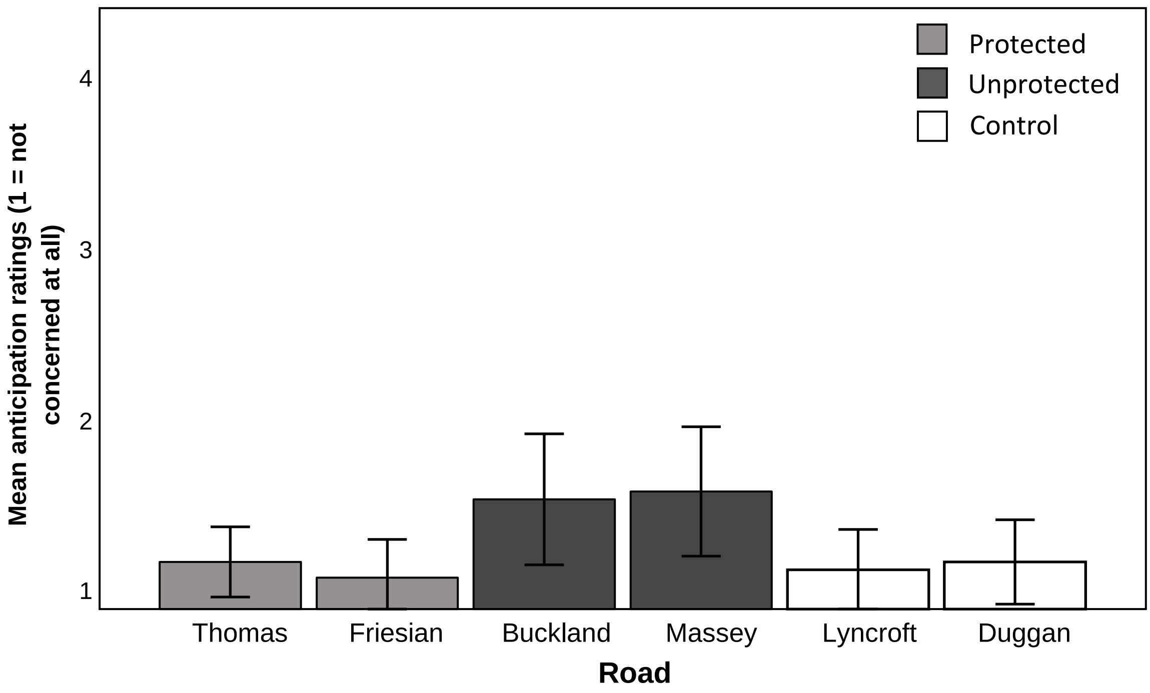


Figure 31 depicts the anticipation scores given for the individual roads. Again, similarly to safety and willingness ratings, the ratings were similar within road types. Figure 31 also shows that both of the Unprotected roads (Buckland M = 1.62, SE = 0.17; Massey M = 1.65, SE = 0.18) had higher anticipation ratings on average than those in the Control (Lyncroft M = 1.22, SE = 0.11; Duggan M = 1.27, SE = 0.11) and Protected groups (Thomas M = 1.26, SE = 0.096; Friesian M = 1.17, SE = 0.11).

Results from a repeated measures 2 (order) x 6 (road condition) ANOVA showed the general within-subjects effect of road condition for anticipation ratings was significant ($F(5,105) = 5.19$, $p < .001$). Again, the effect size was small for this result ($\eta_p^2 = .20$). No order effect was found from the between-subjects test ($F(1,21) = .33$, $p = .57$, $\eta_p^2 = .016$) and no significant interaction between order and road condition was found for participants' anticipation ratings ($F(5,105) = .74$, $p = .59$, $\eta_p^2 = .034$). A post-hoc Bonferroni-adjusted pairwise comparison test failed to indicate significant differences between the means of any of the road pairs.

Figure 31

Mean anticipation ratings for each road (whiskers = 95% Confidence Interval)



3.2.4. Speed (Observed)

To compare the speeds participants rode on the different roads, their average and maximum speeds were compared across road type and individual road. Figure 32 compares participants' average speeds between the road types. As shown, the average speeds between the Unprotected roads and the Protected roads appear similar. Additionally, participants' average speeds on the Control roads (M = 25.43km/h, SE = 0.89) appear higher than both the Unprotected (M = 23.14km/h, SE = 0.88) and Protected roads (M = 23.91km/h, SE = 0.93).

The within-subjects effect of road type for average speed from a repeated measures 2 (order) x 3 (road type) ANOVA was significant ($F(2,44) = 12.17$, $p < .001$, $\eta_p^2 = .36$). Additionally, a significant interaction between order and road type for participants' average speed was also found ($F(2,44) = 3.95$, $p = .026$, $\eta_p^2 = .15$). Generally, as shown in figure 33, participants rode faster if the first route they rode was the Protected loop. However, the effect size for the interaction effect was small. Finally, no significant effect from order was found (F (1,22) = 2.56, p = .12, η_p^2 = .10).

A post-hoc Bonferroni-adjusted pairwise comparison test confirmed the differences shown in Figure 32 were significant to a p = .005 level (Control > Protected) and a p = .001 level (Unprotected < Control). There was no significant difference between participants' mean average speeds on the Protected roads and the Unprotected roads (p = .30).

However, when participants' mean average speeds were compared across individual roads (as illustrated in Figure 34), the Control group had higher average speeds on Duggan Avenue (M = 27.70 Km/h, SE = 1.01) compared to Lyncroft Street (M = 23.09 Km/h, SE = 0.85). Moreover, average speeds on Duggan Avenue were higher than every other road, and, apart from Duggan Avenue, participants looked as if they went similar average speeds along each road.

A two-way repeated measures 2 (order) x 6 (road condition) ANOVA found differences between participants' average speeds for the individual roads (F(5,105) = 17.82, p < .001 , η_p^2 = .46). No significant effect from order was observed for participants' average speed (F(1,21) = 3.67, p = .069, η_p^2 = .15), and no significant interaction effect between which road participants rode on and order was found either (F(5,105) = .42, p = .83, η_p^2 = .020).

A post-hoc Bonferroni-adjusted pairwise comparison test confirmed the mean average speed on Duggan Avenue (M = 27.70 Km/h, SE = 1.01) was significantly higher than every other road including the other Control road, Lyncroft Street, to a p < .01 level. Additionally, it was found that participants rode significantly faster on Thomas Road (M = 24.51 km/h, SE = 1.01 km/h) compared with Massey Road (M = 22.17 km/h, SE = 0.91 km/h**,** p **=** .012).

Figure 32

Mean average speeds by road type (whiskers = 95% Confidence Interval)

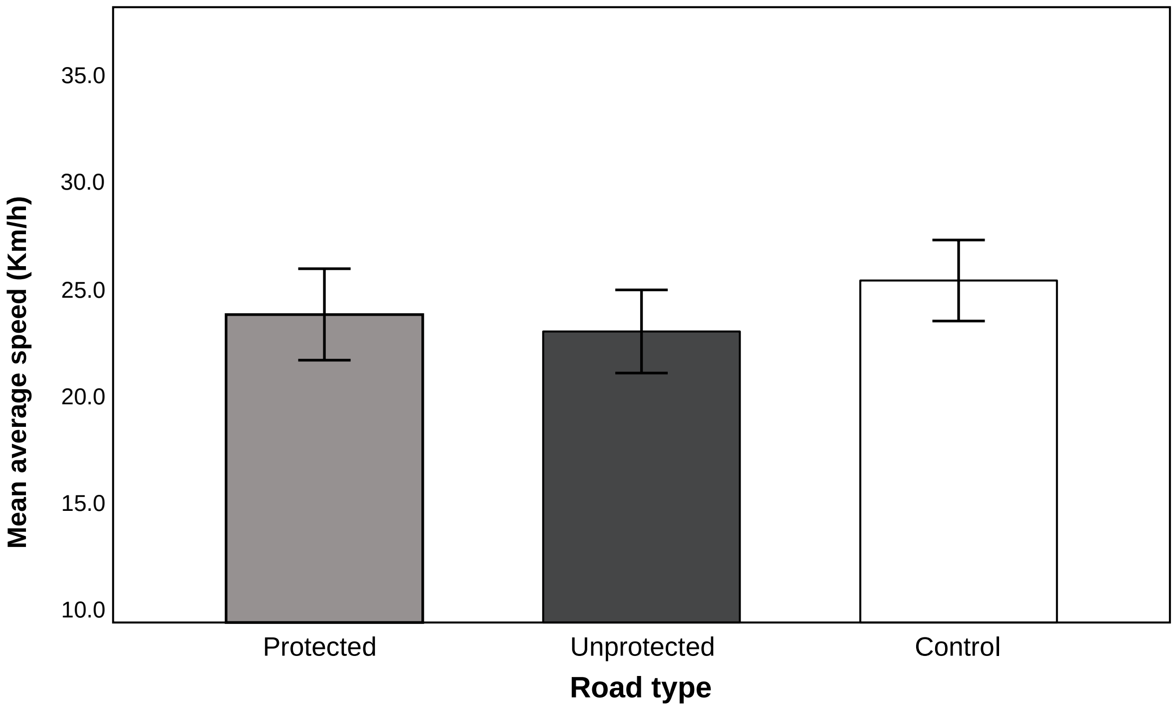


Figure 33

Mean average speeds by road type and experimental order (whiskers = 95% Confidence Interval)

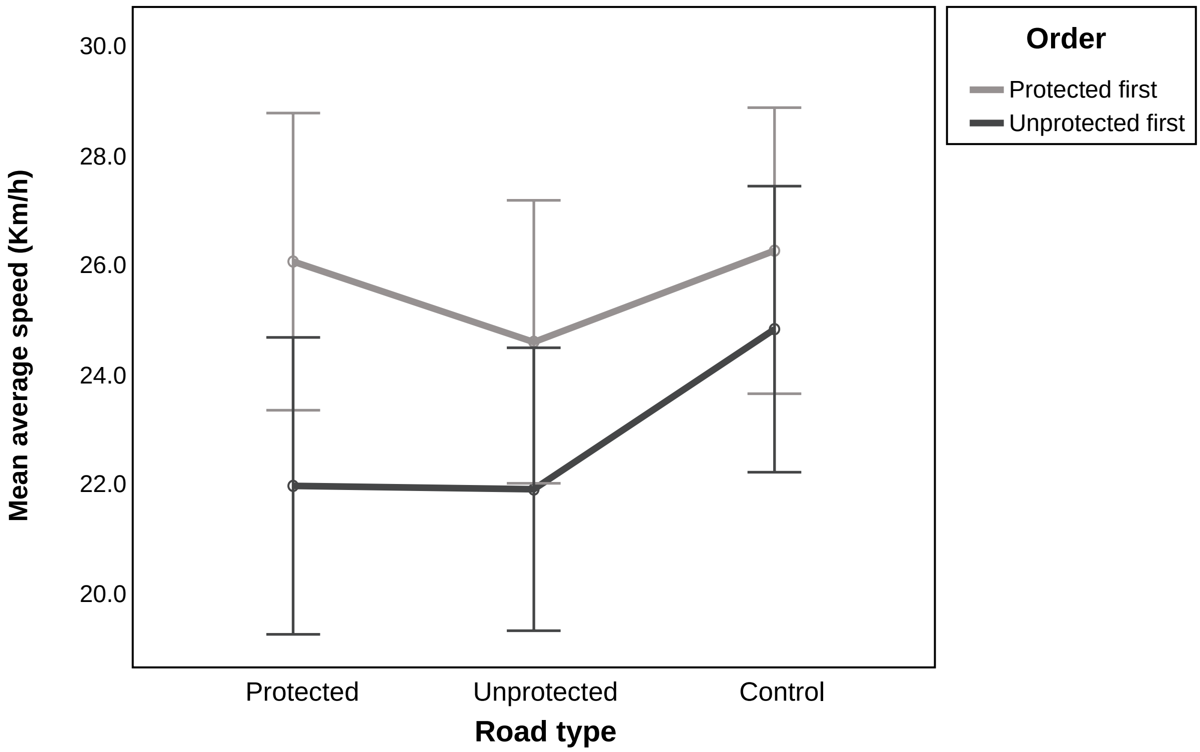
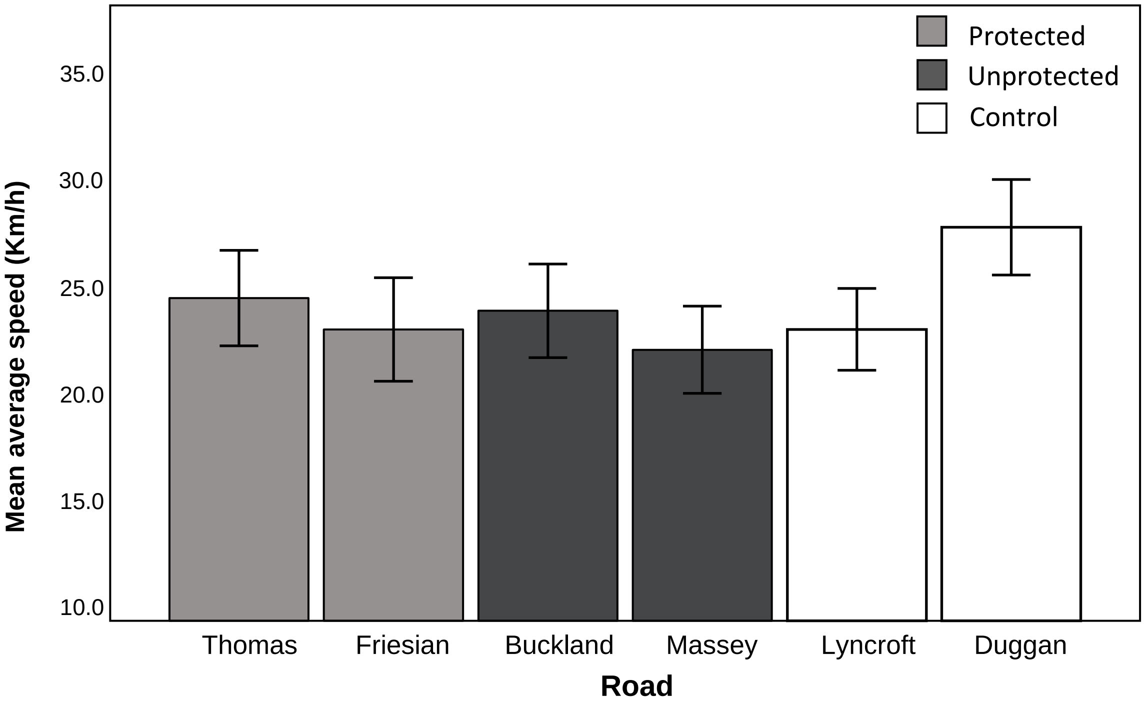


Figure 34

Mean average speeds along each road in the study (whiskers = 95% Confidence Interval)



Below, Figure 35 depicts the mean maximum speed participants rode for each road type. The differences between participants' mean maximum speeds on each road type are larger than those observed for their average speeds (see Figure 32). The Protected roads had the highest maximum speeds on average (*M* = 30.04km/h, *SE* = 0.94), followed by the Control roads (*M* =28.47km/h, *SE* = 0.82), and then the Unprotected roads (*M* = 25.95km/h, *SE* = 0.90).

Results from a 2 (order) x 3 (road type) repeated measures ANOVA showed the effect of road type for maximum speed was significant ($F(2,44) = 28.01$, $p < .001$, $\eta_p^2 = .56$). The between-subjects test found no significant effect from order ($F(1,22) = 2.95$, $p = .10$, $\eta_p^2 = .12$), and no significant interaction between order and road condition was observed for participants' maximum speeds ($F(2,44) = 0.65$, $p = .53$, $\eta_p^2 = .029$). A post-hoc Bonferroni-adjusted pairwise comparison test found significant differences between each road type (Protected > Unprotected $p < .001$; Protected > Control $p = .043$; Control > Unprotected $p < .001$).

Figure 36 then shows participants' mean maximum speeds by individual road. As shown, unlike participant's average speeds, their maximum speeds varied a lot between the roads. The highest maximum speeds were found in the Protected group (Thomas Road, $M = 30.85$ km/h, $SE =$ 1.11 km/h) and Control group (Duggan Avenue, $M = 30.10$ km/h, $SE = 1.07$ km/h) and the lowest speed was seen in the Unprotected group (Massey Road, $M = 24.75$ km/h, $SE = 0.91$ km/h). Moreover, speeds seemed to differ within road type. These differences were most prominent in the Control group and the Unprotected group.

A repeated measures 2 (order) x 6 (road condition) ANOVA confirmed that there were significant differences in participants' maximum speeds between the individual roads ($F(5,105) = 17.79$, $p < .001$, $\eta_p^2 = .46$). No order effect was found for participants' maximum speeds ($F(1,21) = 3.32$, $p = 0.083$, $\eta_p^2 = .14$). Additionally, a significant interaction effect of individual road and order for participants' maximum speeds was not observed either ($F(5,105) = 1.07$, $p = .38$, $\eta_p^2 = .048$).

A post-hoc Bonferroni-adjusted pairwise comparison test was conducted to see which speed differences depicted in Figure 36 were significant. Most interestingly, participants had significantly lower maximum speeds on Massey Road than on other roads (Thomas Road, Friesian Drive and Duggan Ave $p < .001$; Lyncroft Street $p = .020$; Buckland Road $p = .031$). Additionally, participants had significantly higher maximum speeds on Thomas Road compared with Buckland Road ($M = 26.98$ km/h, $SE = 0.95$ km/h, $p = .014$) and Lyncroft Street ($M = 26.70$ km/h, $SE = 0.74$ km/h, $p = .002$). Finally, Duggan Avenue also had significantly higher maximum speeds than Buckland Road ($p = .008$) and Lyncroft Street ($p < .001$).

Figure 35

Mean maximum speeds by road type (whiskers = 95% Confidence Interval)

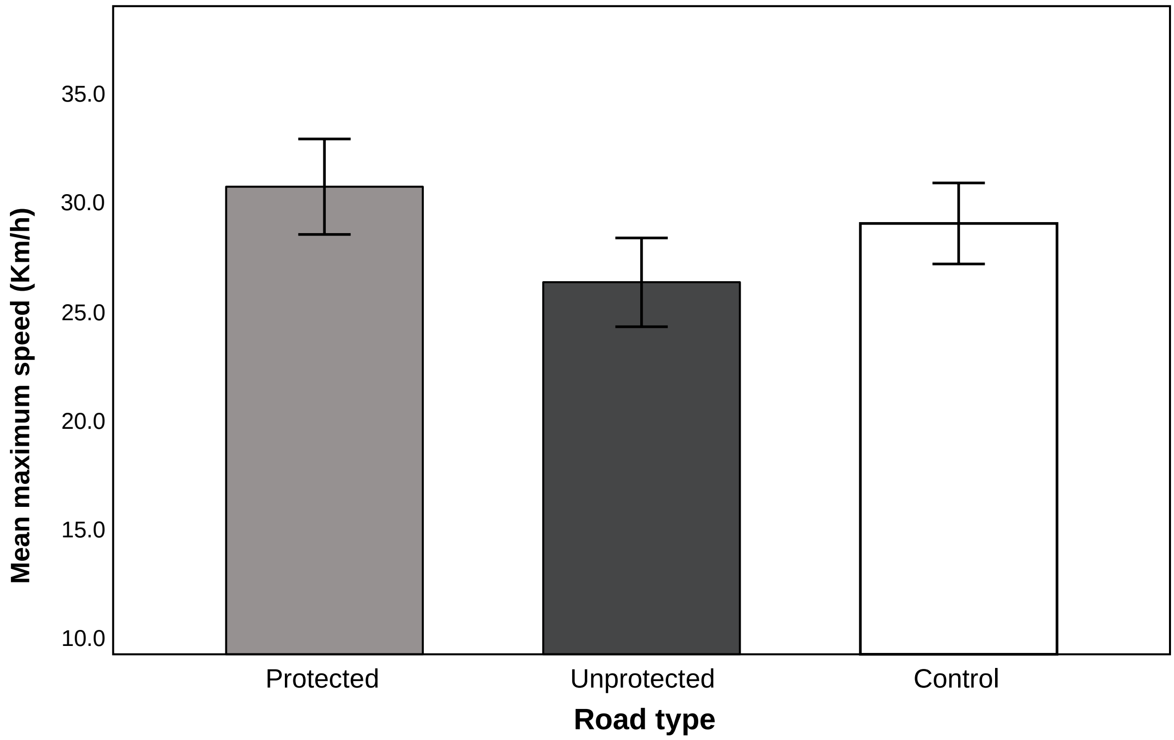
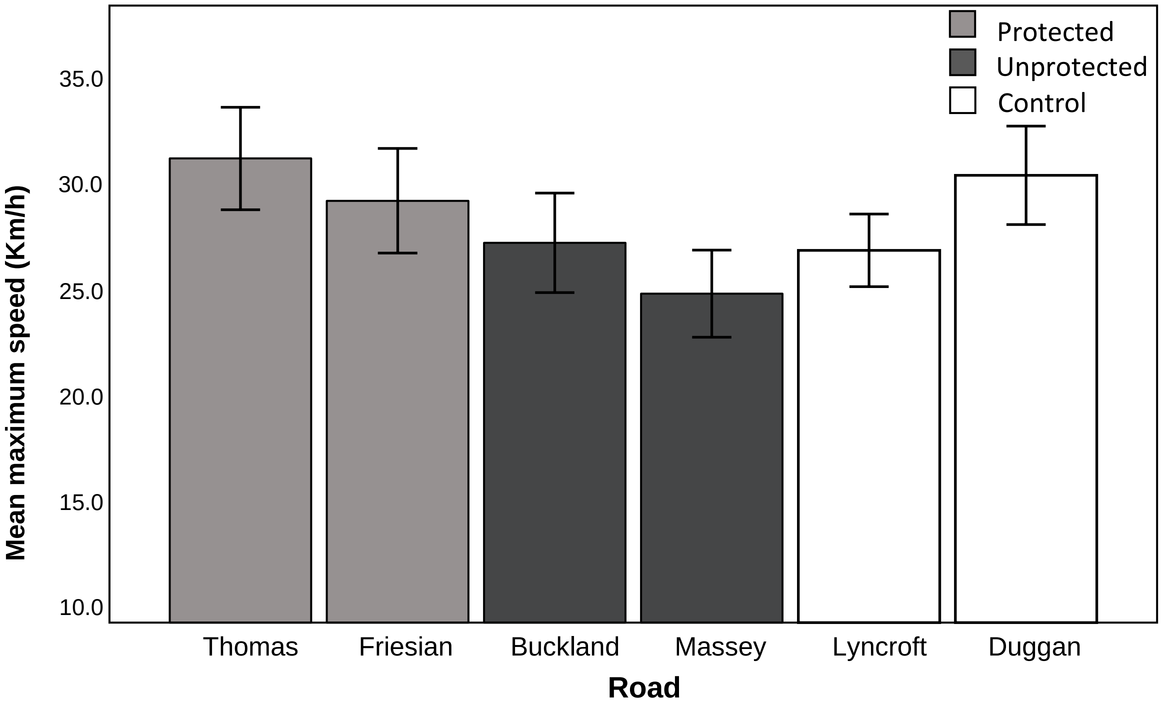


Figure 36

Mean maximum speeds along each road in the study (whiskers = 95% Confidence Interval)



As discussed, there were significant differences in speed in the Control group for average speeds, and in the Control and Unprotected groups for maximum speeds. The Protected group was the only road type that did not contain a significant difference in speed within it in either speed measurements. This finding suggests that grouping the roads by road type is not appropriate for comparing the differences in participants' speed choices.

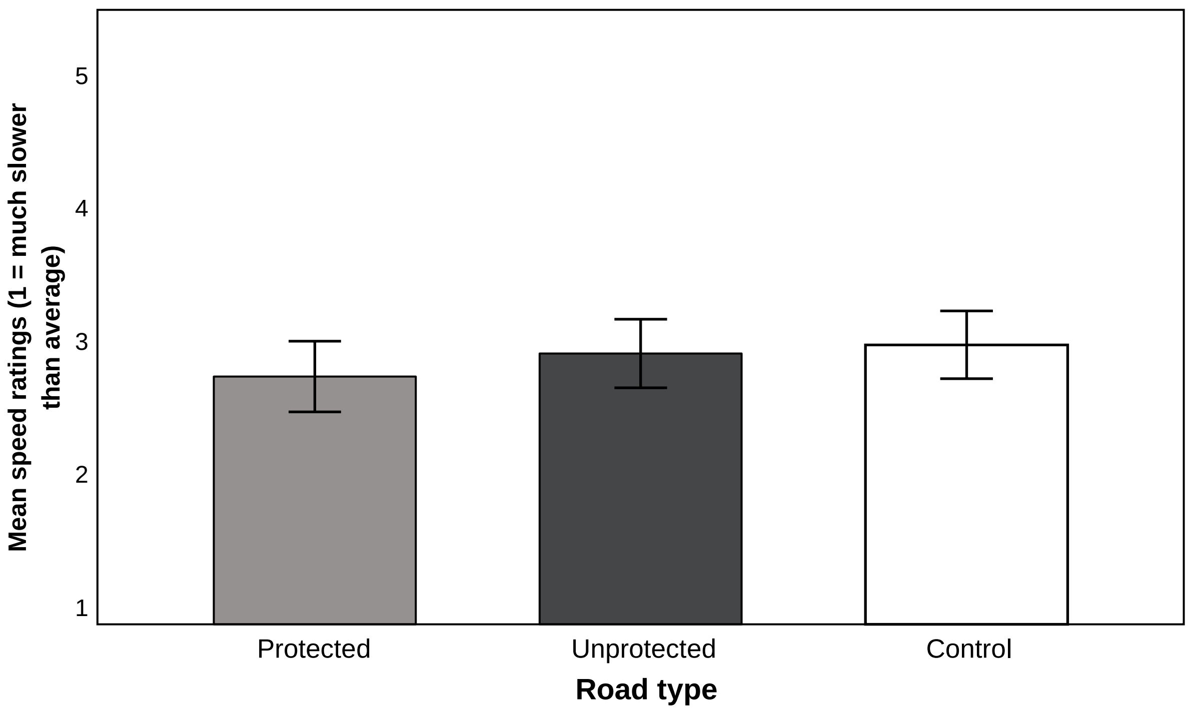
3.2.5. Speed (self-reported)

Additional to recording participants real-time speed, they were also asked how quickly they cycled on each road relative to their average speed. Figure 37 illustrates participants' answers for this question by road type. The similar ratings shown in Figure 37 suggests responses did not vary much between road types. The clustering of answers around three and the small CIs for each road type show participants generally reported travelling at an average speed for themselves regardless of road type.

Results from a repeated measures two-way ANOVA did not find any significant within-subjects differences of reported speed by road type (F(2,44) = 1.76, p = .18, ηp2 = .074) and no between-subjects (order) effect was found (F(1,22) = 2.06, p = .16, ηp2 = .085). No significant interaction between order and road type for participants' speed ratings was found either ($F(2,44)$ = 2.86, p = .068, η_p^2 = .26).

Figure 37

Mean self-report speed ratings by road type (whiskers = 95% Confidence Interval)



Another repeated measures 2 (order) x 6 (individual road) ANOVA was conducted to see if any significant differences existed between the individual roads. No within subjects effect for road condition (F(5,105)= 1.38, p = .24, η_p^2 = .062) and no between-subjects effect for order (F(1,21) = 2.51, p = .13, η_p^2 = .11) was found. Additionally, no significant interaction between order and the road participants cycled on was found for participants' speed ratings (F(5,105) = 1.81, p = .12, η_p^2 = .079). No significant differences were observed between the individual roads for speed ratings in a post-hoc Bonferroni-adjusted pairwise comparison test either.

Two Pearson's correlations between participants' speed ratings (SR) and both speed measurements were also conducted to see how accurately they reported their speeds. Most of the relationships were positive and weak except for negative relationships found for Thomas Road (SR x average speed R = -0.09, p = 0.69; SR x maximum speed R = -0.11, p = 0. 61), and moderate relationships on Duggan Avenue (SR x average speed R = 0.38, p = 0.073; SR x maximum speed R = 0.39, p = 0.066). However, no significant relationship was observed between participants' reported speeds and any of their observed speeds.

3.2.6. Head turns

The amount participants turned their heads were also compared between road type and individual road. These differences were analysed as scattered visual attention can indicate an increased mental workload, and unfocused attention can lead to lowered hazard detection. Therefore, knowing if visual behaviour changes on different road layouts may assist in understanding the state cyclists are in when using them (to infer attractiveness) and safety.

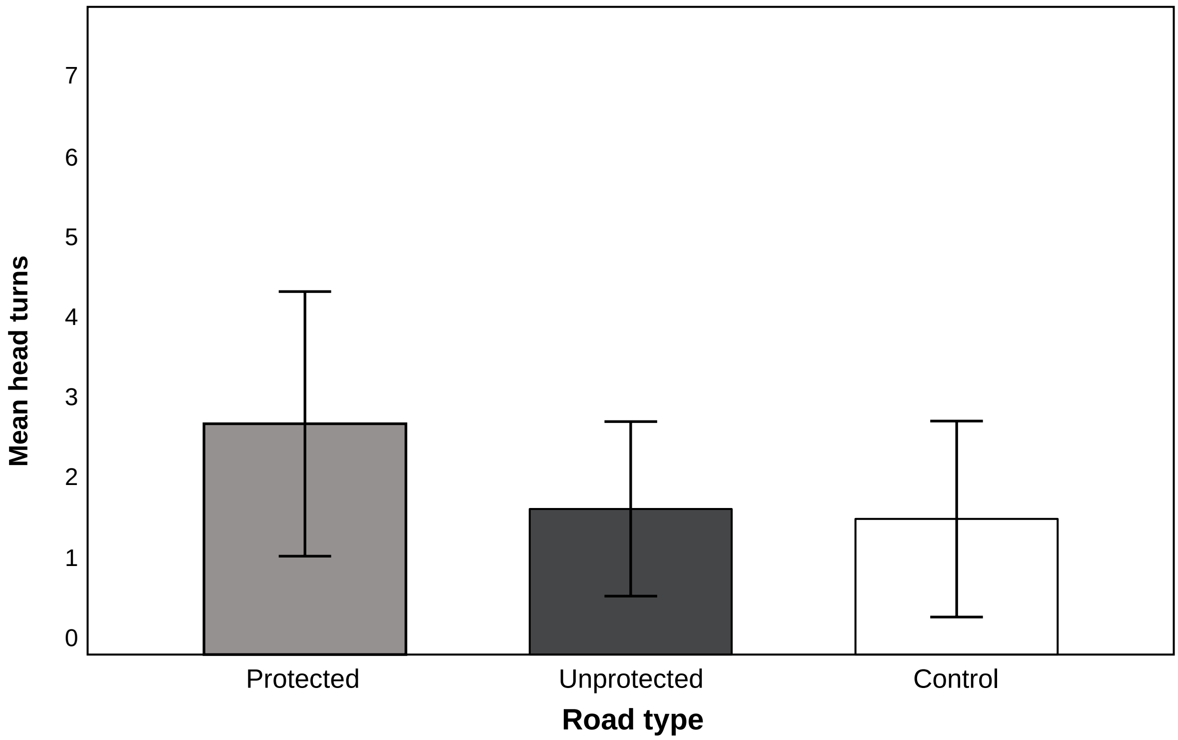
Before analysing the head turn results, an inter-observer reliability test was performed on the counts using an independent observer's head turn count data for the same road sections. The results for this test were above 0.70, indicating a high level of agreement (K = .84, approximate p < .001).

Figure 38 shows the average rate participants turned their heads by road type. As shown, participants tended to complete more head turns when on the Protected roads (*M* = 3.38, *SE* = .67) compared with both the Unprotected (*M* = 2.50, *SE* = .43) and the Control roads (*M* = 2.40, *SE* = .48). However, the CI was also larger for the Protected road type, suggesting more variation in participants' actions between or within the Protected roads.

To see whether these differences were significant (or if experimental order affected participants' rate of head turns), a repeated measures 2 (order) x 3 (road type) ANOVA was conducted on participants' head turns. No significant effect was found of road type for head turns ($F(2,44) = 3.07$, $p = .056$, $\eta_p^2 = .12$), or order and head turns ($F(1,22) = .90$, $p = .35$, $\eta_p^2 = .039$). Additionally, the ANOVA failed to find a significant interaction effect between road type and order for participants' rate of head turns ($F(2,44) = .42$, $p = .66$, $\eta_p^2 = .019$). No statistical differences were found between road types when a post-hoc Bonferroni-adjusted pairwise comparison test was run.

Figure 38

Mean head turns by road type (whiskers = 95% Confidence Interval)



Below, Figure 39 shows how participants' rate of head turns differed between the individual roads. As demonstrated by the graph, Thomas Road had a higher rate of head turns than the others (*M* = 4.48). However, the spread of head turns on Thomas road (95% CI [2.46, 6.50]) was also the greatest comparatively, suggesting that the mean is not a precise metric for assuming what most people would do on this road. On the other hand, Duggan Avenue had the smallest mean rate of head turns (*M* = 1.15, *SE* = .48) and had a CI similar to the other roads. Finally, like the speed data, there seemed to be notable differences in behaviour between the roads in two out of three road types (Protected and Control) (see Figure 39).

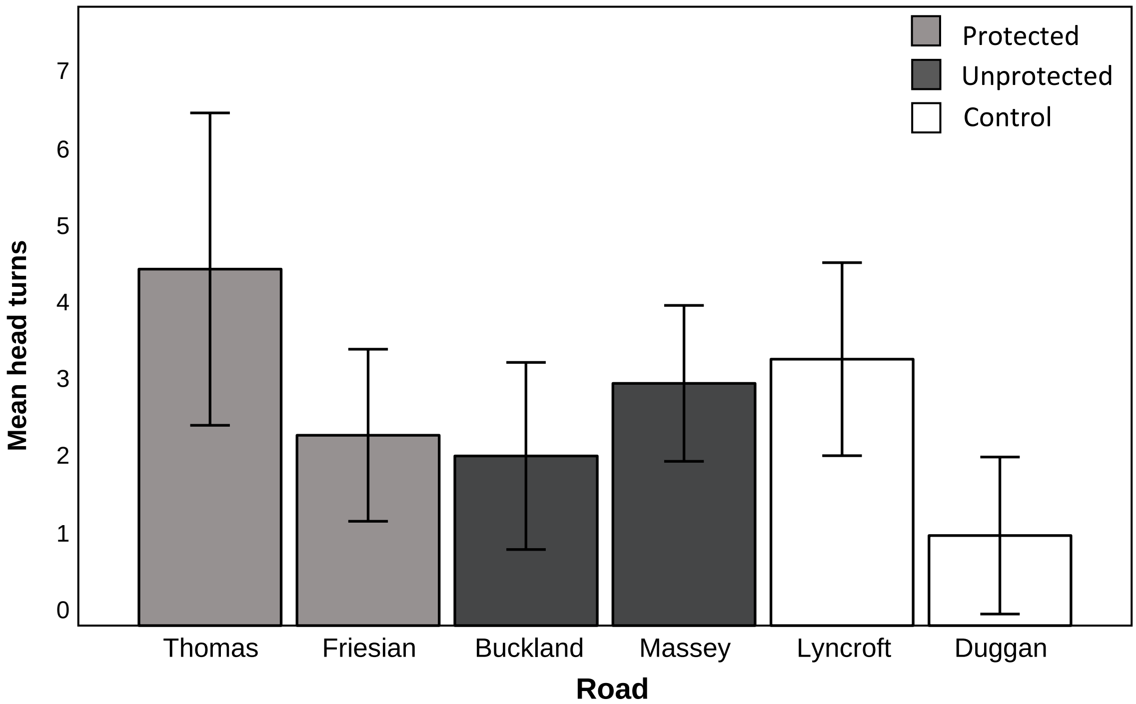
Results from a 2 (order) x 6 (road) repeated measures ANOVA found significant differences between the roads participants cycled on and how many head turns they completed (*F*(5,105) =

7.78, $p < .001$, $\eta_p^2 = .27$). The effect size for this result was small, however. No order effect ($F(1,21) = .89$, $p = .36$, $\eta_p^2 = .041$) or interaction effect between order and road ($F(5,105) = .29$, $p = .92$, $\eta_p^2 = .014$) for participants' head turns was observed.

Results from a post-hoc Bonferroni-adjusted pairwise comparison test showed that participants tended to turn their head significantly more on Thomas Road (*M* = 4.48) compared with Buckland Road (*M* = 2.16, *p* = .011) and Duggan Avenue (*M* = 1.15, *p* = .016). Additionally, participants tended to conduct less head turns on Duggan Avenue compared to Massey Road (*M* = 3.06, *p* = .028) and Lyncroft Street (*M* = 3.38, *p* = .002). A significant difference was also found between Buckland Road (*M* = 2.16) and Lyncroft Street (*M* = 3.38, *p* = .009).

Figure 39

Mean head turns on each road (whiskers = 95% Confidence Interval)



3.2.7. Expected Hazards

For each road, the same two hazard questions from the online questionnaire were asked. As a reminder, the first asked which hazards participants would usually expect on a road like the one in question. The second asked participants to give a concern rating (ranging from 'mildly concerning' to 'very concerning') for each selected hazard. The frequency in which participants selected a hazard per road is shown in Table 5, as well as the median ratings for that hazard in parentheses.

Table 5

Count of each hazard chosen as a concern for each road with median concern rating in parentheses

Hazard	Thomas (Protected)	Friesian (Protected)	Buckland (Unprotected)	Massey (Unprotected)	Lyncroft (Control)	Duggan (Control)
Pedestrians	8 (1)	9 (1)	8 (1)	7 (1)	12 (1)	12 (1)
Other cyclists	8 (1)	4 (1.5)	7 (1)	7 (2)	5 (1)	7 (1)
Vehicles next to/behind you	10 (3)	10 (2.5)	22 (2)	21 (3)	16 (2)	13 (2)
Parked cars/open doors	15 (2.5)	16 (2.5)	20 (3)	16 (3)	20 (2)	19 (2)
Cars driveways	20 (2)	20 (2)	19 (2)	22 (2)	17 (2)	19 (2)
Cars sidestreets	21 (2)	18 (2)	20 (2)	21 (2)	12 (2)	12 (2)
other	6 (3)	4 (3)	4 (2)	2 (2)	2 (2)	4 (3)
Total	88	81	100	96	84	86

The concern ratings participants gave for each hazard on each road were then totalled together to create a dependent variable called total hazard-concern rating. This variable was compared between the roads and road types to observe differences in (total) hazard-related concern. Below, Figure 40 shows the mean total hazard-concern scores participants gave by road type. As shown, the participants' total hazard-concern ratings were highest for the Unprotected group (M = 9.42, SE = .83) followed by the Protected (M = 8.00, SE = 1.12) and Control group (M = 7.40, SE = 1.04). The CIs for the Protected and Control groups are also larger than the Unprotected's, suggesting a greater spread in answers within these groups comparatively.

A repeated measures 2 (order) x 3 (road type) ANOVA was then conducted to determine if any differences in the ratings between the road types were significant. The results showed significant differences between road type for participants' total hazard-concern ratings ($F(2,44) = 5.48$, $p = .008$). The effect size for this result was small, however ($\eta_p^2 = .20$). A significant interaction effect between road type and order for participants' total hazard-concern scores was also found ($F(2,44) = 5.29$, $p = .009$, $\eta_p^2 = .19$). This interaction effect is illustrated in Figure 41. As shown, participants tended to have higher total concern ratings for the Unprotected group when they completed the Unprotected route first. However, the other two road types did not seem affected by order. The interaction effect had a small effect size too. No effect from order alone was found for participants' scores ($F(1,22) = .29$, $p = .59$, $\eta_p^2 = .013$).

Results from a post-hoc Bonferroni-adjusted pairwise comparison test found a significant difference in participants' total hazard-concern scores between the Unprotected and Control roads ($p = .005$). However, no significant difference was observed between the Protected and Unprotected roads' hazard-concern ratings ($p = 1.00$) or the Protected and Control roads' ($p = .11$).

Figure 40

Mean of the total concern rating participants gave for each road type (whiskers = 95% Confidence Interval)

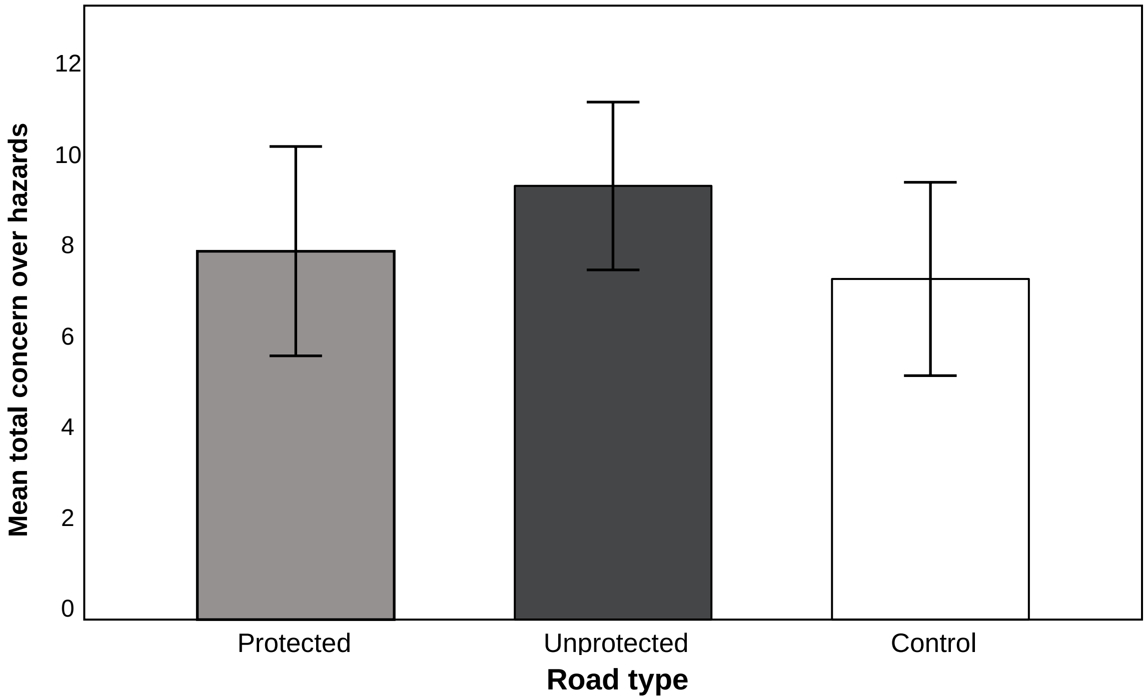
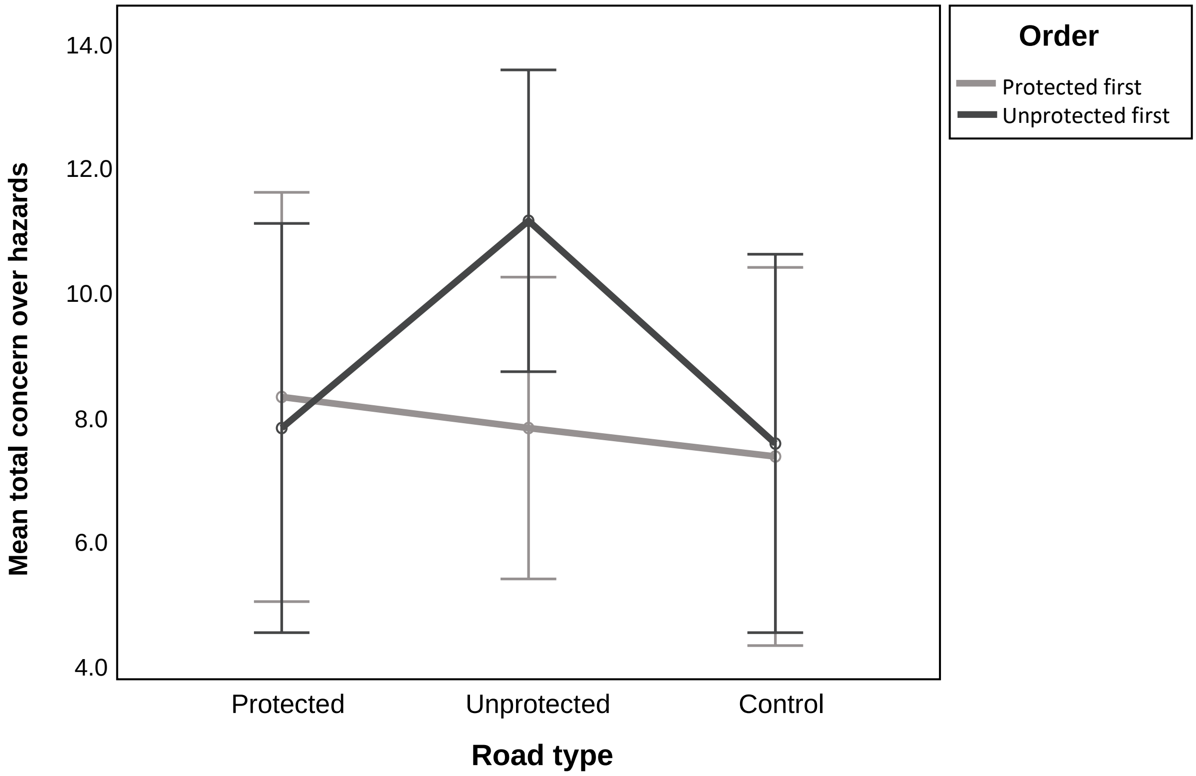


Figure 41

Mean of the total concern rating participants gave by road type and experimental order (whiskers = 95% Confidence Interval)



The differences in total hazard-concern scores for the individual roads were then compared (see Figure 42). As depicted, both the Unprotected roads (Massey M = 9.42, SE = .97; Buckland M = 9.30, SE = .96), had the highest means followed by the Protected roads (Thomas M = 8.38, SE = 1.19; Friesian M = 7.92, SE = 1.18), then the Control roads (Duggan M = 7.68, SE = 1.19; Lyncroft M = 6.68, SE = 1.09). What is also noticeable in Figure 42 is how similar participants' ratings were within each road type. This uniformity is especially prominent for the Unprotected roads, Buckland and Massey Road, and the least for the Control roads, Duggan Avenue and Lyncroft Street.

Results from a repeated measures 2 (order) x 6 (individual road) ANOVA found significant differences between the roads for participants' total hazard-concern scores ($F(5,105) = 3.51$, $p = .006$). Again, the effect size for this statistic was small ($\eta_p^2 = .14$). An interaction effect was also found between order and individual road on participants' total hazard-concern scores which also had a small effect size (F(5,105) = 3.37, p = .007, η_p^2 = .14). As shown in Figure 43, hazard-concern scores increased for both Unprotected roads when participants completed the Unprotected route first (Protected first: Buckland M = 7.18, SE = 1.38, Massey M = 8.09, SE = 1.41; Unprotected first: Massey M = 11.42, SE = 1.33, Buckland M = 10.75, SE = 1.35). This difference was especially prominent for Buckland Road. No effect from order on participants' scores was found (F(1,21) = .31, p = .58, η_p^2 = .015).

A post-hoc Bonferroni-adjusted pairwise comparison test was then conducted to determine pairwise differences between road pairs for mean hazard-concern scores. Only one significant difference was found between Massey Road and Lyncroft Street (p = .003).

Figure 42

Mean of the total hazard-concern rating participants gave for each road (whiskers = 95% Confidence Interval)

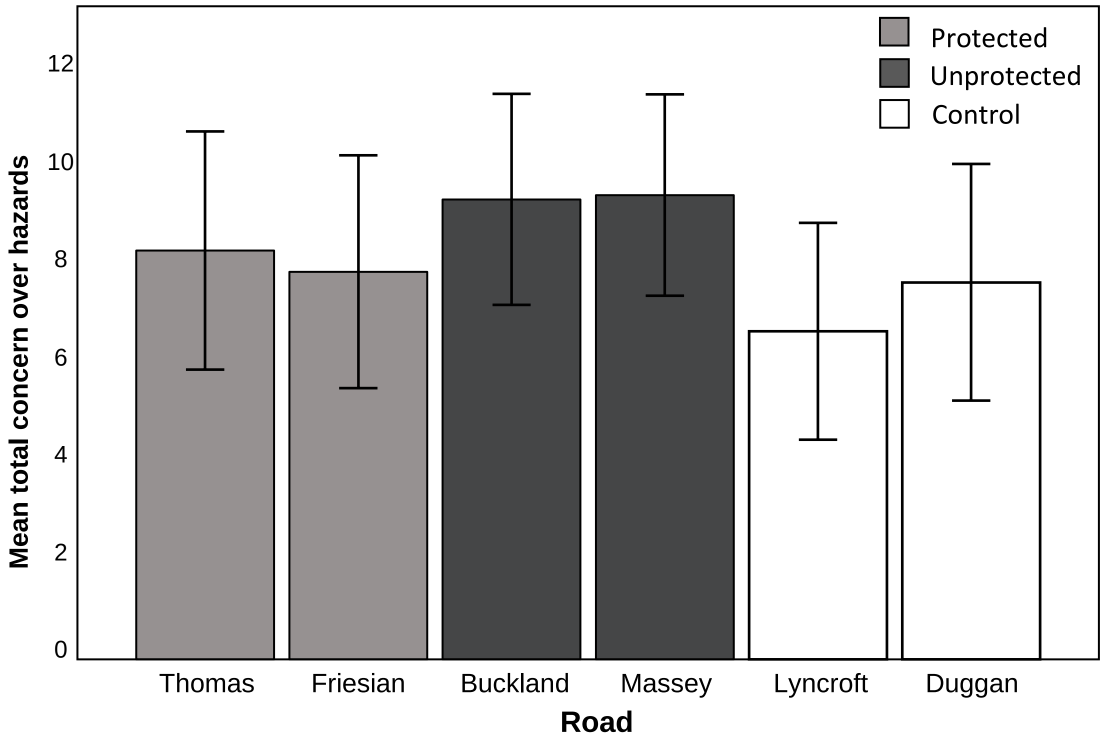
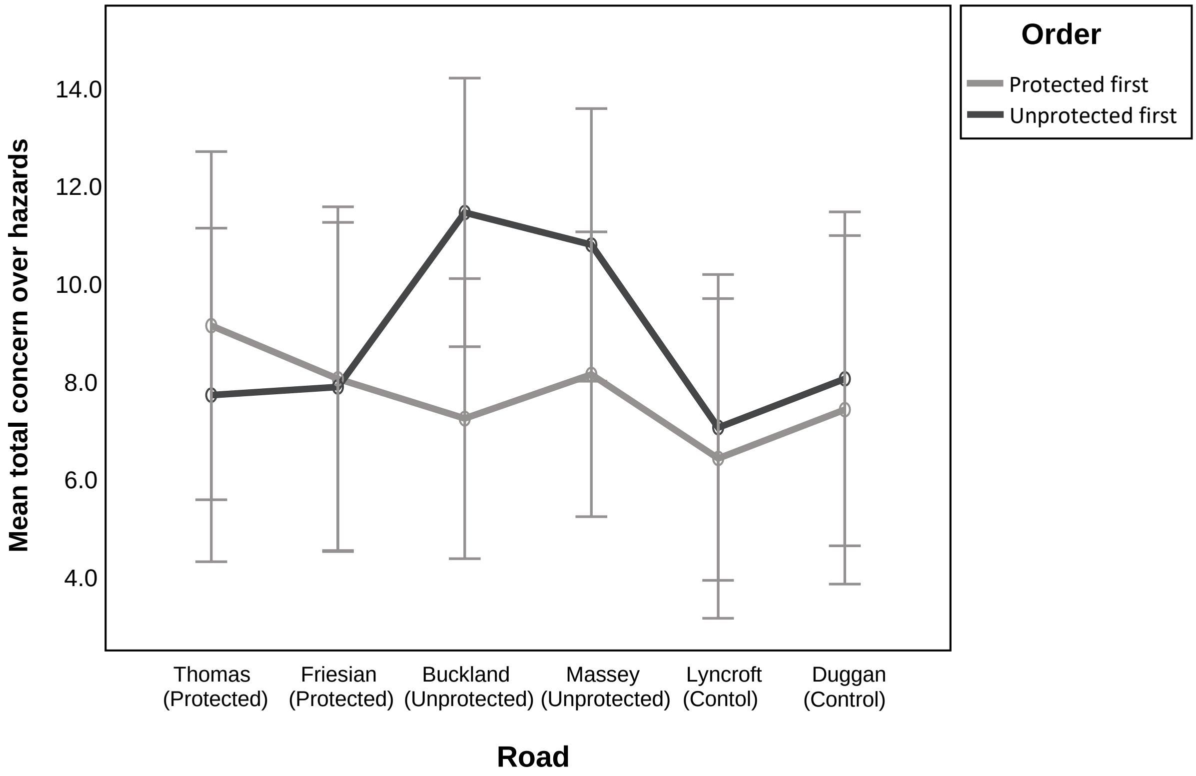


Figure 43

Mean of the total hazard-concern rating participants gave by individual road and experimental order (whiskers = 95% Confidence Interval)



Due to the relatively high ratings the 'other' category received, the text descriptions for this option were reviewed to see if these ratings were interfering with the results. In nearly all instances, 'other' counts related to issues on the road which are not fundamental to its infrastructure or traffic, such as 'broken glass' or 'loose dogs'. Because of this finding, both ANOVAs conducted above were re-run without the scores obtained from the 'other' category to see if removing these (potentially cultural) hazards affected the outcomes.

Results from the repeated measures 2 (order) by 3 (road type) ANOVA showed a significant effect from road type for total hazard-concern ($F(2,44) = 7.26$, $p = .002$) with an increase in (but still small) effect size ($\eta_p^2 = .25$). Again, a significant interaction effect between road type and order was also found on participants' total hazard-concern ratings ($F(2,44) = 4.55$, $p = .016$) with a small effect size (η_p^2 = .17). This interaction effect was very similar to that depicted in Figure 41. No order effect was found *(F*(1,22) = .23, *p* = .64, η_p^2 = .010). Most notably, the post-hoc Bonferroni-adjusted pairwise comparison results now showed a significant difference in total hazard-concern scores between the Protected (*M* = 7.44, *SE* = 1.05) and Unprotected roads (*M* = 9.19, *SE* = .81, p = .030), and again between the Unprotected and the Control groups (*M* = 7.06, *SE* = 1.00, *p* = .003). No significant difference between hazard-concern ratings for the Protected and Control group was found (*p* = 1.00).

The repeated measures 2 (order) by 6 (road) ANOVA revealed a significant effect from road on hazard-concern ratings (*F*(5,105) = 4.49, *p* = .002). Again, the effect size was small (η_p^2 = .17). Another significant interaction effect between individual road and order was found on participants' hazard-concern scores (*F*(5,105) = 2.99, *p* = .015); the effect size was small (η_p^2 = .13). This interaction effect was very similar to that depicted in Figure 43. No order effect was found (*F*(1,21) = .26, *p* = .62, η_p^2 = .012). The post-hoc Bonferroni-adjusted pairwise comparison tests showed another significant difference between road pairs, between Lyncroft Street (*M* = 6.51, *SE* = 1.11) and the other Unprotected road, Buckland Road (*M* = 9.01, *SE* = .92, *p* = .035), in addition to the difference between Lyncroft Street and Massey Road (*M* = 9.25, *SE* = .96, *p* = .005).

It is interesting that when other hazards less fundamental to transport conditions were removed, there was an increased gap between the Protected and Control roads from the Unprotected roads in terms of hazard-concern. However, with the available data, it is impossible to determine whether participants' scores would have remained stable if the 'other' hazard concerns were not there for participants. For example, they may have, relatively, found other things more concerning without them (due to a lack of comparison) or less concerning (due to being relaxed due to a lower workload, perhaps). Because of this lack of clarity, the other-inclusive data has been used in other calculations when determining the relationships between total hazard-concern scores and other data measured.

3.2.8. Self-reported behaviour at intersections

As mentioned, participants were also asked to rate how fast they were travelling as they approached and went past a side street intersection for each road. Predominantly, participants said they went the same speed past the side street on each road, followed by saying they slowed down. Lyncroft Street had the greatest proportion of participants saying they would continue going the same speed, while Duggan Avenue (the other Control road) had the smallest. Several participants also reported they could not remember the side street or their approaching speed for the different roads, the count of which did not differ greatly between the roads.

A related sample two-way Friedman's ANOVA by ranks test was used to calculate whether the differences in speed ratings at intersections was significant. The test results showed a significant difference in how fast participants said they would go through side street intersections between the roads ($X^2_F(5) = 12.88$, $p = .025$). However, post-hoc pairwise Friedman tests did not find any significant differences in speed ratings between road pairs.

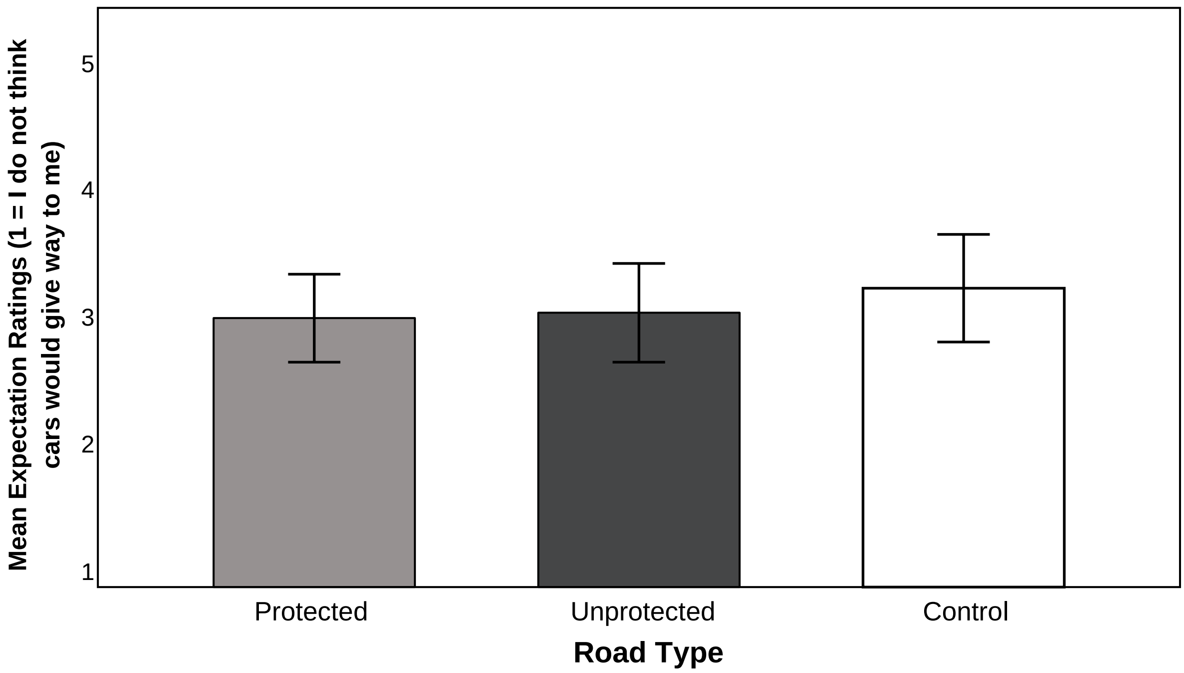
3.2.9. Expectations of cars at intersections

In the post-ride questionnaire, participants also rated whether they thought cars would give way to them at side street intersections for each road. Figure 44 shows how these ratings differed by road type. As shown, the mean for each group was close to three, "I'm not sure whether turning cars would give way or not". Additionally, the CIs were similar in size between road types. Altogether, each group's confidence interval (95%) ranged from a minimum lower bound rating of 2.72 (Unprotected) to an upper bound rating of 3.71 (Control). These results suggest participants generally clustered around a neutral response, where participants neither expected cars to give way or not give way.

An initial 2 (order) x 3 (road type) ANOVA was conducted before doing a paired sample t-tests between each road type pair. The ANOVA failed to indicate a significant difference between road types in terms of participants' expectations of cars at side street intersections ($F(2,44) = 1.05$, $p = .36$, $\eta_p^2 = .045$). A between-subjects test found no significant effect from order ($F(1,22) = .38$, $p = .54$, $\eta_p^2 = .017$), and no significant interaction between order and road type was found for participants' expectations either ($F(2,44) = .13$, $p = .88$, $\eta_p^2 = .006$). No significant differences between each road type pair were found from a post-hoc Bonferroni-adjusted pairwise comparison test. Because of the non-significant result, no further tests were conducted between road type.

Figure 44

Mean side-street expectation ratings by road type (whiskers = 95% Confidence Interval)



Similar to road type, the individual roads each had a mean of around three “I’m not sure whether turning cars would give way or not”. Again, a repeated measures two-way ANOVA between road and order, found no significant differences between the roads and how participants rated them ($F(5,100) = 1.09$, $p = .37$, $\eta_p^2 = .052$) and no order effect was observed either ($F(1,20) = .034$, $p = .86$, $\eta_p^2 = .002$). Again, no significant interaction between order and road condition was found for participants’ expectations ($F(5,100) = .80$, $p = .55$, $\eta_p^2 = .039$), and no significant differences were found from a post-hoc Bonferroni-adjusted pairwise comparison test. Because no significant differences were found, no further tests were conducted on the data.

3.2.10. Observed behaviour at intersections

Unfortunately, speed and head turn data at each intersection were not analysed. This decision was based on a couple of reasons. The first is that ride with GPS does not collect speed data at exact locations, so the spatial parameters for where each intersection began and ended could not be kept stable to consistently record before and after speeds. Secondly, when the speed data was observed in a scope larger than local changes at intersections, most speed changes at intersections were embedded in greater speed-change trajectories that covered bigger distances than the intersection. Because of these two issues, obtaining reliable speed data or attributing observed speed changes to intersections themselves was difficult. Lastly, head turns were not seen as an accurate measurement for eye gaze behaviour at this point in data analysis. Therefore, head turn behaviour at intersections was not analysed either. See section 4.1.2. for more details.

Finally, several Pearson's correlations were carried out to determine if other relationships in the data could enrich the above results. Namely, the relationships between safety ratings and hazard-concern ratings and participants' behaviour were investigated, followed by how safety and hazard-concern ratings related to one another.

3.2.11. Observed Speed, Safety and Total Hazard-Concern Ratings

First, four, two-tailed Pearson's Correlations were run between participants' safety and hazard-concern ratings and how fast they travelled on each road. These tests were conducted to assess whether the hypotheses under the Zero-Risk Theory and the TCI model are correct; that people will travel faster if they feel safer or if they have a smaller mental workload. Both participants' average and maximum speeds on each road were paired with the safety and total hazard-concern ratings for the same road (see Table 6 for results).

As shown in Table 6, there was no consistent direction in the relationships between safety ratings and either speed measurements. However, for total hazard-concern, there was a consistent negative relationship with speed (i.e., as total hazard-concern increased, speed decreased). Regardless, no significant relationships were observed between participants' safety or total hazard-concern ratings and either speed measurements. Additionally, most of the coefficients between speed and total hazard-concern were very weak.

Table 6

Pearson's Correlation results between participants' safety and total hazard-concern ratings, and their average and maximum speeds for each road.

		Protected		Unprotected		Control	
		Thomas	Friesian	Buckland	Massey	Lyncroft	Duggan
Safety x Average speed	Pearson's R	0.074	-0.129	0.044	-0.018	-0.001	0.263
	P	0.731	0.557	0.838	0.934	0.996	0.225
	N	24	23	24	24	24	23
Safety x Maximum speed	Pearson's R	0.150	-0.124	-0.004	0.173	0.103	0.098
	P	0.484	0.574	0.985	0.419	0.633	0.658
	N	24	23	24	24	24	23
Hazards x Average speed	Pearson's R	-0.033	-0.073	-0.067	-0.074	-0.098	-0.359
	P	0.878	0.741	0.757	0.732	0.649	0.093
	N	24	23	24	24	24	23
Hazards x Maximum Speed	Pearson's R	-0.179	-0.093	-0.020	-0.106	-0.126	-0.140
	P	0.401	0.674	0.926	0.623	0.559	0.525
	N	24	23	24	24	24	23

3.2.12. Head Turns and Safety Ratings

The rate participants turned their heads on the individual roads was also compared with safety and hazard-concern ratings to see if feelings of safety or workload overwhelm was correlated with looking around more for participants. A Pearson's two-tailed correlation found no consistent relationship between safety ratings and head turns (see results in Table 7). To expand, most of the relationships were negative (showing a decrease in head turns with higher safety ratings), but on Friesian, it was positive. Similarly, only one road illustrated a significant relationship between head turns and hazard-concern ratings (Thomas Road), while the rest failed to do so. Moreover, the R statistics between hazard-concern ratings and head turns were higher on average than between safety ratings and head turns. Additionally, all the relationships were positive, suggesting that as hazard-concern ratings decreased, so did participants' rate of head turns.

Table 7

Pearson's Correlation results between participants' safety and total hazard-concern ratings and head turns for each road.

		Protected		Unprotected		Control	
		Thomas	Friesian	Buckland	Massey	Lyncroft	Duggan
Safety x Head turns	Pearson's R	-0.034	0.149	-0.250	-0.258	-0.152	-0.013
	P	0.873	0.498	0.238	0.223	0.477	0.952
	N	24	23	24	24	24	23
Hazards x Head turns	Pearson's R	**0.464**	0.340	0.161	0.205	0.252	0.296
	P	**0.022**	0.113	0.452	0.337	0.236	0.171
	N	**24**	23	24	24	24	23

3.2.13. Hazard ratings and Safety Ratings

Finally, a two-tailed Pearson's correlation was again used to examine the relationship between participants' safety ratings and hazard-concern ratings. This relationship was examined to see if a relationship existed between workload and feeling unsafe for participants. The results showed that the relationships between hazard-concern and safety ratings were consistently negative for the roads (see Table 8). However, this relationship was only significant for Thomas Road, Buckland Road and Lyncroft Street (see results in bold). Interestingly, there was no consistent pattern in terms of what road type the significant relationships were in as they occurred in each road type.

Table 8

Pearson's Correlation results between participants' total hazard-concern scores and safety ratings for each road.

		Protected		**Unprotected**		**Control**	
		Thomas	Friesian	Buckland	Massey	Lyncroft	Duggan
Safety x Hazards	Pearson's R	**-0.635**	-0.274	**-0.519**	-0.288	**-0.517**	-0.374
	P	**0.001**	0.205	**0.009**	0.173	**0.010**	0.078
	N	**24**	23	**24**	24	**24**	23

4. Discussion

4.1 Main Findings

To encourage cycling in places with low cycling rates, we need to make it a desirable and safe option. A review of the literature found that a critical part of achieving these goals is decreasing both the subjective and objective risks of cycling. PCLs are a potential option to meet these goals, as several studies have shown they improve both desirability and safety. However, some studies' results have conflicted about whether they decrease crash rates, especially at intersections.

To fill this knowledge gap and make sure PCLs are desirable for New Zealand cyclists, the primary goals of this thesis were to compare PCLs to painted bike lanes in terms of desirability and potential to increase cycling, and whether cyclists changed their behaviour in separated lanes. Understanding both can arm decision-makers to increase cycling rates while keeping cyclists safe.

4.1.1. Factors related to use.

Three measures were collected to see what types of roads in the study may attract more use: safety ratings, measures of willingness to allow children to bike on the road, and levels of anticipation (or dread) in coming up to a road. As a reminder, these three were decided upon for the following reasons: lack of safety is cited as the main barrier to cycling in many countries, including New Zealand (Wang et al., 2011); adults essentially decide if children bike or not, so their willingness to let children ride their bikes is key to increasing children's mode share (Cycling Safety Panel, 2014; Lorenc et al., 2008); and dread creates behavioural resistance to an activity, which may stop people from doing said activity. Therefore, it was concluded that if PCLs improved these measures, installing them might attract more people to cycling. The first two measures were collected in both the post-ride and online questionnaire and the latter, only in the post-ride study

Altogether, the results provide support for the idea that physical separators can increase ratings related to use. Safety and willingness had similar trends in both studies: participants tended to feel safer and more willing (to allow kids to bike on the road). Additionally, participants said they felt less pre-emptive dread towards PCLs than painted bike lanes. Moreover, the results in both studies were consistent between the roads in the Protected group: i.e., regardless of setting, lanes with physical separation were rated favourably. Additionally, PCLs consistently increased respondents' comfort with passing cars, which was also related to higher safety ratings.

The only other roads which matched or came close to the ratings given to PCLs were the quiet residential streets in both studies. These streets were probably rated highly because of decreased traffic flow (and maybe setting), which, unfortunately, cannot be guaranteed on every road. Conversely, as mentioned, the PCLs were rated highly on measures related to use regardless of traffic flow or setting, as shown in the online questionnaire results. Therefore, installing PCLs on roads in New Zealand people feel unsafe on or would not want their children cycling on may be a good intervention to help improve cycling rates. However, as with most studies, there are limitations to the interpretation of these results. These issues will be discussed in sections 4.2. and 4.3.

4.1.2. Behavioural changes, road type and ratings.

Contradicting some of the research overseas, the results from the on-road study suggest cycling speed does not change according to road type, safety ratings or mental workload. Additionally, no significant differences were found in participants' scanning behaviour (head turning). This finding is positive insofar as the concern cyclists may cycle more haphazardly in PCLs is not supported by these results. However, before concluding these relationships never occur, some methodological limitations should be discussed first.

Local complications could have interfered with any effect road type would have had on participants' speed if tested in a controlled setting. For example, participants frequently mentioned rubbish and vehicles parked in the PCLs, which may have prompted them to cycle slower on average even if they did not feel frightened or report more hazard-concern. The same results may not have occurred in an area where these obstacles were absent in the PCLs.

Additionally, the lack of results from the head turn data may be because 'head turns' could not pick up subtler glance shifts. For example, I (the researcher) tested the eye-tracking glasses and the camera for picking up visual behaviour. It was indiscernible from the camera footage when I was scanning intersections from a distance and when the camera randomly shook. This lack of clarity came from the distance between myself and the intersections, i.e., I did not need to move my head much to scan them. It is very likely the same was present for participants when they looked at intersections and other points of interest from afar.

Moreover, sometimes it seemed like participants were looking around for reasons unrelated to hazards or safety concerns. For example, a head turn cannot distinguish between looking at houses while in a state of relaxation and looking at driveways due to fear of reversing vehicles. This false equivalency may be why head turns were not higher on the roads with lower safety or higher hazard-concern ratings.

4.1.3. Implications to theory

As mentioned, there were no consistent relationships between feelings of risk, increased hazard-concern and speed. Because of this, there is little surface-level support for either the TCI model or the Zero-Risk Theory in cyclists' behaviour. Conversely, as mentioned, these results cannot prove that no relationship exists as a range of methodological issues could have interfered with measuring the relevant data, such as noise in the data created by local conditions. Additionally, an issue that has not been discussed yet in relation to methodological limitations or the theories at hand is the speed differences that did exist.

While there was no consistent relationship between speed and road type, one road from both the Protected and Control road types had higher speed measurements than other roads, and one Unprotected Road had lower speeds. Namely, the maximum speeds on Thomas Road (Protected) were higher than the other roads; the average and maximum speeds on Duggan Avenue (Control) were also higher, and participants' speeds on Massey Road (Unprotected) were lower than every other road for both speed measurements. These findings align with what was expected if either the TCI model or the Zero-Risk Theory explain cyclists' speed choices. So, the following sections look at each speed discrepancy to see if they can be explained using either model or if something else may explain the findings better.

Firstly, the maximum speed difference found on Thomas Road may have been due to a decline in elevation that occurred on the road. However, the speeds on Massey Road (Unprotected) and Duggan Avenue (Control) differed from the other roads (including those within their road type) when both the Control and Unprotected road types had internally consistent safety and hazard-concern ratings and elevation.

When these roads are looked at closer, several hypotheses can be made about why Duggan Avenue's and Massey Road's speed ratings differed from the other roads in their road type. Supporting each idea is a concern the safety and mental workload measures may have varied from participants' real-time states on the road.

For example, Duggan Avenue was located after the PCLs, which were rated safer and less hazardous, while Lyncroft Street was located after Buckland and Massey Road, which were rated poorly. It's possible that riding on the lower-rated streets first may have increased participants' arousal states which could have carried onto Lyncroft Street, lowering their speeds. This hypothesis is plausible when considering the interaction effect between participants' average speeds and order of presentation; those who cycled the unprotected route first, which had lower safety and higher hazard-concern ratings, generally biked slower overall. Such findings would align with another research paper published in 2013 on gambling behaviour and arousal. The author found that after participants' heart rates increased from biking, their gambling behaviour became more risk-averse even though their risk ratings for similar gambling actions did not change (Schmidt et al., 2013).

Additionally, it's possible that people felt less safe or overwhelmed on Massey Road than on Buckland Road, even though they were rated similarly. For example, several participants mentioned they had heard Massey Road was "notoriously bad" for cyclists before cycling on the road but did not mention the same for Buckland. So, the cyclists may have felt less safe or more overwhelmed by this road by stress via negative expectations. Furthermore, the distances between the intersections on Massey Road were between 140 metres and 260 metres (approximately), while the gaps were closer to 400 - 550 metres for Buckland Road. Because of this difference, it is possible that instead of slowing down for each side street intersection, participants chose a slower speed in general out of the increase in workload from seeing cars coming in and out of side streets or from feeling less safe.

The hypotheses used to explain the differences between Massey Road and Buckland Road suggest the ratings of safety and hazard-concern scores may not have been fine-tuned enough to pick up subtle differences in what they were measuring. Instead, it might be that they are good at showing more considerable differences, say between road types, but too blunt to reveal subtle differences between similar roads. Additionally, the ratings may not have picked up on differences in participants' states on Lyncroft Street that had nothing to do with perceptions of safety for that street but by a hangover from coming from roads which elicited higher arousal levels.

Lastly, and alternatively to the situations discussed thus far, there could have been other factors outside the explanatory power of the TCI model of driving behaviour and Zero-Risk Theory that could have accounted for participants' speed differences. For example, Duggan Avenue is located just after an incline, which would have required effort and an increase in physical arousal to get up. Therefore, after coming onto the road, participants may have had more energy available to their body and found cycling on a flat surface relatively easy in the state their body had to get into to get up the hill. As a side note, it was considered that participants' original momentums might have been larger coming onto the road after an incline. However, this hypothesis was ruled out as the start speeds on Duggan Avenue and the other roads were not different.

Overall, the explanations provided above are merely speculative. Further research is required to determine factors that affect speed choices in cyclists, as this study was unable to answer this. Some ideas for such research are listed in section 4.4.

4.2. A Wider Discussion

As a reminder, the aim of answering the first two research questions was to provide information to go to creating safe interventions which attract use. However, outside of the questions chosen, several relationships in the data could also contribute to these broader aims. Therefore, the following sections explore secondary relationships in the data to provide extra information for these aims.

First, the relationship between hazard-concern and safety ratings is explored. This test was done to test the connectedness between mental workload and risk ratings to see if similar trends in driving studies were found in this one about cyclists. Understanding more about cyclists' psychology, in general, may help further research looking to create safe infrastructural designs.

Second, other relationships were assessed in the data to see if factors other than road type had greater explanatory power over participants' safety ratings. It was hoped doing so would illuminate more solutions that could increase cyclists' perceptions of safety. Additionally, looking at these relationships was done to ensure PCLs' consistently higher ratings were due to their physical protection and not another factor in their designs.

Third, participants' expectations and (self-reported) behaviour at intersections are discussed. These factors were assessed because intersections were usually the point of contention in the reviewed literature about the safety benefits of PCLs. Additionally, understanding if participants' expectations changed could lead to further research that focuses on cognitive explanations for behavioural changes in cyclists, which is outside the scope of this study. Within this discussion, the relationship between observed and self-reported speed will be reflected on too, as a lot of research conducted on cyclists is self-reported. Finally, the relationship between safety and willingness is discussed as knowing more about what improves willingness ratings may help increase cycling rates for children.

4.2.1. Hazard and safety ratings.

Two primary measurements used to test the TCI model and Zero-Risk Theory in this study were participants' safety and total hazard-concern ratings. Visual behaviour was initially intended to work as a measurement for mental workload; however, as discussed, the validity of head turns for mental workload fell through. Therefore, only post-ride total hazard-concern ratings were used to measure mental workload instead. The logic was that if participants expressed more general concern towards hazards, a lot of attention was likely to be placed on assessing the different hazards, thereby increasing workload. Feelings of safety were used to measure what in other papers is called "feelings of risk". Analysing the relationship between the two variables was done to test Fuller's (2008) findings that feelings of risk and mental workload strongly correlate with one another. If they did, it suggests that mental workload may explain the feelings of fear and heightened arousal cyclists feel on the road in this and other studies. However, if they did not correlate, it may suggest experiences of fear may not always be connected to workload for cyclists like it is for drivers in simulated environments.

The results from both studies indicated that the two variables co-occurred significantly on some roads but not others. Ultimately, the observation that the relationship between total hazard-concern scores and safety ratings was not consistently significant implies they measured distinct variables.

On the one hand, this lack of a relationship could mean that feelings of risk did not come from task difficulty. For example, the different hazards listed more frequently in the different roads that made up their hazard-concern scores may explain the differences. To expand, some of the hazards selected may have only or predominantly contributed to mental workload, while others could have also caused perceptions of risk to increase. For example, ‘cars driving next to/behind me’ was cited more frequently for some roads, and ‘comfort with cars passing’ was highly correlated with safety ratings; while higher citings of ‘pedestrians’ or ‘other’ were cited more for others, and may not have increased feelings of fear but still added to hazard-concern scores. So, because the roads had different ratios of these hazards making up their total hazard-concern, it may have affected whether each, on an individual basis, showed a correlation between the two variables. On the other hand, it is possible total hazard-concern scores were not a precise measure of mental workload.

4.2.2. Other factors and safety ratings.

Knowing that PCLs improve factors relating to use is helpful as it gives decision makers a set design that improves these measurements. What would be even more beneficial is if it was understood why PCLs improve these measurements. Understanding this would go beyond support for a specific intervention to knowing what interventions need to do to improve perceptions related to use, which could increase the number of effective design options available. To test what factors improve ratings related to usage, attention was put to the non-protected roads with similar ratings to those in the Protected group in both studies. Understanding if there was a common factor between these roads, the PCLs, and higher safety ratings may help answer this question.

The relationship found between how comfortable participants were with cars passing them and safety ratings in the online questionnaire may be this common factor. After all, safety ratings were related to comfort ratings in each case, while road type cannot account for the similarly rated

Unprotected roads. Additionally, neither the other car-related hazards and hazard-concern ratings consistently correlated with safety ratings like the comfort ratings did.

Of course, no causal claim can be made here, as the data is only correlational. In saying that, additional confidence may be placed in the hypothesis that comfort with cars passing is related to safety ratings, as it is reflected regularly in other studies. As mentioned in the introduction, stated preference studies repeatedly show the same pattern: being separated from traffic makes interventions more desirable and more contact with traffic makes them undesirable (Bowie et al., 2019; Wang et al., 2011). Lastly, a principal reason people don't cycle is that they feel unsafe (Cycling Safety Panel, 2014; Waka Kotahi, 2021; Wang et al., 2011). Taken together, it is not impossible discomfort with passing vehicles and feelings of safety are related, and that use will increase if they are improved.

If higher levels of comfort with passing cars are related to higher safety ratings, it would be helpful to develop a broader understanding of what increases this comfort for cyclists. It would also be beneficial to know if the physical separation in the PCLs increased participants' comfort or something else about the designs did. Therefore, the following sections explore what it could have been about the other videos in the online questionnaire that contributed to the high comfort ratings participants gave them and if the PCLs had the same characteristics in addition to the physical barriers.

An obvious variable that may have decreased participants' comfort with passing cars is greater traffic volume. Indeed, two of the lowest-rated videos in terms of safety and comfort appeared to have higher traffic volumes (Video 1 (Unprotected) and Video 9 (Control, a 'sharrow'). Additionally, the (low traffic) Control roads in the on-road experiment and the Protected roads had similar safety ratings, which were higher than the Unprotected roads' (which had higher traffic volumes). Suppose a predominant factor to decreasing comfort is busyness. In that case, the findings may support the hypothesis that separators increase comfort as Video 2 in the online questionnaire was busy, yet it still had high safety and comfort ratings.

However, Video 6, the Unprotected road in the 'industrial' pair, was rated unfavourably and was not overly busy. What was consistently different about the lower-rated painted cycle lanes in the online questionnaire was how much designated room was available for the cyclist to manoeuvre in to avoid intercepting traffic. For the lower-rated Control road, it was also a matter of space as the cyclist in the video had no designated cycling area.

For example, the lower-rated unprotected bike lanes (videos 1 and 6) were located to the right of parked cars, and the line separating the cyclist from traffic to their left was a single line (see figures 1 and 3). Conversely, one of the higher-rated unprotected lanes in Video 3 was also to the right of parked traffic; yet, the painted separator from the abutting traffic lane was wide with two solid lines and stripes between them (similar to a mini flush median, see Figure 2). Also, the cyclist was not next to parked traffic in Video 8, which was rated the highest for the 'unprotected' group (see Figure 4). When the hazard and general comments were viewed, most concerns for the two videos rated less safe (and less comfortable) included being pushed out into traffic or being slammed by parked car doors opening. In Video 3, these comments were also present (but in less frequency) alongside others that talked about enjoying the extra room created by the wide separator. Comments about being pushed into traffic were absent for Video 8.

Finally, comments for the low-rated control road (Video 9) showed participants were nervous about having cars behind them. This video took place on a busy sharrow where cars and bicycles shared the road (see Figure 5). Several participants said they would have tried to find space on the left so that vehicles could pass them. It may have been the case that having no separation or no designated area separating participants from traffic could have been the cause for lack of comfort.

Altogether, the results from the online questionnaire suggest participants may experience lower rates of comfort with cars passing them when they feel like they don't have enough designated space on the road to get away from traffic in. However, the findings raise the issue of whether separation itself did anything. For example, none of the PCLs were wedged between parked cars and traffic, so the high safety ratings could have resulted from the lack of parked cars instead. Furthermore, only one Unprotected road was not next to parked cars (Video 8), which had similar safety ratings to the lower-rated PCLs.

However, if Video 8's safety ratings were driven by a lack of parked cars to the left of it, ratings for Massey and Buckland Road in the on-road experiment should have been like the PCLs' (as they were not next to parked traffic). Following this, it's more likely that an interaction between not being next to parked cars and lower traffic levels influenced the lower safety ratings in Video 8. For example, if Video 8 had been busier, it might have had worse ratings, but a busy road in a similar location with a separator might not have had notably different ratings from other PCLs and roads in quieter settings. This hypothesis is also supported by the lack of differences in safety and comfort ratings between the PCLs regardless of setting and adjacent busyness.

Overall, it may be hypothesised, that several factors increase cyclists' comfort with passing traffic like reduced traffic flow and speed, physical separation or increasing the space exclusive to cyclists. Additionally, it may also be hypothesised that physical separation may help increase feelings of comfort and safety in areas where traffic density cannot be reduced. This hypothesis is tentative, however, as it was made with correlational patterns in the data. More controlled research is needed to place confidence in the ideas mentioned above.

4.2.3. Expectations and behaviours at side street intersections.

The results from both studies suggest that regardless of infrastructure, cyclists in New Zealand are unsure whether cars will give way to them at side street intersections. However, results from the online questionnaire suggest their expectations cars will give way may be higher at intersections in residential areas with bike lanes. To explain why the residential roads were rated higher, the general comments were examined. In the comments, some participants stated that they ‘wondered’ whether residents would be more aware of them (cyclists) due to having a PCL on their street (Video 7; Protected-residential). However, the same comments were not found for the other residential street, yet it also had slightly higher expectation ratings on average.

Interpretation of these results is difficult as the same patterns were not found in the on-road and survey studies. For example, Friesian Drive was similar to the residential pair in setting and had a bike lane, yet expectations were not different from the other on-road roads. It’s possible the (lack of) differences in the on-road questionnaire are because cyclists do not change their expectations based on infrastructure when cycling. So, in the on-road study, the participants could have been more aware of the lack of expectations change, having just cycled the roads. Alternatively, it’s also possible that the residential roads in both studies differed in a way not immediately apparent.

Additionally, it was found that the cyclists in the study did not think their speeds would differ when going past intersections on different road types. For example, most participants thought they would either slow down or continue going at the same speed in both questionnaires regardless of road type. Instead, the main differences were seen between the two studies, not the road types. The studies differed insofar as participants said they would continue going at the same speed more frequently in the on-road condition than the online questionnaire.

Again, to explain the differences between the two, it could be that participants’ answers differed due to a greater awareness of their speed in the on-road condition than online. After all, it is more accurate with the on-road data that their speed did not change for intersections. Alternatively, it is also possible the roads in both studies were different, and people would have behaved differently on them.

Lastly, to see whether the differences observed between the two studies are because those on the road are more in touch with their actual behaviour, the differences between participants' speeds and self-reported speeds were examined. As mentioned, observed speed and self-reported speed were not correlated. This finding could mean that participants had no insight into how quickly they were going, or it could be that the self-report scale is blunt in picking up subtle differences in speed. For example, participants tended to say they rode similar to their average speed, which is true for all the roads except Duggan when considering participants' average speeds (in terms of significant differences). Participants may not have considered the extra speed they went on Duggan to be 'faster' or 'much faster' than average, as the question did not give a range of added speeds that would qualify for a jump in rating.

4.2.4. Safety and willingness ratings.

Despite how similarly participants' safety and willingness ratings appeared at face value in both studies (see figures 13, 15, 27 and 29), there was not always a significant relationship between them. However, the correlation coefficients were always positive, suggesting that willingness ratings also increased if something improved safety ratings. So, while the two may not have a direct correlational relationship, the results may indicate that interventions that promote feelings of safety may also increase willingness.

Moreover, the gap between participants' safety and willingness ratings may suggest participants have standards beyond their perceptions of safety when considering if a child should bike on the road. This discrepancy may be due to several reasons. For example, parents may value their children's life above their own or view children's cycling abilities as lower than theirs, so desire increased environmental protection for their children than themselves. Additionally, as Lorenc et al. (2008) suggested, regardless of how parent's feel about their children's capabilities, parents may feel social pressure not to be seen taking risks with their children's lives. So, maybe an interfering factor is less if they think a road is safe, but if they think others would agree with them to allow a kid to bike on the road in question.

4.3. Limitations

Several factors of the studies' methods were identified that limit the confidence placed in the results and the breadth of their application. These limitations included the naturalistic settings the on-road experiment was conducted in and the lack of control over the videos in the online questionnaire; the homogeneity of the samples, and the tools used to assess mental workload and feelings of risk.

The naturalistic setting posed limitations on what can be interpreted from the data as the experimental conditions were not the same each time a participant rode the routes. Additionally, some factors unrelated to bike separation were consistently different between the conditions like lower traffic levels on the Protected roads than the Unprotected roads and the bike lane disappearing on Buckland. This issue was also present in the online questionnaire, as the videos used were pre-recorded and did not control for traffic density, other infrastructural variations, and existing hazards.

The first issue with the differences between participants' experimental conditions would not have been concerning if the study had a larger sample size. However, the sample was small due to budget and time restraints, meaning that these day-to-day variations may have affected the results. Taken together, the study's design poses limitations on what can be interpreted from the results as both issues create doubt that significant effects found in the data were a result of road type and not confounding factors.

Secondly, the participants only represented some demographics and levels of experience, which cannot be separated from the results. Part of this homogeneity was by design, as only people who had cycled in the last twelve months and were relatively comfortable on a bike were recruited. However, as mentioned, most of the participants surpassed these conditions, with most cycling 3 – 5 times a week with high self-reported confidence levels in both samples. Additionally, there was an over-representation of Pākehā males for both the on-road experiment (in comparison to local demographics) and the online questionnaire (in comparison with national demographics). These skewed demographics may indicate higher cycling rates by Pākehā males, that they often belong to cycling groups where the advertisements were publicised, or something else, like higher self-identification as a "cyclist". Regardless, a lack of diversity in confidence levels and demographics restricts the findings to these groups as there is no guarantee other groups would have provided the same ones. This homogeneity is an issue insofar as it only tells us about the groups of people who already cycle (or who turn up to studies) when part of the underlying aims of this study was to attain findings that could help increase cycling rates.

Lastly, the method may not have captured all the information needed to test the TCI model and Zero-Risk Theory on cyclists' behaviour. For example, 'hazard-concern ratings' may not have been an accurate measurement of workload. Also, there was no objective measurement of arousal or risk in the study, such as GSR or heart rate. Although there are limitations to what can be interpreted from GSR or heart rate measurements in terms of arousal or fear, it could have added data for measuring risk/hazard-concern ratings. In saying that, the measurements used may have been accurate, and the theories cannot adequately explain cyclists' behaviour. However, until this is looked into specifically, care needs to be taken in interpreting the lack of findings between speed, feeling unsafe and mental workload.

4.4. Future Directions

First and foremost, more research needs to investigate how infrastructure affects cyclists' behaviour whilst taking the weaknesses and strengths of this study into account. For example, other researchers could use this study's repeated measures design in a high-fidelity laboratory setting to reduce the noise generated from the naturalistic conditions. Additionally, the on-road experiment could be replicated with a larger sample to ensure the validity of the findings. Moreover, if a high-fidelity simulation of cycling environments was created, cyclists with less experience could also take part without the risk of being on the road.

Secondly, the results from these studies opened several topics of study outside of the scope of this thesis that could contribute to research on cyclists and safe design. These topics are included below.

4.4.1. Network effects on speed behaviour

Earlier, it was mentioned that a potential reason for the speed differences on the control roads in the on-road experiment was the arousal and physical states participants were in as they entered each road (see section 4.1.3.). Understanding the effects of antecedent roads on cyclists' behaviour is important in the same way that uncovering behavioural differences associated with immediate infrastructure is: it can help planners create safer designs. For example, knowing where cyclists are more likely to ride faster in cycling networks may help designers decide where to place interventions to either get other transport users to slow down and be more alert, or for cyclists to when sharing the space with pedestrians.

A potential follow-up study to investigate these network effects could include two routes (either simulated or real) which both link to the same road. In one of the routes, the antecedent street/s could be busy without physical separation, and in the other, the antecedent street/s could be quiet with high safety ratings. The researcher could then compare the speed participants went on the experimental road between routes to see if they went faster on one. This design may help test the effects of increased arousal generally, especially if a GSR or heart rate monitor was used. Moreover, the same method could be created to test the impact of hills of subsequent speed; the antecedents in the designed routes would just need to be changed to differences in incline. This general design may be changed to investigate any other domino network effects that may occur.

4.4.2. The role of arousal in cycling

Another interesting question is whether the TCI model or Zero-Risk Theory holds the same explanatory power towards cyclists as drivers concerning increases in risky behaviour. Underpinning this question is another; whether cyclists entering into a state of under arousal happens much, if at all. Both theories are based on the idea that a lower than desired level of arousal, whether caused by decreased perceptions of risk or task difficulty, can result in compensatory behaviours to reach peak arousal. However, as illustrated by Schmidt et al.'s (2013) study, increasing a person's heart rate through exercise may coincide with reducing risky behaviour due to a state change in arousal. Following this point, it may be the case that these theories make more sense for risk-taking in drivers who are not doing anything physically exhaustive but not for cyclists.

The question could be asked if cyclists taking risks has less to do with under-arousal and instead be more cognitively driven. For example, mistakes made by cyclists may be due more to expectations they have in a given circumstance (like misreading the road) or competing goals (like getting somewhere quickly). A study designed to test arousal levels before risk-taking on bicycles may help uncover whether under-arousal is a cause for concern for cycling network designers.

Following this logic, it may also be worthwhile to see how much the physical component of cycling influences feelings of risk, if at all. If it is true that people will alter their behaviour to avoid feeling fear or discomfort, and the most cited barrier for not cycling is feeling unsafe, and physical exertion increases feelings of risk, low cycling rates may be partly attributable to the exercise involved in biking. An interesting study could look at what happens to risk perception and behaviour over time if the option to pedal is removed for participants. For example, participants could be given a motor-powered bicycle that reaches similar levels of speed they are used to instead of a manual bike. Comparing this data to data taken at baseline (with their manual bicycle) could explore whether electric-assisted micro-mobility can lower alternative transport behaviour barriers via a reduction in over-arousal. Additionally, the same study could test if taking physical exertion out of cycling increases risk-taking due to lower feelings of risk.

4.3. Conclusion

Overall, the results from the studies are optimistic in relation to installing PCLs in New Zealand. Participants found them safer and were more willing to let their children bike on them than painted bike lanes. There was also some evidence PCLs can reduce feelings of risk on busy roads. Moreover, the hypothesis that cyclists act riskier in PCLs was not supported. Lastly, neither the TCI model's or the Zero-Risk's hypotheses were supported by this research's findings. Further research is required to test the reliability of the last two findings, as, to the author's knowledge, this study was the first to investigate these subjects directly.

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Appendices

Appendix A: Online Questionnaire Advertisement

Appendix B: The Online Questionnaire

Start of Block: Introduction/consent

Q1.1 To make New Zealand roads safer and more enjoyable for those who live and visit here, we would like to gain insight into the experiences of our road users. We don't seem to know a lot about the experiences of those who ride bicycles in New Zealand. To discover more about this, we want to directly hear from those who bike in New Zealand. You do not have to consider yourself a serious cyclist – just someone who has some recent experience cycling on New Zealand roads.
This Questionnaire is quite long because we want to ask about a range of situations in which you might find yourself. Because of this, we have separated the questions into two chunks which will take approximately 25 minutes each. Halfway through the questionnaire, we will ask you to take a break so that you continue to enjoy it and to stop you from getting too tired to continue. We appreciate the patience, time and expertise you are giving to us by going through with the survey. This research project has been approved by the Human Research Ethics Committee of the Faculty of Arts and Social Sciences. If you have questions about the ethical conduct of this research, you can send them to the Secretary of the Committee via email (alpss-ethics@waikato.ac.nz) or by post (Division of Arts, Law, Psychology and Social Sciences, University of Waikato, Te Whare Wananga o Waikato, Private Bag 3105, Hamilton 3240). If you have any other questions about the study, please contact a member of the research team; Professor Samuel Charlton (samuel.charlton@waikato.ac.nz) or Alexandra Knight (ark24@students.waikato.ac.nz).
All the answers you give us are your property, and by continuing with the survey, you are consenting for us to use them for a masters thesis project and a published research article. The information you provide will be completely anonymous and not linked with any identifying data you provide us. Would you like to continue?

- ○ Yes (1)
- ○ No (2)

Skip To: End of Survey If To make New Zealand roads safer and more enjoyable for those who live and visit here, we would li... = No

---

Q1.2 Have you ridden a bicycle on New Zealand roads within the last 12 months?

- ○ Yes (1)
- ○ No (2)

Skip To: End of Survey If Have you ridden a bicycle on New Zealand roads within the last 12 months? = No

End of Block: Introduction/consent

Start of Block: Introduction 2

Q2.1 Now we want you to answer some questions about a series of videos.

End of Block: Introduction 2

Start of Block: Block 1[1]

Q3.1 Please watch the video and imagine putting yourself in the perspective of the cyclist. Click the video to begin and press the arrow at the bottom of the page once you have finished watching the video.
C9OP6Yovxa4 – (video)

Page Break

[1] Items 3.1 to 3.16 repeat for each video in the study.

Q3.2 In your own words, please describe what you would be thinking about if you were cycling on this road:

____

____

____

____

____

Page Break

Q3.3 What hazards (if any) do you remember seeing in the video?

____

Page Break

Q3.4 What hazards would you be looking out for on a road like this? (select all that apply)

- ▢ Pedestrians (1)
- ▢ Other cyclists (2)
- ▢ Vehicles driving next to you/behind you (3)
- ▢ Parked cars/opening doors (4)
- ▢ Cars turning in and out of driveways (5)
- ▢ Cars turning in and out of side streets (6)
- ▢ Other (please state) (7)

____

Display This Question:

If If What hazards would you be looking out for on a road like this? (select all that apply) q://QID5/SelectedChoicesCount Is Greater Than or Equal to 1

Q3.5 Please rate how much of a concern these hazards are to you from 'mildly concerning' to 'very concerning':

Display This Choice:

If What hazards would you be looking out for on a road like this? (select all that apply) = Pedestrians

Display This Choice:

If What hazards would you be looking out for on a road like this? (select all that apply) = Other cyclists

Display This Choice:

If What hazards would you be looking out for on a road like this? (select all that apply) = Vehicles driving next to you/behind you

Display This Choice:

If What hazards would you be looking out for on a road like this? (select all that apply) = Parked cars/opening doors

Display This Choice:

If What hazards would you be looking out for on a road like this? (select all that apply) = Cars turning in and out of driveways

Display This Choice:

If What hazards would you be looking out for on a road like this? (select all that apply) = Cars turning in and out of side streets

Display This Choice:

If What hazards would you be looking out for on a road like this? (select all that apply) = Other (please state)

	Mildly concerning (1)	Moderately concerning (2)	Quite concerning (3)	Very concerning (4)
Display This Choice: If selected in Q. 3.4 Pedestrians (1)	o	o	o	o
Display This Choice: If selected in Q. 3.4 Other cyclists (2)	o	o	o	o
Display This Choice: If selected in Q. 3.4 Vehicles driving next to you/behind you (3)	o	o	o	o
Display This Choice: If selected in Q. 3.4 Parked cars/opening doors (4)	o	o	o	o
Display This Choice: If selected in Q. 3.4 Cars turning in and out of driveways (5)	o	o	o	o
Display This Choice: If selected in Q. 3.4 Cars turning in and out of side streets (6)	o	o	o	o

Display This Choice: *If selected in Q. 3.4* Other (as written in previous question) (7)	○	○	○	○

Q3.6 How safe would you feel bicycling on this road?

- ○ Very unsafe (-2)
- ○ Somewhat unsafe (-1)
- ○ Neither safe nor unsafe (0)
- ○ Somewhat safe (1)
- ○ Very safe (2)

Q3.7 How willing would you be to let a child (yours or someone else's) ride on this road?

- ○ Very willing (2)
- ○ Somewhat willing (1)
- ○ Neither willing nor unwilling (0)
- ○ Somewhat unwilling (-1)
- ○ Very unwilling (-2)

Q3.8 Would you have chosen to ride in a different space on the road instead of that chosen in the video?

- ◯ Yes, I would have biked on the footpath (3)
- ◯ Yes, I would have biked in the middle of the traffic lane (4)
- ◯ No, I would have stayed in the same space as the cyclist (5)
- ◯ I would not have biked on this road (7)
- ◯ Other (please describe): (6) ____

Display This Question:

If Would you have chosen to ride in a different space on the road instead of that chosen in the video? = Yes, I would have biked on the footpath

Or Would you have chosen to ride in a different space on the road instead of that chosen in the video? = Yes, I would have biked in the middle of the traffic lane

Q3.9 Please explain why you would have chosen that space instead:

____

____

____

____

____

Display This Question:

If Would you have chosen to ride in a different space on the road instead of that chosen in the video? = I would not have biked on this road

Q3.10 Please explain why you would not have biked on this road

____

Page Break

X→

Q3.11 How comfortable would you feel having a vehicle pass you on this road?

- ○ Very comfortable (2)
- ○ Somewhat comfortable (1)
- ○ Neither comfortable nor uncomfortable (0)
- ○ Somewhat uncomfortable (-1)
- ○ Very uncomfortable (-2)

X→

Q3.12 In relation to your average speed, how fast do you think you would cycle on this road?

- ○ Much faster than average (2)
- ○ Somewhat faster than average (1)
- ○ No difference (average) (0)
- ○ Somewhat slower than average (-1)
- ○ Much slower than average (-2)

Display This Question:

If In relation to your average speed, how fast do you think you would cycle on this road? = Somewhat faster than average

Or In relation to your average speed, how fast do you think you would cycle on this road? = Much faster than average

Or In relation to your average speed, how fast do you think you would cycle on this road? = Somewhat slower than average

Or In relation to your average speed, how fast do you think you would cycle on this road? = Much slower than average

Q3.13 In your own words, please explain why your speed would have differed from normal:

____

Q3.14 In approaching the side street the cyclist passed on this road, would you have:

- ◯ Cycled past it in the same speed you were travelling at (1)
- ◯ Increased your speed and cycle past it (2)
- ◯ Slowed down in case you needed to stop (3)
- ◯ I do not remember the cyclist passing a side street (4)

Skip To: Q3.16 If In approaching the side street the cyclist passed on this road, would you have: = I do not remember the cyclist passing a side street

Q3.15 In relation to the side street on this road, please select the statement you most agree with:

- ◯ I am very confident turning cars would give way to me (2)
- ◯ I am somewhat confident turning cars would give way to me (1)
- ◯ I'm not sure whether turning cars would give way or not (0)
- ◯ It's likely some turning cars would not give way to me (-1)
- ◯ I do not think turning cars would give way to me (-2)

Q3.16 How concerned would you have been about cars coming out of their driveways on this road?

- ◯ Very concerned (-2)
- ◯ Somewhat concerned (-1)
- ◯ Neither concerned nor unconcerned (0)
- ◯ Somewhat unconcerned (-1)
- ◯ Very unconcerned (-2)
- ◯ I do not remember any driveways on this road (999)

End of Block: Block 1

Start of Block: midway

Q13.1 Please take a break here to enjoy a coffee or have a stretch! You can come back to the questionnaire in 10 minutes or a couple of hours time, just make sure to leave the browser open. Thank you!

End of Block: midway

Start of Block: Demographics

Q14.1 Now we want to know a little bit more about you and your bicycling habits

---

Q14.2 What is your age (in years)?

____

Q14.3 What gender do you most identify as?

- ○ Male (1)
- ○ Female (2)
- ○ Non-binary/third gender (3)
- ○ Prefer to self-describe: (4) ________________
- ○ Prefer not to answer (5)

Q14.4 Which ethnic groups do you belong to? Identify any that apply.

- ☐ New Zealand European (1)
- ☐ Other European (2)
- ☐ Māori (3)
- ☐ Samoan (4)
- ☐ Tongan (5)
- ☐ Cook Islands Māori (6)
- ☐ Niuean (7)
- ☐ Chinese (8)
- ☐ Indian (9)
- ☐ Other (please state) (10) ________________
- ☐ Prefer not to answer (11)

Q14.5 Where do you live in New Zealand (which province/district)?

- Northland (1)
- Auckland (2)
- Waikato (3)
- Bay of Plenty (4)
- Gisborne (5)
- Hawkes Bay (6)
- Taranaki (7)
- Wanganui (8)
- Manawatu (9)
- Wairarapa (10)
- Wellington (11)
- Nelson Bays (12)
- Marlborough (13)
- West Coast (14)
- Canterbury (15)
- Timaru-Omaru (16)
- Otago (17)
- Southland (18)

Q14.6 How confident do you feel on your bike? Please select the option that **best** describes how you feel.

○ I feel confident in my ability to cycle in all road conditions (1)

○ I feel confident in my ability to cycle in most road conditions but there are some streets/conditions which make me nervous while biking (2)

○ I do not feel safe cycling on most roads (3)

○ I do not feel safe cycling on any roads (5)

○ None of these options describe me at all (comment optional): (4)
____

Q14.7 What is your primary mode of transport?

○ Private vehicle (1)

○ Public transport (2)

○ Walking (3)

○ Bicycling (4)

○ Motorcycling (5)

○ Other (please state): (6)
____

Q14.8 How often do you ride your bicycle in town (on average)?

○ 3 - 5 times per week (1)

○ Once a week (2)

○ Once a month (3)

○ 2 - 4 times per year (4)

○ Once a year (5)

Q14.9 Please indicate the percentage the following trip types contribute to all of your bicycle trips (the total should add up to 100):

	0 10 20 30 40 50 60 70 80 90 100
Commuting to work or school ()	
Off-road recreational cycling ()	
On-road recreational cycling ()	
Other commuting trips (e.g. supermarket, health centers etc.) ()	
Other (please state): ()	

Page Break

Q14.10 Would you like to receive a summary of the findings?

- ☐ I would like to receive a summary of the research findings (1)
- ☐ No thanks (2)

Display This Question:

If Would you like to receive a summary of the findings? = I would like to receive a summary of the research findings

*

Q14.11 Please provide your e-mail address

____

End of Block: Demographics

Appendix C: On-road Study Advertisesemnt

Appendix D: On-road Information Sheet[2]

Cycling on New Zealand roads

Information Sheet

The purpose of the study is to investigate how cyclists feel and behave and what they expect on different roads. All information will be treated in the strictest confidence and if you have any questions, feel free to ask us.

We are asking participants in the study to:

1) **Complete two cycling trips** on their own bike (4.9 km and 6 km long), beginning and ending at the Mangere Town Centre car park.

2) During each trip, we want you to cycle the same way as you would cycle in daily life, following the road rules and staying on the route on a map we will give you.

3**) Each bike ride should take approximately 20 – 30 mins** to complete. If you get lost, have questions, or need assistance at any time, you can ring our mobile number (027-899-8081). Be sure you are stopped while placing the call (riders should not converse on mobile phones while cycling).

4) During the cycling trips, we will be recording audio and video data using a go-pro camera. For those who do not wear glasses, want to, and are scheduled during over-cast conditions, we will also record video and eye-tracking data using Tobii eye-tracking glasses. A cell phone app, Ride with GPS, will also record GPS coordinates and speed, through a cell phone we will provide you with during the experiment. Anything you say or do during the trip will be kept confidential and only accessible by the study team.

5) When you return to the car park after each ride, we will remove the camera, the eye-tracking glasses and the laboratory cell phone and ask you to complete a **short 10-15 minute questionnaire** about your ride.

6) As a thank you for participating, we will offer you a $40 voucher for the Warehouse.

You can withdraw from the study at any time simply by returning to the meeting place here at the Mangere Town Centre car park (you will still receive the vouchers). All information will be treated in the strictest confidence and the data can only be accessed by the study team. Any paper forms will be placed in a folder during the experiment, and then stored in a locked cabinet in the TRG office. Electronic data will be stored on a secure server in a password protected file. Data will be kept for 5 years. The findings may be written up as a report or as a conference paper.

If you have any questions about the study, please contact Allie Knight (trg@waikato.ac.nz)

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[2] In the header of the original document there was the University of Waikato's crest.

This research project has been approved by the Human Research Ethics Committee of the Division of Arts, Law, Psychology, and Social Sciences. Any questions about the ethical conduct of this research may be sent to the Secretary of the Committee, email fass-ethics@waikato.ac.nz, postal address, Division of Arts, Law, Psychology, and Social Sciences, University of Waikato, Te Whare Wananga o Waikato, Private Bag 3105, Hamilton 3240.

Appendix E: On-road Study Consent Form[3]

CONSENT FORM

A completed copy of this form should be retained by both the researcher and the participant.

Research Project: Cycling on New Zealand roads

Please complete the following checklist. Tick (✓) the appropriate box for each point.	**YES**	**NO**
1. I have read the Participant Information Sheet (or it has been read to me) and I understand it.		
2. I have been given sufficient time to consider whether or not to participate in this study		
3. I am satisfied with the answers I have been given regarding the study and I have a copy of this consent form and information sheet		
4. I understand that taking part in this study is voluntary and that I may withdraw from the study at any time without penalty		
5. I have the right to decline to participate in any part of the research activity		
6. I know who to contact if I have any questions about the study in general.		
7. I understand that my participation in this study is confidential and that no material, which could identify me personally, will be used in any reports on this study		
8. I understand that I will be audio and video recorded during this study and that all recordings will be available only to members of the research team		
9. I understand that during the experiment my GPS co-ordinates will be recorded and that this information will be available only to members of the research team		
10. I wish to receive a copy of the findings		
11. I would like to receive information about future studies conducted by the Transport Research Group		

Declaration by participant:
I agree to participate in this research project and I understand that I may withdraw at any time.

Participant's name (Please print): ______________________

Signature: ______________________ Date: ______________________

Contact details ______________________

If you would like to receive a copy of the research findings, or are interested in taking part in future studies conducted by TRG please provide your email address here

____

[3] In the header of the original document, there was the University of Waikato's crest.

Declaration by member of research team:
I have given a verbal explanation of the research project to the participant, and have answered the participant's questions about it. I believe that the participant understands the study and has given informed consent to participate.

Researcher's name (Please print): ______________________________

Signature: ______________________________ Date: ______________

Appendix F: Post-ride Questionnaire

Start of Block: For researcher to fill out

Q1.1 Please enter the participant ID number:

____

Q1.2 Please select route order:

○ A (1)

○ B (2)

Page Break

Q1.3 We are conducting a series of studies exploring how cyclists experience riding on different types of New Zealand roads. We want to ask you a few questions about the ride you took today, yourself and your transportation habits.

Any answers you provide are anonymous and cannot be linked to your name in any way. You can stop taking the survey at any time by closing the browser window. At the end of the research, the findings may be written up for publication and may be presented at relevant conferences. This study has been approved by the Human Research Ethics Committee of the Division of Arts, Law, Psychology, and Social Sciences. Any questions about the ethical conduct of this research may be sent to the Secretary of the Committee, email fass-ethics@waikato.ac.nz, postal address, Division of Arts, Law, Psychology, and Social Sciences, University of Waikato, Te Whare Wananga o Waikato, Private Bag 3105, Hamilton 3240.

End of Block: For researcher to fill out

Start of Block: Introduction to Questions

Q2.1 For the following questions, we want you to think about how you felt, what you were thinking about and the choices you made on the ride you took today. We will also be asking you about what your general cycling experiences are like on roads like the ones you cycled on today.

End of Block: Introduction to Questions

Start of Block: Thomas Road_A[4]

Q3.1 The following questions refer to Thomas Road which is where this photo was taken:[5]

Q3.2 In your own words, please describe what you were thinking about as you cycled on this road:

____

____

____

____

[4] Questions 3.1 to 3.13 are repeated for each of the roads discussed in the study.
[5] Refer to figures 6, 7 and 8 for the photographs used in this survey.

____

Page Break

Q3.3 What hazards (if any) do you remember seeing on this road?

____

Page Break

Q3.4 What hazards are typical on roads like the one you cycled on? (select all that apply)

- ▢ Pedestrians (1)
- ▢ Other cyclists (2)
- ▢ Vehicles driving next to you/behind you (3)
- ▢ Parked cars/opening doors (4)
- ▢ Cars turning in and out of driveways (5)
- ▢ Cars turning in and out of side streets (6)
- ▢ Other (please state) (7) ____

Display This Question:

If If What hazards are typical on roads like the one you cycled on? (select all that apply) q://QID4/SelectedChoicesCount Is Greater Than or Equal to 1

Q3.5 Please rate how much of a concern these hazards are to you from 'mildly concerning' to 'very concerning':

Display This Choice:

If What hazards are typical on roads like the one you cycled on? (select all that apply) = Pedestrians

Display This Choice:

If What hazards are typical on roads like the one you cycled on? (select all that apply) = Other cyclists

Display This Choice:

If What hazards are typical on roads like the one you cycled on? (select all that apply) = Vehicles driving next to you/behind you

Display This Choice:

If What hazards are typical on roads like the one you cycled on? (select all that apply) = Parked cars/opening doors

Display This Choice:

If What hazards are typical on roads like the one you cycled on? (select all that apply) = Cars turning in and out of driveways

Display This Choice:

If What hazards are typical on roads like the one you cycled on? (select all that apply) = Cars turning in and out of side streets

Display This Choice:

If What hazards are typical on roads like the one you cycled on? (select all that apply) = Other (please state)

	Mildly concerning (1)	Moderately concerning (2)	Quite concerning (3)	Very concerning (4)
Display This Choice: If selected in Q. 3.4. Pedestrians (1)	○	○	○	○
Display This Choice: If selected in Q. 3.4. Other cyclists (2)	○	○	○	○
Display This Choice: If selected in Q. 3.4. Vehicles driving next to you/behind you (3)	○	○	○	○
Display This Choice: If selected in Q. 3.4. Parked cars/opening doors (4)	○	○	○	○
Display This Choice: If selected in Q. 3.4. Cars turning in and out of driveways (5)	○	○	○	○
Display This Choice: If selected in Q. 3.4. Cars turning in and out of side streets (6)	○	○	○	○

Display This Choice: *If selected in Q. 3.4.* Other (as written in previous question) (7)	○	○	○	○

X→

Q3.6 How safe did you feel bicycling on this road?

○ Very unsafe (-2)

○ Somewhat unsafe (-1)

○ Neither safe nor unsafe (0)

○ Somewhat safe (1)

○ Very safe (2)

X→

Q3.7 How willing would you be to let a child (yours or someone else's) ride on this road?

○ Very willing (2)

○ Somewhat willing (1)

○ Neither willing nor unwilling (0)

○ Somewhat unwilling (-1)

○ Very unwilling (-2)

Q3.8 Would you have any anticipation to cycle on this road if it was part of the most direct route between you and your destination?

- ◯ No, I would not be concerned about cycling on this road at all (1)
- ◯ I would feel a little apprehensive before reaching it (2)
- ◯ I would feel very apprehensive coming up to it (3)
- ◯ I would take a detour so I wouldn't have to bike on it (4)

X→

Q3.9 In relation to your average speed, how fast do you think you were cycling on this road?

- ◯ Much faster than average (2)
- ◯ Somewhat faster than average (1)
- ◯ No difference (average) (0)
- ◯ Somewhat slower than average (-1)
- ◯ Much slower than average (-2)

Display This Question:

If In relation to your average speed, how fast do you think you were cycling on this road? != No difference (average)

Q3.10 In your own words, please explain why your speed was different than normal:

____

Page Break

Q3.11 (Picture of side street)

Q3.12 In approaching the side street captured in the above photo, did you:

- Cycle past in the same speed you were travelling at (1)
- Increase your speed and cycle past it (2)
- Slow down in case you needed to stop (3)
- I do not remember going past this intersection (4)
- I do not remember how fast I went through this intersection (5)

Q3.13 In relation to this side street, please select the statement you most agree with:

- I am very confident turning cars would give way to me (2)
- I am somewhat confident turning cars would give way to me (1)
- I'm not sure whether turning cars would give way or not (0)
- It's likely some turning cars would not give way to me (-1)
- I do not think turning cars would give way to me (-2)

End of Block: Thomas Road_A

Start of Block: Mid point

Q6.1 You've reached the end of the questions for the first route. Please hand the tablet back to the researcher

End of Block: Mid point

Start of Block: Demographics

Q10.1 Now we want to know a little bit more about you and your bicycling habits

---

Q10.2 What is your age (in years)?

____

Q10.3 What gender do you most identify as?

- ○ Male (1)
- ○ Female (2)
- ○ Non-binary/third gender (3)
- ○ Prefer to self-describe: (4) ____
- ○ Prefer not to answer (5)

Q10.4 Which ethnic groups do you belong to? Identify any that apply.

- ▢ New Zealand European (1)
- ▢ Other European (2)
- ▢ Māori (3)
- ▢ Samoan (4)
- ▢ Tongan (5)
- ▢ Cook Islands Māori (6)
- ▢ Niuean (7)
- ▢ Chinese (8)
- ▢ Indian (9)
- ▢ Other (please state) (10) ____
- ▢ Prefer not to answer (11)

Q10.5 How confident do you feel on your bike? Please select the option that **best** describes how you feel.

- ◯ I feel confident in my ability to cycle in all road conditions (1)
- ◯ I feel confident in my ability to cycle in most road conditions but there are some streets/conditions which make me nervous while biking (2)
- ◯ I do not feel safe cycling on most roads (3)
- ◯ I do not feel safe cycling on any roads (5)
- ◯ None of these options describe me at all (comment optional): (4) ____

Q10.6 What is your primary mode of transport?

- ◯ Private vehicle (1)
- ◯ Public transport (2)
- ◯ Walking (3)
- ◯ Bicycling (4)
- ◯ Motorcycling (5)
- ◯ Other (please state): (6) ____

Q10.7 How often do you ride your bicycle in town (on average)?

- ◯ 3 - 5 times per week (1)
- ◯ Once a week (2)
- ◯ Once a month (3)
- ◯ 2 - 4 times per year (4)
- ◯ Once a year (5)

Q10.8 Please indicate the percentage the following trip types contribute to all of your bicycle trips (the total should add up to 100):

	0 10 20 30 40 50 60 70 80 90 100
Commuting to work or school ()	
Off-road recreational cycling ()	
On-road recreational cycling ()	
Other commuting trips (e.g. supermarket, health centers etc.) ()	
Other (please state): ()	

End of Block: Demographics