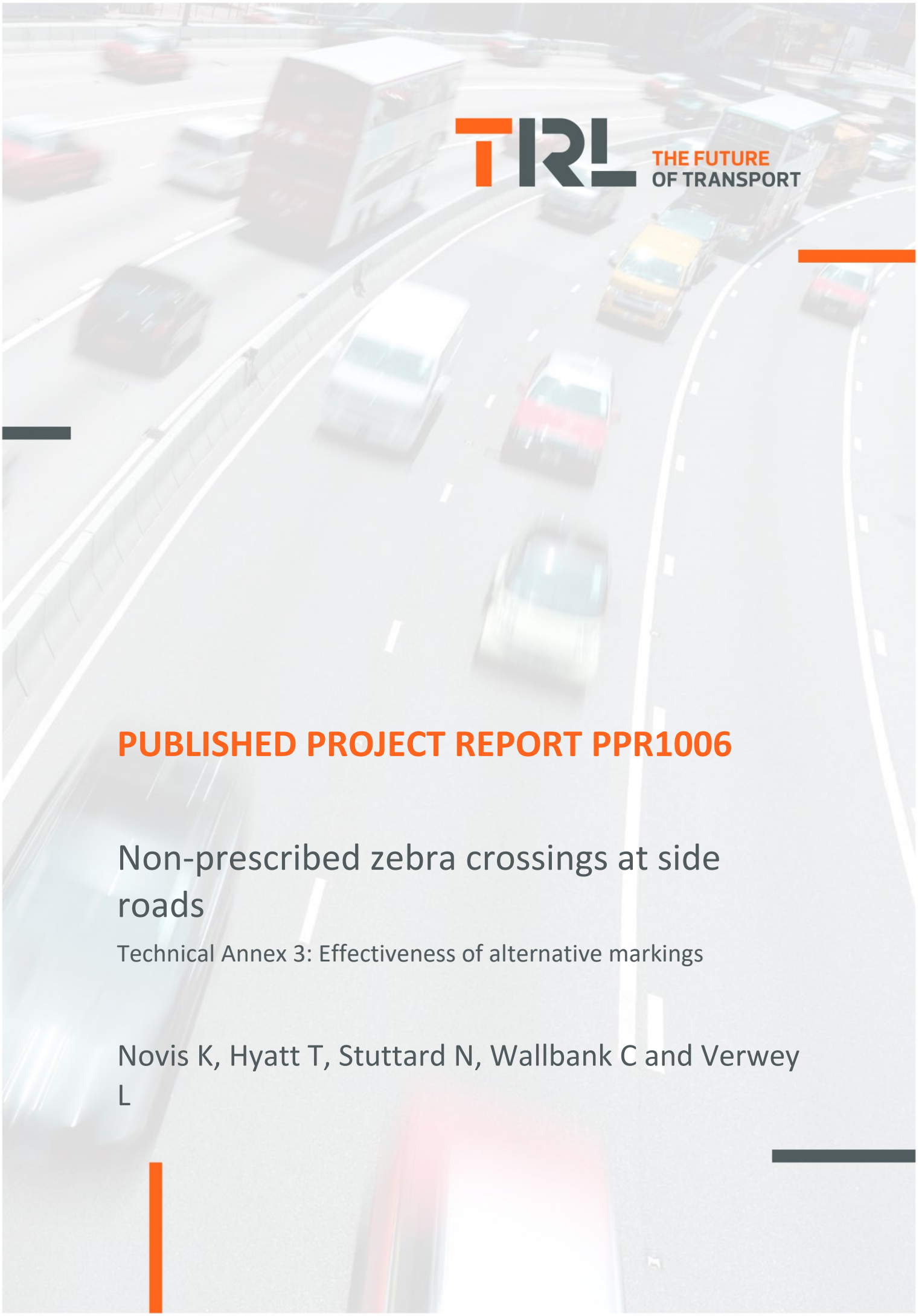

THE FUTURE OF TRANSPORT

PUBLISHED PROJECT REPORT PPR1006

Non-prescribed zebra crossings at side roads

Technical Annex 3: Effectiveness of alternative markings

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Executive Summary

This document forms a Technical Annex to the report *Trials of non-prescribed Zebra crossings at side roads: Final Report* and presents the methodology and findings from a reaction-time study that compared a number of potential alternatives to zebra markings.

Alternative pedestrian crossing designs

The markings, equipment and signs used to denote a zebra crossing in the UK are prescribed in statutory government regulations[1]. The purpose of this study was to investigate several alternative non-prescribed pedestrian crossing designs, alongside a non-prescribed zebra. The aim was to determine the design that is most correctly identified and understood by pedestrians and car drivers.

Six alternative crossing designs were tested (see Figure 1). These designs were selected through a review of pedestrian crossing designs used in other countries, and through consultation with TfGM. Except for the non-prescribed zebra, the crossing designs selected did not mimic a zebra (they had no stripes perpendicular to the walking line), and they were not overly complex (so as not to require excessive costs for installation and maintenance).

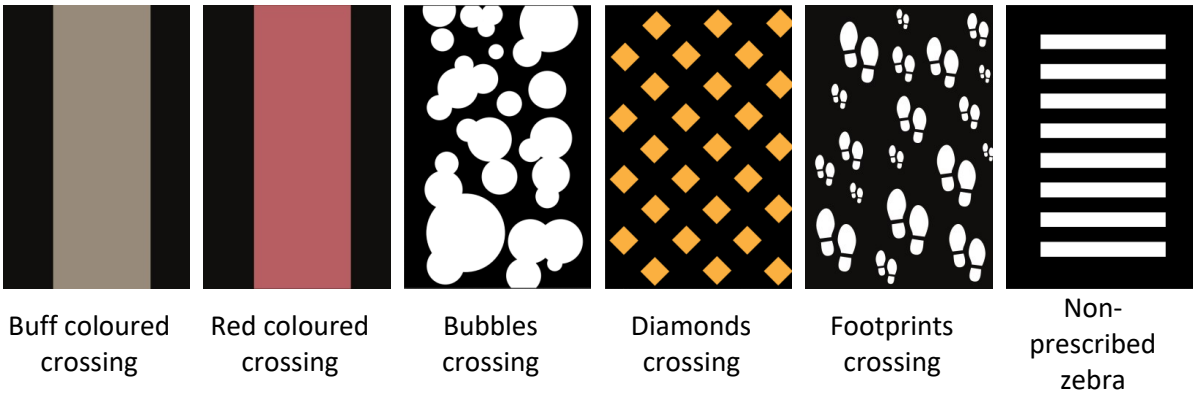


Figure 1: Alternative crossing designs included in this study

Method

The study consisted of a response time trial and a post-trial questionnaire conducted in a controlled laboratory environment. Fifty-six unique stimuli were created by superimposing each of the six crossing designs (plus a control condition which showed no crossing) on to photographs of four different real-world side road junctions, taken from a driver and pedestrian perspective. The 56 unique stimuli were each presented twice, resulting in a total of 112 stimuli viewed by each participant.

The response time trial consisted of rapid (3s) presentation of the stimuli to participants on a computer screen. Upon the presentation of a stimulus, participants were asked to press a designated key on the computer keyboard to indicate whether they noticed a dedicated point at which a pedestrian can cross the road. The trial measured whether or not participants noticed a crossing in the road scene, and the speed (response time) at which they made the

[1]The Stationery Office Limited (2016). *The Traffic Signs Regulations and General Directions 2016*. Retrieved from https://tsrgd.co.uk/pdf/tsrgd/tsrgd2016.pdf

decision. Following the response time test, participants completed a post-trial questionnaire to gather data about their understanding, confidence and perceived safety of the crossing designs.

Results

The results showed that the **non-prescribed zebra** crossing performed best on all the measures in this trial: participants more commonly recognised this as a crossing and identified it in the quickest time; they also reported feeling more confident and safer when imagining using this crossing relative to the alternative designs.

Of all the alternative designs:

- The **footprints** crossing performed the best. This was identified as a crossing in almost two thirds of stimuli, and the reported confidence and safety were the highest of all the alternative crossings.
- The **buff coloured** crossing was the least preferred and performed worse on the confidence and safety measures than no crossing (the control condition).
- The **bubbles** crossing also performed poorly on the confidence and safety questions relative to no crossing (the control).
- The **red coloured** and **diamonds** crossings performed similarly to no crossing (the control) on both the feelings of confidence and safety questions; but performed similarly to the footprints crossing when colour and design were investigated.

Conclusions

The purpose of this study was to investigate several alternative non-prescribed pedestrian crossing designs, with the aim of determining the design that is most correctly identified and understood by road users. Based on these results, the main recommendations is to undertake the on-street trials using the non-prescribed zebra crossing. Should a second design option be taken forward for further investigation, the footprints design could be considered alongside the non-prescribed zebra crossing.

1 Introduction

1.1 This document

This document forms a Technical Annex to the report Trials of non-prescribed Zebra crossings at side roads: Final Report, which presents the findings of a programme of user research and trials into the proposed use of a non-prescribed form of zebra crossing at side-roads. Technical Annex 3 sets out the methodology and findings from a reaction time study to assess to what extent the design of crossings influences pedestrians' and drivers' ability to correctly identify and understand a pedestrian crossing in a road scene. The overall conclusions from the research programme are set out in the Final Report.

1.2 Background

Transport for Greater Manchester (TfGM) commissioned TRL to undertake research into the use of non-prescribed zebra crossings at side roads, in order to provide evidence for the Department for Transport (DfT) regarding whether this form of crossing should be given regulatory approval.

Key differences between a prescribed and non-prescribed zebra crossing are shown in Table 1. A prescribed zebra crossing is indicated by a series of alternate black and white stripes on the carriageway; a yellow globe is positioned at each end of the crossing (commonly referred to as a Belisha beacon); and the crossing area is marked with a line of studs and zigzag markings. The minimum distance at which the crossing must be setback from the junction with the main road is 5m.

Conversely, non-prescribed crossings exclude studs, zigzag markings and Belisha beacons. This simplification should lower implementation and maintenance costs for local authorities. In addition, removing the requirement to locate the crossing at least 5m away from the junction has an advantage of keeping pedestrians on their desired walking line, giving them a more direct route across the mouth of the junction.

Table 1: Key differences in the design of a prescribed vs. non-prescribed zebra crossing

Design feature	Prescribed zebra crossing	Non-prescribed zebra crossing
Crossing markings	Black and white stripes	Black and white stripes
Peripheral markings	• Line of studs • Zigzag markings	–
Set-back distance from junction	• No minimum set-back distance • The requirement for at least two zigzag markings creates a set-back distance of around 5 m	No minimum distance, could be flush with end of side road
Additional equipment	Yellow globe on a black and white striped pole (Belisha beacon)	–

Both prescribed and non-prescribed crossings are intended to give pedestrians wishing the

cross the side road priority over vehicles; this applies to vehicles on the side road approaching the junction, and to vehicles on the main road wishing to turn into the side road. Drivers (and to a lesser extent pedestrians) have a short time in which to determine what to do when confronted with an unfamiliar road layout. The key to effective road markings is the ability to quickly and accurately convey the intended message to road users, so that both drivers and pedestrians can intuitively take appropriate action.

This study aimed to provide insight into road user perceptions of a set of alternative pedestrian crossing designs, including the non-prescribed zebra crossing, to inform understanding of how the crossing design impacts road users' ability to correctly interpret the road scene. The study therefore aimed to address the following research question:

- To what extent does the design of crossings influence pedestrians' and drivers' ability to correctly identify and understand a pedestrian crossing in a road scene?

1.3 Alternative pedestrian crossing designs

Six alternative pedestrian crossing designs were included in this trial. The designs were selected through a review of pedestrian crossing designs used in other countries, and through consultation with TfGM. The requirements for selection of alternative crossing designs were:

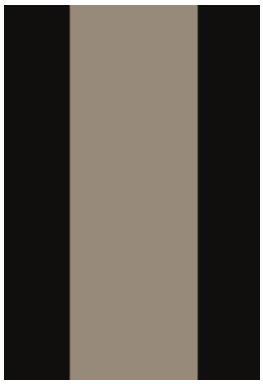
- Alternative crossing markings must not mimic a zebra, with no black and white stripes, or stripes perpendicular to the walking line, and;
- Not an overly complex design that requires excessive costs for installation and maintenance

The alternative crossing designs are shown in Figure 2. They are:

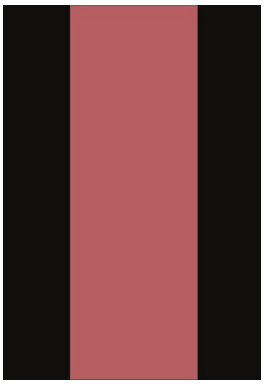
1. *Buff coloured crossing*: A solid strip of buff coloured paint or surfacing. The width of the buff colouring defines the limits of the pedestrian crossing.
2. *Red coloured crossing*: A solid strip of red coloured paint or surfacing. The width of the red colouring defines the limits of the pedestrian crossing.
3. *Bubbles crossing*: A crossing that is made up of solid white circles of various sizes. Many of the circles overlap, creating a bubble effect.
4. *Diamonds crossing*: A crossing that is made up of a matrix of solid yellow diamond shapes. The diamonds are of equal size and there is uniform spacing between each row and column in the matrix.
5. *Footprints crossing*: A crossing made up of one type of solid white footprints of various sizes. The footprints are all facing in the same direction.

In addition to the alternative designs, the non-prescribed zebra crossing design was also included:

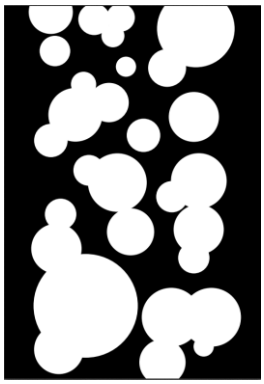
6. *Non-prescribed zebra crossing*: In this design, the limits of the pedestrian crossing are marked with a series of alternate black and white stripes



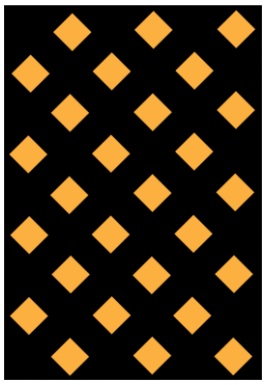
1. Buff coloured crossing



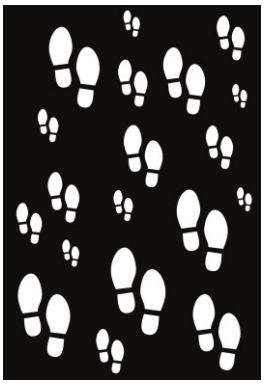
2. Red coloured crossing



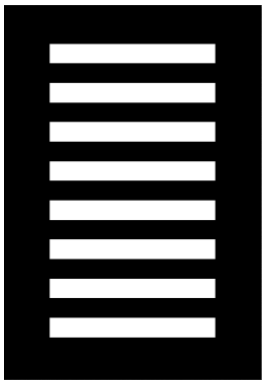
3. Bubbles crossing



4. Diamonds crossing



5. Footprints crossing



6. Non-prescribed zebra

Figure 2: Alternative pedestrian crossing designs used in the trial

2 Method

User trials were conducted in a controlled laboratory environment with the aim of understanding the effectiveness of alternative pedestrian crossing markings from both a pedestrian and driver's perspective.

2.1 Study design

The study used a repeated measures design, in which participants were each presented with 112 images of road scenes on a computer screen and asked to indicate whether or not they identified a pedestrian crossing.

2.2 Data collection

Two types of data were collected:

- Objective data:
    - Identification of the presence of a pedestrian crossing (Yes or No response to indicate whether the participant thought a pedestrian crossing was present in the road scene).
    - The response time in which the participant made the Yes/No decision.
- Subjective data:
    - Participants' perceived usability and level of safety for each crossing design.

2.3 Stimuli

As explained above, six alternative crossing designs were investigated in the trial, along with a control condition in which no crossing was present. A set of visual stimuli were developed by superimposing each of the six designs onto photographs of real-world side road junctions. A total of 56 stimuli were created, varying in terms of the site, viewing perspective and crossing design, as outlined in Table 2.

Table 2: The number of variables used in the trial

Variable	Description	Number of options
Site	Four different side road junctions were used	4
Viewing perspective	Two viewpoints were used; a pedestrian viewpoint and a driver viewpoint	2
Crossing design	The six alternative crossing designs, plus a control condition with no crossing	7
Total number of stimuli		**56**

The 56 unique stimuli (4 sites x 2 viewing perspectives x 7 crossing designs) were presented to participants twice, resulting in a total of 112 stimuli viewed by each participant. See

Appendix B for a full list of the stimuli used in the trial.

2.4 Equipment and software

The trial was conducted using a Dell Optiplex 5040 desktop computer, a BenQ GW2270 21.5-inch computer monitor, with a screen resolution of 1920 x 1080, and a keyboard. The trial was designed and run using E-Prime experimental software, version 2.0 (Psychology Software Tools Inc.). E-Prime is a software program designed to accurately measure user choices and reaction time and is commonly used in psychological research.

2.5 Participants

Participants were recruited through TRL's Participant Database (of around 1,500 people based in Berkshire and surrounding areas who had expressed their interest in being contacted about research). A filter survey was sent to potential participants which collected background information including their age, the length of time they had held a valid UK driving licence and their self-reported driving frequency per week. Respondents who completed the filter survey were considered for the trial if they were over 18 years old, had held a valid UK driving licence for more than a year and had normal or corrected to normal vision.

Ninety participants were recruited for the trial. Of the 90 participants who completed the trial, six were excluded due to misunderstandings of the trial instructions or due to erroneous response times. The final sample therefore included data from 84 participants.

Figure 3 provides an overview of the age and gender profile of the final sample. An equal number of male and female participants took part. More men tended to be over the age of 55, while more women tended to be less than 55 years old. There were only a small number of participants under the age of 25 years old.

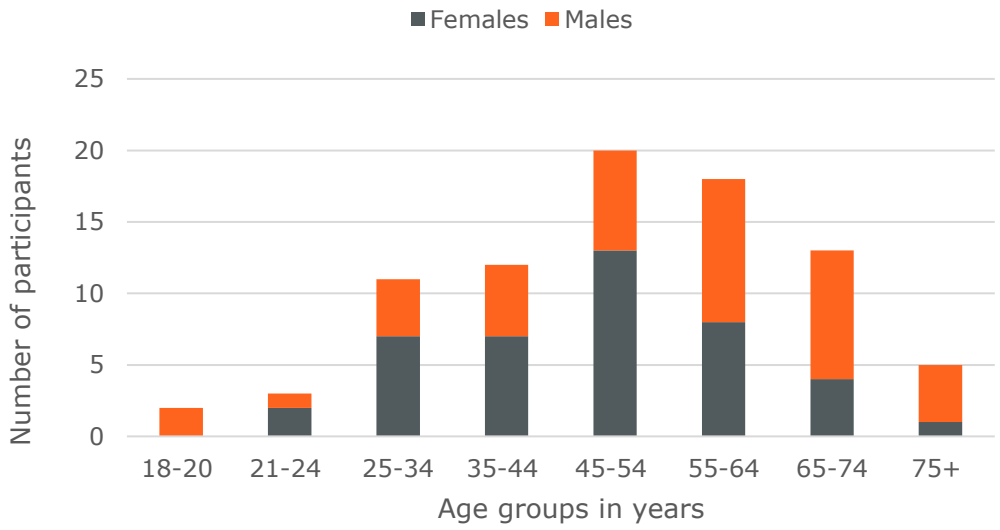


Figure 3: Spread of age and gender characteristics of participants

Most participants (89%) indicated they had held a UK driving licence for more than 10 years (see Figure 4).

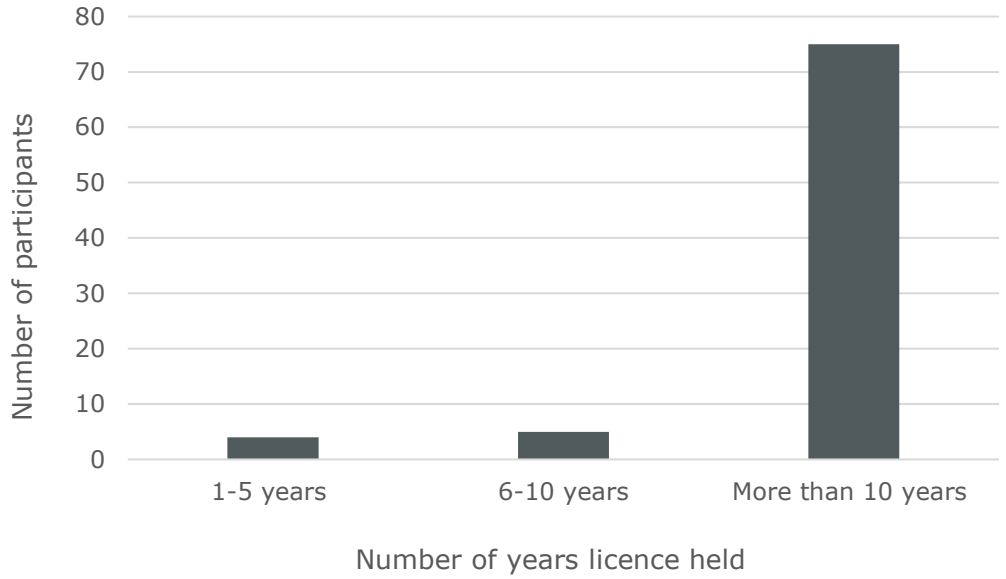


Figure 4: Number of years participants have held a UK driving licence

Sixty-three percent of participants indicated that they drove every day, and 33% indicated that they drove on most days. Only 4% of participants indicated they drove once a week or less (see Figure 5).

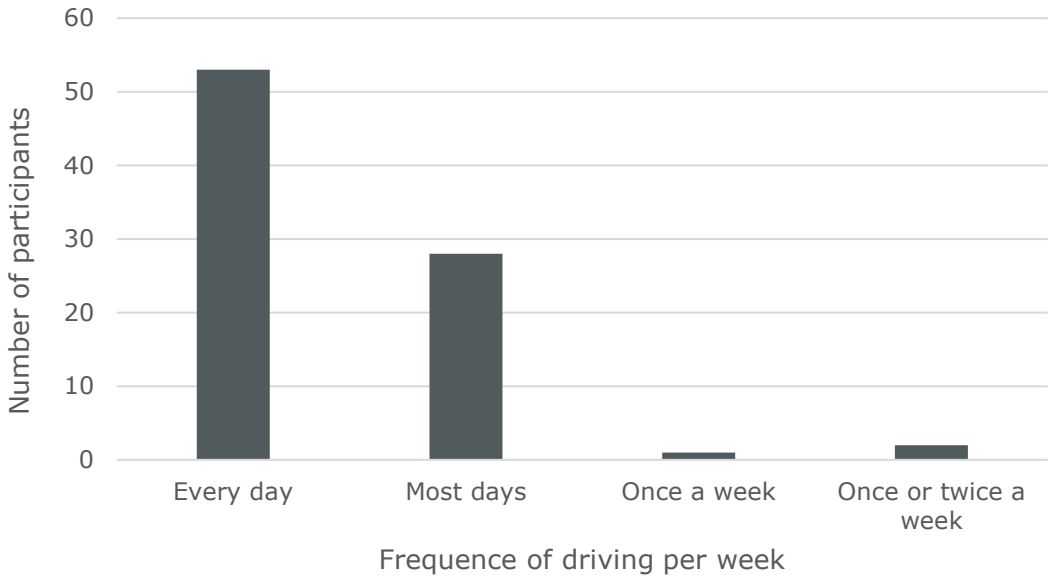


Figure 5: Driving frequency of participants

2.6 Procedure

Prior to starting the trial, participants read a Participant Information Sheet and signed a Consent Form. They were then asked to sit at the experimental station (see Figure 6). The positions of the keyboard and monitor were adjusted as necessary so that participants were comfortable and ready to start. Participants were informed that the trial would take approximately 30 minutes to complete. The trial consisted of a response time trial and a post-trial questionnaire.

Figure 6: The set-up of the experiment station

2.6.1 Response time trial

The response time trial consisted of randomly presenting the 112 stimuli to participants (one at a time) and asking them to press a button to indicate whether or not they noticed a dedicated point at which a pedestrian can cross the road.

2.6.1.1 Practice

Participants were given a chance to practice before the main trial started. This enabled them to become familiar with the procedure before the main trial started. In the practice trial, participants were presented with 28 stimuli, fourteen of which contained a car in the scene and fourteen of which did not. The participant was instructed to indicate whether they noticed a car in the scene by pressing the M and Z on the computer keyboard keys for 'No' and 'Yes', respectively. At the end of the practice trial, the main trial started.

2.6.1.2 Main trial

Participants were presented with on-screen instructions which asked them to indicate whether or not they noticed a *dedicated point at which a pedestrian can cross the road* in each stimulus presented to them. These instructions were presented before the main trial stimuli appeared on screen. They indicated their response by pressing a key on the computer keyboard (Z for 'No' and M for 'Yes').

Before the presentation of each stimulus, a fixation point was shown for 1s in the centre of the computer screen. Immediately after the presentation of the fixation point, a stimulus appeared on screen for up to 3s, to give participants sufficient time to respond. During the presentation of each stimulus, the participant indicated on the keyboard (M for 'no' or Z for 'yes') whether they noticed a pedestrian crossing in the road scene. The order in which the 112 stimuli were displayed was randomised. After the participant inputted their response (or after 3s, should no response be given), the screen went blank for 0.1 s (see Figure 7.)

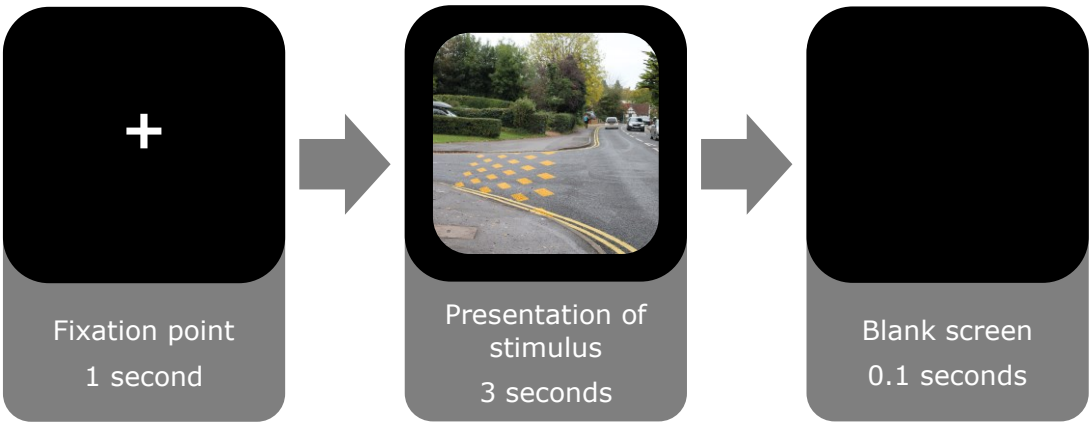


Figure 7: Procedure for the presentation of the 112 stimuli. Participants focussed on a fixation point in the centre of the screen (1 s duration), then a stimulus was presented (3 s duration), then the screen went blank (0.1 s duration) before the presentation of the next fixation point.

2.6.2 Post-trial questionnaire

Following the response time test, participants completed a questionnaire. Each crossing design was presented one at a time, with an image of the crossing from the Driver and Pedestrian points of view presented alongside each other. The questions posed related to confidence and safety. For example, one question asked the participants to rate how confident or unconfident they would feel when deciding to step out onto the crossing. Another question asked the participants to rate how safe or unsafe they would feel using the crossing to cross the road. The questionnaire was used to examine the participants' understanding of the alternative crossing designs, as well as the perceived safety and usability of each crossing design. See Appendix C for the questionnaire used in the study.

2.7 Data analysis

Following the data collection and cleaning, the data were summarised, and statistical tests were performed to test for a difference in the results between the different crossing designs – results are presented in section 3.

For the response time trial (including the crossing identification and response time measures), generalised linear mixed models were used to understand the extent to which various factors (crossing type, viewing perspective and side road location) were able to predict whether participants identified a crossing in the image / their response time. Mixed models were used

for this analysis to account for the fact there were multiple responses from the same participant (repeated measures design).

For the questionnaire data, non-parametric Wilcoxon signed rank tests were used to test for a difference in responses for pairs of crossing types.

For both analyses, p-values are presented, and results are deemed significant at the 5% level (a frequent standard in the behavioural sciences) if the p-value was less than 0.05.

3 Results

3.1 Response time test

This section presents the results of the response time test to understand crossing identification rates (Section 3.1.1), and the time taken to identify that a crossing was present (Section 3.1.2).

3.1.1 Crossing identified

When presented with each of the 112 stimuli, the participants were asked to press a button to indicate whether they noticed a dedicated point at which a pedestrian can cross the road. The results are presented in Figure 8. In 4% of cases the image timed out (i.e. the participant took longer than 3 seconds to respond). These were recoded as 'no response'.

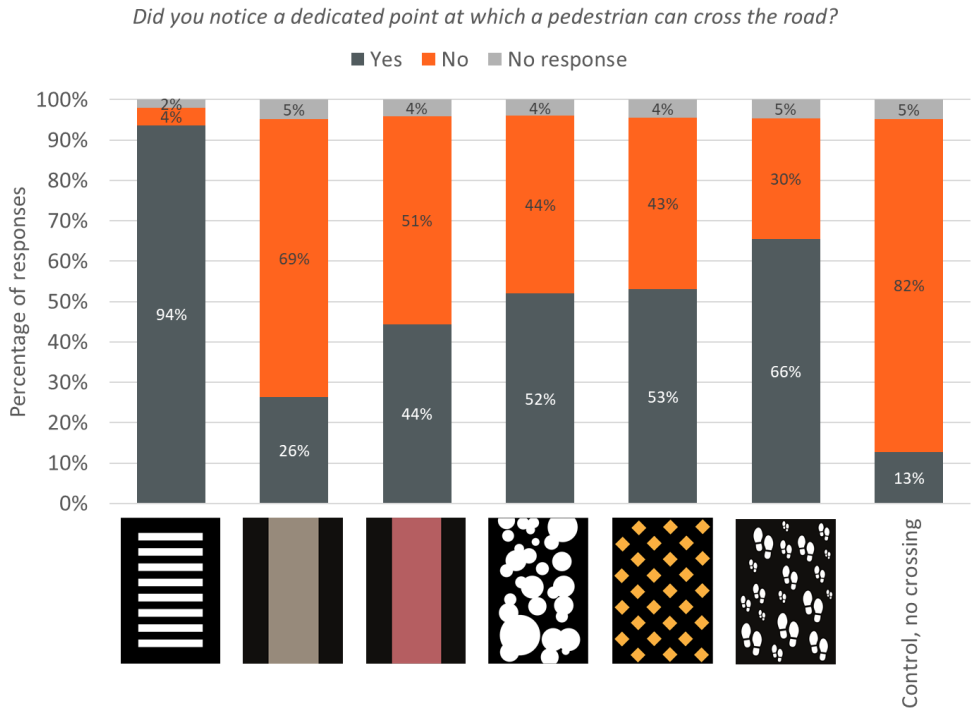


Figure 8: Percentage of responses to the question "Did you notice a dedicated point at which a pedestrian can cross the road?" by crossing type

For the non-prescribed zebra crossing, 94% responses correctly identified there was a crossing present in the image. For the control condition with no crossing, 82% correctly identified there was not a crossing present in the image, whilst 13% of responses incorrectly identified there was a crossing present. For all other crossings, the rate of correct identification ranged from 26% (for the buff coloured crossing) to 66% (for the footprint markings). This suggests that compared to the current non-prescribed zebra crossing, all of the other crossing options were harder to identify.

Statistical modelling was undertaken to understand the extent to which various factors were able to predict whether participants identified a crossing in the image. Full details of the modelling are given in Appendix A, Section A.1, but the results by crossing type are

summarised here. Compared to the non-prescribed zebra crossing, all other crossing types showed statistically significant negative coefficients, indicating that participants were significantly less likely to identify a crossing in the images with these types of crossing, compared with images showing the non-prescribed zebra crossing.

Figure 9 presents the proportion of 'yes there was a crossing' responses split by viewing perspective.

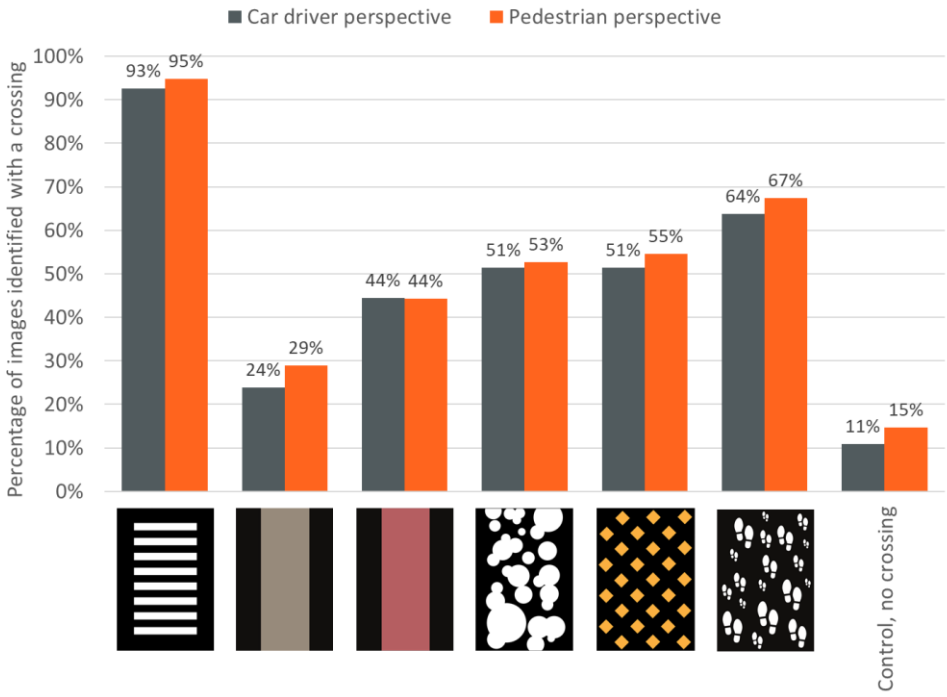


Figure 9: Percentage of responses which identified a crossing in the image by crossing type and viewing perspective

This shows that for all crossing types, a slightly larger proportion of responses identified a crossing in the image when it was presented from a pedestrian perspective compared with a driver perspective.

Statistical modelling (see Appendix A Section A.1) indicated that participants were significantly more likely to identify a crossing when the image was presented from the pedestrian perspective compared to the car driver perspective.

Figure 10 presents the responses for each of the four side roads.

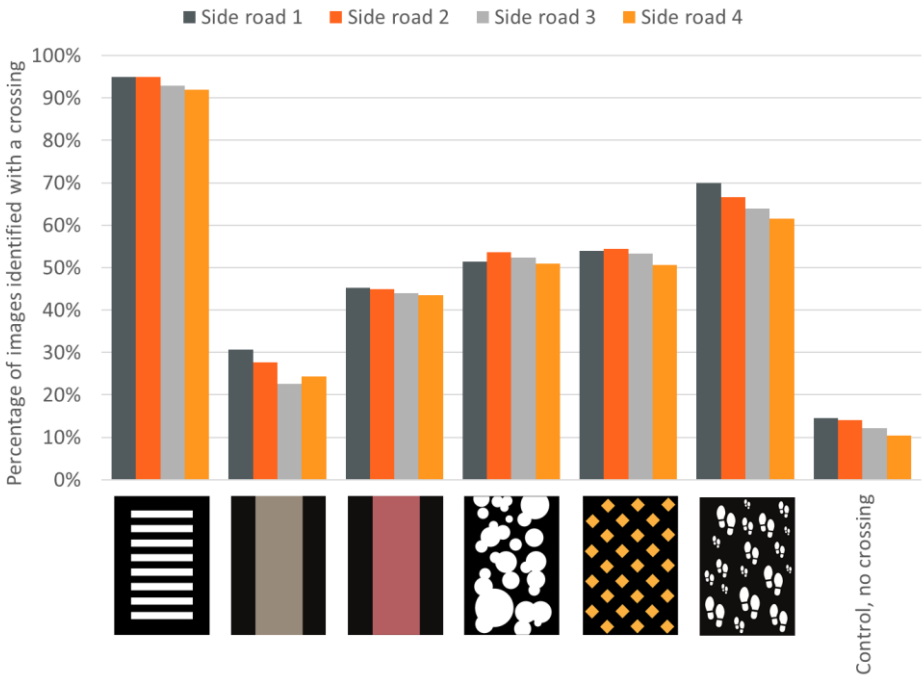


Figure 10: Percentage of responses which identified a crossing in the image by crossing type and side road location

This shows that in general, the crossings were identified more frequently when the crossing was presented on the left of the image (side roads 1 and 2) compared with the right (side roads 3 and 4). This shows that in general, the crossings were identified more frequently when the crossing was presented on the left of the image (side roads 1 and 2) compared with the right (side roads 3 and 4). Drivers in the UK drive on the left-hand side of the road and thus when images are presented from the driver's perspective, the driver is closer to this side of the road. As a result, when presented with the stimuli (see Appendix B), side roads on the left-hand side of the image appear larger than those presented on the right, which may explain the differences in crossing identification.

This may be related to the fact that when the crossings were presented on from the driver's perspective on left-hand side of the road, the driver was closer to the side road and therefore the image of the crossing comprised a larger proportion of the image (see Appendix B for the stimuli).

3.1.2 Response time

In addition to a record of whether a crossing was identified, participants' response times for each stimulus were recorded. If we consider only "correct" identifications of crossings i.e. a 'yes' response for each of the images with crossings (zebra, solid colour and recurring shapes) , we can look at the average (mean) time it took to identify a crossing (Figure 11 and Figure 12). The standard deviation (a measure of the variability of response times) is shown by the error bars.

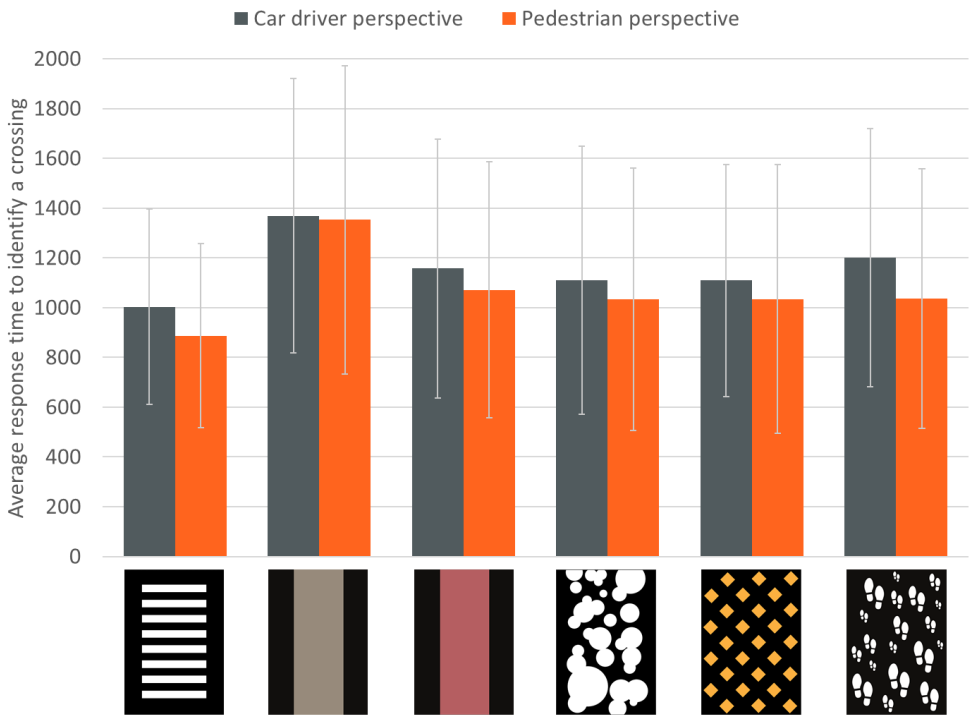


Figure 11: Average response time (m/s) to correctly identify a crossing in the image by crossing type and perspective

The average response time was quicker for the non-prescribed zebra crossing relative to the other crossings. Statistical modelling (see Appendix A Section A.2) shows these differences were significant. Response times were also significantly quicker for stimuli presented in the pedestrian perspective compared with the car driver perspective.

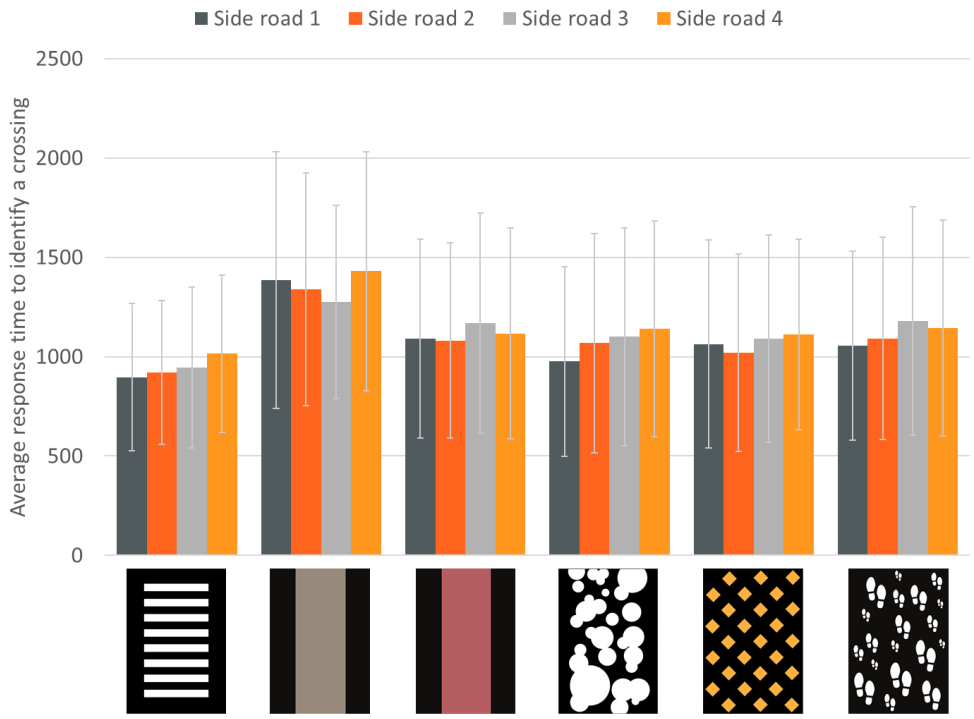


Figure 12: Average response time to correctly identify a crossing in the image by crossing type and side road

For most crossing types (the exception being the buff coloured crossing), response times were quicker for side roads 1 and 2 (which appeared on the left-hand side of the images) relative to side roads 3 and 4 (which appeared on the right-hand side of the images). Statistical modelling (see Appendix A, Section A.2) shows that when comparing the average response times for each side road, side road 1 was significantly different to side roads 3 and 4 but no significant difference was detected with side road 2.

3.2 Post-trial questionnaire

This section presents the results of the post-trial questionnaire which asked questions related to driver and pedestrian confidence with use of the crossings (section 3.2.1); overall feelings of safety and use of the crossings (section 3.2.2) and feelings of safety in response to specific features of the crossings (section 3.2.3). Respondents were also asked to rank the crossings from most preferred to least preferred (section 3.2.4).

3.2.1 Confidence

Figure 13 presents the reported levels of confidence with use of each crossing type when participants were asked to imagine encountering the crossing as a pedestrian in the real world.

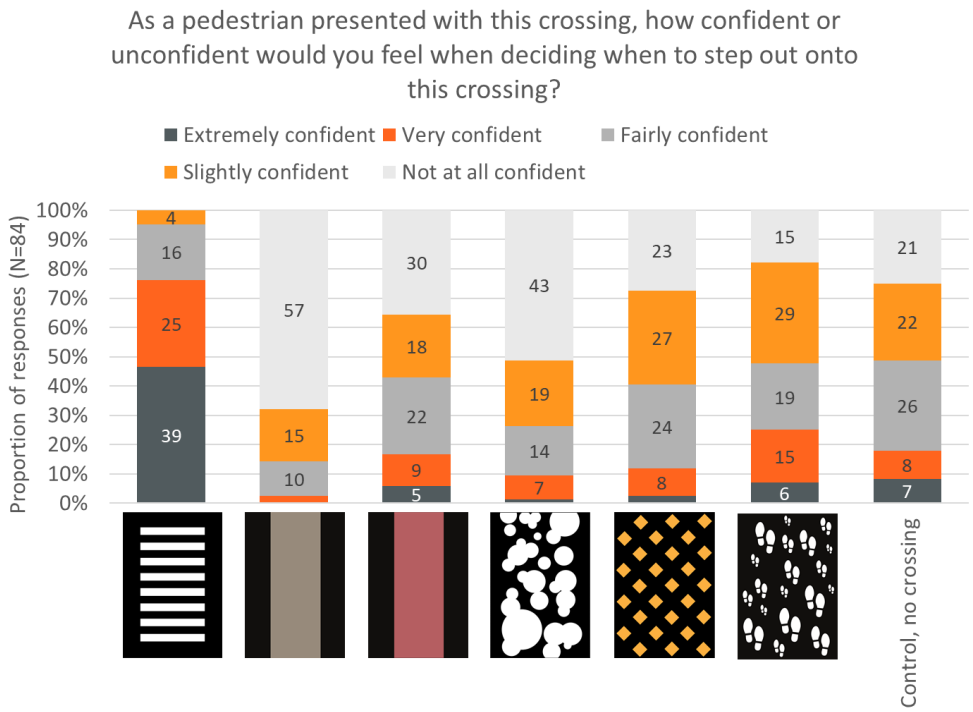


Figure 13: Reported confidence with imagined use of crossing as a pedestrian by crossing type

Most participants (64) reported being extremely or very confident when they imagined using the current non-prescribed zebra crossing. Participants' ratings indicated they were much less confident with all other crossing types (including no crossing at all); over a third of participants for the buff coloured (57), red coloured (30) and bubbles (43) crossings reported feeling 'not at all confident' when they imagined using this crossing. Of all the alternative crossings tested, the footprints crossing scored best in terms of self-reported confidence; generally, participants reported being more confident using this one than no crossing at all.

Statistical comparison of the responses[2] for each pair of crossing types shows that responses were significantly different for all pairs except red coloured vs. diamonds, red coloured vs. footprints, red coloured vs. control, diamonds vs. control and footprints vs. control (see Table 3 – significant figures presented in red).

Table 3: P-values from pairwise comparison of reported confidence with imagined use of

[2] The Wilcoxon signed rank test was used to test for a difference in the distribution of the pairwise responses. Comparisons were deemed to be significant if the p-value is less than 0.05.

crossing as a pedestrian for each pair of crossings (red indicates significant difference)

	Zebra	Buff	Red	Bubbles	Diamonds	Footprints	Control
Zebra		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Buff			<0.001	0.003	<0.001	<0.001	<0.001
Red				0.001	0.969	0.060	0.292
Bubbles					<0.001	<0.001	<0.001
Diamonds						0.009	0.333
Footprints							0.383
Control							

Figure 14 presents similar results when participants were asked to imagine as a car driver how confident they would feel about deciding whether to give way to a pedestrian.

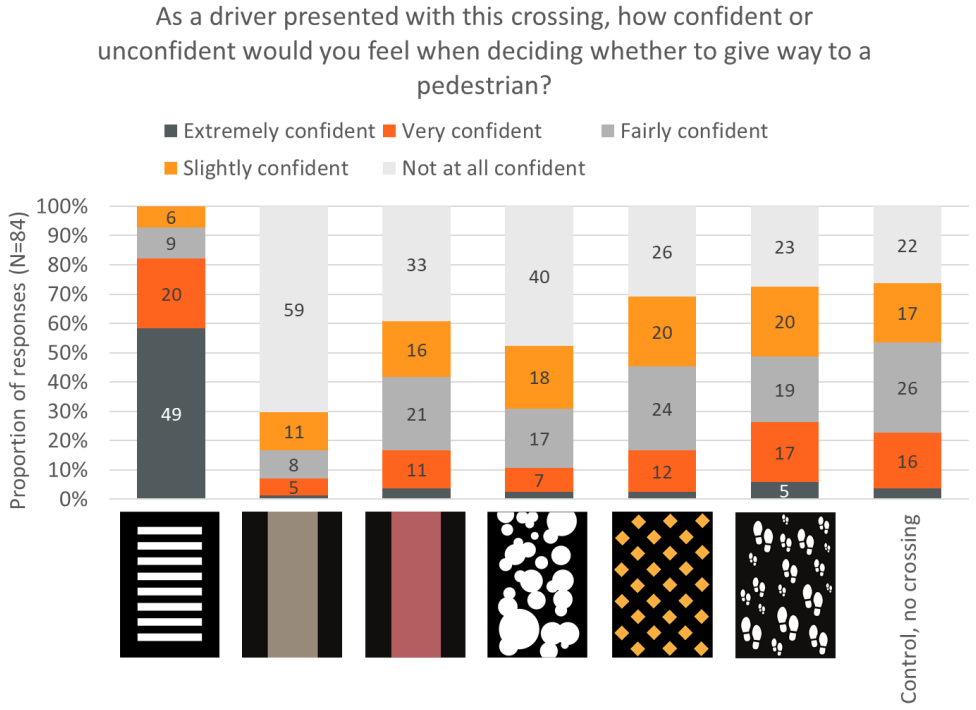


Figure 14: Reported driver confidence with the imagined decision of when to give way to a pedestrian at the crossing by crossing type

Pairwise comparisons of the responses[2] for each crossing type showed that responses were significantly different for all pairs except red coloured vs. bubbles, red coloured vs. diamonds, red coloured vs. control, diamonds vs. footprints, diamonds vs. control and footprints vs. control (see Table 4 - significant figures presented in red).

Table 4: P-values from pairwise comparison of reported driver confidence with imagined decision of when to give way to a pedestrian for each pair of crossings (red indicates

significant difference)

	Zebra	Buff	Red	Bubbles	Diamonds	Footprints	Control
Zebra		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Buff			<0.001	0.014	<0.001	<0.001	<0.001
Red				0.19	0.409	0.020	0.174
Bubbles					0.019	<0.001	0.012
Diamonds						0.088	0.520
Footprints							0.486
Control							

3.2.2 Feelings of safety and use of the crossing

Participants were asked "how safe or unsafe would you feel using this crossing to cross the road?". Results are presented in Figure 15.

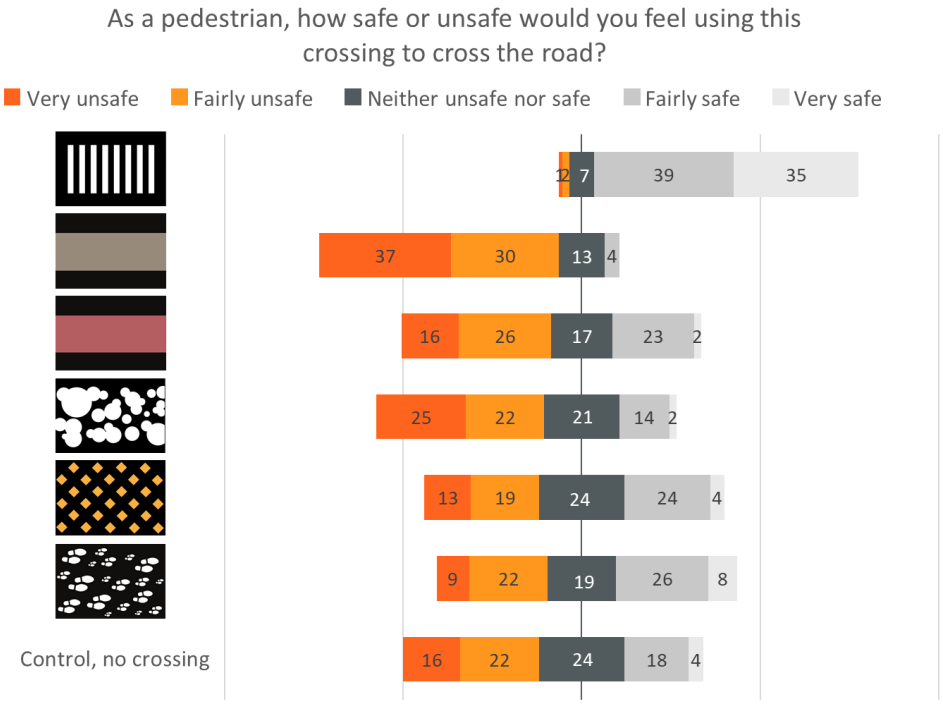


Figure 15: Reported feelings of safety by crossing type

Most of the participants (74) reported feeling fairly safe or very safe when imagining using the non-prescribed zebra crossing. In contrast, many fewer participants reported they would feel fairly safe or very safe using the other crossing types (ranging from 4 participants for the buff coloured crossing up to 34 for the footprints crossing). Participants were much more likely to report feeling fairly unsafe or very unsafe for the alternative crossing types, and for no crossing at all.

Pairwise comparison of the results[2] for each crossing type shows that responses are

significantly different for all pairs except red coloured vs. bubbles, red coloured vs. diamonds, red coloured vs. control, bubbles vs. control, diamonds vs. footprints, diamonds vs. control and footprints vs. control (see Table 5 - significant figures presented in red).

Table 5: P-values from pairwise comparison of reported driver confidence with imagined decision of when to give way to a pedestrian for each pair of crossings (red indicates significant difference)

	Zebra	Buff	Red	Bubbles	Diamonds	Footprints	Control
Zebra		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Buff			<0.001	<0.001	<0.001	<0.001	<0.001
Red				0.124	0.094	0.025	0.894
Bubbles					<0.001	<0.001	0.091
Diamonds						0.243	0.259
Footprints							0.063
Control							

The high levels of perceived safety reported for the non-prescribed zebra crossing are supported by qualitative comments provided by participants. Many participants stated that they were familiar with the zebra crossing and felt safe as a result, and that it was a universal design. Example comments are shown below:

- *"I think familiarity with this crossing is why I'm more confident of using it."*
- *"Used to this type of crossing and has always given pedestrians the right of way over vehicles."*
- *"It's what you're used to seeing and aware of so well trained in looking for it and using it."*
- *"Markings are used often and understood."*
- *The zebra crossing it universally utilized and has been the demarcation for pedestrian crossings in this country for many years."*

The lower levels of perceived safety reported for the buff coloured crossing are supported by qualitative comments provided by participants. Participants stated that they were unsure what the crossing represented; in many cases it was suggested that the crossing appeared to be a repair in the road or a resurface. Example comments are shown below:

- *"Looks like a road repair job not a crossing."*
- *"This type of road surface indicates a special thin surface dressing to aid friction at points on the road where extra friction was needed. I would not associate it with a pedestrian crossing."*
- *"This does not look like a crossing. it could be just a road resurfacing area of different colour."*

- *"Just looks like the road has been patched up with non matching tarmac."*

Similarly, qualitative comments regarding the bubbles crossing also support the finding that participants perceived this crossing to be less safe. Participants stated that the crossing appeared to look like a paint spill on the road, or in some cases, that the crossing resembled artwork. Example comments are shown below:

- *"This looks like a paint spill, not a crossing."*
- *"Not very clear what this is ... could be a paint spill from a lorry."*
- *"Bubbles? It does not look like an official crossing place, just like some children's art project."*
- *"Looks like fun artwork rather than anything for crossing so no one would stop or walk across it."*
- *"The bubbles do not look like a crossing. Instead, they reminded me of painting on a pavement for children, or a school playground. There isn't a clear directive indicator (unlike the footprints), and at times the bubbles look more like 'mess' or a spill on the road rather than specific crossing paintwork*."

Participants were asked to imagine when they would cross the road relative to a car approaching; participants' reported actions are presented in Figure 16.

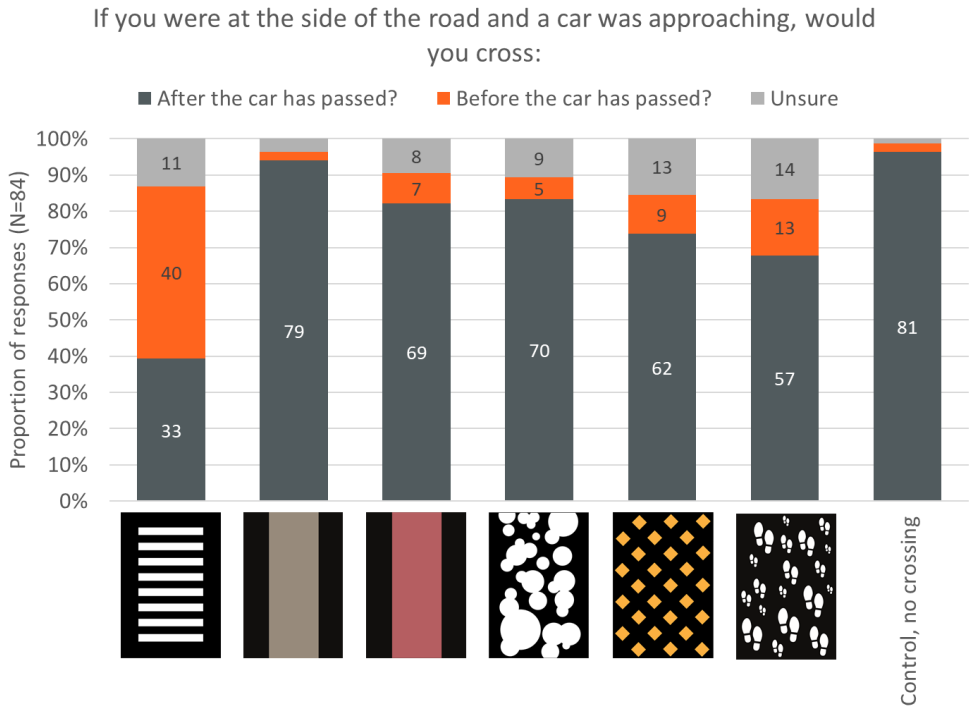


Figure 16: Reported crossing time relative to car approaching by crossing type

The majority of participants (40) reported that they would cross using a non-prescribed zebra crossing before the car had passed. This figure was much lower for the alternative crossing types suggesting that participants would more commonly wait until after the car had passed before crossing. The buff coloured crossing and no crossing scenarios scored similarly suggesting that participants did not trust that the car would stop in these scenarios.

3.2.3 *Crossing features*

Questions were posed to participants about how individual crossing features would affect feelings of safety. Figure 17 presents the results relating to the colour of the markings.

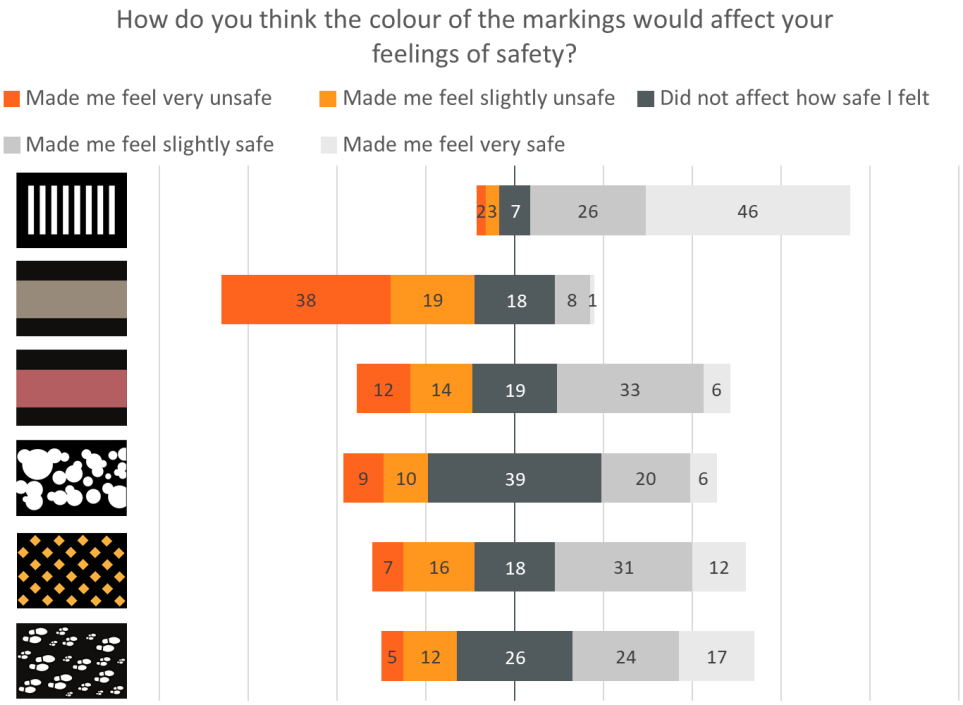


Figure 17: Reported feelings of safety about the colour of the markings by crossing type

The current black and white non-prescribed zebra crossing was reported as making most participants (78) feel slightly or very safe. The other white crossings (bubbles and footprints) scored lower (13 and 42 respectively) suggesting that responses did not solely consider the colour of the markings but also took into account other aspects of the design. The buff coloured crossing was rated as making the majority of participants (50) feel slightly or very unsafe; and the responses for the diamonds and red coloured crossings were similar to each other (23 and 26 reported as slightly or very safe respectively).

Pairwise comparison of the results[2] for each crossing type shows that responses are significantly different for all pairs except red coloured vs. bubbles, red coloured vs. diamonds, red coloured vs. footprints, bubbles vs. diamonds and diamonds vs. footprints (see Table 6 – significant figures in red).

Table 6: P-values from pairwise comparison of reported feelings of safety about the colour

of the markings by crossing type (red indicates significant difference)

	Zebra	Buff	Red	Bubbles	Diamonds	Footprints
Zebra		<0.001	<0.001	<0.001	<0.001	<0.001
Buff			<0.001	<0.001	<0.001	<0.001
Red				0.748	0.077	0.061
Bubbles					0.103	0.003
Diamonds						0.414
Footprints						

The high levels of perceived safety reported for the non-prescribed zebra crossing were supported by the qualitative findings provided by participants. Participants stated that the colour of the crossing made it easy to identify it as a crossing.

- *"Well recognized colour and pattern scheme"*
- *"It is a recognized crossing point with white markings"*

The finding that participants felt less safe when presented with the buff coloured crossing is supported by the qualitative evidence. Participants stated that the colour of the crossing made it difficult to identify it as a crossing.

- *"Very indistinctive. better than nothing, just. Needs a different colour."*
- *"The road crossing needs to be bold and then it would be more clear and install confidence."*
- *"Completely the wrong colour."*
- *"Again - not clear if it's a crossing - could be a different colour patch up on the road*."
- *"Bland colour that merges into the other surfaces. Does not look like a crossing."*
- *"This is a good idea but the solid red or white would be more visible and stand out more to both pedestrians and drivers."*

The evidence from the qualitative findings supports the finding that participants felt less safe when presented with the bubbles crossing Participants stated that the colour of the crossing, in relation to its design, made it difficult to identify it as a crossing. For example:

- *"The only colour that would make me feel safer is "RED" unless it contained "footprints"*

Figure 18 presents responses in relation to the design of the crossing.

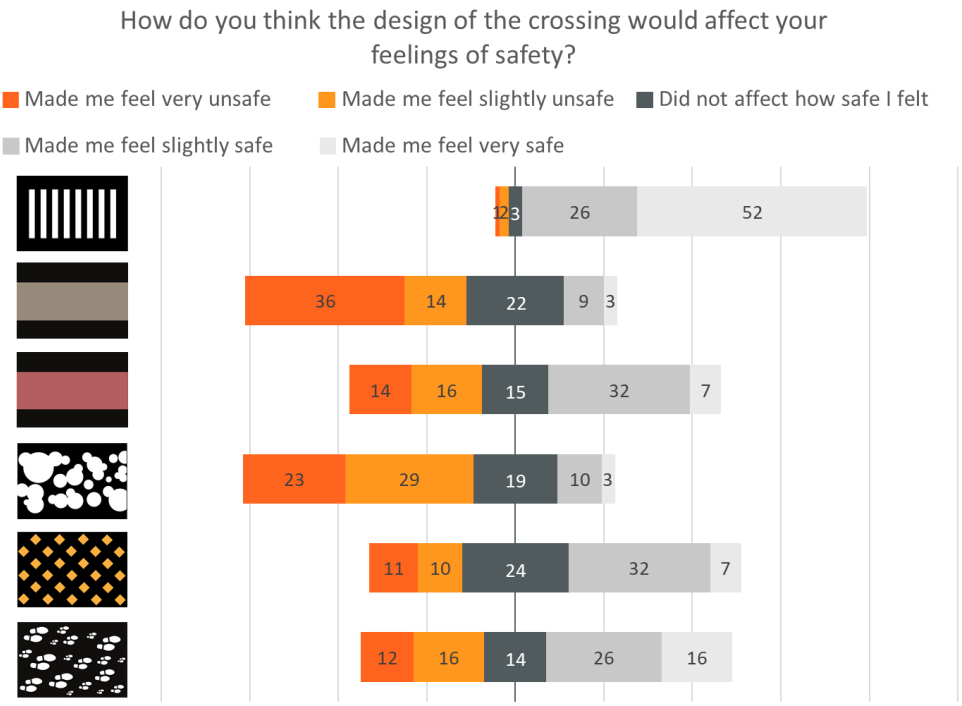


Figure 18: Reported feelings of safety about the design of the crossing by crossing type

As with the overall ratings of safety and those related to colour, the design of the current non-prescribed zebra crossing made most participants feel slightly or very safe (78). The footprints, diamonds and red coloured crossings resulted in a similar number of participants that reported feeling safe as a result of the design (42, 39 and 39 respectively), but this figure was much lower for the buff coloured crossing and bubbles crossing (12 and 13 respectively).

Pairwise comparison of the results[2] for each crossing type shows that responses are significantly different for all pairs except buff coloured vs. bubbles, red coloured vs. diamonds, red coloured vs. footprints and diamonds vs. footprints (see Table 7 – significant figures are in red).

Table 7: P-values from pairwise comparison of reported feelings of safety about the design of the crossing by crossing type (red indicates significant difference)

	Zebra	Buff	Red	Bubbles	Diamonds	Footprints
Zebra		<0.001	<0.001	<0.001	<0.001	<0.001
Buff			<0.001	0.399	<0.001	<0.001
Red				<0.001	0.249	0.296
Bubbles					<0.001	<0.001
Diamonds						0.913
Footprints						

Qualitative evidence reflects the finding that participants rated the buff coloured crossing as less safe. Participants stated that the design of the crossing made it hard to identify the design

as a crossing. Example comments are shown below:

- *"Not clearly identified as a crossing."*
- *"Does not appear to be a clear marking on the road. As such, this would not give me the confidence as a pedestrian or driver to make the correct decision."*
- *"Its purpose is not very clear."*
- *"Very poor. Easily shielded by a vehicle."*

Qualitative evidence supports the finding that participants felt less safe when presented with the bubbles crossing. Participants reported that the design of the crossing made it difficult to identify it as a crossing. Example comments included:

- *"It looks messy and did not represent very well. Does not look like a crossing to me, just a mess."*
- *"I am assuming the circles indicate I can cross like a zebra crossing, but I am not sure."*
- *"The circles don't mean anything. They are too irregular and random."*

For the bubbles and diamonds crossings, participants were also asked to comment on how the size of the markings affected their feelings of safety (Figure 19).

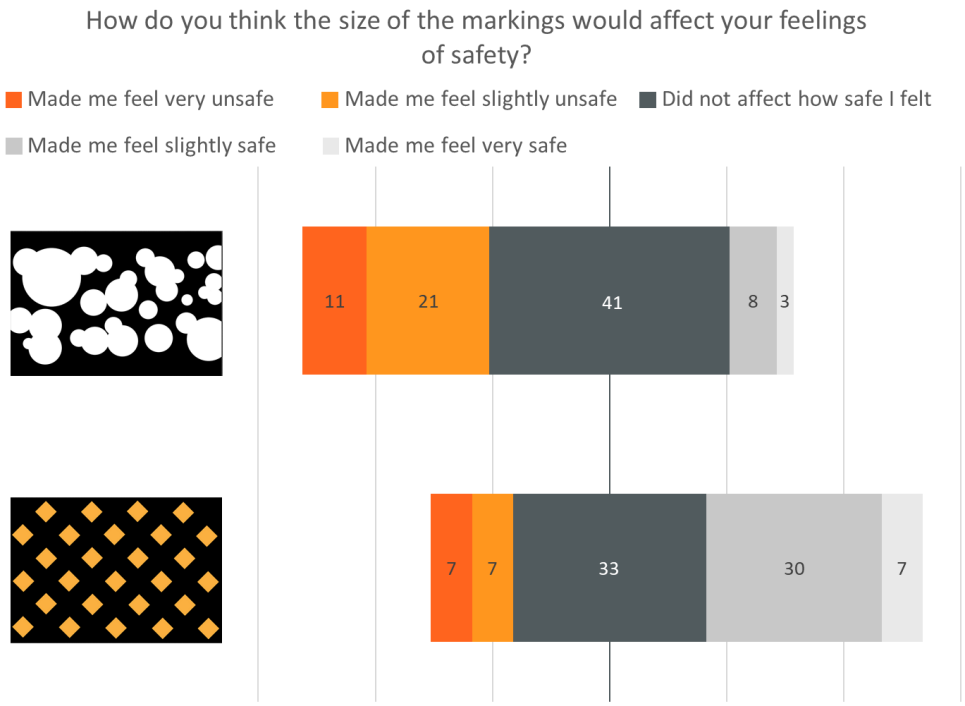


Figure 19: Reported feelings of safety in relation to the size of the markings by crossing type (only relevant to the bubbles and diamonds crossings)

The size of the bubble markings made participants feel less safe than the smaller diamond markings (32 reported feeling slightly or very unsafe compared to 14 respectively). These

differences were significant[3] ($p < 0.001$). The finding that participants felt less safe when presented with the bubble markings compared to the diamonds is supported by the qualitative comments provided by participants. Example comments from the qualitative findings included:

- *"As it's not something your trained to see as a regular crossing it didn't look right and also not as clear as thick bold lines a zebra crossing"*
- *"The circles don't mean anything. They are too irregular and random."*
- *"It isn't regular and therefore does not seem to be authoritative"*

Comments concerning the diamonds crossing design included:

- *"Could get used to this. Diamond shape stands out. As driver I would be careful."*
- *"Yellow and Red are a safety trigger for me. Shapes not so much."*

For the footprints crossing participants were asked: "How do you think the direction of the shoeprints would affect your feelings of safety?" (Figure 20).

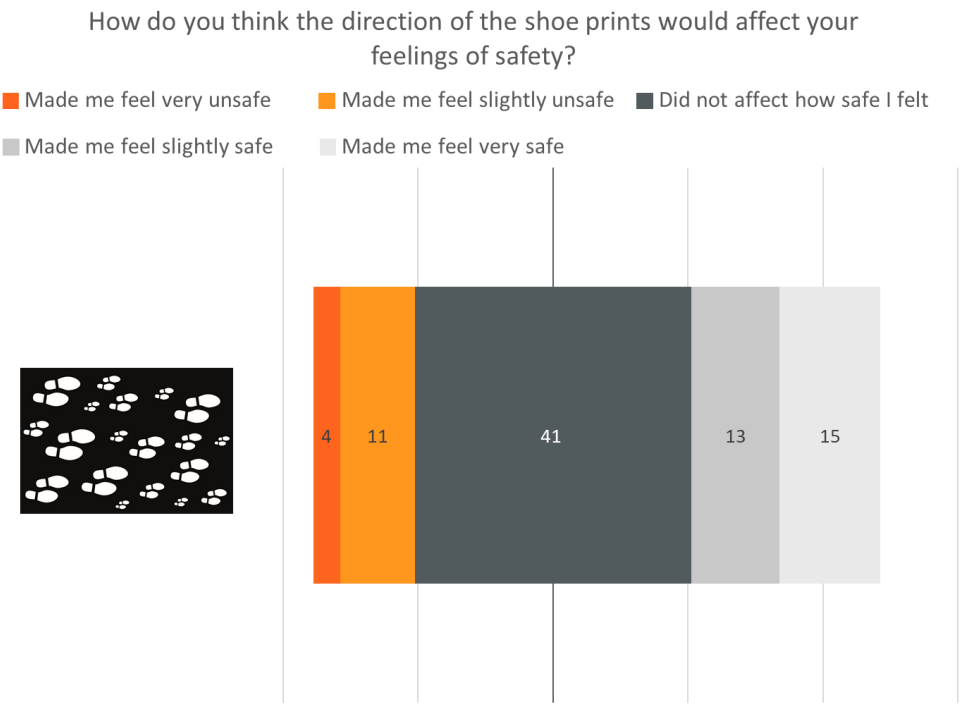


Figure 20: Reported feelings of safety in relation to the direction of the shoe prints (only relevant to the shoeprints crossing)

Almost half of participants (41) reported that the direction of the footprints did not affect how safe they felt. The remaining participants more commonly said they made them feel safe

[3] Using the Wilcoxon signed rank test to test for a difference in the distribution of the responses. Comparisons are deemed to be significant if the p-value is less than 0.05 (a frequent standard).

(28) than unsafe (15). Comments concerning the direction included:

- *"Footprints going both ways would be better."*
- *"Not distinct enough, also only one directional - will confuse"*
- *"I feel that the footprints should be going in both directions to show that you can cross from both sides."*
- *"Direction of footprints could cause some concern."*

For comparison to the results for the rest of the features presented in this section, participants were asked about feelings of safety when a crossing was absent (Figure 21).

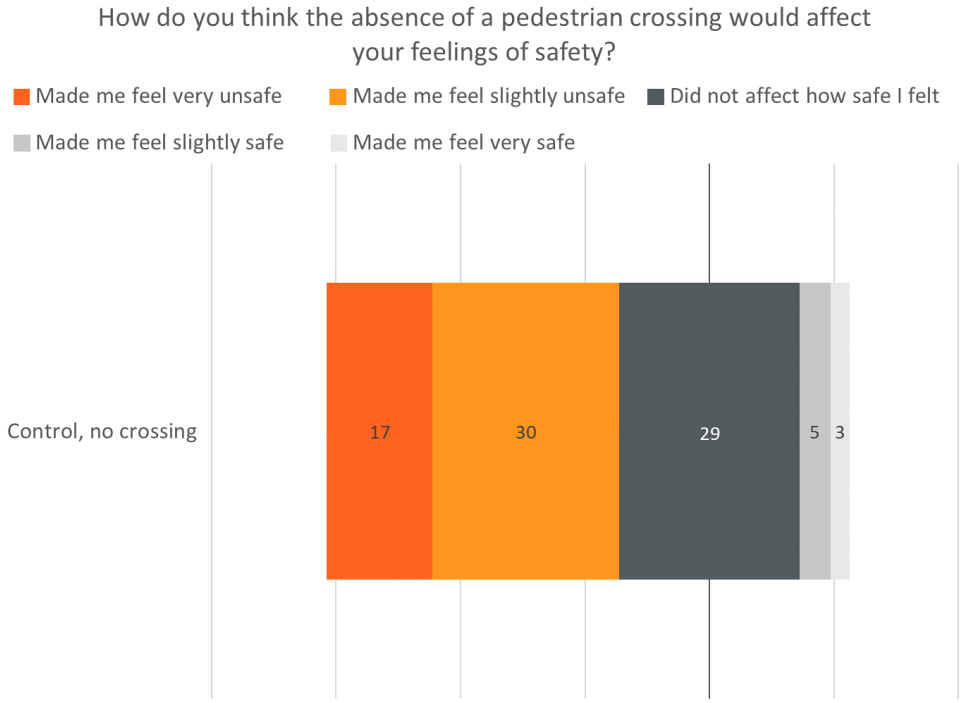


Figure 21: Reported feelings of safety in for the control condition with no crossing

For comparison to the results above, the absence of a crossing typically made participants feel slightly or very unsafe (47), although over a third (29) reported that it did not affect how safe they felt.

The qualitative evidence obtained reflects the finding that participants felt less safe when presented with a side road without a crossing. Participants generally stated that, without a crossing in place, they did not feel safe crossing the road. Comments concerning the control crossing included:

- *"I would probably cross here as it's on a junction but I should not cross here as there is no crossing."*
- *"Not having a crossing can be quite dangerous, so having something visible would be easier."*
- *"This type of crossing can never be safe."*
- *"I would be more careful that I would if there was any sort of crossing there."*

3.2.4 Ranking of crossings

Participants were asked to rank the crossing designs and the absence of a crossing (control) from most preferred to least preferred. The average (mean) rank is presented in Figure 22; the standard deviation (a measure of the variability of the results) is shown by the error bars.

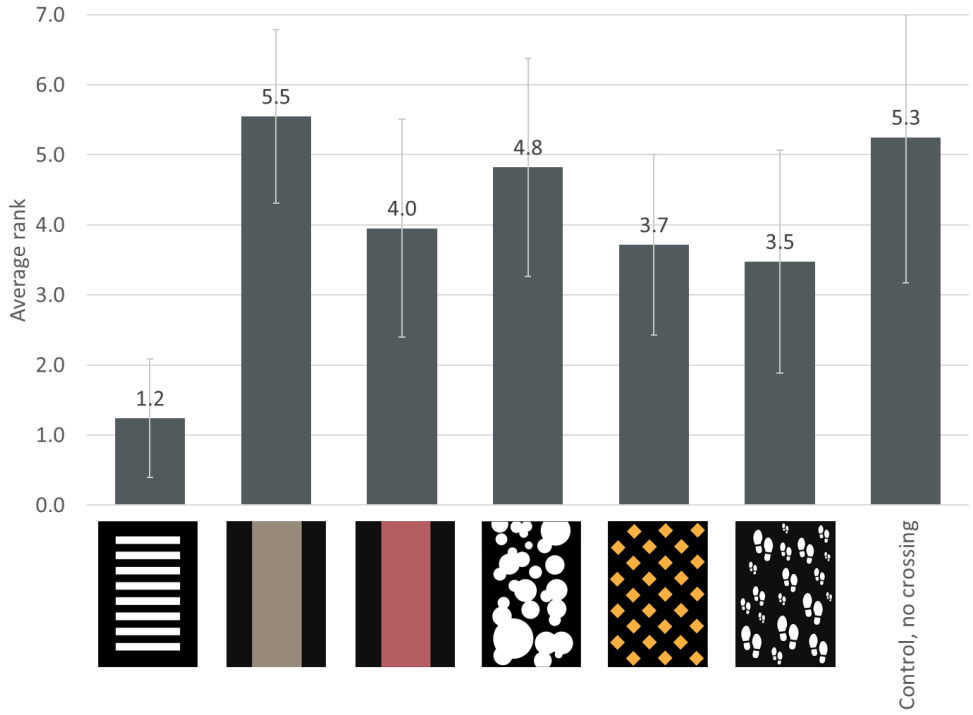


Figure 22: Average rank and standard deviation for each crossing type, on a scale of 1 (most preferred) to 7 (least preferred).

Participants consistently ranked the current non-prescribed zebra crossing as the most preferred option (75 participants ranked this crossing as number 1), followed by the footprints, diamonds and red coloured crossing (which are similar in rank). On average the buff coloured crossing ranked lower than no crossing at all, although the ranking for the latter was more variable across participants.

Pairwise comparison of the results[4] for each crossing type shows that responses are significantly different for all pairs except buff coloured vs. control (no crossing), red coloured vs. diamonds, red coloured vs. footprints, bubbles vs. control (no crossing) and diamonds vs. footprints (see Table 8 and Table 7 – significant figures are in red).

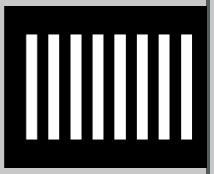
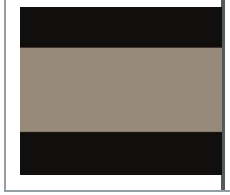
[4] Using repeated measures analysis of variance.

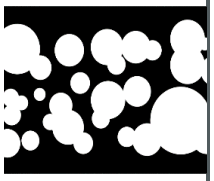
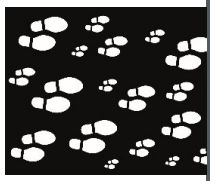
Table 8: P-values from pairwise comparison of average rank for each pair of crossings (red indicates significant difference)

	Zebra	Buff	Red	Bubbles	Diamonds	Footprints	Control
Zebra		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Buff			<0.001	0.004	<0.001	<0.001	0.251
Red				0.004	0.255	0.103	<0.001
Bubbles					<0.001	<0.001	0.185
Diamonds						0.275	<0.001
Footprints							<0.001
Control							

4 Conclusion

The table below summarises the results from the trials, comparing each of the crossings to the non-prescribed zebra. Figures in red indicate that the crossing performed significantly worse on that measure relative to the non-prescribed zebra crossing.

	Response time test (N=9408 stimuli)		Questionnaire (N = 84 participants)					
	Crossing identification	**Response time**	**Reported confidence as a pedestrian**	**Reported confidence as a driver**	**Reported feelings of safety**	**Features of the crossing: colour of markings**	**Features of the crossing: design**	**Ranking of crossing**
Result for non-prescribed zebra 	**94%** of stimuli were identified as having a crossing	Average response time to identify a crossing was **994 m/s**	**64** participants reported feeling confident when imagining using this crossing	**69** participants reported feeling confident when imagining giving way to a pedestrian this crossing	**74** participants reported feeling safe when imagining using this crossing	**72** participants reported the colour of markings would make them feel safe	**78** participants reported the design of the crossing would make them feel safe	Average rank was **1.2** (on a scale of 1 = most preferred to 7 = least preferred)
	26%	1360 m/s	2	6	4	9	12	5.5

	Response time test (N=9408 stimuli)		Questionnaire (N = 84 participants)					
	Crossing identification	Response time	Reported confidence as a pedestrian	Reported confidence as a driver	Reported feelings of safety	Features of the crossing: colour of markings	Features of the crossing: design	Ranking of crossing
	44%	1114 m/s	14	14	25	39	39	4.0
	52%	1071 m/s	8	9	16	26	13	4.8
	53%	1071 m/s	10	14	28	43	39	3.7
	66%	1116 m/s	21	22	34	41	42	3.5
No crossing	13%	N/A	15	19	22	N/A	N/A	5.3

The non-prescribed zebra crossing performed best on all the measures in this trial: participants more commonly recognised this as a crossing and identified it in the quickest time; they also reported feeling more confident and safer when imagining using this crossing relative to the alternatives. When asked to rank the crossings from most preferred to least preferred this scored the best (with 75 of the 84 participants ranking this as their most preferred option).

On balance, of all the alternative crossings, the footprints crossing performed the best. This was identified as a crossing in almost two thirds of stimuli, and the reported confidence and safety were the highest of all the alternative crossings. When asked to comment specifically on the direction of the footprints, almost half of participants reported that the direction of the footprints did not affect how safe they felt however, some people suggested that "footprints going both ways would be better" whilst others thought the fact they were only one directional "will confuse" pedestrians.

The buff coloured crossing was the least preferred and performed worse on the confidence and safety measures than no crossing at all. Only one quarter of the stimuli with this crossing were identified as having a crossing, and the average response time to do so was over 300m/s longer than for the non-prescribed zebra crossing. Comments stated that the colour was not clear on the road and looked like a different coloured patch of road.

The bubbles crossing also performed poorly on the confidence and safety questions relative to no crossing at all. However, more of the stimuli containing this alternative were identified as having a crossing in them than the red coloured and buff coloured crossings, perhaps due to the colour of the markings (white being the colour used for the non-prescribed zebra). Comments stated that this option looked like a paint spill or children's art project and not a crossing.

The other two alternative crossings (red coloured and diamonds) performed similarly to no crossing on both the feelings of confidence and safety questions; but performed similarly to the favoured footprints crossing when colour and design were investigated. The colours yellow and red were described as safety triggers for some participants, and the use of a regular shape was described as more authoritative than an irregular pattern (like the bubbles).

Based on these results, the recommendations are:

1. Pursue the non-prescribed zebra crossing by taking it forward to the next stages of the research (RQ2 Public understanding, RQ3 Effects of Flow).
2. Should a second design option be taken forward for further investigation, the footprints design could be considered alongside the non-prescribed zebra crossing.

Appendix A Statistical modelling

A.1 Crossing identified

Statistical modelling[5] was undertaken to understand the extent to which various factors were able to predict participants' responses: in this case, whether participants identified a crossing in the image (yes/no). The analysis excluded the 4% of cases where no response was recorded because the stimuli timed out. The factors tested in the model were crossing type, viewing perspective and side road location. Factors identified as 'significant'[6] indicates that they contributed towards a successful prediction of whether a crossing was identified.

Overall the accuracy of the final model was found to be 88.7%, meaning it was able to correctly predict participants' responses 88.7% of the time. Classification figures are presented in Table 9; figures in green indicate that the model correctly classified whether a crossing would be identified or not; figures in red show where the model made incorrect classifications.

Table 9: Classification table for model

		Predicted		
		Yes	No	Total
Observed	Yes	4198 (89.8%)	478 (10.2%)	4676 (100%)
	No	545 (12.5%)	3802 (87.5%)	4347 (100%)

The model results are presented in Table 10 and the coefficients for this model in Table 11.

Table 10: Fixed effects in the model

	F	df	Significance
Overall model	181.43	10	<0.001
Crossing type	301.70	6	<0.001
Viewing perspective	19.09	1	<0.001
Side road location	6.50	3	<0.001

The results show that all three factors (crossing type, viewing perspective and side road location) were significant predictors of whether a crossing was identified.

Table 11: Model coefficients

[5] Generalised linear mixed models with a binary logit function (an extension of logistic regression) were used for this analysis to account for the fact there were multiple responses from the same participant (repeated measures design).

[6] Factors were deemed significant at the 5% level (a frequent standard in the behavioural sciences) if the p-value was less than 0.05.

	Coefficient	Exp(coefficient)	Significance
Intercept	5.164	174.781	<0.001
Crossing type: Zebra	-	-	-
Crossing type: Buff coloured	-7.020	0.001	<0.001
Crossing type: Red coloured	-5.548	0.004	<0.001
Crossing type: Bubbles	-4.903	0.007	<0.001
Crossing type: Diamonds	-4.822	0.008	<0.001
Crossing type: Footprints	-3.652	0.026	<0.001
Crossing type: Control	-8.436	0.000	<0.001
Viewing perspective: car driver	-	-	-
Viewing perspective: pedestrian	0.294	1.342	<0.001
Side road location: side road 1	-	-	-
Side road location: side road 2	-0.029	0.971	0.760
Side road location: side road 3	-0.268	0.765	0.005
Side road location: side road 4	-0.345	0.708	<0.001

Since each of the factors included in the model are categorical, the coefficients for each term are presented relative to a 'reference level'.

For the crossing type factor, the reference level was the non-prescribed zebra crossing. All other crossing types showed statistically significant negative coefficients, indicating that participants were significantly less likely to identify a crossing in the images with these types of crossing, compared with images showing the non-prescribed zebra crossing.

For the viewing perspective factor, the car driver perspective was used as the reference level. The coefficient for the pedestrian perspective was statistically significant and positive, which indicates that participants were significantly more likely to identify a crossing when the image was presented from the pedestrian perspective compared to the car driver perspective.

For the side road location factor, side road 1 was used as the reference level. Side road 3 and 4 were both significantly different from side road 1 (although side road 2 was not). The negative coefficient indicates that at these locations (where the side road was shown on the right-hand side) a crossing was significantly less likely to be identified than at side road location 1 (where the side road was shown on the left-hand side).

A.2 Response time

This analysis includes only those stimuli where a crossing was identified. Similar statistical

modelling[7] to that carried out for the categorical yes/no crossing identification indicates that for the response time all three factors (crossing type, viewing perspective and side road location) were significant (Table 12).

Table 12: Fixed effects in the model

	F	df	Significance
Overall model	53.83	10	<0.001
Crossing type	72.99	6	<0.001
Viewing perspective	79.39	1	<0.001
Side road location	13.10	3	<0.001

Table 13 presents the coefficients relative to the reference levels (non-prescribed zebra, car driver and side road 1 respectively).

Table 13: Model coefficients

	Coefficient	Significance
Intercept	971.229	<0.001
Crossing type: Zebra	-	-
Crossing type: Buff coloured	474.125	<0.001
Crossing type: Red coloured	222.113	<0.001
Crossing type: Bubbles	205.358	<0.001
Crossing type: Diamonds	178.110	<0.001
Crossing type: Footprints	189.139	<0.001
Crossing type: Control	497.157	<0.001
Viewing perspective: car driver	-	-
Viewing perspective: pedestrian	-108.819	<0.001
Side road location: side road 1	-	-
Side road location: side road 2	19.887	0.241
Side road location: side road 3	63.734	<0.001
Side road location: side road 4	98.092	<0.001

For the crossing type factor, the reference level was the non-prescribed zebra crossing. All other crossing types showed statistically significant positive coefficients, indicating that response times significantly slower with these types of crossing, compared with images

[7]For this analysis linear mixed models were used as the dependent variable (response time) is continuous rather than categorical.

showing the non-prescribed zebra crossing.

For the viewing perspective factor, the car driver perspective was used as the reference level. The coefficient for the pedestrian perspective was statistically significant and negative, which indicates that response times were significantly quicker for a crossing when the image was presented from the pedestrian perspective compared to the car driver perspective.

For the side road location factor, side road 1 was used as the reference level. Side road 3 and 4 were both significantly different from side road 1 (although side road 2 was not). The positive coefficient indicates that at these locations (where the side road was shown on the right-hand side) the response time was slower than at side road location 1 (where the side road was shown on the left-hand side).

Appendix B Stimuli presented in the trial

B1. Non-prescribed zebra crossing

Location 1	Location 2	Location 3	Location 4
			
Pedestrian perspective			
			
Car driver perspective			

B2. Buff coloured crossing

Location 1	Location 2	Location 3	Location 4
			

Pedestrian perspective

Car driver perspective

B3. Bubbles crossing

Location 1	Location 2	Location 3	Location 4
			

Pedestrian perspective

Car driver perspective

B4. Diamonds crossing

Location 1	Location 2	Location 3	Location 4
			

Pedestrian perspective

Car driver perspective

B5. Footprints crossing

Location 1	Location 2	Location 3	Location 4
			

Pedestrian perspective

Car driver perspective

B6. Red coloured crossing

Location 1	Location 2	Location 3	Location 4
			

Pedestrian perspective

Car driver perspective

B7. No crossing, control

Location 1	Location 2	Location 3	Location 4
			

Pedestrian perspective

Car driver perspective

Appendix C Post-Trial Questionnaire

Please enter your Participant Number:

☐

1. [Crossing Name][8]

Please inspect the images below and answer the following questions about this type of crossing. Imagine you are encountering the pedestrian crossing when on a journey in the real world.

Pedestrian view

Driver view

1.a. As a pedestrian presented with this crossing, how confident or unconfident would you feel when deciding when to step out onto this crossing?

Not at all confident	Slightly confident	Fairly confident	Very confident	Extremely confident
☐	☐	☐	☐	☐

[8] Questions 1a to 1g were repeated for all six crossing designs, plus the control condition where no crossings were present. The photographs from the pedestrian and driver views were also changed to reflect the crossing design for which the questions were being answered.

1.b. As a driver presented with this crossing, how confident or unconfident would you feel when deciding whether to give way to a pedestrian?

Not at all confident	Slightly confident	Fairly confident	Very confident	Extremely confident
☐	☐	☐	☐	☐

1.c. As a pedestrian, how safe or unsafe would you feel using this crossing to cross the road?

Very unsafe	Fairly unsafe	Neither unsafe nor safe	Fairly safe	Very safe
☐	☐	☐	☐	☐

1.d What are the reasons for your answer to the question above?

1.e. If you were at the side of the road and a car was approaching, would you cross:

Before the car has passed?	After the car has passed?	Unsure
☐	☐	☐

1.f. How do you think the following features would affect your feelings of safety?

	Made me feel very unsafe	Made me feel slightly unsafe	Did not affect how safe I felt	Made me feel slightly safe	Made me feel very safe
Colour of road markings	☐	☐	☐	☐	☐

	Made me feel very unsafe	Made me feel slightly unsafe	Did not affect how safe I felt	Made me feel slightly safe	Made me feel very safe
Design of crossing (i.e. the use of white lines)[9]	☐	☐	☐	☐	☐
The size of the circles[10]	☐	☐	☐	☐	☐

1.g. Do you have any additional comments about this crossing type?

[9] The wording of this statement was modified for each of the crossing types:

- Non prescribed zebra: Design of crossing (i.e. the use of white lines)
- Red coloured crossing, buff coloured crossing: Design of crossing (i.e. the use of a solid colour)
- Bubbles crossing: Design of crossing (i.e. the use of circles)
- Diamonds crossing: Design of crossing (i.e. the use of diamond symbols)
- Footprints: Design of crossing (i.e. the use of footprint symbols)
- No crossing, control: The absence of crossing markings

[10] This statement was included for the Bubbles crossing only. Additional statements were included for the Diamonds and Footprints crossings. These were:

- Diamonds crossing: The size of the diamonds
- Footprints: The direction of the footprints

3. Drag each crossing to rank them from most preferred to least preferred using a 1-7 number scale (where 1 is most preferred, 7 is least preferred):

Buff coloured crossing	
Bubbles crossing	
Diamonds crossing	
Footprints crossing	
Red coloured crossing	
Zebra crossing	
No markings	

3. About you

3a. Gender: How would you describe your gender?

- ☐ Male
- ☐ Female
- ☐ Prefer not to say
- ☐ Prefer to self-describe (please specify): _____

3b. Age: What is your age group?

☐ 18-20 years	☐ 21-24 years	☐ 25-34 years	☐ 35-44 years
45-54 years	55-64 years	65-74 years	75+ years

3c. Do you hold a valid UK driving licence?

- [ ] Yes
- [ ] No

3d. How long have you held a driving licence for?

- [ ] Less than 1 year
- [ ] 1-5 years
- [ ] 6-10 years
- [ ] More than 10 years

3e. On average, how often do you drive your vehicle?

- [ ] Every day
- [ ] Most days
- [ ] Once or twice a week
- [ ] Once a week
- [ ] Less than once a week

Non-prescribed zebra crossings at side roads

Technical Annex 3: Effectiveness of alternative markings

This report contains the results of a lab-based trial of five alternative pedestrian crossing designs, alongside a non-prescribed zebra crossing (black and white stripes only). The aim was to determine the design that was most correctly identified and understood by pedestrians and car drivers.

It is part of a project commissioned by TfGM which seeks to understand how such crossings could be used in urban areas to provide direct but safe crossing options for pedestrians. The project involves desk-based research, laboratory-based trials and on-road trials.

The trial consisted of a response time test and a post-trial questionnaire conducted in a controlled laboratory environment. The non-prescribed zebra crossing performed best on all the measures. Participants more commonly recognised this as a crossing and identified it in the quickest time; they also reported feeling more confident and safer when imagining using this crossing relative to the alternative designs. Of all the alternative designs, the footprints crossing performed the best. This was identified as a crossing in almost two thirds of stimuli, and the reported confidence and safety were the highest of all the alternative crossings. The recommendations were to pursue the non-prescribed zebra into the next stages of the research. Should a second design option be taken forward for further investigation, the footprints design could also be considered.

Titles in this subject area

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